

**FOUNDATION INVESTIGATION AND DESIGN REPORT  
SCHEEL DRIVE TWIN OVERPASS STRUCTURES  
HIGHWAY 17 – 417 FOUR LANING  
NEAR ARNPRIOR, ONTARIO  
G.W.P. 4067-03-00**

**GEOCRES Number: 31F-167**

**Report to**

**McCormick Rankin Corporation**

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

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**PART 1: FACTUAL INFORMATION**

**1 INTRODUCTION**

This report presents the factual findings obtained from a foundation investigation conducted at the locations of the proposed Scheel Drive Twin Overpass structures. These structures will carry the proposed Highway 17/417 WBL and EBL (existing Highway 17) over the realigned Scheel Drive near the Town of Arnprior, Ontario. Foundation information obtained from previous investigations in the vicinity of these structures is included in References 1 and 2 noted below.

The purpose of the investigation was to explore the subsurface conditions at the site and, based on the data obtained, to provide borehole location plans and soil strata drawings, stratigraphic profiles and selected cross-sections, records of boreholes, laboratory test results and a generalized description of the subsurface conditions.

Thurber Engineering Ltd. (Thurber) carried out the investigation as a sub-consultant to McCormick Rankin Corporation (MRC), under the Ministry of Transportation Ontario (MTO) Agreement Number 4006-E-0003.

Reference is made to the following documents during the preparation of this report.

- Thurber Engineering Ltd. report titled "Foundation Investigation and Design Report, Scheel Drive Underpass, Highway 17 Twinning, Arnprior to Renfrew, Ontario", G.W.P. 647-92-00, Site No. 29-414, GEOCRES No.31F-126, File No.19-3745-0, August 27, 2004 (Reference 1).
- Thurber Engineering Ltd. report titled "Foundation Investigation and Design Report, High Embankments, Scheel Drive Underpass Approaches, WBL Mainline Section and Campbell Drive Interchange, Highway 17-417 Four Laning, Near Arnprior, Ontario", G.W.P. 4067-03-00, GEOCRES No. 31F-163, File No. 19-1351-125, February 19, 2008 (Reference 2).

**2 SITE DESCRIPTION**

The site is located in the vicinity of the existing intersection between Highway 17 and Scheel Drive in the Township of McNab, County of Renfrew, Ontario. The general site location is shown on the Borehole Locations and Soil Strata drawing in Appendix F.



The site is situated in an area of relatively flat terrain characterized by shallow bedrock underlying glacio-lacustrine clays and sandy silt to sand. All four quadrants of the intersection are moderately vegetated with trees and shrubs of various sizes. Local drainage in the area is likely governed by the nearby Dochart Creek, which flows in a southwest-northeast orientation and crosses under the existing Highway 17 at a location some 600 m west of the intersection.

In general, the project area is located within a physiographic region known as the Ottawa Valley Clay Plains. This area is located between the Laurentian upland to the north and west, and the Ottawa lowland to the south and east. Native soil deposits typically consist of glacio-lacustrine clayey silts to silty clays that were deposited when the Champlain Sea inundated the Ottawa – St. Lawrence lowland. In Renfrew County, there are prominent east-west trending scarps (fault zones), including a major depression geologically known as the “Ottawa-Bonnechere” graben. Bedrock in the site area consists of crystalline limestone of the Ordovician Period that had been subjected to faulting, weathering and erosion.

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

The site investigation and field testing program was carried out during the period of August 25 to 27, 2008, and consisted of advancing 24 boreholes (08-SCH-01 to 08-SCH-24) at the proposed twin structure locations. The depths of the boreholes ranged from approximately 0.4 m (bedrock just beneath ground surface) to 7.2 m depth below existing ground surface. All boreholes were advanced to refusal on probable bedrock or boulders, and selected boreholes were further advanced by coring into bedrock. The approximate locations of the boreholes are shown on the Borehole Locations and Soil Strata Drawing in Appendix F.

Prior to the start of drilling, the borehole locations were staked in the field and utility clearances were obtained by Thurber. Relocation of some boreholes from the proposed structure locations was necessary due to the presence of rock outcrop, ditches and sloping ground.

A track mounted drill rig was used to drill and sample all but Boreholes 08-SCH-05 and -10 where a shovel was used to manually excavate the shallow pits. The sampled boreholes were advanced by a combination of hollow stem augers through the soil and NQ size coring equipment into bedrock at selected locations. Soil samples were obtained at selected intervals using a 50 mm outside diameter split spoon sampler in conjunction with Standard Penetration Testing (SPT).

Groundwater conditions were observed and noted throughout the drilling operations and upon completion of the boreholes. Standpipe piezometers consisting of 19 mm diameter Schedule 40 PVC pipe with a slotted screen were installed in selected boreholes to allow longer term monitoring of the groundwater level. The completion details of all boreholes, including the piezometer installations, are presented in Table 3.1 below.



**Table 3.1 – Borehole Completion Details**

<b>Borehole Location</b>	<b>Borehole Depth</b>	<b>Piezometer Tip Depth / Elevation (m)</b>	<b>Completion Details</b>
08-SCH-01	5.9	None Installed	Sealed with bentonite and gravel to surface
08-SCH-02	2.1	2.1 / 121.3	Sand from 2.1 to 1.2 m, bentonite to surface
08-SCH-03	1.0	None Installed	Drill cuttings for full depth
08-SCH-04	4.7	None Installed	Sealed with bentonite and gravel to surface
08-SCH-05	0.5	None Installed	Drill cuttings for full depth
08-SCH-06	0.5	None Installed	Drill cuttings for full depth
08-SCH-07	5.7	None Installed	Sealed with bentonite and gravel to surface
08-SCH-08	0.4	None Installed	Drill cuttings for full depth
08-SCH-09	4.3	4.3 / 120.2	Sand from 4.3 to 2.4 m, bentonite to surface
08-SCH-10	0.4	None Installed	Drill cuttings for full depth
08-SCH-11	0.7	None Installed	Drill cuttings for full depth
08-SCH-12	0.6	None Installed	Drill cuttings for full depth
08-SCH-13	5.1	5.1 / 120.1	Sand from 5.1 to 1.5 m, bentonite to surface
08-SCH-14	1.5	None Installed	Gravel to surface
08-SCH-15	2.8	None Installed	Gravel to surface
08-SCH-16	7.2	None Installed	Sealed with bentonite and gravel to surface
08-SCH-17	0.9	None Installed	Gravel to surface
08-SCH-18	1.8	None Installed	Gravel to surface
08-SCH-19	7.1	None Installed	Sealed with bentonite and gravel to surface
08-SCH-20	1.9	None Installed	Gravel to surface
08-SCH-21	2.8	2.8 / 123.6	Sand from 2.8 to 1.0 m, bentonite to surface
08-SCH-22	7.0	None Installed	Sealed with bentonite and gravel to surface
08-SCH-23	0.6	None Installed	Drill cuttings for full depth
08-SCH-24	2.8	None Installed	Sealed with bentonite and gravel to surface

A member of Thurber's technical staff supervised the drilling and sampling operations on a full time basis. The supervisor logged the boreholes, secured the soil samples in labelled and sealed containers, placed the rock cores in wooden core boxes which were then transported to Thurber's laboratory for further examination and testing. All rock cores were logged, the Total Core Recovery (TCR), the Rock Quality Designation (RQD) and the Fracture Indices (FI) were determined.

#### **4 LABORATORY TESTING**

The recovered soil samples were subjected to visual identification and to natural moisture content determination. At least 25% of soil samples were subjected to grain size distribution analysis and Atterberg limits tests where appropriate. The results of this testing are shown on the Record of Borehole sheets and the figures in Appendix B. Point load testing was carried out on selected rock cores. The results of this testing program are reported in Table 1 immediately following the text and on the Records of Boreholes in Appendix A.



## 5 DESCRIPTION OF SUBSURFACE CONDITIONS

### 5.1 General

Details of the encountered stratigraphy are presented on the Records of Boreholes in Appendix A and on the “Borehole Locations and Soil Strata” drawing in Appendix F. A summary description of the stratigraphy is given in the following paragraphs. The factual information at the borehole locations governs any interpretation of site conditions.

In general, the subsurface conditions encountered in the borehole locations consist of asphalt, topsoil or fill overlying silty clay and/or silty sand to sand. The relatively thin overburden soils is underlain by crystalline limestone bedrock.

### 5.2 Asphalt, Topsoil and Fill

Asphalt of about 50 to 150 mm in thickness was encountered on the existing highway shoulder in Boreholes 08-SCH-21 and 08-SCH-22.

