

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
OTTAWA AVENUE OVERPASS SBL  
HIGHWAY 11 BURK'S FALLS TO SOUTH RIVER  
ONTARIO  
G.W.P. 759-93-00, W.P. 750-93-01, SITE: 44-414**

**Geocres Number: 31E-251**

**Report to**

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## **FOUNDATION INVESTIGATION AND DESIGN REPORT**

### **OTTAWA AVENUE OVERPASS SBL**

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## **PART 1: FACTUAL INFORMATION**

### **1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at the Ottawa Avenue Overpass SBL structure on the proposed four-lane of Highway 11 west of the Town of South 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, stratigraphic profile and cross-sections, laboratory test results and a written description of the subsurface conditions. A model of the subsurface conditions was developed from the data obtained in the course of the present investigation.

Thurber carried out the investigation as a sub-consultant to Marshall Macklin Monaghan, under the Ministry of Transportation Ontario (MTO) Agreement Number 5005-A-000188.

### **2 SITE DESCRIPTION**

The site is located at Ottawa Avenue, at approximately 1.4 km west of the existing Highway 11, west of the Village of South River in the Township of Machar. The topography is rolling with dry highland areas and swampy lowlands. Vegetation in the immediate vicinity of the site consists of grass and small shrubs at the south side of Ottawa Avenue and large trees at the north side of Ottawa Avenue. Vegetation further beyond the site consists of large trees. A number of beaver dams have created ponded water south of Ottawa Avenue. The southwest quadrant of the site is occupied by a small cemetery and a house.

The general site area is located within the physiographic region known as the Canadian Shield, characterized by Pre-Cambrian bedrock typically occurring as rounded knobs and ridges where exposed. Locally, however, the site lies in a gently rolling area with glacio-fluvial overburden over bedrock. These glacio-fluvial soils are part of a minor physiographic region known as The Number 11 Strip, which follows Highway 11 from Gravenhurst to North Bay. Locally, the ground surface

elevation changes abruptly, creating numerous steep slopes and the low-lying areas are occupied by beaver ponds.

### **3 SITE INVESTIGATION AND FIELD TESTING**

The site investigation and field testing for this project were carried out between October 18 and November 08, 2005 and consisted of drilling and sampling four boreholes at the foundation elements to depths ranging from 37.6 m to 40.5 m and two boreholes at the approach embankments to depths of 12.0 m. The boreholes were numbered 414-101 to 414-106 and their approximate locations are shown on the attached Borehole Locations and Soil Strata Drawing in Appendix F.

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

Access to the specific borehole locations at the north abutment foundation element was difficult due to a locally steep slope and a buried natural gas pipeline on the north side of Ottawa Avenue. The locations of the boreholes drilled for the north abutment were selected to be as close as feasible to the abutment location while allowing safe operation of the drill rig. Borehole 414-103 was drilled approximately 4.8 m north of the proposed north abutment location and Borehole 414-104 was drilled approximately 4.4 m north of the proposed north abutment location. Due to the presence of an abandoned house at the location of the south approach embankment, Borehole 414-105 was drilled approximately 5.5 m west of the SBL centreline.

Drilling was carried out using a track mounted CME 75 drill rig. A combination of hollow-stem auger drilling techniques and casing and washboring methods were used to advance the boreholes and samples were obtained at selected intervals using a split spoon sampler in conjunction with Standard Penetration Testing (SPT) in the overburden soils. In Boreholes 414-101 to 414-104 diamond coring was required to penetrate large boulders encountered at depths ranging from 27.8 m to 35.8 m. Boreholes 414-101 to 414-104 were also advanced 3.0 m to 3.9 m into bedrock by NQ size diamond coring techniques.

Groundwater conditions in the open boreholes were observed throughout the drilling operations. Standpipe piezometers consisting of 19 mm PVC pipe with slotted screens were installed and enclosed in filter sand in two boreholes (one at each foundation element) to permit longer term groundwater level monitoring. The locations and completion details of the piezometers are shown in Table 3.1.

**Table 3.1 – Piezometer Installation Details**

Piezometer Location	Piezometer Details	
	Tip Depth/ Elevation (m)	Completion Details
414-101	39.0/304.9	Piezometer with 3.0 m slotted screen installed with sand filter to 35.7 m, bentonite grout seal from 35.7 m to 0.9 m, and bentonite seal from 0.9 m to ground surface.
414-102	None	Grouted from 37.8 to ground surface.
414-103	None	Grouted from 40.5 to ground surface.
414-104	39.3/306.1	Piezometer with 1.5 m slotted screen installed with sand filter to 35.4 m, bentonite seal from 35.4 m to 34.4 m, bentonite grout from 34.4 m to 0.6 m and bentonite seal from 0.6 m to ground surface.
414-105	None	Grouted from 12.0 to ground surface.
414-106	None	Grouted from 12.0 to ground surface.

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

All rock cores were logged, and the Total Core Recovery (TCR), Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to Visual Identification (VI) and to natural moisture content determination. The results of this testing are shown on the Record of Borehole sheets in Appendix A. Selected samples were also subjected to gradation analysis and the results of this testing program are shown on the Record of Borehole sheets in Appendix A and on the figures contained in Appendix B. The results of point load tests on rock cores retrieved from the boreholes are shown in Table B1 in Appendix B.

#### **5 DESCRIPTION OF SUBSURFACE CONDITIONS**

Reference is made to the Record of Borehole sheets in Appendix A. Details of the encountered soil and rock stratigraphy are presented in these appendices and on the "Borehole Locations and Soil Strata" drawing in Appendix F. 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. Boreholes 414-103 and 414-104 were located approximately 4.8 m and 4.4 m away from the centre line of the north abutment respectively. However, the soil stratigraphy encountered is similar in all boreholes drilled for this structure and similar to that

encountered in the investigation for the adjacent NBL structure. The stratigraphic model developed from this information is considered to be representative of the conditions at the abutments. Variation in the elevations of stratigraphic contacts should be expected, but not of a magnitude that is expected to have a significant impact on the project.

In general, the site is underlain by 34.5 m to 37.2 m of overburden soils overlying Pre-Cambrian bedrock. The overburden soils consist of topsoil, fill, sand, silt to silty sand, and sand with some gravel, cobbles and boulders.

### **5.1 Topsoil and Fill**

Topsoil in the range of 50 mm in thickness was encountered at the south abutment. Topsoil thickness may vary between and beyond the boreholes.

Fill was encountered at the south approach in Borehole 414-105, which was located on the driveway to a house. The fill consisted of dense sand and gravel, underlain by sandy silt and sand to a depth of 3.0 m or an elevation of 342.3 m.

The water content of the fill ranged from 2 to 8%. The gradation of a selected sample of the fill is shown in Figure B1 in Appendix B.

### **5.2 Upper Sand**

The topsoil and ground surface are underlain by a brown deposit of dry to wet silty sand to sandy silt that extends to depths ranging from 2.3 m to 4.0 m or to elevations ranging from 342.5 m to 341.0 m.

SPT 'N' values ranged from 3 to 29 blows for 0.3 m penetration in this stratum indicating a very loose to compact relative density. The moisture content of samples from this deposit ranged from 5% to 23%.

A sample from this deposit was subjected to grain size distribution testing and the results are reported on the Record of Borehole Sheets and are plotted in Figure B2 in Appendix B.

### **5.3 Silt to Silty Sand**

Across the site the topsoil and upper sand deposits are further underlain by a major deposit of wet silt to silty sand below the water table. The deposit consists of zones of silt with trace to some sand, sand and silt, and fine to medium grained silty sand. This deposit was penetrated in all of the boreholes where it was found to extend to depths ranging from 28.3 m to 31.1 m or to elevations ranging between 313.2 m and 317.1 m. A pocket of sand with some silt was encountered within this deposit in Borehole 414-104 from 13.2 m to 22.4 m depth or elevation 332.2 m to 323.0 m.

Samples from this deposit were subjected to grain size distribution tests and the results are reported on the Record of Borehole Sheets and are plotted in Figures B3 to B6 in Appendix B.

Standard Penetration tests in this deposit gave 'N' values ranging from 13 to 66 blows per 0.3 m penetration indicating a compact to very dense relative density. Higher 'N' values (more than 50 blows for under 0.3 m penetration) are attributed to the probable presence of cobbles and boulders within the deposit.

The moisture content of samples from this deposit varies between 18% and 30%.

#### **5.4 Lower Sand with Cobbles and Boulders**

A deposit of wet sand (lower sand) was encountered below the silt to silty sand. The deposit is a medium to fine grained sand with some gravel, trace silt and occasional cobbles and boulders and exists below the water table. This deposit extends to depths ranging from 34.5 m to 37.2 m or to elevations ranging between 310.0 m and 308.0 m. Boulders were also encountered in this deposit below depths ranging from 29.9 m to 33.5 m or below elevations of 314.5 m to 311.9 m.

The results of grain size distribution tests conducted on samples from this deposit are presented in Figure B 7 in Appendix B.

Standard Penetration tests in this deposit yielded 'N' values generally ranging from 16 to 92 blows per 0.3 m penetration. One Standard Penetration test gave an 'N' value of 1 blow per 0.3 m penetration, which is attributed to a locally disturbed zone due to the drilling process. Higher 'N' values (more than 50 blows for under 0.3 m penetration) are attributed to the presence of cobbles and boulders within the deposit. Based on these results the deposit is considered to have a compact to very dense relative density.

The moisture content of samples from this deposit ranged from 18% to 26%.

Upon encountering boulders, the boreholes were typically advanced using diamond coring techniques. Coring and washboring continued through the soils between the boulders, although recovery was limited to a few pieces of gravel and cobbles. The boulders were measured to range from 0.1 m to 0.5 m in thickness along the axes of the boreholes.

#### **5.5 Bedrock**

The overburden soils described above are underlain by gneiss bedrock. Bedrock was proved by coring at both abutments. Table 5.1 summarizes the bedrock depth and the elevations to the top of bedrock.



**Table 5.1 – Depth to Bedrock**

<b>Location</b>	<b>BH Number</b>	<b>Depth to Bedrock (m)</b>	<b>Top of Bedrock Elevation (m)</b>
South Abutment	414-101	36.0	308.0
South Abutment	414-102	34.5	309.0
North Abutment	414-103	37.2	309.3
North Abutment	414-104	35.4	310.0

The gneiss bedrock is described as fresh to slightly weathered. Its colour is pink with visible black sub-vertical banding in most cores.

Core recovery in the bedrock was generally between 85% and 100%. The RQD values generally ranged from 67% to 100% indicating fair to excellent rock quality. However, in Borehole 414-103 an RQD value of 0% was recorded in a 0.2 m long run and an RQD value of 39% was recorded in the bottom run of core.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, was generally low ranging from 0 to 5 although isolated zones of >10 fractures per 0.3 m of core were recorded in Boreholes 414-103 and 414-104. Sub-vertical joints were encountered within the rock mass at Borehole 414-103. They were mostly tight with no infilling or secondary weathering material.

The unconfined compressive strength of the rock cores is estimated to range between 135 and 201 MPa indicating very strong rock. These estimated rock strength values are based on point load tests that were conducted on rock cores recovered from the boreholes. A summary of the Point Load Test Results is presented in Table B1 in Appendix B.

## **5.6 Depths to Refusal**

Effective refusal, defined as an SPT value exceeding 100 blows for 0.3 m of penetration (or 50 blows for less than 150 mm penetration), was encountered in the gravelly sand, cobbles and boulders above the bedrock surface in the three deep boreholes. The depths at which effective refusal was encountered, and the depth to the bedrock surface, are shown in Table 5.2.

**Table 5.2 – Refusal and Bedrock Depths**

Location	Borehole	Refusal		Bedrock	
		Depth (m)	Elevation	Depth (m)	Elevation
South Abutment	414-101	28.3	315.6	36.0	308.0
	414-102	29.9	313.6	34.5	309.0
North Abutment	414-103	31.1	315.4	37.2	309.3
	414-104	29.9	315.5	35.4	310.0

### 5.7 Water Levels

A standpipe piezometer was installed in one borehole at each abutment and water levels were measured on several visits made after the completion of drilling. The water level readings are presented in Table 5.2.

Based on these observations, local groundwater levels exist at Elevations 341 m to 341.9 m. All groundwater observations at this site are short term and the levels are expected to fluctuate seasonally and after severe weather events.

**Table 5.2 – Water Level Measurements**

Date	BH 414-101		BH 414-104	
	Depth	Elev.	Depth	Elev.
October 22, 2005	2.1	341.9		
October 24, 2005	2.3	341.7		
October 26, 2005	2.2	341.8		
October 27, 2005	2.3	341.7		
November 5, 2005	2.1	341.9	4.1	341.3
November 7, 2005	2.1	341.9	4.2	341.2
November 15, 2005	2.2	341.8	4.3	341.1
November 17, 2005	2.2	341.8	4.3	341.1
November 21, 2005	2.2	341.8	4.4	341.0
November 23, 2005	2.2	341.8	4.4	341.0

## 6 MISCELLANEOUS

Borehole locations were selected by Thurber Engineering Ltd. Surveyors from Marshall Macklin Monaghan Ltd. staked these locations in the field, confirmed the co-ordinates and obtained the ground surface elevations.

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

Eastern Ontario Soil Investigations of Hawkesbury supplied a track mounted CME 75 drill rig and conducted the drilling, sampling and in-situ testing operations.

The field program was supervised on a full time basis by Mr. George Azzopardi of Thurber.

Routine laboratory testing was carried out by Thurber Engineering Ltd.

Overall supervision of the field program, interpretation of the data and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng.

The report was reviewed by 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 to assist the design team to select and design a suitable foundation system and approach embankments for the proposed structure.

It is understood that Highway 11 SBL will cross over Ottawa Avenue via a single span structure spanning 28 m between abutments. The proposed finished grade at the structure will be about Elevation 351.1 m at the north abutment and the original ground surface is at average Elevation 346.0, resulting in an approach embankment up to 5.1 m high. At the south abutment, the finished grade will be at Elevation 351.9 and the original ground surface is at average Elevation 343.8, resulting in an approach embankment up to 8.1 m high.

The discussion and recommendations presented in this report are based on our understanding of the project and on the factual data obtained in the course of the investigations.

**8 STRUCTURE FOUNDATIONS**

The proposed bridge is a single-span overpass structure with two abutments as foundation elements.

The stratigraphy encountered at the abutment locations consist of 34.5 m to 37.2 m of sands and silts including a layer of cobbles and boulders in the final 5 m to 7 m above bedrock. The groundwater level is high and lies at elevations ranging from Elevations 341 m to 341.9 m and as a result most of the sands and silts are below the groundwater level.

Initial consideration was given to the following foundation types:

- Spread footings
- Augered Caissons (drilled shafts)
- Driven piles

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

### **8.1 Spread Footings on Native Ground**

The near surface soils generally consist of loose to compact sand underlain by very loose to compact sandy silt. The geotechnical resistance of these deposits is relatively low and settlements in these deposits under the footing load will be relatively large. Moreover, in order to maintain the proposed profile grade approximately 10 m high abutment stems will be required if footings are placed on these native deposits. Consequently, spread footings on native ground are not considered to be a feasible foundation alternative and are not recommended.