Topsoil of about 100 mm in thickness was encountered in Boreholes 08-SCH-01 and SCH-08-02, and about 500 mm in Borehole 08-SCH-06. Topsoil thickness may vary between and beyond borehole locations, and this limited data should not be used for topsoil quantity estimates.

Silty sand, gravelly sand to sand and gravel fill containing cobbles, rock pieces/slabs was encountered at ground surface or beneath the asphalt in 14 boreholes located adjacent to the roadway. The approximate depths and underside elevations of fill are as shown in the following Table 5.1.

**Table 5.1 Fill Thickness and Underside Elevations**

<b>Borehole</b>	<b>Fill Thickness (m)</b>	<b>Fill Underside Elevation (m)</b>
08-SCH-11	0.7	122.6
08-SCH-12	0.6	123.0
08-SCH-13	0.9	124.3
08-SCH-14	0.9	124.3
08-SCH-15	0.8	125.4
08-SCH-16	0.9	125.3
08-SCH-17	0.9	124.7
08-SCH-18	0.7	125.4
08-SCH-19	1.4	123.8
08-SCH-20	0.5	124.7
08-SCH-21	0.6	125.8
08-SCH-22	0.9	125.6
08-SCH-23	0.6	125.0
08-SCH-24	0.7	125.0



Measured SPT 'N' values ranged from 3 blows to 51 blows per 0.3 m penetration indicating loose to very dense conditions. The measured moisture contents of samples of the fill were typically in the order of 2 to 8%, although a value up to 20% was recorded.

Figures B1 and B2 in Appendix B present grain size distribution curves for samples of the gravelly sand to sand and gravel fill. Results of these tests are presented on the Record of Borehole sheets in Appendix A and as follows:

Soil Particles	%
Gravel	21 to 37
Sand	52 to 63
Silt and Clay	10 to 24

### 5.3 Silty Sand and Sand

Layers of brown native silty sand to sand containing pieces or slabs of rock were encountered at ground surface or immediately below the existing fill in Boreholes 08-SCH-03, -04, -05, -07, -08, -16, -18, -21, -22 and -24. The thickness of these brown deposits ranged between 0.4 and 2.0 m and the underside of these soils varied from Elevation 121.0 to 126.2 m.

Measured SPT 'N' values typically ranged from 6 to 28 blows per 0.3 m penetration indicating loose to compact conditions, except in Boreholes 08-SCH-03, -15, -16, -21 and -22 where very dense conditions represented by 'N' values of 86 blows per 0.3 m penetration and >50 blows for less than 0.3 m penetration were recorded, respectively, likely due to the presence of rock pieces, rock slabs, cobbles, boulders and particularly above the bedrock contact. The measured moisture contents of samples of these cohesionless soils were in the order of 2 to 20%.

Figure B3 in Appendix B shows the grain size distribution curves for two samples of the silty sand. These test results are summarized as follows:

Soil Particles	%
Gravel	1 to 4
Sand	59 to 61
Silt	28 to 32
Clay	6 to 9

### 5.4 Silty Clay and Clay

Deposits of brown to grey brown silty clay and clay containing trace gravel and pieces of rock were encountered at ground surface or underlying the topsoil, fill and silty sand in Boreholes 08-SCH-01, -02, -09, -10, -13, -14, -19, -20, -21 and -24. The silty clay typically





contains varying proportion of sand. These deposits ranged from 0.4 to 2.8 m in thicknesses with the underside level lying between Elevations 119.5 and 124.3.

Measured SPT 'N' values generally ranged from 3 to 8 blows for 0.3 m penetration indicating a soft to stiff consistency, except just above the bedrock contact where occasional very high 'N' values were noted that were likely due to the presence of rock pieces or slabs. The measured moisture contents of samples of the silty clay typically ranged between 12% and 42%, except in Borehole 08-SCH-01 where a value of 72% was recorded.

Figures B4 to B7 in Appendix B present the laboratory testing results of samples of the clay and silty clay. These test results are summarized as follows:

Clay

<b>Soil Particles</b>	<b>%</b>
Gravel	0 to 2
Sand	6
Silt	57 to 67
Clay	25 to 37
<b>Index Property</b>	<b>%</b>
Liquid Limit	55 to 56
Plastic Limit	23 to 26
Plasticity Index	30 to 32

The above results show that the clay is of high plasticity with a group symbol of CH.

Silty Clay

<b>Soil Particles</b>	<b>%</b>
Gravel	3
Sand	49 to 57
Silt	30 to 32
Clay	8 to 18
<b>Index Property</b>	<b>%</b>
Liquid Limit	36 to 37
Plastic Limit	18 to 19
Plasticity Index	17 to 19

The above results show that the silty clay is of medium plasticity with a group symbol CI.

## 5.5 Bedrock

The soils described above are underlain by bedrock or boulders that was inferred from refusal to auger penetration or shallow bedrock under a thin veneer of soil in all of the boreholes advanced during this investigation. Bedrock was proven by coring in selected boreholes.



Inferred or proven bedrock surface depths and elevations at the borehole locations are summarized in the following table.

**Table 5.2 – Depth and Elevation of Inferred Bedrock Surface  
Scheel Drive Twin Structures**

<b>Borehole Number</b>	<b>Ground Surface Elevation (m)</b>	<b>Inferred Depth to Bedrock (m)</b>	<b>Inferred Top of Bedrock Elevation (m)</b>
<b>WBL Structure West Abutment</b>			
08-SCH-01	122.4	2.9*	119.5*
08-SCH-02	123.4	2.1	121.3
08-SCH-03	126.4	1.0	125.4
08-SCH-04	127.3	1.1*	126.2*
08-SCH-05	121.5	0.5	121.0
08-SCH-06	124.3	0.5	123.8
SCH-6	121.5	2.6**	118.9**
<b>WBL Structure East Abutment</b>			
08-SCH-07	122.9	1.5*	121.4*
08-SCH-08	122.8	0.4	122.4
08-SCH-09	124.5	0.8*	123.7*
08-SCH-10	124.7	0.4	124.3
08-SCH-11	123.3	0.7	122.6
08-SCH-12	123.6	0.6	123.0
<b>EBL Structure West Abutment</b>			
08-SCH-13	125.2	1.4*	123.8*
08-SCH-14	125.2	1.5	123.7
08-SCH-15	126.2	2.8	123.4
08-SCH-16	126.2	2.6*	123.6*
08-SCH-17	125.6	0.9	124.7
08-SCH-18	126.1	1.8	124.3
<b>EBL Structure East Abutment</b>			
08-SCH-19	125.2	2.5*	122.7*
08-SCH-20	125.2	1.9	123.3
08-SCH-21	126.4	2.8	123.6
08-SCH-22	126.4	2.1*	124.3*
08-SCH-23	125.6	0.6	125.0
08-SCH-24	125.7	2.8	122.9

Notes :      Rock surface inferred by auger refusal except otherwise noted.  
               \*      Rock proven by coring during current investigation.  
               \*\*     Rock proven by coring during previous investigation (Reference 2).

The bedrock surface varies across the site with depths below existing ground surface varying from 0.4 m to 2.9 m, or between approximate Elevations 119.5 m and 126.2 m. Based on the rock cores, the bedrock at this site is a grey crystalline limestone of the Ordovician Period.



The bedrock is typically in a moderately to slightly weathered state, thinly bedded with sub-vertical joints.

The measured Total Core Recovery (TCR) values for the core runs vary between 50% and 100%. The measured Rock Quality Designation (RQD) values range between 0% and 100% indicating very poor to excellent rock quality.

The Fracture Index (FI) of the rock, expressed as fractures per 0.3 m of core, generally range between 0 and 4, except for zones near the rock surface and in Boreholes 08-SCH-11 where higher values of up to 6 were measured. Calcite infilling is frequently present within the joints.

Point load tests were carried out on the intact rock cores at selected intervals. Results of these tests are presented in Table 1 following the text. The inferred Unconfined Compressive Strengths (UCS) of the rock cores (expressed as an average per run) range between 50 and 250 MPa, indicating that the intact limestone is strong to very strong.

#### 5.5.1 Groundwater

Free water was not observed in the boreholes upon completion of drilling. Standpipe piezometers were installed in selected boreholes for longer term monitoring. Measured water levels are presented in the table below.

**Table 5.3 – Depth and Elevation of Water Levels  
Scheel Drive Twin Structures**

<b>Borehole (screen location)</b>	<b>Date of Reading</b>	<b>Water Level Depth (m)</b>	<b>Water Level Elevation (m)</b>
08-SCH-02 (silty clay)	September 12, 2008	1.7	121.7
08-SCH-09 (bedrock)	September 12, 2008	dry	-
08-SCH-13 (bedrock)	September 12, 2008	dry	-
08-SCH-21 (silty sand/clayey silt)	September 12, 2008	dry	-

The piezometer reading measured in Borehole 08-SCH-02 likely reflects the presence of perched water above the bedrock. The remaining three piezometers were dry possibly indicating that there is downward drainage into the bedrock. This observation is consistent with the conditions reported in Reference 2.

It should be noted that the above groundwater conditions are short term observations and the water levels are subject to seasonal fluctuations and severe climatic events. It is also



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anticipated that the local groundwater conditions at this site is influenced by the nearby Dochart Creek.

## **6 MISCELLANEOUS**

The borehole locations were initially staked/marked by Thurber who subsequently surveyed the as-drilled locations to establish the coordinates and geodetic elevations using the in-house GPS system. Thurber obtained utility clearances prior to drilling at all borehole locations.

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

The drilling and sampling operations in the field were supervised on a full time basis by Mr. Luke Gilarski of Thurber.

Laboratory testing was carried out by Thurber in its MTO-approved laboratory.

Dr. Sydney Pang, P.Eng. directed the field operations and prepared the report.

Dr. P.K. Chatterji, P.Eng., a Designated Principal Contact for MTO Foundations projects, reviewed the report.





Engineering Analysis and Report Preparation by:  
Sydney Pang, P.Eng.,  
Associate, Senior Project Engineer



Report Reviewed by:  
P. K. Chatterji, P.Eng.,  
Review Principal, Designated MTO Contact



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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 foundation design recommendations to assist the design team to select and design a suitable foundation system and road cuts for the proposed structure. Foundation design issues associated with the permanent road cut to be formed in the vicinity of the proposed structures are also discussed.

It is understood that the current design plan calls for the construction of twin structures to carry the future Highway 17/417 Westbound Lanes (WBL) and Eastbound Lanes (EBL) (existing Highway 17) over the realigned Scheel Drive that will be constructed in a cut.

Each of the proposed single span, reinforced concrete rigid framed overpass structures will have an approximate length of 36 m (along the Scheel Drive alignment) and an approximate clear span width of 18 m (perpendicular to the Scheel Drive alignment). The abutments will be skewed at about 45° to the Highway 17/417 centreline.

It is understood that the proposed Highway 17/417 EBL and WBL mainlines will be at the existing Highway 17 grade between approximate Elevations 125 and 126 m. The realigned Scheel Drive will be in a cut with a proposed centreline grade varying from approximate Elevation 120 m just north and east of the EBL embankment to Elevation 117.7 m just south and west of the WBL embankment, or about 4 to 7 m depths below the final highway grade.

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

**8 STRUCTURE FOUNDATIONS**

**8.1 General**

It is understood that the proposed overpass for this site will consist of two twin rigid frame structures each with an abutment on either side of Scheel Drive.

The stratigraphy encountered at the site of the proposed structures typically consists of existing cohesionless fill and/or topsoil overlying deposits of silty sand, silty clay or clayey



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silt. Rock pieces, rock slabs, cobbles and boulders were inferred within the soils. The soils are underlain by crystalline limestone bedrock. The elevations at which bedrock was inferred or encountered at the foundation elements are summarized in Table 5.2.

At the WBL West Abutment, the bedrock surface at the borehole locations varied from Elevation 118.9 m near the northerly limit to Elevation 126.2 m near the southerly limit. At the WBL East Abutment, the bedrock surface at the borehole locations varied from Elevation 121.4 m near the northerly limit to Elevation 124.3 m near the southerly limit.

At the EBL West Abutment, the bedrock surface at the borehole locations varied between Elevations 123.4 and 124.7 m. At the WBL East Abutment, the bedrock surface at the borehole locations varied between Elevations 122.7 and 125.0 m.

## **8.2 Foundation Alternatives**

This section discusses the feasible foundation alternatives, provides geotechnical design parameters and recommends a preferred foundation scheme.

Initial consideration was given to the following foundation types:

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

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

Given the proposed grade of the realigned Scheel Drive which will be formed in cut in the order of 7 m deep into soils and rock, it is considered that spread footings on bedrock is the most practical and cost-effective option for foundation support for the abutments at this site.

Footings on engineered fill is not considered feasible at this site. Due to the anticipated presence of bedrock throughout the entire base of the road cut, footings may be founded directly on bedrock. Footings founded on compacted granular pads would require a longer bridge span resulting in a reduction of the cost effectiveness of the option.

Both integral and semi-integral abutment designs are not applicable to rigid frame structures.

Augered caissons are not considered to be practical due to the anticipated rock cut.

In view of the above and the proposed rigid frame design, it is recommended that the structure be supported by spread footings founded on bedrock.



### 8.3 Spread Footings on Bedrock

#### 8.3.1 General

It is anticipated that the lower part of the road cut will be formed entirely in the strong to very strong limestone bedrock. Further comments on the design and construction of the rock cut are presented later in the report.

Once the cut is formed, inspection should be carried out to confirm that the bedrock conditions, as exposed at the founding level, are consistent with the design assumptions. All shattered and loosened rock fragments should be removed from the footprint of the footing and replaced with mass concrete fill, where necessary. Where bedrock is lower than anticipated, mass concrete fill with a structural strength of 30 MPa should be used to raise the subgrade to the design footing level. The QVE should certify the footing subgrade inspection work as per Special Provision 902S01. Suggested wordings for an NSSP on the use of mass concrete for footing subgrade preparation are included in Appendix E.

Rock blasting could result in uneven rock surfaces at the base of the cut. Mass concrete fill in conjunction with minor sub-excavation of loose or shattered rock may be required in order to develop a level bearing surface. After excavation, footings should be formed on undisturbed, sound bedrock in accordance with the requirements of SP 902S01.

It is recommended that the top of footings be in the order of 0.5 m below the proposed final grade of Scheel Drive such that the footings will not be exposed. Frost protection is not required for footings founded on bedrock. Based on information provided by MRC, the following footing elevations are recommended.

**Table 8.1 – Recommended Footing Elevations  
Scheel Drive Twin Structures**

Foundation Location	Approximate Cut Centreline Elevation (m)	Highest Footing Elevations (m)
WBL Structure West and East Abutments	117.7 (north)	~116.5 (north)
	117.7 (south)	~116.5 (south)
EBL Structure West and East Abutments	118.0 (north)	~116.8 (north)
	119.2 (south)	~117.8 (south)

\* The highest footing elevations have been inferred based on information provided by MRC. Variations to these values are acceptable as long as the top of footing is at least 0.5 m below the final grade.

#### 8.3.2 Bearing Resistance

It is recommended that footings bearing on sound crystalline limestone bedrock be designed on the basis of a geotechnical resistance of 5,000 kPa at factored ULS for vertical, concentric loads. Effects of load inclination and eccentricity should be taken into account as illustrated in the CHBDC, 2006 Clause 6.7.3 and Clause 6.7.4. The design of the footing may be governed by other considerations such as sliding resistance or overturning moment.





The SLS condition will not govern for footings founded on bedrock.

The same value of resistance may be used where mass concrete of strength equal to or greater than 30 MPa is placed in neat contact with a clean, sound bedrock surface.

### **8.3.3 Horizontal Resistance of Footings**

Resistance to lateral forces / sliding resistance between the concrete footing and the bedrock surface should be evaluated in accordance with the CHBDC, 2006 assuming an ultimate coefficient of friction of 0.85.

If the frictional component is insufficient to resist lateral forces, the horizontal resistance may be increased by dowelling into the rock mass. Dowels are considered to be comparatively short steel bars that may be assumed to provide only shear resistance.

The dowel may be considered as acting as a fully embedded short pile in the rock. The unconfined compressive strength (UCS) of intact limestone bedrock, taking into account the joints and fissures within the rock mass, is expected to be higher than that of the grout. An assumed UCS value of 30 MPa for the grout, which fills the annular space between the dowel and the surrounding rock mass, will govern design. An ultimate horizontal resistance of 1.3 MN was calculated for a 50 mm steel dowel embedded 500 mm into the rock. The depth of embedment is measured below the bearing surface prepared to receive the concrete footing. The holes should have a nominal diameter of 100 mm. Suggested wordings of an NSSP on installation and testing of rock dowels are included in Appendix E.

The shearing resistance of the selected dowel must be checked structurally.

### **8.3.4 Frost Cover**

The design depth of frost penetration is 1.9 m for this site and any footing founded on soil will need a frost cover of 1.9 m or its thermal equivalent. However, it is not required to provide frost cover for footings founded on limestone bedrock.