### **8.2 Spread Footings on Engineered Fill**

Consideration was also given to placing spread footings on an engineered fill pad but the geotechnical resistance of the underlying soils is relatively low and settlements under the footing load will be relatively large. Therefore, the option of spread footings on an engineered fill pad is not recommended for the support of the main structure at this site.

### **8.3 Augered Caissons (Drilled Shafts)**

Augered caisson foundations were also considered for the support of the structure. However, the overburden is not considered to be suitable for this scheme and the caissons must be founded on the bedrock at depths in the order of 34.5 to 37.2 m below original ground surface. The base of the caissons would be about 32 to 33 m below the groundwater level, resulting in high hydrostatic heads at the base.

The permeable nature of the overburden soil and the presence of boulders above the bedrock would make it difficult to seal the bottom of the caisson liner into the founding stratum to exclude groundwater. Unwatering of the caisson would be impractical and attempts to do so might result in continued flow of fines into the excavation.

Installation of deep caissons to bedrock is also expected to be a more expensive option than driven piles.

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

## 8.4 Driven Piles

The subsurface conditions at the site are considered suitable for the design of foundations supported on steel H-piles driven to achieve resistance in the very dense soil or on bedrock.

The bedrock is overlain by a layer of very dense sand with gravel, cobbles and boulders that varied in thickness up to 6 m at the north abutment and to between 4 and 6 m at the south abutment. The presence of this variable layer makes it difficult to predict the depth at which piles will achieve resistance. In some cases, resistance will be developed in the very dense soil but in other cases, piles may fully penetrate the soil layer and achieve resistance on the underlying bedrock. Consequently, it is recommended that the foundations be designed on the basis of the geotechnical resistance achieved by piles driven into the very dense soil. Piles reaching bedrock will develop a higher axial resistance than those stopping in the soil and thus the design assumption is safe.

Two steel pile sections believed to be currently available have been considered for use in the proposed foundations.

### 8.4.1 Axial Resistance

The factored, vertical, axial, geotechnical resistances for these pile sections when driven into very dense soil, and their approximate tip elevations, are presented in Table 8.1.

**Table 8.1 – Axial Resistance of Various Pile Sections**

Pile Section	Piles Driven Into Sand with Cobbles and Boulders			
	ULS (Factored)	SLS (25 mm Settlement)	Estimated Pile Tip Elevation	
			N. Abutment	S. Abutment
HP 310 X 110	1,800 kN	1,600 kN	315.4±	314.6±
HP 310 X 152	1,900 kN	1,700 kN	315.4±	314.6±

The structural resistance of the pile should be checked by the structural designer.

The pile tip elevations shown in Table 8.1 should be used for cost estimating purposes only. The actual pile tip elevations will be controlled as described in Section 8.4.4 Pile Driving.

### 8.4.2 Pile Tips

Due to the presence of cobbles and boulders in the expected founding layer, the tips of all piles should be fitted with cast steel, H-section rock points from an approved manufacturer such as Titus Steel (Standard H-point) or APF hard Bite or approved equivalent.

The use of rock points is recommended for the following reasons:

- The piles will be driven into soil containing cobbles and boulders, which requires a higher level of protection than driving into soils containing only smaller particle sizes

- Some piles may achieve refusal on large boulders, which will require the same pile tip protection and reinforcement as founding on bedrock
- Some piles may achieve resistance on the bedrock.

#### 8.4.3 Pile Installation

Pile installation should be in accordance with Special Provision No. 903S01.

The Contract Documents should contain a NSSP alerting the Bidders to:

- The presence of cobbles and boulders in the expected bearing stratum.
- The possibility of piles within a group achieving the specified resistance at different elevations.
- The possibility of some piles meeting refusal on a large boulder.

#### 8.4.4 Pile Driving

Pile driving 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 approaching the bearing stratum below Elevation 318 at the north abutment and 316 at the south abutment. The appropriate pile driving note is "Piles to be driven in accordance with Standard SS 103-11 using an ultimate resistance of "R" kN per pile".

"R" must have the minimum values shown in Table 8.2.

**Table 8.2 – Ultimate Geotechnical Resistance of Piles**

<b>Pile</b>	<b>Ultimate Resistance (R) (kN)</b>
HP 310X110	3,600 kN
HP 310X152	3,800 kN

The NSSP should require the QVE to terminate driving before the pile is damaged by overdriving.

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.

#### 8.4.5 Downdrag

Downdrag on the piles is not considered to be an issue at this site.

#### 8.4.6 Integral Abutment Considerations

The ground conditions at this site are considered suitable for an integral abutment design.

The integral abutment design requires that the piles possess flexibility in the upper 3 m of the pile length. The near surface, native soils at this site are loose to compact and the lateral resistance of a pile in this soil might provide sufficient flexibility. However, the upper 3 m of the pile may lie partially within the compacted fill of the approach embankment and partially in the underlying native soils, which may become densified under the embankment loading. Accordingly, to provide the required flexibility in the piles, the upper 3 m of the piles should be surrounded by a 600 mm diameter CSP as specified by the integral abutment design procedures.

After the pile is driven, the space between the pile and the CSP should be filled with sand. An NSSP should be included in the contract drawings specifying the gradation of the sand according to Table 8.3.

**Table 8.3 – Integral Abutment Sand Grading**

MTO Sieve Designation		Percentage Passing
2 mm	#10	100%
600 µm	#30	80%-100%
425 µm	#40	40%-80%
250 µm	#60	5%-25%
150 µm	#100	0%-6%

#### 8.4.7 Lateral Resistance

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

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

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

where

$$z = \text{depth of embedment of pile in metres}$$

$$D = \text{pile width in metres}$$

$$n_h = \text{coefficient of horizontal subgrade reaction (Table 8.4)}$$

$$\gamma = \text{unit weight (Table 8.4)}$$

$$K_p = \text{passive earth pressure coefficient}$$



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,  $K = k_s \times L \times D$  (kN/m), where  $k_s$  is the coefficient of horizontal subgrade reaction (kN/m<sup>3</sup>),  $D$  is the pile width (m) and  $L$  is the length (m) of the pile segment or element used in the analysis. The ultimate lateral resistance,  $P_{ult}$ , may be obtained from the expression,  $P_{ult} = p_{ult} \times L \times D$ .

**Table 8.4 – Recommended Soil Parameters**

Location	Elevation	$n_h$ (kN/m <sup>3</sup> )	$K_p$	Unit Weight* (kN/m <sup>3</sup> )	Soil Conditions
North Abutment BH 414-103 BH 414-104	OGL to 343.0	1,200	2.8	20	Sand and Sandy Silt
	343.0 to 337.0	1,200	3.0	10	Silt
	337.0 to 315.0	3,000	3.0	10	Sand
	Below 315.0	5,000	3.3	12	Sand, silt, cobbles and boulders, very dense
South Abutment BH 414-101 BH 414-102	OGL to 342.0	1,200	2.8	20	Silty sand
	342.0 to 320.0	2,000	3.0	10	Silt and sand
	320.0 to 315.0	3,000	3.0	10	Silt, compact
	Below 315.0	5,000	3.3	12	Sand, silt, cobbles and boulders, very dense

\*Buoyant unit weight below the water table.

Since the piles are end bearing on rock, the vertical resistance will not be significantly affected by the pile spacing. Pile interaction should be considered with reference to CHBDC Clause 6.8.9.2.

For lateral soil/pile group interaction analysis, the equation for  $k_s$  quoted above may be used in conjunction with appropriate reduction factors.

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.

For conventional abutments, the lateral resistance may be provided by battered piles.

### 8.5 Recommended Foundation

The use of H-piles at the abutments allows for the design of an integral abutment structure. From a geotechnical point of view, it is recommended that all foundations for the main bridge structure be supported on steel H-piles driven into the very dense soil or to bedrock.

### 8.6 Frost Cover

Pile caps and footings should be provided with a minimum of 1.9 m of earth cover over the footing base (founding elevation).

## 9 EXCAVATION

All excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the soils within the probable depth of excavation at this site may be classed as Type 3 soils above the water table and Type 4 soils below the water table. This classification is based on the lack of cohesion in the soils and the resulting possibility that excavation slopes will slough if excavated vertically for the lower 1.2 m. Excavation slopes should not exceed 1V:1H above the groundwater level.

Excavation below the groundwater level without prior dewatering is not recommended since the inflow of groundwater will cause boiling and sloughing of the soil below the water table making it difficult to maintain a dry, sound base on which to work.

Prior to excavation below the natural groundwater level, the groundwater must be depressed to a level below the deepest excavation level sufficient to maintain a stable base and prevent soil disturbance by construction traffic.

## 10 UNWATERING

Based on the preliminary GA for the bridge structure and the use of a piled foundation, it is not expected that work at the abutments will require excavation below the groundwater level.

However, the Contractor should be prepared to pump from sumps to remove any seepage water or surface water collecting in an excavation.

The design of the dewatering system that may be required should be the responsibility of the Contractor and the Contract Documents should alert him to this responsibility and the need to engage a dewatering specialist. While the responsibility for dewatering should remain with the Contractor, suitable systems that might be employed include pumping from filtered sumps for penetration of no more than 0.5 m below the groundwater level and the use of vacuum wellpoints for deeper penetration below the groundwater level.

## **11 APPROACH EMBANKMENTS**

Approach embankment construction using either earth fill or rock fill is feasible on the foundation soils encountered at this site. Settlement in the order of 100 to 150 mm will occur under the loading imposed by approximately 5 to 8 m of approach fill but due to the non-cohesive nature of the foundation soils, the settlement will be immediate and essentially complete when construction of the fill is completed.

The immediate approach embankments should be constructed using non-cohesive fill. The embankments will also experience settlement resulting from consolidation of the fill. This settlement is expected to be approximately 50 to 80 mm for 5 to 8 m high embankments. The settlement within the non-cohesive fill should be immediate in nature and essentially be complete shortly after construction has been completed.

The global, internal and surficial stability of the approach embankment fill will depend on the slope geometry and also to a large degree on the material used to construct the embankment. If the embankment is constructed of blast rock fill, it may be assumed that the side slopes will be stable at inclinations up to 1.25H:1V. Embankments constructed using granular material, select subgrade material or non-cohesive earth fill will have stable side slopes at inclinations of up to 2H:1V.

For the purpose of embankment stability analyses, the commercially available slope stability program GSLOPE developed by Mitre Software Inc. was used. The Bishop's simplified method for stability analysis was employed.

Global stability analyses were conducted for 2H:1V SSM or earth fill embankments and for 1.25H:1V rock fill embankments. The stability of the embankments was also checked under seismic loading assuming an acceleration of 0.18g. The computed factors of safety are as shown in Table 11.1.

**Table 11.1 Computed Factors of Safety**

<b>Location / Material</b>	<b>Condition</b>	<b>Factor of Safety</b>	<b>Figure</b>
<b>South Approach</b>			
Rock Fill	Normal	1.7	E1
Rock Fill	Seismic = 0.18g	1.2	E2
Earth Fill	Normal	1.5	E3
Earth Fill	Seismic = 0.18g	1.0	E4
<b>North Approach</b>			
Rock Fill	Normal	1.8	E5
Rock Fill	Seismic = 0.18g	1.3	E6
Earth Fill	Normal	1.7	E7
Earth Fill	Seismic = 0.18g	1.1	E8

In each case of normal loading, the factor of safety against global failure was greater than 1.5. Under the assumed seismic loading, the minimum factor of safety calculated was 1.0. These factors of safety are considered to be acceptable for the proposed embankment bearing on non-cohesive soil.

It is recommended that all topsoil and peat be stripped prior to constructing the approach fills. Embankment construction should be in accordance with OPSS 206, as amended by Special Provision "Amendment to OPSS 206, December 1993", dated November 2002.

The approach fills should be constructed in advance of pile driving operations.

Where earth fill embankments are higher than 6 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 6 m
- be at least 2 m wide
- have 2% positive drainage to shed run-off water.

Where rock fill embankments are higher than 6 m, mid-height berms should be incorporated in the design. The berms should:

- extend for the length through which the embankment height exceeds 6 m
- be at least 2 m wide

Earth fill embankment slopes must be provided with erosion protection in accordance with OPSS 572.

## **12 RETAINED SOIL SYSTEMS**

The General Arrangement drawings indicate that retaining walls may be used beyond both abutments to retain the forward slope of the approach fills. Retained soil system (RSS) walls may be used subject to the requirements presented in this section.

RSS walls should be specified to be “High Performance” and “High Appearance”. The contract drawings should include information on the longitudinal alignment of the wall in plan, the top and base elevations of the wall in profile, cross-sectional space constraints and an NSSP for the RSS wall.

### **12.1 Foundation**

The performance of a RSS is dependent, among other factors, on the characteristics of its foundation. Failure to provide an adequate foundation may lead to settlement and distortion of the RSS and, in severe cases, to possible failure of the system. The foundation of the entire RSS mass must be considered.

At this site, the foundation conditions under the entire width of the RSS mass must be considered, i.e. from the face of the wall to the furthest extent of the reinforcement.

All topsoil, peat and organic soil must be stripped from the area extending beyond the footprint of the RSS mass for a distance equal to the height of thickness of any engineered fill placed below the RSS.

To provide an acceptable foundation for this RSS mass, the following conditions must be met:

- All fill placed below the RSS mass must be OPSS Granular A engineered fill compacted to 100% of its SPMDD at  $\pm 2\%$  of optimum moisture content.
- The underside of the fill must be placed no higher than Elev. 341.5 m at the north abutment and Elev. 340.0 m at the south abutment.
- The geometry of the engineered fill must conform to the limits illustrated in Figure 1.

The subgrade should be competent and free of organics, soft or deleterious soils. The native soil under the RSS foundation should be re-compacted

Dewatering may be required to prepare the subgrade for placement and compaction of the engineered fill pads. The contractor must be prepared to install an appropriate dewatering system and to maintain the excavation in an unwatered condition.

The following parameters may be used for the design of the RSS:

- Ultimate coefficient of sliding resistance of cast in-situ concrete levelling pad on Granular A = 0.7

- Ultimate coefficient of sliding resistance of RSS mass on Granular A = 0.7

All topsoil, organics and soft soils should be removed from the subgrade of the RSS wall prior to placement of the fill.

The entire block of reinforced earth must also be designed against various modes of failure including sliding and overturning.

Settlement under a RSS mass constructed as outlined above is expected to be less than 25 mm and to occur essentially as the RSS is constructed.

## **12.2 Global Stability**

The global stability of the RSS wall is dependent on the characteristics of the embankment fill and the foundation soils, the geometry of the embankment and location of the RSS within the embankment.

RSS walls are likely to be used beyond both abutments. It is envisaged that the RSS will be founded on an engineered fill core as shown in Figure 1 and will be located up the slope in the embankment fill.