## **9 PERMANENT CUT**

### **9.1 General**

A permanent cut is required to construct the realigned Scheel Drive at this site. The cut will be formed through 0.5 to approximately 3 m of soils consisting of cohesionless fill, loose to compact silty sand overlying typically firm silty clay. The cut will extend 1 to 5 m into crystalline limestone bedrock.



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## **9.2 Earth Cut**

The extent of earth excavation will be relatively small at this site. Where space permits, temporary open cut excavation through earth with a slope inclination of 1H : 1V may be carried out. Flatter slopes may be required at the locations where the soils are less competent than what is assumed during design or where water seepage affects surficial stability. Where there is space restriction or in order to minimize excavation, steel soldier pile and timber lagging walls may be used to provide temporary support to the soils during excavation. Groundwater control, where required, will likely be in the form of pumping from filtered sumps as discussed in Section 10.

Unsupported permanent earth cuts in compact silty sand or firm silty clay will be stable provided that the slope inclinations are not steeper than 2H : 1V. Interceptor ditches and/or toe drains are recommended to provide permanent drainage, and reference can be made to OPSD 200.010 and 200.020 for typical arrangements.

Design of a soldier pile and lagging system may be carried out as recommended in Section 9.4.3. The sockets within bedrock must be formed below the base of the earth cut.

Vegetation cover should be established on all exposed permanent earth slopes to protect against surficial erosion. Reference may be made to SP 572S01 for more detailed requirements. Where continual seepage and surficial instability are evident, particularly in the sands and silts above bedrock, remedial measures including the use of gravel sheeting is recommended.

## **9.3 Rock Cut**

A portion of the excavation to form a permanent cut for the realigned Scheel Drive will be extended up to the order of 5 m into the strong to very strong crystalline limestone. It is anticipated that heavy excavating equipment, ripping machinery and rock breakers/splitters will be required to break up hard limestone and other intact rock slabs. Blasting techniques may also be considered (see Section 9.4.4).

Rock cuts should generally conform to OPSD 201.010 or 201.020 where applicable. The cut face should be formed at a slope of 1H : 4V for depths of rock cut ranging between 4 and 7m. Drainage within the cut may be provided by 0.3 m of shattered rock below the pavement structure and ditching along the toe of the rock face.

Depending on the location, orientation and height of the rock cut with respect to the pattern of joints or fractures in the rock mass, potentially unstable rock wedges may exist along the final cut slope face at and beyond the bridge abutments.

After blasting and excavation of the rock cut in the vicinity of the structure, the Contractor should scale all loosened rock from the face and the Contract Administrator should retain a rock slope stability expert to examine the cut and provide recommendations for stabilizing the



slope if required. Where the wall of the rock cut at and beyond the foundation develops potentially unstable wedges or where over-breaking occurs, the Contractor should place mass concrete fill or install rock bolts as required. The remedial work should be designed by and carried out under the direction of the rock slope stability expert retained by the Contract Administrator. Suggested wordings for an NSSP pertaining to these requirements are included in Appendix E.

#### **9.4 Excavation and Backfill**

##### **9.4.1 General**

All temporary excavation must be carried out in accordance with the Occupational Health and Safety Act (OHSA). For the purposes of the OHSA, the firm native silty clay and the compact silty sand are classified as Type 3 soils, while the soft silty clay and loose silty sand are classified as Type 4 soils.

##### **9.4.2 Foundations**

The excavation and backfilling for foundations must be carried out in accordance with SP 902S01.

##### **9.4.3 Earth Excavation**

In addition to SP 902S01, an NSSP should be included in the contract alerting the Contractor to the possible presence of cobbles, boulders, rock pieces and rock slabs in the overburden. Suggested wordings of this NSSP are included in Appendix E.

Where open cutting with inclined temporary slopes (typically not steeper than 1H : 1V for Type 3 soils according to OHSA) is not feasible, a braced soldier pile and lagging wall is considered to be suitable for use as temporary shoring at this site. The soldier piles will need to be socketted into bedrock through pre-drilled holes. It is anticipated that the shoring system may be stiffened by struts or cross bracings, where applicable.

An item titled "Temporary Protection Systems" as per SP 539S01 will have to be included in the contract documents. It is recommended that Performance Level 2 as per Clause 539.04.02.01 be specified for this site.

For a temporary braced soldier pile and lagging wall, the lateral pressure diagram as shown on Figure D1 may be used for design in conjunction with the following parameter values.

$\gamma$	=	20 kN/m <sup>3</sup>
$\gamma_w$	=	10 kN/m <sup>3</sup>
$K_a$	=	0.4 (silty clay / silty sand)
$h_w$	=	0
		(assuming that there is no hydrostatic pressure build-up behind a presumably permeable wall)
H	=	depth to base of excavation (rock surface), m



Below the excavation base, lateral earth pressures are applied over a width of  $3B$ , where  $B$  is the diameter of the socket in rock, to take into account three dimensional effects. The ultimate passive force that can be mobilized by the embedded portion of a socket within rock is constant with depth and is given by :

$$P_p = 6 c B L$$

$$\begin{aligned} \text{Where } c &= 2,000 \text{ kPa (equivalent Mohr-Coulomb cohesion} \\ &\quad \text{based on Hoek and Brown rock mass classification)} \\ L &= \text{depth of socket in rock, m} \end{aligned}$$

#### 9.4.4 Rock Excavation

In addition to SP 902S01, any rock excavation should be carried out in accordance with the SP 299F04 Rock Excavation (Trim Blasting), SP 299F06 Rock Excavation (Controlled Blasting) and OPSS 120 Use of Explosives listed in Appendix E.

It is anticipated that blasting methods will be used to form the rock cut. The Contractor may elect to use carefully controlled drill (line drilling) and blast techniques to enhance a neat excavation line and minimize face instabilities. The design of the blast and removal procedures should be the responsibility of the Contractor. However, it is important that the Contractor's procedures incorporate methods of avoiding damage to the founding surfaces and nearby roads and structures. Any damage to the founding surfaces on bedrock must be adequately repaired prior to constructing the foundation. Open joints and fractures may be encountered at the design foundation elevations. These fractures must be cleaned out and the voids must be filled by grouting prior to constructing the footing.

The Contractor's blasting and monitoring plan must not result in damage to any nearby roadways, buildings or other structures. The contract documents should alert the contractor of any such structures. During construction, it is recommended that the Contract Administrator retain the services of blasting and rock mechanics specialists to examine and assess the Contractor's procedures prior to approving them.

## 10 GROUNDWATER CONTROL

The excavation base for the foundation elements and the base of the permanent cut may be below the groundwater table at this site. Due to the fractured nature of the rock, however, it is anticipated that accumulation of water within the cut will largely be due to surface precipitation and runoff.

The design of the unwatering system should be the responsibility of the Contractor. However, suitable systems might include pumping from filtered sumps. All footing construction must be carried out in the dry.



## **11 ROAD EMBANKMENTS**

Approach fills in the order of 1 to 2 m for this structure will be constructed on firm silty clay and/or loose to compact silty sand overlying bedrock. These soils will satisfactorily support the low road embankment fills at this site. Global stability of the approach fills is not considered to be a design issue at this site provided that all permanent earth fill slopes are maintained at inclinations not steeper than 2H : 1V.

Small magnitudes of settlement, in the order of 10 mm or less, will occur due to compression within the well-compacted granular or SSM fill. The settlement should be complete by the end of construction and post construction settlement is considered to be negligible.

Where applicable, embankment construction should be in accordance with OPSS 206, as amended by SP 206S03 "Amendment to OPSS 206, December 1993", dated July 2007 included in Appendix E.

Earth fill embankment slopes must be provided with erosion protection in accordance with SP 572S01.

## **12 BACKFILL TO ABUTMENTS**

For 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 with a maximum dimension of not greater than 300 mm and including adequate spalls to fill voids in the rock fill.

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

The backfill to the abutment walls should be in accordance with OPSS 902 as amended by Special Provision 902S01. Granular backfill should be placed to the extents shown in OPSD 3101.150, and rock backfill should be placed to the extents shown in OPSD 3101.200.

All granular materials should meet the specifications of Special Provision 110F13 "Amendment to OPSS 1010, March 1993".

Compaction equipment to be used adjacent to retaining structures should be restricted in accordance with OPSS 501.06.

The design of the abutment should incorporate a subdrain as shown in OPSD 3102.100.

## **13 EARTH PRESSURE**

For cases where backfill to the abutment is placed in accordance with OPSD 3101.150 or OPSD 3101.200, as recommended, the lateral earth pressure will be governed by the properties of the



material within the backfill limits shown in the respective OPSD, i.e. a line projected up at 1.5H:1V for granular backfill and 1.25H:1V for rock backfill.

If the support system allows yielding of the wall (unrestrained system), active horizontal earth pressure may be used in the foundation design of the structure. If the support system does not allow yielding (restrained system), at-rest horizontal earth pressures should be used. The amount of wall movement required for development of active, passive and at rest earth pressures may be interpreted using Figure C6.9.1(a) in the Commentary to the CHBDC.

Earth pressures acting on the structure should be computed in accordance with Clause 6.9 of the CHBDC but generally are given by the expression:

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

where  $P_h$  = horizontal pressure on the wall at depth  $h$  (kPa)  
 $K$  = 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 at a depth of 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 the following table.

Wall 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 $\phi = 42^\circ, \gamma = 19.0 \text{ kN/m}^3$	
	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 (Unrestrained Wall)	0.27	0.40*	0.31	0.48*	0.2	.28*
At rest (Restrained Wall)	0.43	-	0.47	-	0.33	-
Passive (Movement Towards Soil Mass)	3.7	-	3.3	-	5.0	-

\* For wing walls.



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. However, the use of Granular B Type I may be restricted if the approach embankment consist of rock fill.

The factors in the table above 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 CHBDC 2006.

## 14 SEISMIC CONSIDERATIONS

### 14.1 Seismic Design Parameters

The following seismic parameters are provided in Table A3.1.7 of the CHBDC for the Arnprior/Renfrew area:

- Velocity Related Seismic Zone: 2
- Zonal Velocity Ratio: 0.10
- Acceleration Related Seismic Zone: 4
- Zonal Acceleration Ratio: 0.20

The soils at this site consist of firm clays and loose to compact sands generally less than 2 to 3m. The Soil Profile Type at these locations is classified as Type 1, which, according to Table 4.4.6.1 of the CHBDC is, associated with a Site Coefficient, S (also referred to as ground motion amplification factor) of 1.0.

### 14.2 Liquefaction Potential

The structures will be founded on bedrock, and the cut will be formed through a thin layer of soil into the bedrock. Weak soils immediately adjacent to the cut are anticipated to be removed. As such, there is negligible potential for liquefaction of these soils. The rock has no potential for liquefaction.

The embankments are low and will be constructed above the groundwater table on firm clay, compact sand or engineered fill. They are, therefore, not considered to be in danger of liquefaction. Some toe failure may occur but it is expected to be of limited nature and readily repairable.

### 14.3 Retaining Wall Dynamic Earth Pressures

In accordance with Clause C4.6.4 of the CHBDC 2006, retaining structures should be designed using active ( $K_{AE}$ ) and passive earth pressure ( $K_{PE}$ ) coefficients that incorporate



effects of earthquake loading. The rigid frame structure should be designed for at-rest pressure ( $K_{OE}$ ). The following design parameters were used to calculate the seismic earth pressures:

$\phi'$  = angle of internal friction of backfill

$\delta$  = the angle of friction between the wall and the backfill.

The seismic earth pressure coefficients to be used in design at this site are shown in the table below.

Wall Condition	Earth Pressure Coefficient (K) for Earthquake Loading						
	Height of Application From Base as Percentage of Wall Height	Granular A or Granular B Type II $\phi = 35^\circ, \delta = 17.5^\circ$		OPSS Granular B Type I $\phi = 32^\circ, \delta = 16^\circ$		Rock Fill $\phi = 42^\circ, \delta = 21^\circ$	
		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 ( $K_{AE}$ )*	40%	0.33	0.70	0.37	0.90***	0.26	0.40
Passive ( $K_{PE}$ )	33%	3.5	-	3.0	-	4.8	-
At Rest ( $K_{OE}$ )**	45%	0.67	-	0.72	-	0.58	

\* After Mononobe and Okabe

\*\* After Woods

\*\*\* Slope may undergo movement for short durations during seismic activities

## 15 CONSTRUCTION CONCERNS

During construction, the Contract Administrator should employ experienced geotechnical staff to observe construction activities related to foundation construction.

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

- If blasting is to be employed, blasting and rock mechanics experts should be retained to review the contractor's proposed work procedures, to monitor the contractor's work, and to ensure that there will be no adverse effects on nearby highways, roads, structures and buried utilities.
- Rock mechanics specialist(s) should be retained to inspect all exposed rock slopes and faces, regardless of the methods of excavation, to confirm short and long term stability and to provide recommendations for remedial measures if required.





- Potential disturbance of the founding bedrock surface due to blasting or other excavation procedures.
- Excavating, dislodging, handling and disposing of boulders, cobbles, rock pieces and slabs.
- Stability of the earth cuts during and after construction.
- Temporary unwatering of the permanent cut and footing excavations to allow construction to be carried out in the dry.

## **16 CLOSURE**

Engineering analysis and preparation of this foundation design report was carried out by Dr. S. Pang, P.Eng. The report was reviewed by Dr. P. K. Chatteriji, P.Eng., a Designated Principal Contact for MTO Foundations Projects.





Engineering Analysis and Report Preparation by:  
Sydney Pang, P.Eng.,  
Associate, Senior Project Engineer



Report Reviewed by:  
P. K. Chatterji, P.Eng.,  
Review Principal, Designated MTO Contact



**TABLE 1 -Point Load Test Results and Unconfined Compression Strength Correlations  
Highway 17/417 Widening – Scheel Twin Overpass Structures**

SCH08-01	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											
	10	6	3.20	12.1	D	47.00	5.478	5.311	OK	127.46	limestone
	10	11	3.33	16.8	D	47.00	7.605	7.374	OK	176.97	limestone
	11	5	3.48	10.3	D	47.00	4.663	4.521	OK	108.50	limestone
	12	4	3.76	20.7	D	47.00	9.371	9.085	OK	218.05	limestone
	12	8	3.86	15.2	D	47.00	6.881	6.671	OK	160.11	limestone
	13	4	4.06	15.5	D	47.00	7.017	6.803	OK	163.27	limestone
RUN #2	13	6	4.11	15.8	D	47.00	7.153	6.935	OK	166.43	limestone
	14	3	4.34	9.9	D	47.00	4.482	4.345	OK	104.28	limestone
	14	10	4.52	17.4	D	47.00	7.877	7.637	OK	183.29	limestone
	15	7	4.75	14.0	D	47.00	6.338	6.145	OK	147.47	limestone
	16	5	5.00	15.3	D	47.00	6.926	6.715	OK	161.17	limestone
RUN #3	18	8	5.69	5.0	D	47.00	2.263	2.195	OK	52.67	limestone

SCH08-04	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											
	3	11	1.19	12.9	D	47.00	5.840	5.662	OK	135.88	limestone
	4	11	1.50	15.6	D	47.00	7.062	6.847	OK	164.33	limestone
	7	0	2.13	15.5	D	47.00	7.017	6.803	OK	163.27	limestone
	8	1	2.46	20.0	D	47.00	9.054	8.778	OK	210.67	limestone
RUN #2	8	10	2.69	11.2	D	47.00	5.070	4.916	OK	117.98	limestone
	9	10	3.00	5.5	D	47.00	2.490	2.414	OK	57.94	limestone
	11	4	3.45	15.1	D	47.00	6.836	6.627	OK	159.06	limestone
	11	11	3.63	14.8	D	47.00	6.700	6.496	OK	155.90	limestone
	12	10	3.91	20.6	D	47.00	9.325	9.041	OK	216.99	limestone
RUN #3	14	1	4.29	12.0	D	47.00	5.432	5.267	OK	126.40	limestone
	14	8	4.47	15.0	D	47.00	6.790	6.584	OK	158.00	limestone
	15	2	4.62	11.0	D	47.00	4.980	4.828	OK	115.87	limestone

**TABLE 1 -Point Load Test Results and Unconfined Compression Strength Correlations  
Highway 17/417 Widening – Scheel Twin Overpass Structures**

SCH08-07	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											limestone limestone limestone
	5	6	1.68	9.2	D	47.00	4.165	4.038	OK	96.91	
	6	11	2.11	11.5	D	47.00	5.206	5.047	OK	121.14	
	7	7	2.31	14.3	D	47.00	6.474	6.276	OK	150.63	
RUN #2	9	8	2.95	17.4	D	47.00	7.877	7.637	OK	183.29	limestone limestone limestone limestone limestone limestone
	10	5	3.18	7.8	D	47.00	3.531	3.423	OK	82.16	
	11	4	3.45	14.6	D	47.00	6.609	6.408	OK	153.79	
	12	0	3.66	16.7	D	47.00	7.560	7.330	OK	175.91	
	12	7	3.84	5.0	D	47.00	2.263	2.195	OK	52.67	
	13	5	4.09	9.4	D	47.00	4.255	4.126	OK	99.02	
RUN #3	14	1	4.29	11.8	D	47.00	5.342	5.179	OK	124.30	limestone limestone limestone limestone
	15	0	4.57	21.8	D	47.00	9.869	9.568	OK	229.63	
	16	1	4.90	12.3	D	47.00	5.568	5.399	OK	129.56	
	17	6	5.33	12.7	D	47.00	5.749	5.574	OK	133.78	