Stability analyses were carried out based on the following variables:

- RSS founded on engineered fill – Granular A or Granular B Type II compacted to 100% SPMDD at  $\pm 2\%$  optimum moisture content, with a slope of 2H:1V (angle of internal friction,  $\phi$ , of  $35^\circ$ , cohesion of 0, and unit weight,  $\gamma$ , of  $22.8 \text{ kN/m}^3$ ) immediately below the levelling pad and the RSS mass and Granular B as abutment backfill.
- Embankment fill behind the RSS is inclined at 2H:1V.
- Groundwater level at approximate Elev. 341 m

Analysis carried out on RSS walls located in the embankment fill indicates that the factor of safety for global stability is 1.2. This is the worst case, highest wall and an assumption of infinitely long wall. In reality the wall is of finite length, reducing in height, built against the abutment and returning on itself. With these conditions, the global stability of the RSS wall is considered to be satisfactory.

The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

## **12.3 Global Stability**

The global stability of the RSS wall is dependent on the characteristics of the embankment fill and the foundation soils, the geometry of the embankment and location of the RSS within the embankment.

RSS walls are likely to be used beyond both abutments. It is envisaged that the RSS will be founded on an engineered fill core as shown in Figure 1 and will be located up the slope in the embankment earth fill.

Stability analyses on selected configurations were carried out considering the following variables:

- RSS founded on engineered fill – Granular A compacted to 100% SPMDD at  $\pm 2\%$  optimum moisture content, with a slope of 2H:1V (angle of internal friction,  $\phi$ , of  $35^\circ$ , cohesion of 0, and unit weight,  $\gamma$ , of  $22.8 \text{ kN/m}^3$ ) immediately below the levelling pad and the RSS mass and earth fill beyond – outer slope of 2H:1V (angle of internal friction,  $\phi$ , of  $30^\circ$ , cohesion of 0, and unit weight,  $\gamma$ , of  $19 \text{ kN/m}^3$ ).
- Embankment fill behind the RSS is inclined at 2H:1V.
- Groundwater level at Elev. 341 m at the north abutment location and Elev. 342 m at the south abutment location.

Analysis carried out on RSS walls located in the embankment earth fill indicate that anchor lengths of up to 1.3 times the wall height are required to achieve an acceptable factor of safety of 1.3.

Consequently, if the RSS wall has to be founded in the embankment slope, the specific geometry and soil conditions must be analyzed to determine the requirements for global stability. The actual design configuration must be checked for global stability prior to finalization.

The internal stability of the RSS wall should be analyzed by the supplier/designer of the proprietary product selected for this site.

### **13 BACKFILL TO ABUTMENTS**

In the case of integral or semi-integral abutments, backfill to the abutment should be granular material.

In the case of a conventional abutment, granular backfill is recommended but rock backfill can be permitted. A NSSP is required to specify grading limits for the rock fill. The rock fill used as backfill to the abutment should be limited to fragments no greater than 75 mm.

In all cases where the approach embankment consists of rock fill and granular backfill to the abutment wall is used, the granular backfill must consist of OPSS Granular "B" Type II.

The backfill to the abutment walls must be in accordance with OPSS 902 as amended by Special Provision 902S01. Granular backfill must be placed to the extents shown in OPSD 3501.000, and

rock backfill must be placed to the extents shown in OPSD 3505.000. All granular material should meet the requirements of SP 110F13 Amendment to OPSS 1010, March 1993.

Compaction equipment to be used adjacent to retaining structures must be restricted in accordance with SSP 105S10.

The design of the abutment must incorporate a subdrain as shown in OPSD 3501.000 or OPSD 3505.000, as applicable.

## **14 EARTH PRESSURE**

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

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

Where:

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

$K$  = earth pressure coefficient (see table below)

$\gamma$  = 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)

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.

Earth pressure coefficients for backfill to the abutment wall are dependent on the material used as backfill. Typical values are shown in Table 14.1.

In conventional design, the use of a material with a high friction angle and low active pressure coefficient (e.g. Granular A, Granular B Type II) might be preferred as it results in lower earth pressures acting on the wall. In the case of integral abutments, material with a lower passive pressure coefficient (e.g. Granular B Type I) might be preferred as it results in lower forces acting on the ballast wall as the wall moves toward the soil mass.

The factors in Table 14.1 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 C6.9.1 (a) in the Commentary to the Canadian Highway Bridge Design Code.



**Table 14.1 – Earth Pressure Coefficient (K)**

Condition	Earth Pressure Coefficient (K)					
	OPSS Granular A or OPSS Granular B Type II $\phi = 35^\circ, \gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ, \gamma = 21.2 \text{ kN/m}^3$		Rock Fill (Limited to 300 mm size) $\phi = 42^\circ, \gamma = 19 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall(2H:1 V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall(2H:1 V)
Active (Unrestrained Wall)	0.27	0.40*	0.31	0.48*	0.2	.28*
At rest (Restrained Wall)	0.43	-	0.47	-	.33	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	5.0	-

\* For wing walls.

## 15 SEISMIC CONSIDERATIONS

### 15.1 Seismic Design Parameters

The site is treated as lying in Seismic Zone 2. The following seismic parameters should be used for design:

- Velocity Related Seismic Zone 2
- Zonal Velocity Ratio 0.1
- Acceleration Related Seismic Zone 2
- Zonal Acceleration Ratio 0.1
- Peak Horizontal Acceleration 0.11

The soil profile type at this site has been classified as Type I. Therefore, according to Table 4.4.6.1 of the CHBDC, a Site Coefficient “S” (ground motion amplification factor) of 1.0 should be used in seismic design.

## 15.2 Liquefaction Potential

The potential for liquefaction of the foundations soils was assessed using the Seed and Idriss (1971) method<sup>1</sup>.

Using this method, it is estimated that under the existing conditions the foundation soils at both abutments are not prone to liquefaction. At the abutments, the approach embankments will increase the effective stress on the soil under the embankment and around the piles and as a result, liquefaction at the foundation is not considered to be likely.

The foundation loads will be transferred by steel piles to very dense sand with cobbles and boulders, or possibly to bedrock. In either case, it is not considered likely that the vertical geotechnical resistance of the piles will be compromised.

## 15.3 Retaining Wall Dynamic Earth Pressures

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.

In calculating the active, passive and at rest earth pressure coefficients the angle of friction between the wall and backfill material is assumed to be  $0.5 \phi$ . For the design of retaining walls, the coefficients of horizontal earth pressure in Table 15.1 may be used:

**Table 15.1 – Earth Pressure Coefficient for Earthquake Loading**

Earth Pressure Coefficient (K) for Earthquake Loading						
Wall Condition	Granular A or Granular B Type II $\phi = 35^\circ$ ; $\delta = 17.5^\circ$ $\gamma = 22.8 \text{ kN/m}^3$		OPSS Granular B Type I $\phi = 32^\circ$ ; $\delta = 16^\circ$ $\gamma = 21.2 \text{ kN/m}^3$		Rock Fill $\phi = 42^\circ$ ; $\delta = 21^\circ$ $\gamma = 19.0 \text{ kN/m}^3$	
	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)	Horizontal Surface Behind Wall	Sloping Surface Behind Wall (2H:1V)
Active ( $K_{AE}$ )*	0.3	0.45	0.33	0.54	0.23	0.31
Passive ( $K_{PE}$ )	6.3	6.3	5.4	5.4	12.0	12.0
At Rest ( $K_{OE}$ )**	0.59		0.63		0.33	

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

\*\* After Woods

<sup>1</sup> Seed, H.B. and Idriss, I.M. 1971, "Simplified Procedure for Evaluating Soil Liquefaction Potential" *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 101, No. SM9, September, pp. 1249-1273.

## 16 CONSTRUCTION CONCERNS

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

- The possibility of piles reaching refusal on large boulders. In this case, the Hiley formula is not appropriate and site staff must make a decision regarding pile resistance and the appropriateness of continued driving.
- The potential variability of pile lengths at refusal.
- Unwatering in the case of excavations that must penetrate below the groundwater level

## 17 CLOSURE

Engineering analysis and preparation of the report were carried out by Mr. Alastair E. Gorman, P.Eng.

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

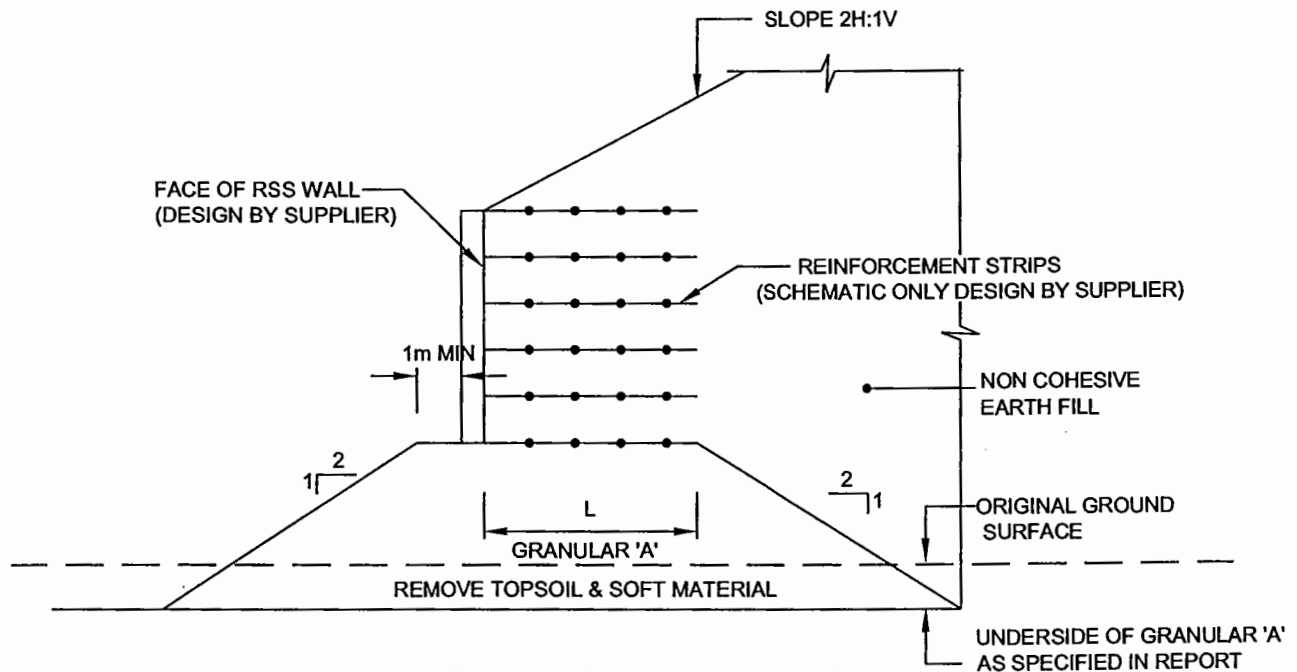
Thurber Engineering Ltd.

Alastair E. Gorman, P.Eng., M.Sc.  
Senior Foundations Engineer



Report reviewed by:  
P.K. Chatterji, P.Eng., Ph.D.  
Review Principal

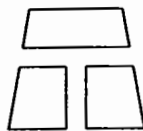




**LONGITUDINAL SECTION**  
**NOT TO SCALE**

**NOTES:**

1. REMOVE TOPSOIL AND OR SOFT SUBSOIL UNDER AREA OF COMPACTED GRANULAR 'A' AND EARTH FILL.
2. PLACE GRANULAR 'A' BELOW PLAN AREA OF RSS MASS.
3. CONSTRUCT RSS MASS
4. PLACE REMAINDER OF GRANULAR 'A' AND EARTH FILL AS REQUIRED.
5. MODIFIED FROM M.T.C 1982.

ENGINEER	AEG	 <b>THURBER</b>
DRAWN	SS	
DATE	MAR. 2006	
APPROVED	PKC	
SCALE	NTS	
RSS MASS ON COMPACTED FILL SHOWING GRANULAR A CORE		DWG. NO. FIGURE 1

**Appendix A**

**Record of Borehole Sheets**

# RECORD OF BOREHOLE No 414-101

1 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 419.9 E 312 856.5 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 18.10.05 - 20.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
344.0												
0.0	TOPSOIL (50mm)		1	SS	20		344					
0.1	Silty SAND, fine grained Compact Brown Dry to Wet		2	SS	23		343					
			3	SS	23		342					
341.7			4	SS	18		341					
2.3	SILT, trace to some sand, trace clay Compact Brown Wet		5	SS	25		340					
			6	SS	50		339					
	Becoming Very Dense		7	SS	63		338					
			8	SS	45		337					
336.3			9	SS	66		336					
7.6	Silty SAND, fine to medium grained Very Dense to Dense Brown Wet						335					

Continued Next Page

+<sup>3</sup> ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 414-101

3 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 419.9 E 312 856.5 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 18.10.05 - 20.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	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					
			16	SS	44		324							
							323							
							322							
			17	SS	66		321							
							320							
							319							
			18	SS	54		318							
							317							
							316							
315.6							315							
28.3	SAND, trace silt, trace gravel, occasional cobbles Brown Wer		19	SS	100	.025								

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

ONTMT4S 414.GPJ 15/03/06








# RECORD OF BOREHOLE No 414-101

4 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 419.9 E 312 856.5 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 18.10.05 - 20.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa								WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE	×						
								● QUICK TRIAXIAL	×	LAB VANE						
							20 40 60 80 100									
313.2							314									
30.8 312.9	BOULDER						313									
31.1	SAND, trace silt Compact Brown Wet		20	SS	30		312									
310.7							311									
33.2	BOULDER						310									
310.3							309									
33.7	SAND, some gravel, trace silt, occasional cobbles Very Dense Brown Wet		21	SS	92		308									
308.0							307									
36.0	GNEISS BEDROCK Fresh to slightly weathered, thinly bedded, pink with black subvertical banding		1	RUN			306									
			2	RUN												
			3	RUN												
304.9																
39.0	END OF BOREHOLE AT 39.01m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 3.05m slotted screen.															