[illegible]

**TABLE 1 -Point Load Test Results and Unconfined Compression Strength Correlations  
Highway 17/417 Widening – Scheel Twin Overpass Structures**

SCH08-013	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											limestone limestone
	7	7	2.31	22.2	D	47.00	10.050	9.744	OK	233.85	
	8	5	2.57	14.5	D	47.00	6.564	6.364	OK	152.74	
RUN #2											limestone limestone limestone limestone limestone limestone
	9	3	2.82	8.6	D	47.00	3.893	3.775	OK	90.59	
	10	8	3.25	19.4	D	47.00	8.782	8.515	OK	204.35	
	11	4	3.45	13.5	D	47.00	6.111	5.925	OK	142.20	
	11	9	3.58	19.6	D	47.00	8.873	8.602	OK	206.46	
	12	4	3.76	15.1	D	47.00	6.836	6.627	OK	159.06	
RUN #3	12	10	3.91	12.0	D	47.00	5.432	5.267	OK	126.40	limestone limestone limestone
	13	7	4.14	13.0	D	47.00	5.885	5.706	OK	136.94	
RUN #3	14	0	4.27	10.3	D	47.00	4.663	4.521	OK	108.50	limestone limestone limestone limestone
	14	5	4.39	14.9	D	47.00	6.745	6.540	OK	156.95	
	15	0	4.57	17.0	D	47.00	7.696	7.461	OK	179.07	
	15	7	4.75	12.3	D	47.00	5.568	5.399	OK	129.56	

SCH08-16	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											limestone limestone limestone
	9	6	2.90	5.2	D	47.00	2.354	2.282	OK	54.78	
	10	0	3.05	8.9	D	47.00	4.029	3.906	OK	93.75	
RUN #2	10	11	3.33	13.8	D	47.00	6.247	6.057	OK	145.36	limestone limestone limestone limestone limestone limestone
RUN #3	14	4	4.37	14.0	D	47.00	6.338	6.145	OK	147.47	limestone limestone limestone limestone limestone limestone
	15	2	4.62	15.5	D	47.00	7.017	6.803	OK	163.27	
	15	7	4.75	11.2	D	47.00	5.070	4.916	OK	117.98	
	16	7	5.05	16.9	D	47.00	7.651	7.417	OK	178.02	
	17	6	5.33	13.3	D	47.00	6.021	5.837	OK	140.10	
RUN #3	18	11	5.77	10.3	D	47.00	4.663	4.521	OK	108.50	limestone limestone limestone limestone limestone limestone limestone
	19	4	5.89	13.3	D	47.00	6.021	5.837	OK	140.10	
	19	10	6.05	8.2	D	47.00	3.712	3.599	OK	86.38	
	20	4	6.20	18.5	D	47.00	8.375	8.120	OK	194.87	
	21	3	6.48	9.1	D	47.00	4.120	3.994	OK	95.86	
	22	5	6.83	16.6	D	47.00	7.515	7.286	OK	174.86	
	23	4	7.11	9.8	D	47.00	4.436	4.301	OK	103.23	

**TABLE 1 -Point Load Test Results and Unconfined Compression Strength Correlations  
Highway 17/417 Widening – Scheel Twin Overpass Structures**

SCH08-19	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											limestone limestone
	10	4	3.15	14.3	D	47.00	6.474	6.276	OK	150.63	
	11	9	3.58	17.3	D	47.00	7.832	7.593	OK	182.23	
RUN #2											limestone limestone
	14	6	4.42	12.6	D	47.00	5.704	5.530	OK	132.72	
	14	9	4.50	16.5	D	47.00	7.469	7.242	OK	173.81	
RUN #3	19	0	5.79	14.4	D	47.00	6.519	6.320	OK	151.68	limestone limestone limestone limestone limestone limestone limestone limestone limestone limestone
	19	7	5.97	12.0	D	47.00	5.432	5.267	OK	126.40	
	19	11	6.07	17.5	D	47.00	7.922	7.681	OK	184.34	
	20	4	6.20	12.1	D	47.00	5.478	5.311	OK	127.46	
	20	10	6.35	18.5	D	47.00	8.375	8.120	OK	194.87	
	21	4	6.50	14.3	D	47.00	6.474	6.276	OK	150.63	
	21	10	6.65	14.8	D	47.00	6.700	6.496	OK	155.90	
	22	3	6.78	14.3	D	47.00	6.474	6.276	OK	150.63	
	22	8	6.91	12.5	D	47.00	5.659	5.486	OK	131.67	
	22	11	6.99	18.7	D	47.00	8.465	8.207	OK	196.98	

SCH08-22	DEPTH			FORCE (kN)	AXIAL / DIAMETRIC	DISTANCE (mm)	Is (MPa)	Is50 (MPa)	BREAK	UCS (Mpa)	Rock Type
	FT.	IN.	(m)								
RUN #1											limestone
	7	9	2.36	11.2	D	47.00	5.070	4.916	OK	117.98	
RUN #2	10	2	3.10	13.1	D	47.00	5.930	5.750	OK	137.99	limestone limestone limestone
	10	8	3.25	9.1	D	47.00	4.120	3.994	OK	95.86	
	11	2	3.40	10.0	D	47.00	4.527	4.389	OK	105.34	
RUN #3	13	6	4.11	4.0	D	47.00	1.811	1.756	OK	42.13	limestone limestone
	16	10	5.13	10.6	D	47.00	4.799	4.652	OK	111.66	
RUN #4	18	10	5.74	10.2	D	47.00	4.617	4.477	OK	107.44	limestone limestone limestone limestone
	19	2	5.84	11.6	D	47.00	5.251	5.091	OK	122.19	
	20	8	6.30	17.2	D	47.00	7.786	7.549	OK	181.18	
	21	4	6.50	16.3	D	48.00	7.075	6.932	OK	166.36	

## **Appendix A**

### **Records of Boreholes**



## 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 <sup>(1)</sup> '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<sub>pen</sub>

Shear Strength Determination by Pocket Penetrometer


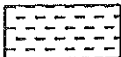



- (1) SPT 'N' Value Standard Penetration Test 'N' Value – refers to the number of blows from a 63.5kg hammer free falling a height of 0.76m to advance a standard 50 mm outside diameter split spoon sampler for 0.3 m depth into undisturbed ground.
- (2) DCPT Dynamic Cone Penetration Test – Continuous penetration 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		SYMBOLS	
Fresh (FR)	No visible signs of weathering.		
Fresh Jointed (FJ)	Weathering limited to the surface of major discontinuities.		CLAYSTONE
Slightly Weathered (SW)	Penetrative weathering developed on open discontinuity surfaces, but only slight weathering of rock material.		SILTSTONE
Moderately Weathered (MW)	Weathering extends throughout the rock mass, but the rock material is not friable.		SANDSTONE
Highly Weathered (HW)	Weathering extends throughout the rock mass and the rock is partly friable.		COAL
Completely Weathered (CW)	Rock is wholly decomposed and in a friable condition, but the rock texture and structure are preserved.		Bedrock (general)

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

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.



RECORD OF BOREHOLE No 08-SCH-01

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 196.3 E 308 126.4 ORIGINATED BY LG  
HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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			SHEAR STRENGTH kPa						
122.4								20 40 60 80 100						
0.0 0.1	TOPSOIL, roots							○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    X LAB VANE						
	CLAY, some silt, trace sand Firm Brown to Gray Brown Moist		1	SS	4		122							
			2	SS	8		121							2 6 67 25
			3	SS										
	Moist to Wet													
			4	SS	7		120							
119.5	AUGER REFUSAL AT 2.9m.													
2.9	CRYSTALLINE LIMESTONE (BEDROCK). moderately to slightly weathered, grey, thinly bedded, calcite infilling throughout, very strong Sub-vertical joints at 3.00m, 3.09m, 3.14m, 3.27m, 3.38m, 3.55m, 3.58m, 3.63m, 3.71m, 3.76m, 3.86m  Sub-vertical joints at 4.14m, 4.39m, 4.55m, 4.77m, 5.00m		1	RUN			119							RUN 1# TCR=87%, SCR=30%, RQD=30%, UCS=108 to 218MPa

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

# RECORD OF BOREHOLE No 08-SCH-02

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 194.4 E 308 128.5 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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						
							20 40 60 80 100							
							40 80 120 160 200							
123.4	TOPSOIL		1	SS	3									
0.0	CLAY, some silt, trace sand, trace rootlets													
0.1	Soft to Firm													
	Brown to Light Brown		2	SS	4									
	Moist													
121.3														
2.1	END OF BOREHOLE AT 2.1m.													
	AUGER REFUSAL AT 2.1m.													
	Piezometer installation consists of													
	19mm diameter Schedule 40 PVC pipe													
	with a 0.9m slotted screen.													
	BOREHOLE BACKFILLED WITH													
	CUTTINGS.													
	WATER LEVEL READINGS:													
	DATE DEPTH (m) ELEV. (m)													
	2008.09.12 1.7 121.7													

# RECORD OF BOREHOLE No 08-SCH-03

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 157.7 E 308 148.7 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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			20	40	60	80	100		
126.4													
0.0	Silty SAND, trace gravel, trace clay Loose Brown Moist		1	SS	7								1 61 32 6
125.4			2	SS	50/								
1.0	END OF BOREHOLE AT 1.0m. AUGER REFUSAL AT 1.0m. BOREHOLE BACKFILLED WITH CUTTINGS.				.75								

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




20  
15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-SCH-04

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 159.0 E 308 151.4 ORIGINATED BY LG  
HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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 (%)  GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
								20 40 60 80 100						
127.3														
0.0	Silty SAND, trace gravel, rootlets		1	SS	6		127							
126.2	AUGER REFUSAL AT 1.1m.													
1.1	CRYSTALLINE LIMESTONE (BEDROCK) moderately to slightly weathered, grey, thinly bedded, calcium infilling, strong to very strong Sub-vertical joints at 25 to 50mm intervals		1	RUN			126							
	Sub-vertical joints at 50 to 75mm intervals, calcite infilling at 3.3m and 4.1m.		2	RUN			125							
	Sub-vertical joints at 100mm intervals		3	RUN			124							
122.6	END OF BOREHOLE AT 4.8m. BOREHOLE SEALED WITH BENTONITE AND GRAVEL.						123							
4.7														

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

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 08-SCH-05

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 177.1 E 308 141.3 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Shovel COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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	20			40	60	80	100	W <sub>P</sub>	W	W <sub>L</sub>			
121.5																		
0.0	Silty SAND, rootlets		1	AS														
121.0	Brown																	
	Moist																	
0.5	END OF BOREHOLE AT 0.5m. EXPOSED BOULDER OR BEDROCK. BOREHOLE BACKFILLED WITH CUTTINGS.																	

RECORD OF BOREHOLE No 08-SCH-06

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 177.7 E 308 127.7 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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					
124.3																	
0.0	TOPSOIL, organics, clayey silt Firm		1	SS	5												
123.8	Black to Brown Moist																
0.5	END OF BOREHOLE AT 0.5m. AUGER REFUSAL AT 0.5m. BOREHOLE BACKFILLED WITH CUTTINGS.																

ONTMT4S 1125 GPJ 11/6/08

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

20  
15 5  
10 (%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 08-SCH-07

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 182.2 E 308 159.6 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27 CHECKED BY SKP


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			SHEAR STRENGTH kPa									
122.9								20	40	60	80	100					
0.0	Silty SAND, trace clay, trace gravel Loose Brown Moist		1	SS	7												GR SA SI CL
121.4	AUGER REFUSAL AT 1.5m.																
1.5	CRYSTALLINE LIMESTONE (BEDROCK), moderately to slightly weathered, grey, thinly bedded, occasional calcite infilling, strong to very strong Sub-vertical joints, 25mm calcite infilling at 1.96m.  Sub-vertical joints at 125 to 175mm intervals, occasional calcite infilling		1	RUN												FI	RUN 1# TCR=100%, SCR=13%, RQD=13%, UCS=97 to 150MPa
			2	RUN												4	RUN 2# TCR=100%, SCR=75%, RQD=75%, UCS=52 to 183MPa
			3	RUN												1	RUN 3# TCR=75%, SCR=57%, RQD=57%, UCS=124 to 229MPa
117.2	END OF BOREHOLE AT 5.7m. BOREHOLE SEALED WITH BENTONITE HOLEPLUG AND GRAVEL.															2	
5.7																	

RECORD OF BOREHOLE No 08-SCH-08

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 180.7 E 308 162.4  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27  
 ORIGINATED BY LG  
 COMPILED BY FK  
 CHECKED BY SKP







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 (%)
122.8								20	40	60	80	100						
0.0	Silty <b>SAND</b> , trace rock pieces Brown		1	SS														
122.4	Moist																	
0.4	END OF BOREHOLE AT 0.4m. AUGER REFUSAL AT 0.4m. BOREHOLE BACKFILLED WITH CUTTINGS.																	

RECORD OF BOREHOLE No 08-SCH-09

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 156.2 E 308 181.3 ORIGINATED BY LG  
HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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 (%)  GR SA SI CL		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED    + FIELD VANE ● QUICK TRIAXIAL    x LAB VANE							WATER CONTENT (%) w <sub>p</sub> w    w <sub>L</sub>	
124.5							20	40	60	80	100	20	40	60		
0.0	Silty CLAY, some roots. trace gravel Firm Brown Moist		1	SS	6											
123.7	AUGER REFUSAL AT 0.8m.															
0.8	CRYSTALLINE LIMESTONE (BEDROCK), moderately to slightly weathered, grey, thinly bedded, calcite infilling, very strong Sub-vertical joints at 0.93m, 0.99m, 3.42m, 3.58m, and 3.92m; calcite infilling Sub-vertical joints at 1.2m - 1.5m; calcite infilling Vertical fracture from 1.57m to 1.98m; calcite seam from 2.3m to 2.7m  Vertical fracture from 3.45m to 3.68m Sub-vertical joints at 3.12m, 3.316m 3.68m, 3.92m, and 4.01m; calcite infilling		1	RUN												
			2	RUN												
			3	RUN												
120.2																
4.3	END OF BOREHOLE AT 4.3m. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE    DEPTH (m)    ELEV. (m) 2008.09.12    dry    -															

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

20  
15 5  
10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 08-SCH-10

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 155.8 E 308 183.0 ORIGINATED BY LG  
HWY 17/417 BOREHOLE TYPE Manual with shovel COMPILED BY FK  
DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP


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	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>P</sub> W W <sub>L</sub>				
124.7														
0.0	Silty CLAY, roots, trace gravel													
124.3	Moist													
0.4	END OF BOREHOLE AT 0.4m. EXPOSED BOULDER OR BEDROCK. BOREHOLE BACKFILLED WITH CUTTINGS.													

# RECORD OF BOREHOLE No 08-SCH-11

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 168.3 E 308 175.6 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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									
123.3								20	40	60	80	100					
0.0	Silty <b>SAND</b> , rootlets, organics, trace gravel Compact Brown		1	SS	18		123										
122.6	Moist (FILL)																
0.7	END OF BOREHOLE AT 0.7m. AUGER REFUSAL AT 0.7m. BOREHOLE BACKFILLED WITH CUTTINGS.																

ONTMT4S 1125 GPJ 11/17/08

# RECORD OF BOREHOLE No 08-SCH-12

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 164.9 E 308 192.3 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.25 - 2008.08.25 CHECKED BY SKP

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													
123.6							20	40	60	80	100										
0.0	Gravelly SAND, some rootlets, some silt		1	SS	27												GR SA SI CL				
123.0	Compact Brown																				30 55 15
0.6	Moist (FILL)																				(SH+CL)
	END OF BOREHOLE AT 0.6m. AUGER REFUSAL AT 0.6m. BOREHOLE BACKFILLED WITH CUTTINGS.																				

## METRIC

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV. DEPTH	DESCRIPTION	STRAT PLOT	NUMBER			TYPE	"N" VALUES	20 40 60 80 100	W <sub>p</sub>		
125.2						SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE 40 80 120 160 200				20 40 60	
										γ	GR SA SI CL

[illegible]

CONTMT4S 1125.GPJ 3/23/09

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

# RECORD OF BOREHOLE No 08-SCH-14

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 129.4 E 308 182.0 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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			20 40 60 80 100	40 80 120 160 200					
125.2														
0.0	Silty SAND, trace to some gravel Loose Brown to Black Moist (FILL)		1	SS	7									
124.3														
0.9	CLAY, some sand Firm Brown		2	SS	6									
123.7														
1.5	END OF BOREHOLE AT 1.5m. AUGER REFUSAL AT 1.5m. BOREHOLE BACKFILLED WITH GRAVEL.													