Continued Next Page

+<sup>3</sup> × 3<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

ONTMT4S 414.GPJ 15/03/06

RECORD OF BOREHOLE No 414-101

5 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 419.9 E 312 856.5 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 18.10.05 - 20.10.05 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa					WATER CONTENT (%)			
						20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100					W <sub>p</sub> W W <sub>L</sub> 20 40 60					
WATER LEVEL READINGS: DATE DEPTH(m) Oct. 22, 05 2.09 Oct. 24, 05 2.34 Oct. 26, 05 2.23 Oct. 27, 05 2.26 Nov. 5, 05 2.07 Nov. 7, 05 2.06 Nov. 15, 05 2.17 Nov. 17, 05 2.15 Nov. 21, 05 2.19 Nov. 23, 05 2.16																

ONTMT4S 414.GPJ 15/03/06



# RECORD OF BOREHOLE No 414-102

2 OF 4

METRIC

W.P. 750-93-01 LOCATION N 5 077 424.4 E 312 868.3 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 07.11.05 - 09.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	Becoming Compact		8	SS	24		333							
							332							
							331							
			9	SS	28		330							
							329							
							328							
			10	SS	26		327							
							326							
							325							
							324							

Continued Next Page

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

# RECORD OF BOREHOLE No 414-102

3 OF 4

METRIC

W.P. 750-93-01 LOCATION N 5 077 424.4 E 312 868.3 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 07.11.05 - 09.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
321.7																	
21.8	SAND, fine grained, trace to some silt Compact Brown Wet																
	occasional silt pockets		11	SS	29											0 72 28 (SI+CL)	
	Occasional cobbles																
	Very Loose		12	SS	1												
315.7																	
315.8	Boulder		1	RUN													
28.0	Compact		13	SS	16												
313.6			14	SS	50/												

Continued Next Page

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

ONTMT4S 414.GPJ 15/03/06

# RECORD OF BOREHOLE No 414-102

4 OF 4

METRIC

W.P. 750-93-01 LOCATION N 5 077 424.4 E 312 868.3 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 07.11.05 - 09.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT  γ  kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED      + FIELD VANE ● QUICK TRIAXIAL    × LAB VANE								
							20	40	60	80	100					
323.5	BOULDER				.000											
30.0	SAND, some gravel, trace silt, occasional cobbles Brown Wet		2	RUN												
312.8																
30.8	BOULDER															
312.5																
31.0																
312.1			15	SS	50/											
31.4	BOULDER				.000											
311.8																
31.7			3	RUN												
			4	RUN												
309.0																
34.5	GNEISS BEDROCK Fresh to slightly weathered, thinly bedded, pink with black subvertical banding		5	RUN											FI	RUN 5# TCR=100%, SCR=100%, RQD=100%, UCS=160MPa

ONTMT4S 414.GPJ 15/03/06

# RECORD OF BOREHOLE No 414-103

1 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 450.8 E 312 845.0 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 01.11.05 - 03.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
346.5												
0.0	Silty <b>SAND</b> , fine grained Compact Brown Dry		1	SS	12		346					
345.8												
0.7	Sandy <b>SILT</b> Loose Brown Dry		2	SS	6		345					
345.0												
1.5	<b>SILT and SAND</b> , trace clay Very Loose Brown Dry  Becoming Compact		3	SS	3		344					0 35 63 2
			4	SS	16		343					
			5	SS	25		342					
342.5	Becoming Wet						341					
4.0	<b>SILT</b> , trace to some sand, trace clay Compact Brown Wet		6	SS	25		340					0 7 91 2
			7	SS	24		339					
			8	SS	21		338					
			9	SS	21		337					
	Becoming Dense											

Continued Next Page

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

# RECORD OF BOREHOLE No 414-103

2 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 450.8 E 312 845.0 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 01.11.05 - 03.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
								SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE				
								20 40 60 80 100				
			10	SS	40		336					
							335					
			11	SS	37							0 13 85 2
							334					
			12	SS	41		333					
							332					
331.7			13	SS	100/ 250		331					
14.8	SAND and SILT Very Dense to Dense Brown Wet		14	SS	65		330					
							329					
			15	SS	46		328					0 58 42 (SI+CL)
							327					
			16	SS	60							

Continued Next Page


+<sup>3</sup> ×<sup>3</sup>: 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 LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE			"N" VALUES			
							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 20 40 60		

[illegible]

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-103

4 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 450.8 E 312 845.0 Ottawa Avenue SBL ORIGINATED BY MEF  
HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
DATUM Geodetic DATE 01.11.05 - 03.11.05 CHECKED BY AEG

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 <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR   SA   SI   CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa			WATER CONTENT (%)				
								○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE	w <sub>p</sub>	w		
						20	40	60	80	100	20	40	60		

RUN 5#  
TCR=100%,  
SCR=88%,  
RQD=0%,  
UCS=MPa

FI  
5  
4  
1  
0  
2  
5  
>10  
>10  
3

RUN 6#  
TCR=100%,  
SCR=89%,  
RQD=73%,  
UCS=201MPa

RUN 7#  
TCR=100%,  
SCR=100%,  
RQD=0%,  
UCS=MPa  
RUN 8#  
TCR=100%,

Continued Next Page

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-103

5 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 450.8 E 312 845.0 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 01.11.05 - 03.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
306.0																	
40.5	END OF BOREHOLE AT 40.51m. BOREHOLE OPEN TO 3.0 m UPON COMPLETION. BOREHOLE BACKFILLED WITH BENTONITE HOLEPLUG AND DRILL CUTTINGS TO SURFACE.						306										

ONTMT4S 414.GPJ 15/03/06

+<sup>3</sup> ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-104

1 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 454.6 E 312 836.7 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 03.11.05 - 05.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	× LAB VANE						
345.4							20 40 60 80 100	20 40 60							
0.0	SAND and SILT, fine grained Loose Brown Moist		1	SS	6		345								
344.3															
1.1	Sandy SILT, trace clay Compact Brown Moist		2	SS	22		344								
							343								
342.4			3	SS	29		342							0 21 77 2	
3.0	SILT, trace to some sand, trace clay Dense Brown Wet						341								
			4	SS	30		340								
							339								
			5	SS	31		338								
							337								
			6	SS	32		336							0 9 88 3	
	Becoming Very Dense to Dense		7	SS	65										

Continued Next Page

+ 3 . × 3 : Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-104

2 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 454.6 E 312 836.7 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 03.11.05 - 05.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES								
332.2			8	SS	40								0 8 90 2
13.2	SAND, some silt Dense to Very Dense Brown Wet		9	SS	42								
			10	SS	42								
			11	SS	54								0 87 13 (SI+CL)

Continued Next Page

+ 3 . X 3 : Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 414-104

4 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 454.6 E 312 836.7 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 03.11.05 - 05.11.05 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE LIMIT CONTENT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH m	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		SHEAR STRENGTH kPa				W <sub>p</sub>	W	W <sub>L</sub>		
							20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
			15	SS	50/ .125										
			1	RUN		315									
			16	SS	50/ .000	314									
			2	RUN		313									
			17	SS	50/ .000	312									
311.9			3	RUN		311									
311.7	BOULDER														
311.3															
311.0	BOULDER														
310.0			18	SS	50/ .100	310									
309.3	GNEISS BEDROCK Fresh to slightly weathered, thinly bedded, pink with black subvertical banding		4	RUN		309									
			5	RUN		308									
			6	RUN		307									
306.1															
306.1	END OF BOREHOLE AT 39.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.														

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-104

5 OF 5

METRIC

W.P. 750-93-01 LOCATION N 5 077 454.6 E 312 836.7 Ottawa Avenue SBL ORIGINATED BY MEF  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing/NQ Core Barrel/Dynamic Cone COMPILED BY HS  
 DATUM Geodetic DATE 03.11.05 - 05.11.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa	WATER CONTENT (%)					
	WATER LEVEL READINGS: DATE DEPTH(m) Nov. 5, 05 4.10 Nov. 7, 05 4.20 Nov. 15, 05 4.29 Nov. 17, 05 4.28 Nov. 21, 05 4.41 Nov. 23, 05 4.38													



## METRIC

[illegible]

+ 3, X 3: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 414-105

2 OF 2

METRIC

W.P. 750-93-01 LOCATION N 5 077 402.2 E 312 864.0 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY HS  
 DATUM Geodetic DATE 24.10.05 - 24.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
			10	SS	28												
	Becoming very dense																
333.3			11	SS	59												
12.0	END OF BOREHOLE AT 12.04m. BOREHOLE OPEN TO BOTTOM AND WATER LEVEL AT 3.0m UPON COMPLETION. BOREHOLE GROUTED WITH BENTONITE TO SURFACE.																

+<sup>3</sup>, ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-106

1 OF 2

METRIC

W.P. 750-93-01 LOCATION N 5 077 471.7 E 312 844.2 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY HS  
 DATUM Geodetic DATE 27.10.05 - 27.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
344.1								SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								WATER CONTENT (%)						
								20	40	60				
0.0	SAND, fine grained, trace silt Compact Brown Dry		1	SS	12		344							
			2	SS	15		343							
			3	SS	13		342							
341.8			4	SS	19		341							
2.3	SILT, trace to some sand, trace clay Compact Brown Wet		5	SS	16		340							
			6	SS	22		339							
338.6			7	SS	15		338							
5.5	SILT, some sand to sandy, trace clay Compact Brown Wet		8	SS	23		337							
			9	SS	34		336							
	Becoming dense						335							

Continued Next Page

+<sup>3</sup> ×<sup>3</sup>: Numbers refer to  
Sensitivity

20  
15-5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 414-106

2 OF 2

METRIC

W.P. 750-93-01 LOCATION N 5 077 471.7 E 312 844.2 Ottawa Avenue SBL ORIGINATED BY GA  
 HWY 11 BOREHOLE TYPE Hollow Stem Augers/NW Casing COMPILED BY HS  
 DATUM Geodetic DATE 27.10.05 - 27.10.05 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
								SHEAR STRENGTH kPa						
								○ UNCONFINED + FIELD VANE						
								● QUICK TRIAXIAL × LAB VANE						
								20	40	60	80	100		
								WATER CONTENT (%)						
								PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
								W <sub>P</sub> W W <sub>L</sub>						
								20 40 60						
332.1			10	SS	39		334							0 17 81 2
	Becoming very dense						333							
12.0	END OF BOREHOLE AT 12.04m. BOREHOLE OPEN TO BOTTOM AND WATER LEVEL AT 2.13m UPON COMPLETION. BOREHOLE GROUTED WITH BENTONITE TO SURFACE.		11	SS	50									

## **Appendix B**

### **Laboratory Test Results**

DRAFT

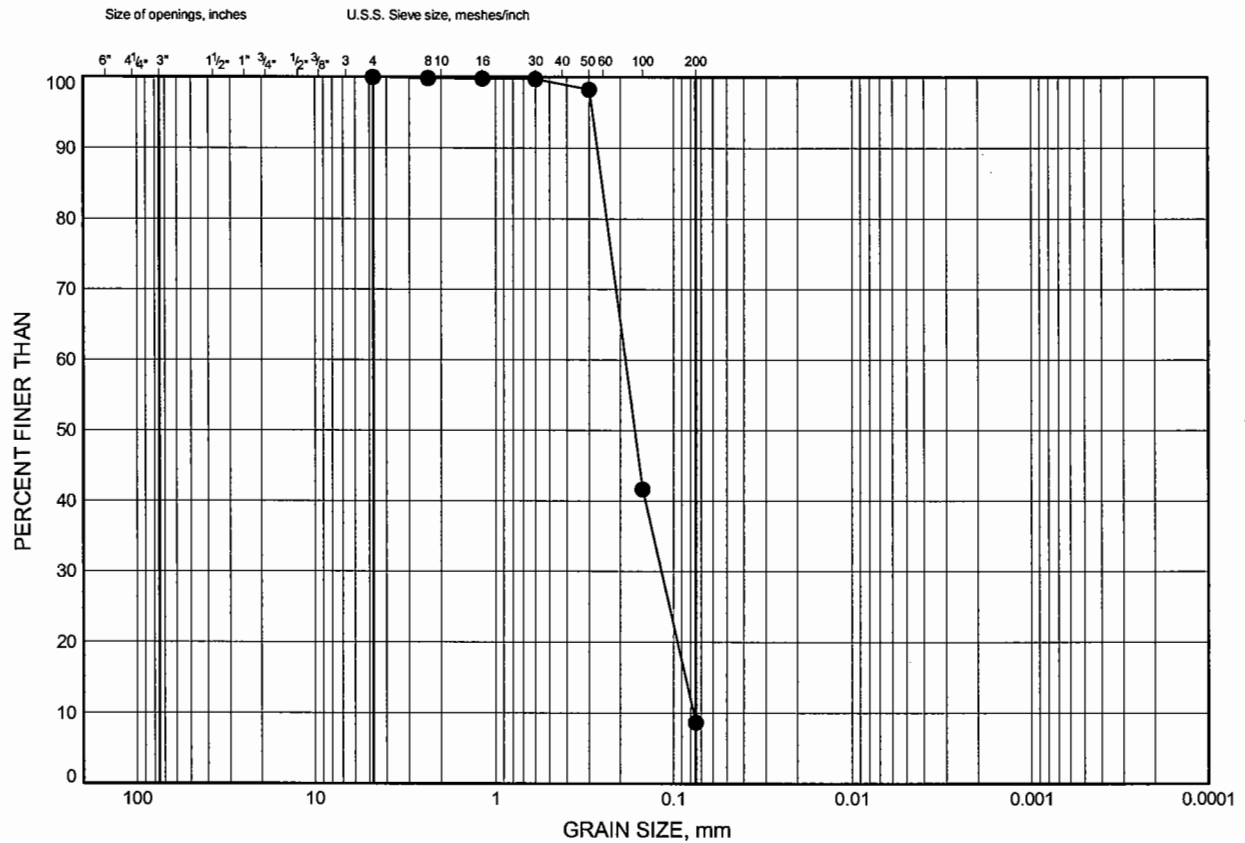


# Hwy 11 Four Laning

## GRAIN SIZE DISTRIBUTION

FIGURE B1

### FILL

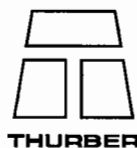


COBBLE SIZE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT and CLAY
	GRAVEL		SAND			FINE GRAINED

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	414-105	2.59	342.75

Date March 2006

Project 749-93-01



Prep'd JHL

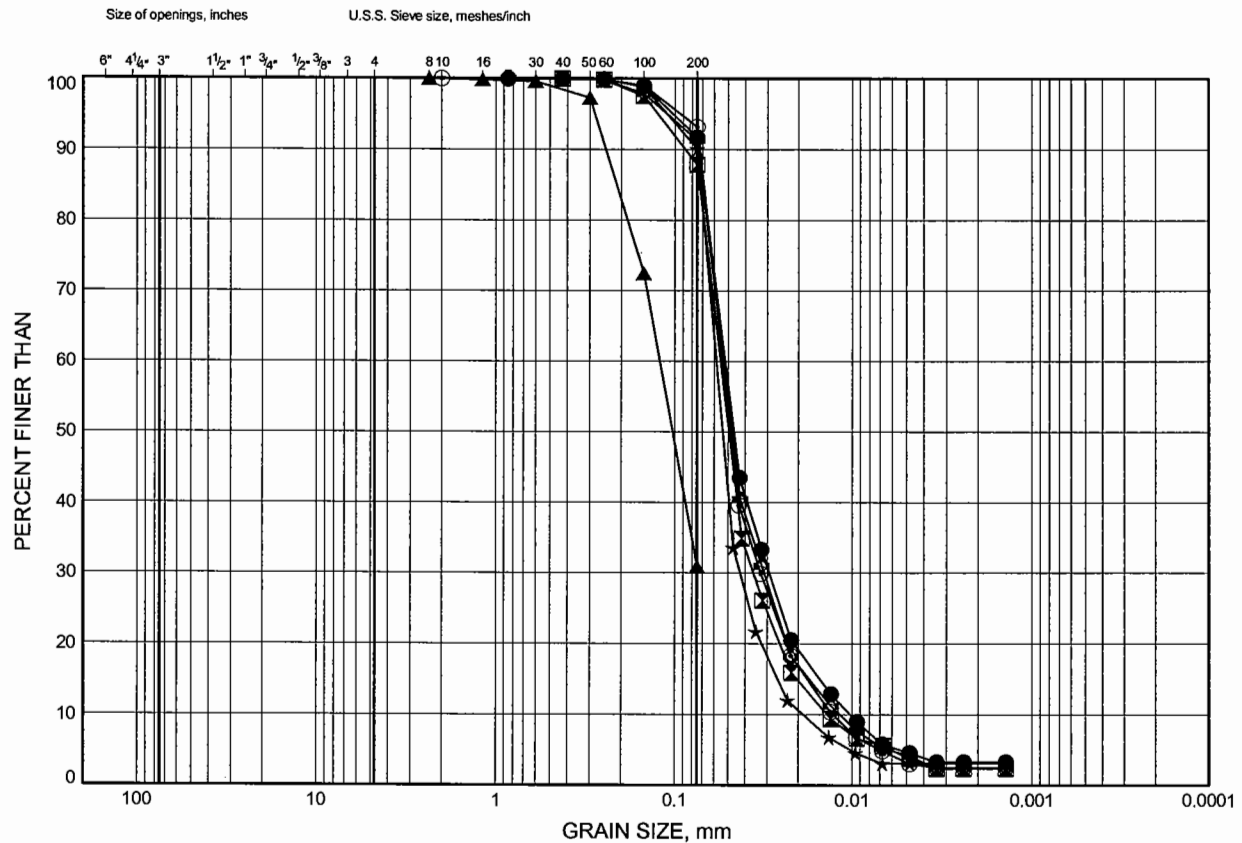
Chkd. MEF



# Hwy 11 Four Laning GRAIN SIZE DISTRIBUTION

FIGURE B3

## SILT TO SILTY SAND



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	414-101	2.59	341.36
⊠	414-101	6.40	337.55
▲	414-101	10.97	332.98
★	414-101	15.47	328.48
⊙	414-102	2.79	340.75
⊕	414-102	8.89	334.65

Date March 2006

Project 749-93-01



Prep'd JHL

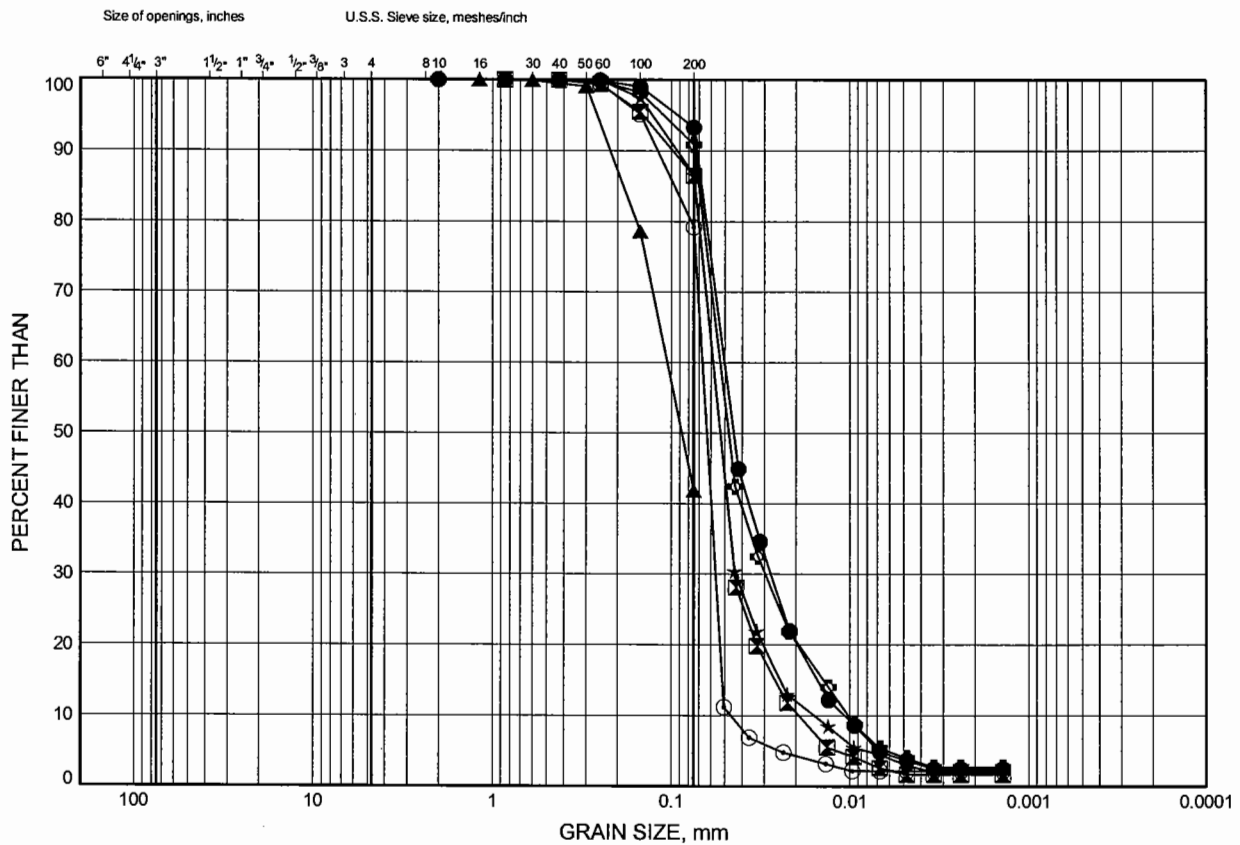
Chkd. MEF



# Hwy 11 Four Laning GRAIN SIZE DISTRIBUTION

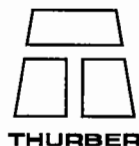
FIGURE B4

## SILT TO SILTY SAND



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	414-103	5.92	340.58
⊠	414-103	12.02	334.48
▲	414-103	18.11	328.39
★	414-103	28.78	317.72
⊙	414-104	2.87	342.53
⊕	414-104	7.44	337.96

Date March 2006  
Project 749-93-01

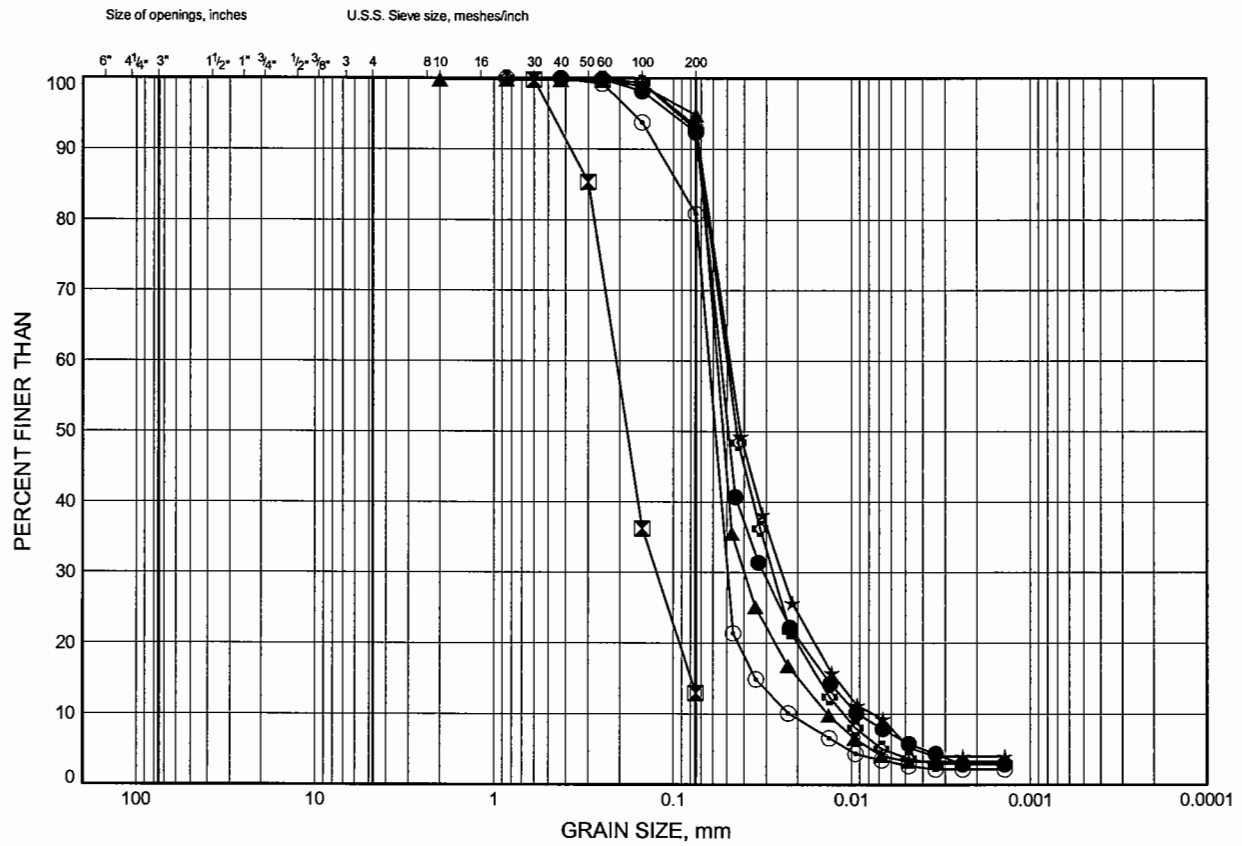


Prep'd JHL  
Chkd. MEF

# Hwy 11 Four Laning GRAIN SIZE DISTRIBUTION

FIGURE B5

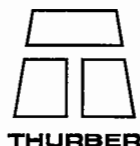
## SILT TO SILTY SAND



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	414-104	10.49	334.91
⊠	414-104	19.64	325.76
▲	414-104	25.73	319.67
★	414-105	5.72	339.62
⊙	414-105	8.76	336.57
⊕	414-106	2.51	341.59

Date March 2006  
Project 749-93-01



Prep'd JHL  
Chkd. MEF

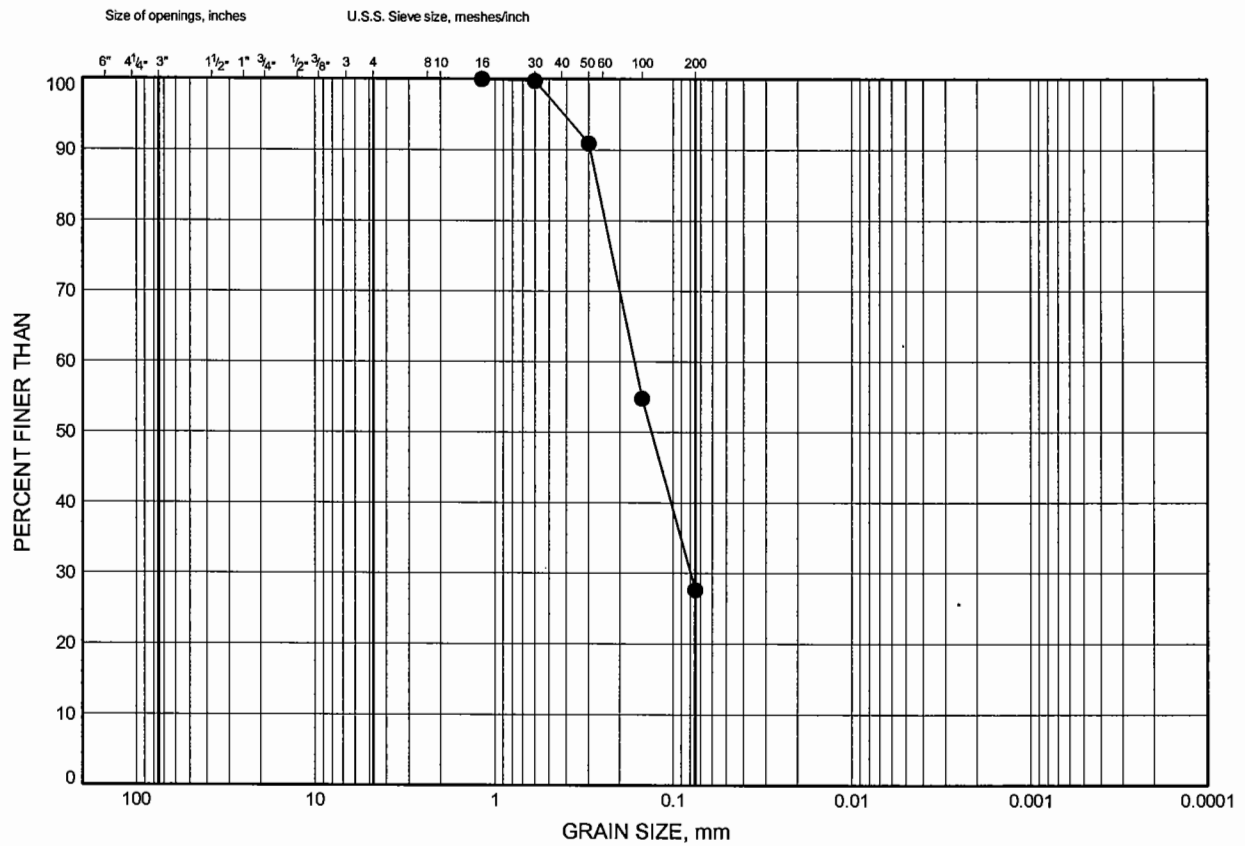


# Hwy 11 Four Laning

## GRAIN SIZE DISTRIBUTION

FIGURE B7

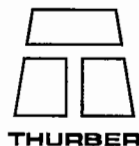
### SAND



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

SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	414-102	22.60	320.94

Date March 2006  
Project 749-93-01



Prep'd JHL  
Chkd. MEF

**TABLE B1 - Point Load Test Results  
Ottawa Avenue Overpass SBL**

RUN	Depth			Is50	UCS (MPa)					
	feet	Inches	m							
414-101										
1	119	0	36.27	7.05	169.12	}	Total Rock Core			
	120	0	36.58	6.94	166.52		Average	Minimum	Maximum	MPa
	121	6	37.03	8.67	208.14		185	164	208	
2	122	6	37.34	8.46	202.94	}	Run #	Average		
	123	7	37.67	8.24	197.74		1	181.26		
	124	7	37.97	8.67	208.14		2	193.18		
3	125	11	38.38	6.83	163.91	}	2	193.18		
	127	5	38.84	6.83	163.91		3	163.91		

RUN	Depth			Is50	UCS (MPa)					
	feet	Inches	m							
414-102										
5	113	8	34.65	6.18	148.30	}	Total Rock Core			MPa
	114	6	34.90	6.50	156.11		Average	Minimum	Maximum	
	115	5	35.18	7.37	176.92		149	83	182	
	115	10	35.31	4.99	119.68					
	116	6	35.51	7.59	182.13					
6	117	10	35.92	7.37	176.92	}	Run #	Average		
	118	9	36.20	7.48	179.52		5	160.01		
	119	9	36.50	3.47	83.26		6	135.20		
	120	10	36.83	4.77	114.48					
	121	5	37.01	6.81	163.45					
	121	10	37.13	5.64	135.29					

RUN	Depth			Is50	UCS (MPa)					
	feet	Inches	m							
414-103										
6	124	3	37.87	6.83	163.91	}	Total Rock Core			MPa
	125	7	38.28	9.21	221.15		Average	Minimum	Maximum	
	126	4	38.51	9.11	218.55		172	62	221	
	129	11	39.60	2.60	62.44					
8	131	1	39.95	6.46	155.07	}	Run #	Average		
	132	0	40.23	7.37	176.92		6	201.21		
	132	6	40.39	8.72	209.18		8	150.90		

RUN	Depth			Is50	UCS (MPa)				
	feet	Inches	m						
414-104									
4	116	5	35.48	4.77	114.48	Total Rock Core			
	117	9	35.89	7.59	182.13				
5	121	0	36.88	6.50	156.11	Average	Minimum	Maximum	MPa
	122	0	37.19	6.50	156.11	155	114	210	
6	123	5	37.62	6.94	166.52	Run #	Average		
	124	2	37.85	5.29	126.97	4	148.30		
	125	4	38.20	6.94	166.52	5	159.58		
	126	5	38.53	8.76	210.23	6	154.62		
	127	8	38.91	4.77	114.48				
	127	8	38.91	7.48	179.46				
	128	8	39.22	5.42	130.09				

## **Appendix C**

### **Foundation Comparison**

**COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT**

Foundation Element	Driven Piles	Augered Caissons	Footings on Native Soil	Footings on Engineered Fill
North & South Abutment	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance available by driving piles to achieve resistance in the very dense soil overlying bedrock.</li> <li>ii. Allows choice of conventional, integral or semi-integral abutment design.</li> <li>iii. Readily installed.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost compared to footings.</li> <li>ii. Construction concerns related to the possibility of piles being obstructed by a boulder during driving.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. High geotechnical resistance available for units founded in very dense soil or on bedrock.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Higher unit cost compared to other foundation options such as footings or driven piles.</li> <li>ii. High risks associated with inflow of groundwater and soil fines.</li> <li>iii. Relatively high construction effort required to install caissons to bedrock compared to driven piles.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Economical to install.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Comparatively longer abutment stem.</li> <li>ii. Low geotechnical resistance may result in uneconomically large footing sizes.</li> <li>iii. Potential for unacceptable settlements.</li> </ul>	<p><b>Advantages:</b></p> <ul style="list-style-type: none"> <li>i. Possibility of shortening the abutment height.</li> <li>ii. Higher geotechnical resistance than is available on native soil.</li> <li>iii. Lower cost compared to deep foundations.</li> <li>iv. Allows use of perched abutments.</li> <li>v. Allows choice of semi-integral abutment.</li> </ul> <p><b>Disadvantages:</b></p> <ul style="list-style-type: none"> <li>i. Lower geotechnical resistance than piles.</li> <li>ii. High cost of constructing engineered fill.</li> <li>iii. Footings have to be placed further away from Ottawa Ave. to accommodate forward slope of fill.</li> <li>iv. Potential for unacceptable settlements.</li> </ul>
	<b>RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>	<b>NOT RECOMMENDED</b>

## **Appendix D**

### **NSSP's**



The following Special provisions are referenced in this report:

- Amendment to OPSS 206, December 1993
- Special Provision 599S22
- Special Provision No. 902S01
- Special Provision No. 903S01

Suggested text for a NSSP on Pile Installation should contain the following:

*“The soil overlying the bedrock contains cobbles and boulders, particularly below Elevation 275. The presence of cobbles and boulders will potentially have an impact on the installation of piles at the site. Some possible impacts that must be taken into consideration include, but are not necessarily limited to:*

- *The cobbles and boulders may impede the driving of the piles resulting in more arduous driving*
- *Some piles may meet refusal on boulders that are large enough not to be dislodged or broken by the pile driving*
- *As a result of the presence of boulders, piles may meet refusal at varying depths*
- *Pile driving must be controlled according to the criteria specified for the site*
- *If a pile meets refusal at a depth less than the anticipated depth, the QVE must terminate driving before the pile is damaged due to over-driving*

Suggested text for a NSSP on Dewatering should contain the following:

*“The soils underlying this site are cohesionless in nature and the observed groundwater table lies close to the surface. Excavation below the groundwater level is expected to lead to instability and slough of the sides of the excavation and boiling of the base, accompanied by loss in geotechnical resistance of the soils. If excavation is required to be carried out below the groundwater level prevailing at the time of construction, appropriate means of dewatering must be implemented to depress the groundwater level sufficiently far below the base of the excavation to prevent any instability, sloughing, or boiling and so as to preserve the stability of the excavation and to allow the work to proceed in the dry.”*

## **Appendix E**

### **Slope Stability Output**

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 South Approach Rock fill

	Gamma C	Phi	Min	Piezo
	kN/m <sup>3</sup>	deg	c/p	Surf.
Rock Fill	20	45	0	1
Silty Sand	21	30	0	1

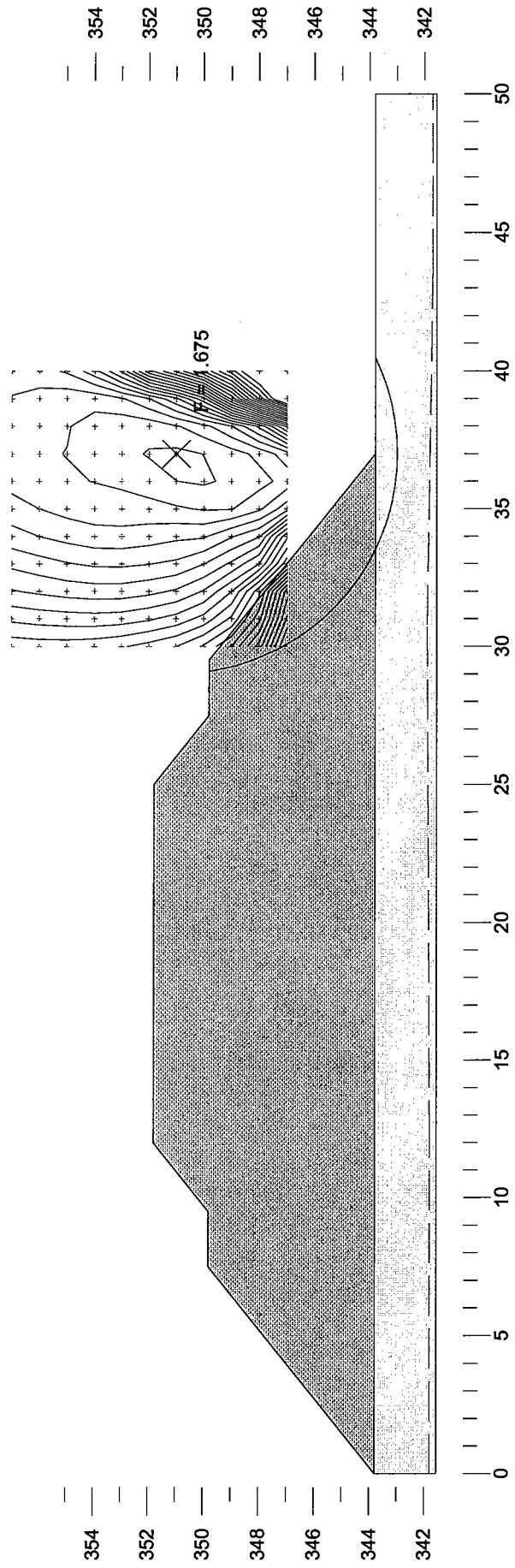


Figure E1

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 South Approach Rock fill  
 Seismic 0.18

	Gamma C	Phi	Min	Piezo
	kN/m <sup>3</sup>	deg	c/p	Surf.
Rock Fill	20	45	0	1
Silty Sand	21	30	0	1
Seismic coefficient = 0.18				

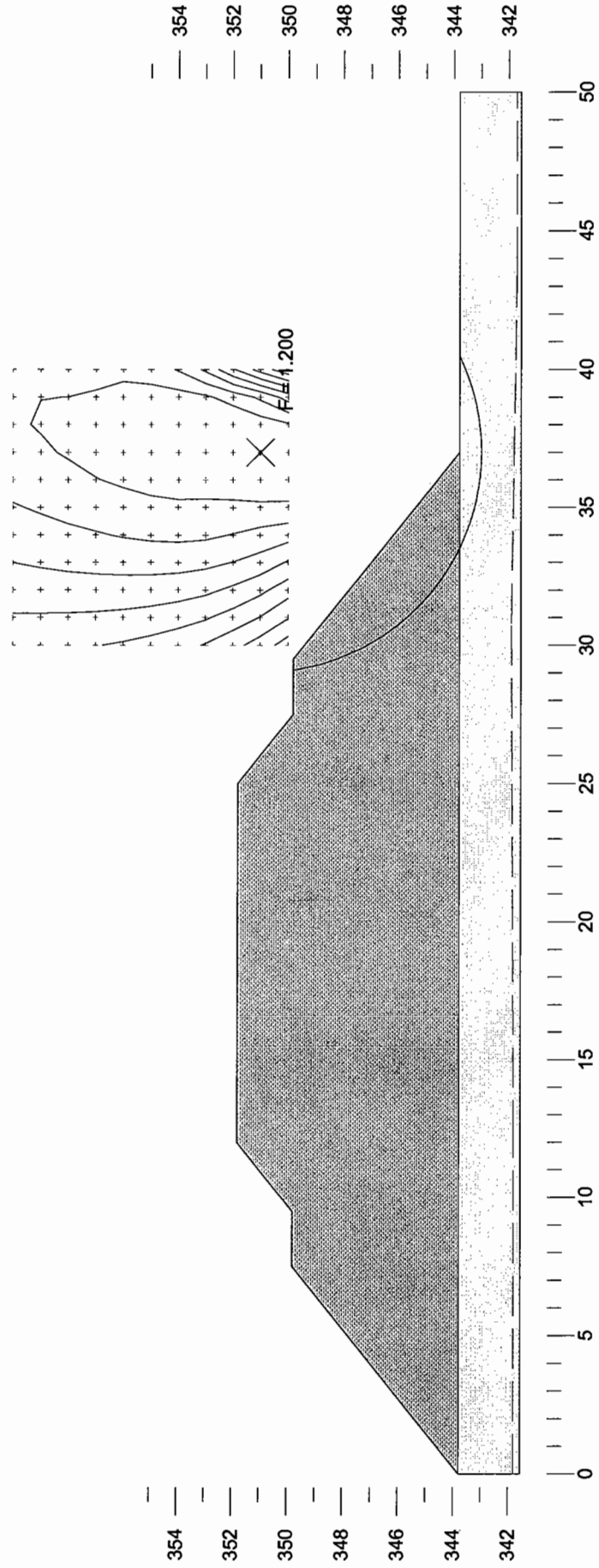


Figure E2

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 South Approach Earth Fill

	Gamma C	Phi	Min	Piezo
	kN/m <sup>3</sup>	deg	c/p	Surf.
Earth Fill	21	0	0	1
Silty Sand	21	0	0	1

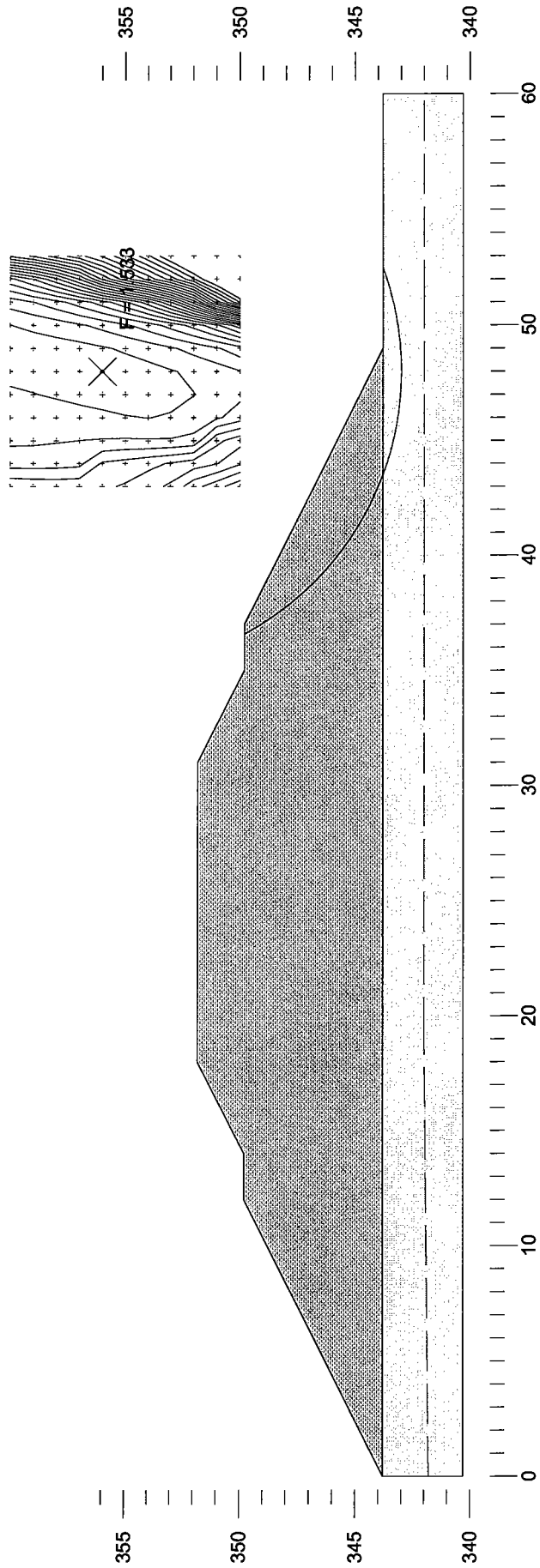


Figure E3

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 South Approach Earth Fill  
 Seismic 0.18

	Gamma C	Phi	Min	Piezo
	kN/m3	deg	c/p	Surf.
Earth Fill	21	0	0	1
Silty Sand	21	0	0	1

Seismic coefficient = 0.18

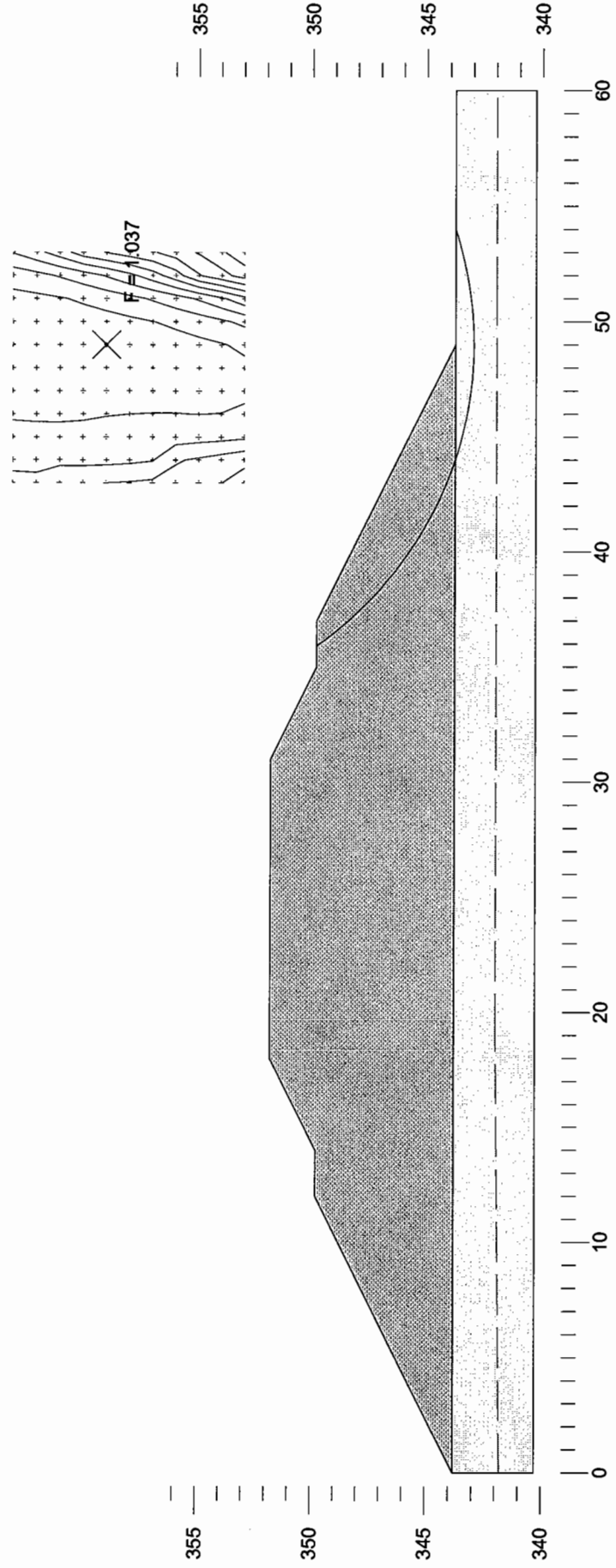


Figure E4

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 North Approach Rock fill

	Gamma C	Phi	Min	Piezo
	kN/m3	deg	c/p	Surf.
Rock Fill	20	45	0	1
Silty Sand	21	30	0	1

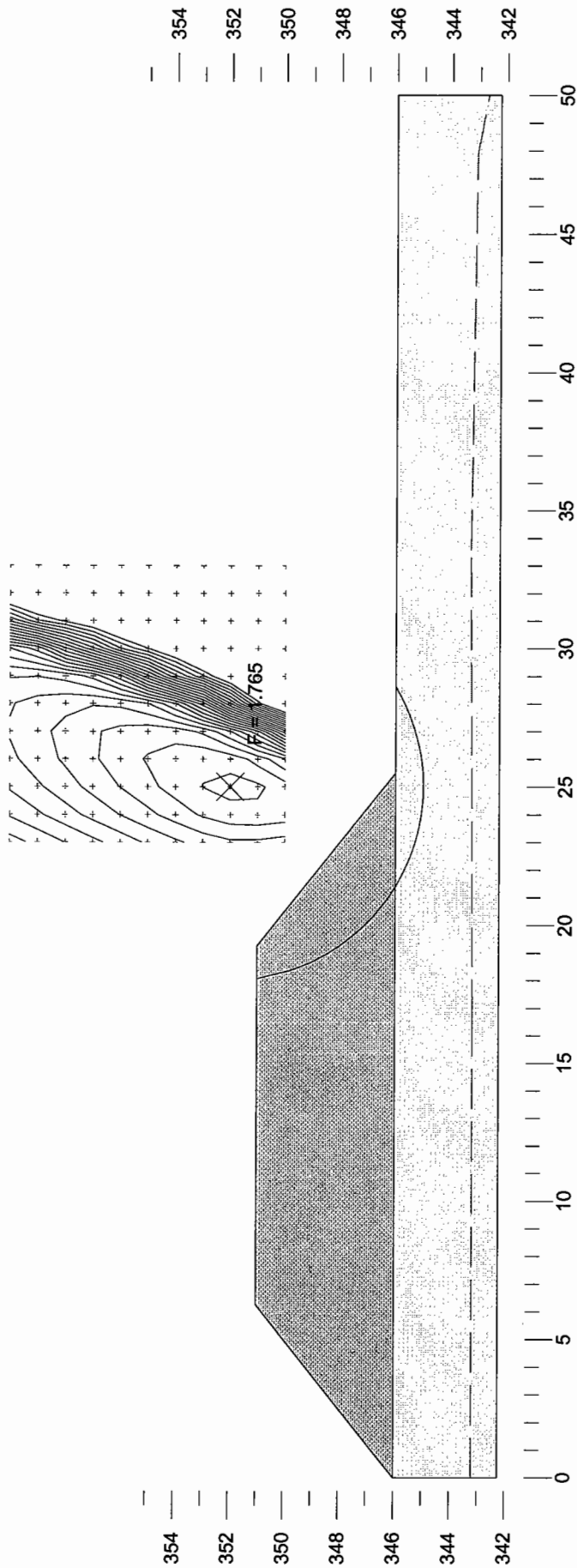


Figure E5

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 North Approach Rock fill  
 Seismic 0.18

	Gamma C	Phi	Min	Piezo
	kN/m3	deg	c/p	Surf.
Rock Fill	20	45	0	1
Silty Sand	21	30	0	1

Seismic coefficient = 0.18

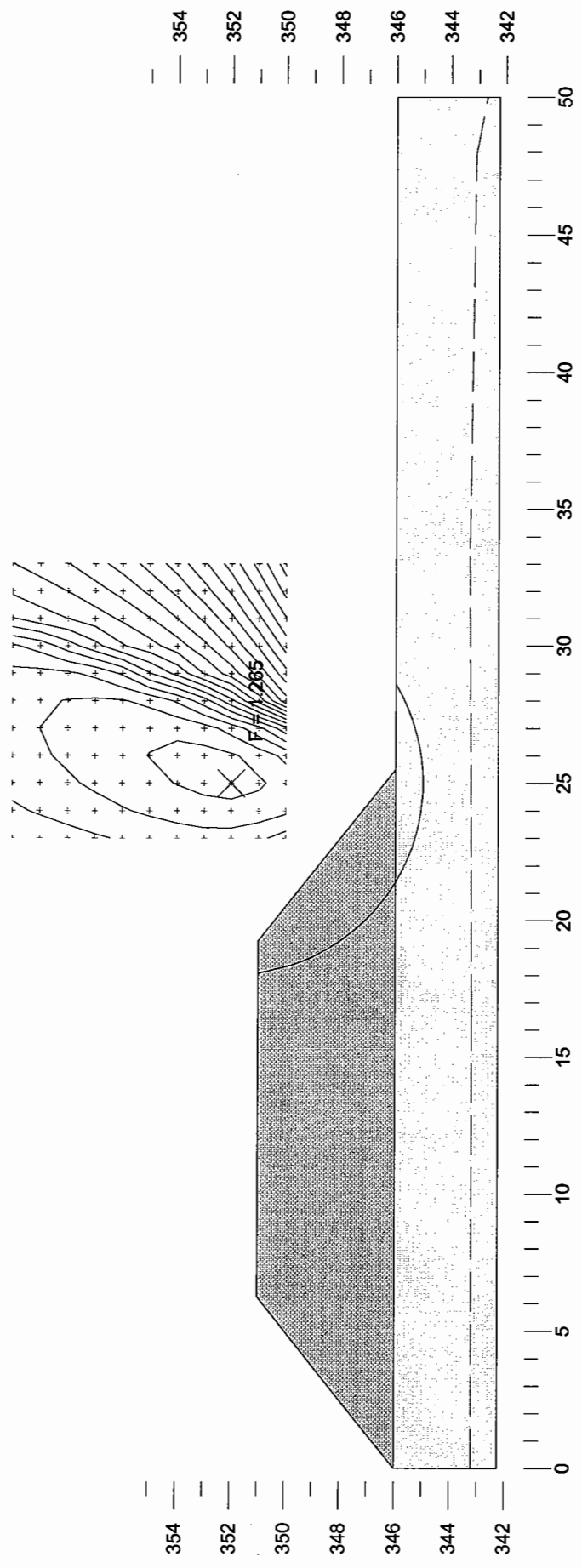


Figure E6



Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 North Approach Earth Fill

	Gamma C	Phi	Min	Piezo
	kN/m3	deg	c/p	Surf.
Earth Fill	21	30	0	1
Silty Sand	21	30	0	1

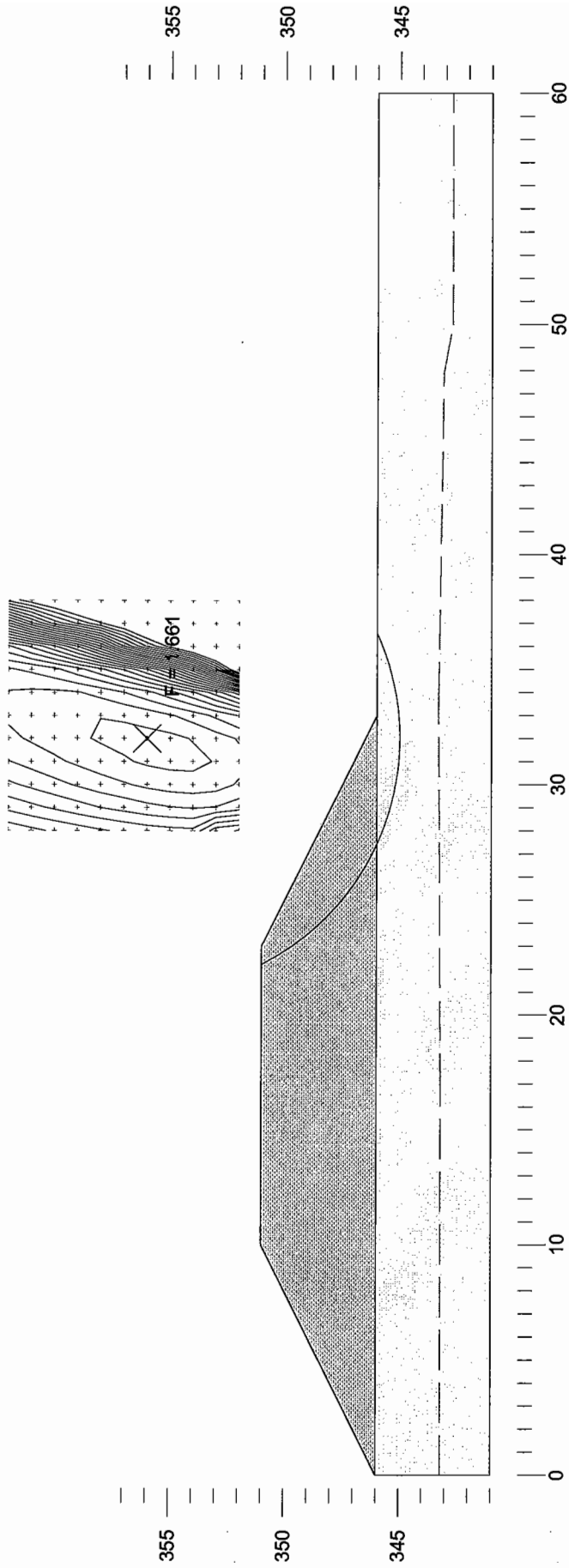


Figure E7

Thurber Engineering Ltd. - Toronto  
 19-1423-12 Hwy 11 Burk's Falls  
 Ottawa Ave. SBL  
 March 15, 2006  
 North Approach Earth Fill  
 Seismic 0.18

	Gamma C	Phi	Min	Piezo
	kN/m3	deg	c/p	Surf.
Earth Fill	21	30	0	1
Silty Sand	21	30	0	1

Seismic coefficient = 0.18

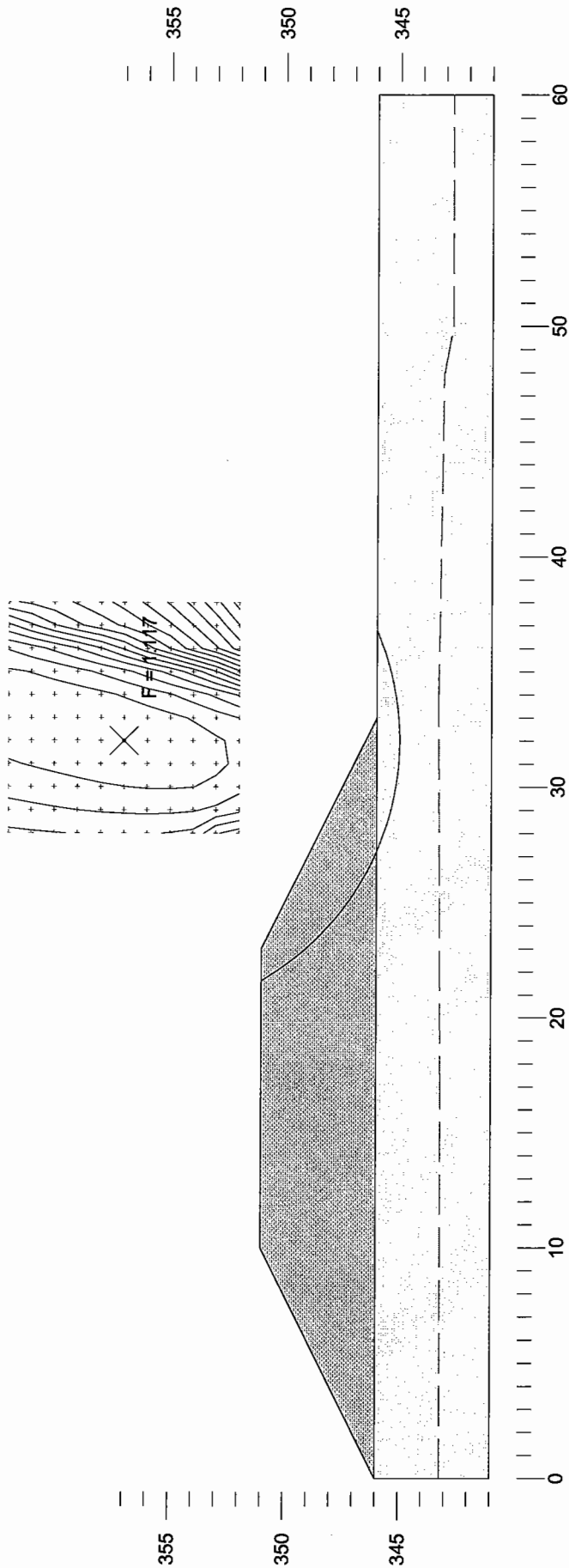
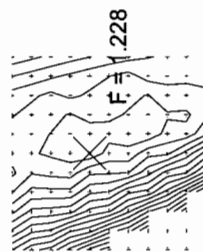


Figure E8

Thurber Engineering Ltd. - Toronto  
 19-1423-12  
 Ottawa Ave SBL  
 March 31, 2006  
 South Abutment RSS Walls  
 RSS Height 2.7m

	Gamma C	Phi	Piezo
	kN/m3	deg	Surf.
Gran A Cap	22.8	0	0
RSS Core	21.2	0	0
Approach Fill	19	0	0
Gran A Pad	22.8	0	0
Sand & Silt	20	0	0
Slp Circ Limit	(Infinitely Strong)		



Elevation 349.9

Elevation 346.5

Elevation 343.8

Elevation 341.8

Approach Fill

Gran A Pad

Sand & Silt

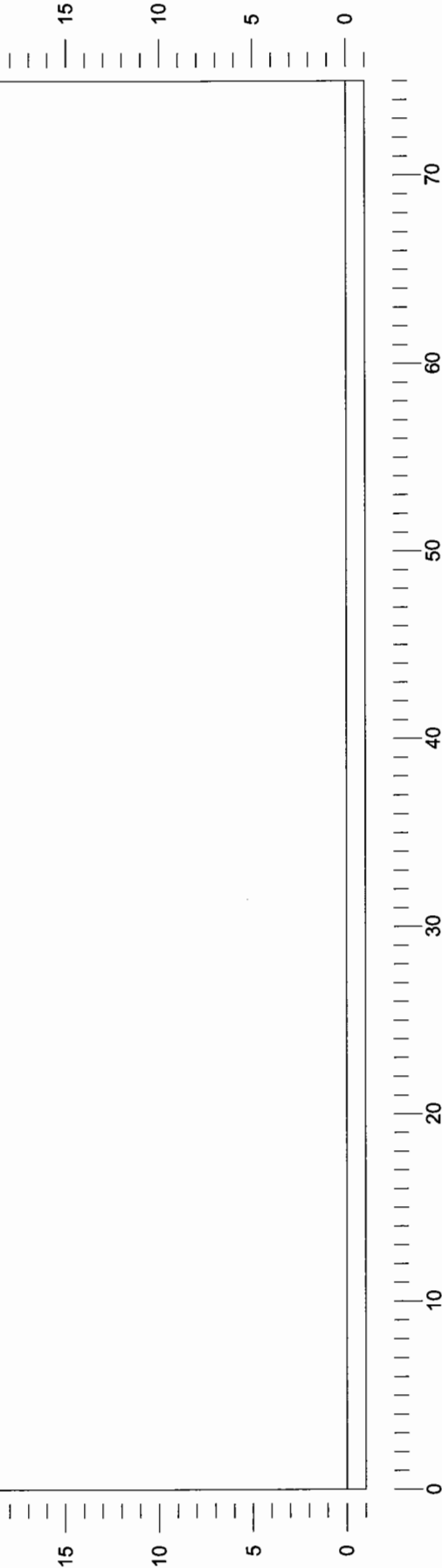
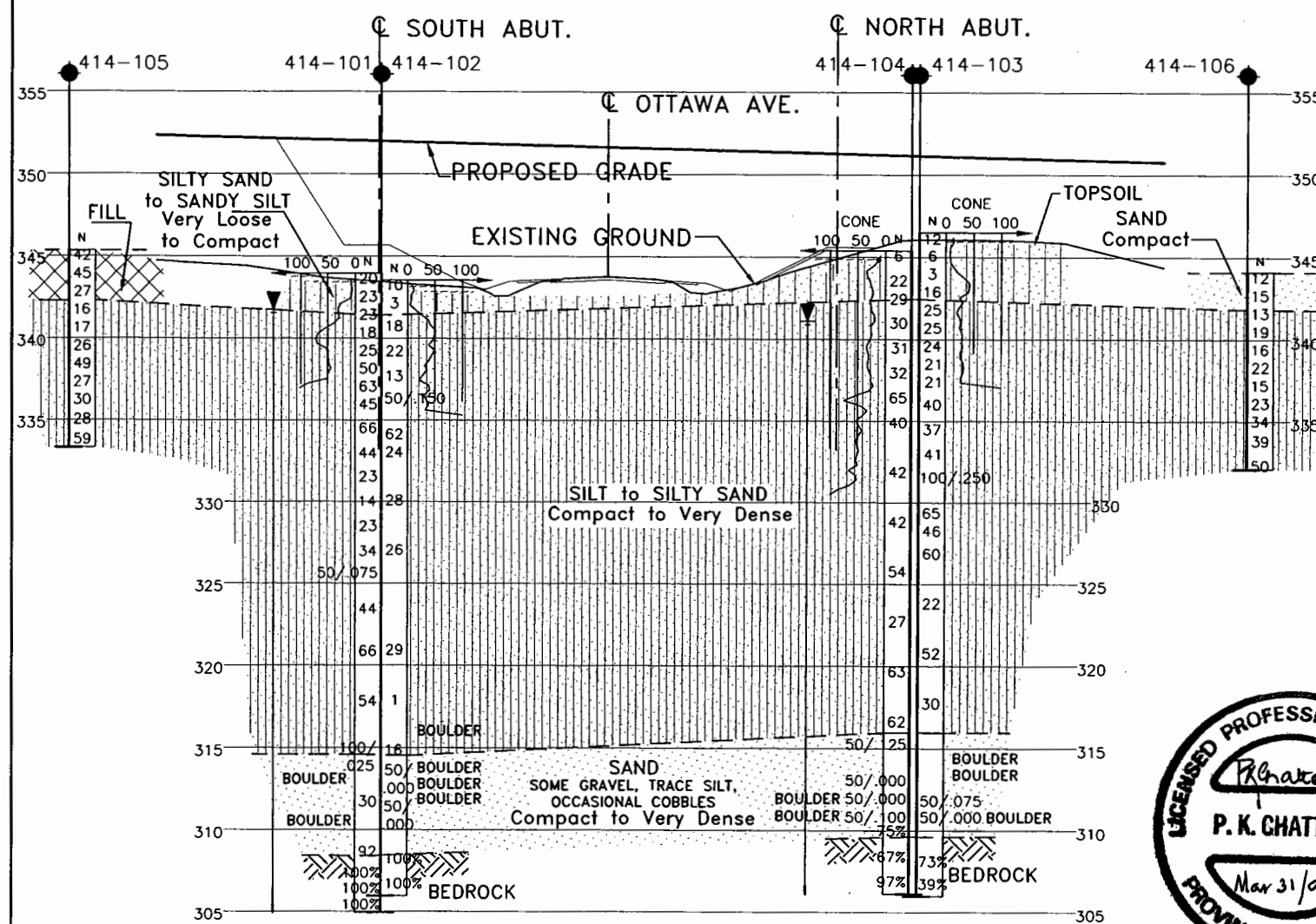
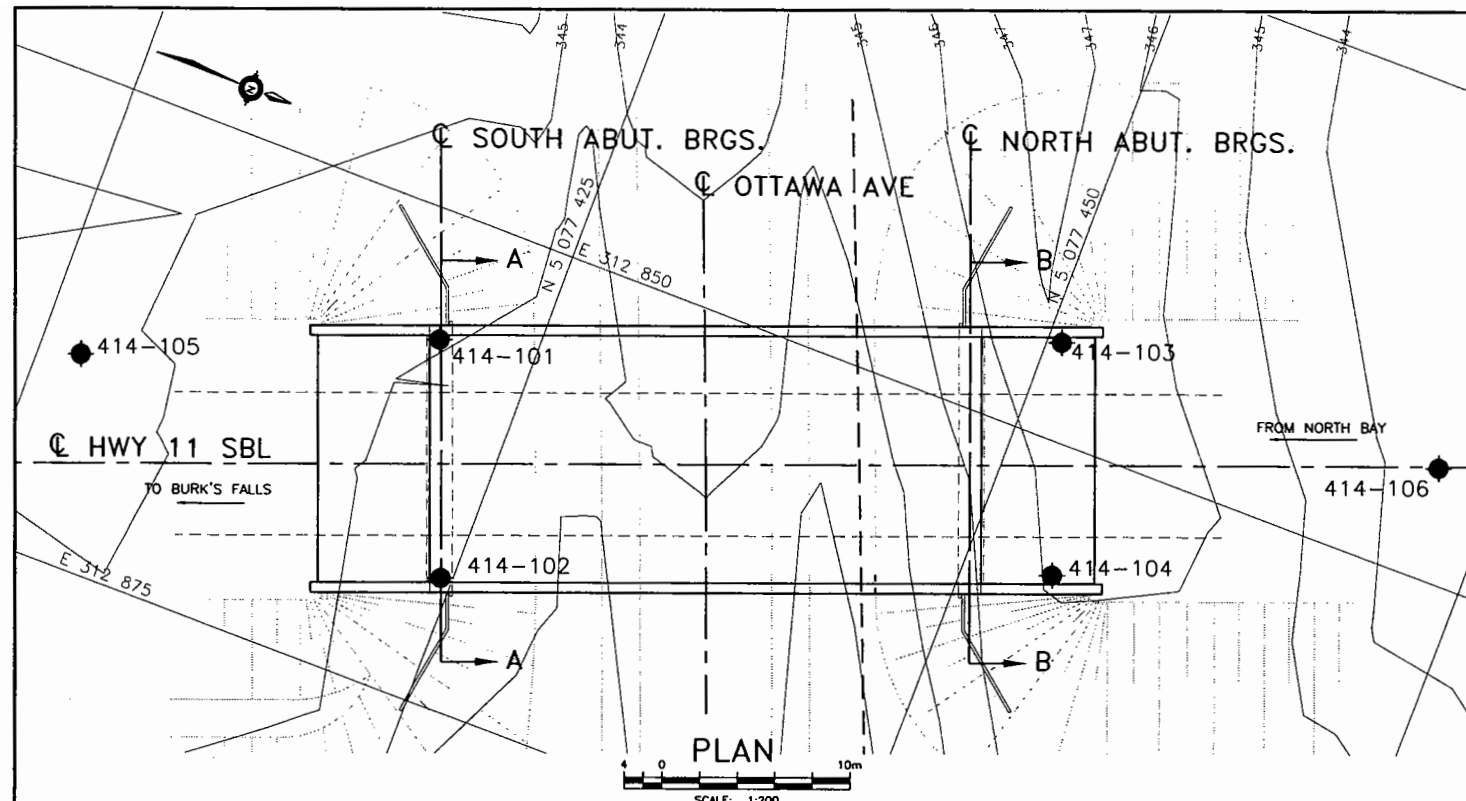


Figure E9

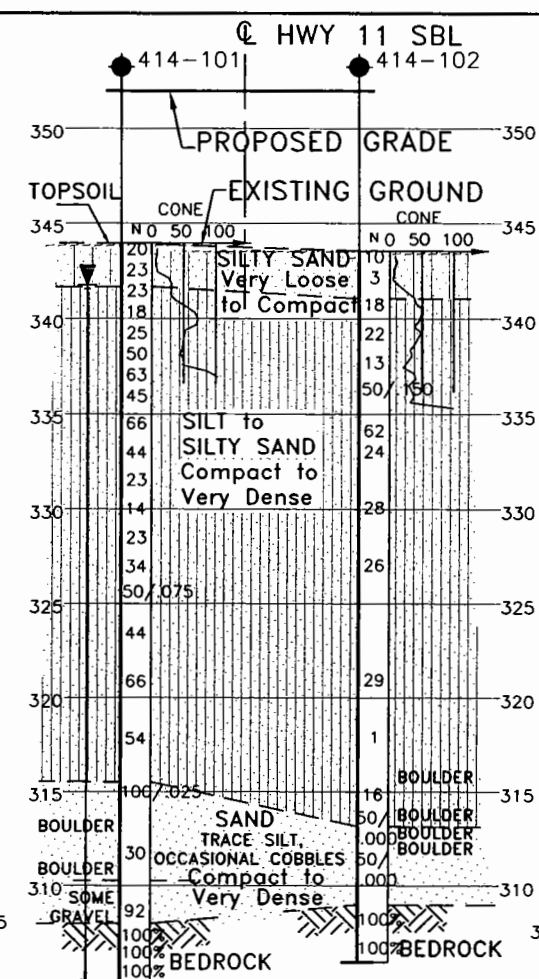
**Appendix F**

**Drawing**

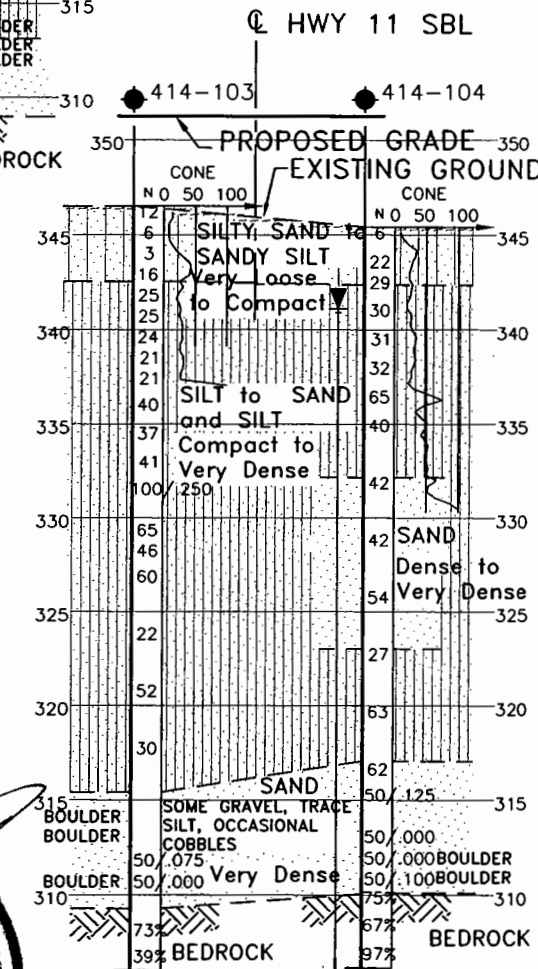
**Borehole Locations and Soil Strata**



PROFILE A-A HWY 11 SBL



SECTION A-A



SECTION B-B

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

HWY 11  
CONT No 2006-5151  
WP No 750-93-01

OTTAWA AVENUE  
OVERPASS SBL

BOREHOLE LOCATIONS AND SOIL STRATA

**Marshall Macklin Monaghan**  
PROJECT MANAGERS • ENGINEERS • SURVEYORS • PLANNERS

**THURBER ENGINEERING LTD.**

**KEYPLAN**

LEGEND			
●	Bore Hole By Thurber		
⊙	Bore Hole By Golder		
N	Blows/ 0.3m (Std Pen Test, 475 J/blow)		
CONE	Blows/ 0.3m (60° Cone, 475 J/blow)		
PH	Pressure, Hydraulic		
⬇	WL at Time of Investigation		
⊕	Head Artesian Water		
⊕	Piezometer		
90%	Rock Quality Designation (RQD)		
NO	ELEVATION	NORTHING	EASTING
414-101	344.0	5077419.9	312856.5
414-102	343.5	5077424.4	312868.3
414-103	346.5	5077450.8	312845.0
414-104	345.4	5077454.6	312856.7
414-105	345.3	5077402.2	312864.0
414-106	344.0	5077471.7	312844.2
NOTE			
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.			
DATE	BY	DESCRIPTION	
DESIGN	AEG	CHK PKC	CODE CHBDC 2000/LOAD CL-625-ONT/DATE NOV, 2005
DRAWN	HS	CHK AEG	SITE 44-414 STRUCT SCHEME DWG 2

**P. K. CHATTERJI**  
LICENSED PROFESSIONAL ENGINEER  
PROVINCE OF ONTARIO  
Mar 31/06

**A. E. GORMAN**  
REGISTERED PROFESSIONAL ENGINEER  
PROVINCE OF ONTARIO  
Mar 31/06

DRAWING NOT TO BE SCALED  
100 mm ON ORIGINAL DRAWING