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

20  
15  
10  
(%) STRAIN AT FAILURE





# RECORD OF BOREHOLE No 08-SCH-15

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 106.9 E 308 195.4 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27 CHECKED BY SKP




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 (%)
126.2								20	40	60	80	100			
0.0	Gravelly SAND, trace silt, some pieces of rock Very Dense Brown Moist (FILL)		1	SS	51		126								27 63 10 (SI+CL)
125.4			2	SS	50/										
0.8	Silty SAND, trace clay Loose to Compact Brown Moist				.075		125								
			3	SS	7										
							124								
			4	SS	10										
123.4															
2.8	END OF BOREHOLE AT 2.8m. AUGER REFUSAL AT 2.8m. BOREHOLE BACKFILLED WITH GRAVEL.														

# RECORD OF BOREHOLE No 08-SCH-16

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 106.0 E 308 199.3 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27 CHECKED BY SKP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT      NATURAL LIMIT      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				w <sub>p</sub> w      w <sub>L</sub>				
								● QUICK TRIAXIAL      × LAB VANE								
126.2							20	40	60	80	100					
0.0	Silty SAND, some to trace gravel, inferred cobble Dense Brown Moist (FILL)		1	SS	47		126						○			
125.3			2	SS	177											
0.9	Silty SAND, trace to some clay Compact Brown Moist				.050		125									
			3	SS	13								○			
	trace to some pieces of rock						124									
123.6	AUGER REFUSAL AT 2.6m.												○			
2.6	CRYSTALLINE LIMESTONE (BEDROCK), slightly weathered, thinly bedded, calcium infilling, strong to very strong Sub-vertical joints at 125 to 175mm intervals		1	RUN			123								FI	RUN 1# TCR=100%, SCR=90%, RQD=48%, UCS=54 to 145MPa
	Sub-vertical joints at 75 to 100mm intervals						122								2	RUN 2# TCR=100%, SCR=67%, RQD=35%, UCS=117 to 178MPa
	Sub-vertical joints at 75 to 150mm intervals		2	RUN			121								5	
															4	
															4	
															3	RUN 3# TCR=100%, SCR=65%, RQD=37%, UCS=86 to 194MPa
															4	
															4	
			3	RUN			120								2	
															2	
															3	
119.0	becoming Reddish Grey														2	
7.2	END OF BOREHOLE AT 7.2m. BOREHOLE BACKFILLED WITH BENTONITE AND GRAVEL.															

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

20  
15  
10



(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 08-SCH-17

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 125.8 E 308 184.6 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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									
125.6								20	40	60	80	100					
0.0	Silty SAND, trace to some gravel Dense Moist (FILL)		1	SS	41												
124.7			2	SS	8/												Sampler bouncing
0.9	END OF BOREHOLE AT 0.9m. AUGER REFUSAL AT 0.9m. BOREHOLE BACKFILLED WITH GRAVEL				.050												

# RECORD OF BOREHOLE No 08-SCH-18

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 114.3 E 308 176.7  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27  
 ORIGINATED BY LG  
 COMPILED BY FK  
 CHECKED BY SKP

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		
126.1														
0.0	Silty SAND, trace to some gravel, some pieces of rock Dense to Compact Brown		1	SS	45		126							
125.4	Moist (FILL)													
0.7	Silty SAND, trace to some gravel Compact Brown Moist		2	SS	28		125							
124.3														
1.8	END OF BOREHOLE AT 1.8m. BOREHOLE BACKFILLED WITH GRAVEL.													



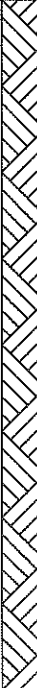
ONTMT4S 1125.GPJ 11/17/08

RECORD OF BOREHOLE No 08-SCH-19

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 122.2 E 308 215.4 ORIGINATED BY LG  
HWY 17/417 BOREHOLE TYPE Hollow Stem Augers / NQ Coring COMPILED BY FK  
DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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			SHEAR STRENGTH kPa								WATER CONTENT (%)			GR	SA
125.2								20	40	60	80	100								
0.0	Gravelly <b>SAND</b> , some silt , trace clay Compact Brown Moist (FILL) trace limestone pieces		1	SS	10		125										21	55	18	6
			2	SS	13		124													
123.8																				
1.4	Silty <b>CLAY</b> , with sand, trace gravel Soft to Firm Brown Moist		3	SS	4		123										3	57	32	8
			4	SS	5/		122													
122.7	AUGER REFUSAL AT 2.5m																			Sampler bouncing
2.5	<b>BEDROCK</b> , moderately to highly weathered, grey, thinly bedded, calcium infilling, very strong Sub-horizontal joints at 50 to 75mm		1	RUN	.150		122										Fi			RUN 1# TCR=100%, SCR=20%, RQD=20%, UCS=150 to 182MPa
	Encountered voids; poor recovery within sections of broken core		2	RUN			121										2			RUN 2# TCR=50%, SCR=35%, RQD=18%, UCS=132 to 173MPa
							120										2			
	slightly weathered to fresh		3	RUN			119										2			RUN 3# TCR=100%, SCR=80%, RQD=80%, UCS=126 to 197MPa
																	0			
																	1			
118.1																	2			
7.1	END OF BOREHOLE AT 7.1m. BOREHOLE SEALED WITH BENTONITE HOLEPLUG AND GRAVEL.																			

# RECORD OF BOREHOLE No 08-SCH-20

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 121.0 E 308 219.0 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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 (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa						
125.2								20 40 60 80 100						
0.0	Silty SAND, some gravel Compact		1	SS	20		125	○ UNCONFINED + FIELD VANE						
124.7	Moist (FILL)													
0.5	Silty CLAY, some sand, trace rock pieces Firm Brown to Reddish Brown Moist		2	SS	7									
			3	SS	56/ .250		124							
123.3														
1.9	END OF BOREHOLE AT 1.9m. AUGER REFUSAL AT 1.9m. BOREHOLE BACKFILLED WITH GRAVEL.													

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









20  
15 5  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 08-SCH-21

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 097.0 E 308 231.3 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.27 - 2008.08.27 CHECKED BY SKP

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    x LAB VANE								
126.4								20	40	60	80	100				
0.9	ASPHALT: (50mm)		1	SS	24		126							○		37 52 11
125.8	SAND and GRAVEL, trace to some pieces of rock Compact to Very Dense Brown Moist (FILL)		2	SS	86									○		(SI+CL)
0.6	Silty SAND, trace to some rock pieces Very Dense Brown Moist		3	SS	50/ .200		125							○		
124.1																
2.3	Silty CLAY, some sand, trace gravel Firm Brown Moist		4	SS	4		124							○		
123.6																
2.8	END OF BOREHOLE AT 2.8m. AUGER REFUSAL AT 2.8m. BOREHOLE BACKFILLED WITH BENTONITE. Piezometer installation consists of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen. WATER LEVEL READINGS: DATE      DEPTH (m)      ELEV. (m) 2008.09.12      dry      -															

+<sup>3</sup> . X<sup>3</sup> : Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

## METRIC

[illegible]

(%) STRAIN AT FAILURE



# RECORD OF BOREHOLE No 08-SCH-23

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 117.1 E 308 222.4 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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						
125.6 0.0	Silty SAND, trace gravel, trace pieces of rock Brown Moist (FILL)													
125.0 0.6														
END OF BOREHOLE AT 0.6m. AUGER REFUSAL AT 0.6m. BOREHOLE BACKFILLED WITH CUTTINGS.														

# RECORD OF BOREHOLE No 08-SCH-24

1 OF 1

METRIC

G.W.P. 4067-03-00 LOCATION Scheel Drive N 5 033 119.0 E 308 238.5 ORIGINATED BY LG  
 HWY 17/417 BOREHOLE TYPE Hollow Stem Auger COMPILED BY FK  
 DATUM Geodetic DATE 2008.08.26 - 2008.08.26 CHECKED BY SKP

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			SHEAR STRENGTH kPa									
125.7								20	40	60	80	100					
0.0	Gravelly <b>SAND</b> Compact to Loose Brown (FILL)		1	SS	21												28 62 10 (SI+CL)
125.0							125										
0.7	Silty <b>SAND</b> , trace to some gravel Loose Brown Moist		2	SS	6												
124.5																	
1.2	Silty <b>CLAY</b> , with sand, trace gravel, trace pieces of rock Firm Moist		3	SS	7		124										
			4	SS	8												3 49 30 18
122.9							123										
2.8	END OF BOREHOLE AT 2.8m. AUGER REFUSAL AT 2.8m. BOREHOLE SEALED WITH GRAVEL AND BENTONITE.																

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

20  
15 5  
10  
(%) STRAIN AT FAILURE

## **Appendix B**

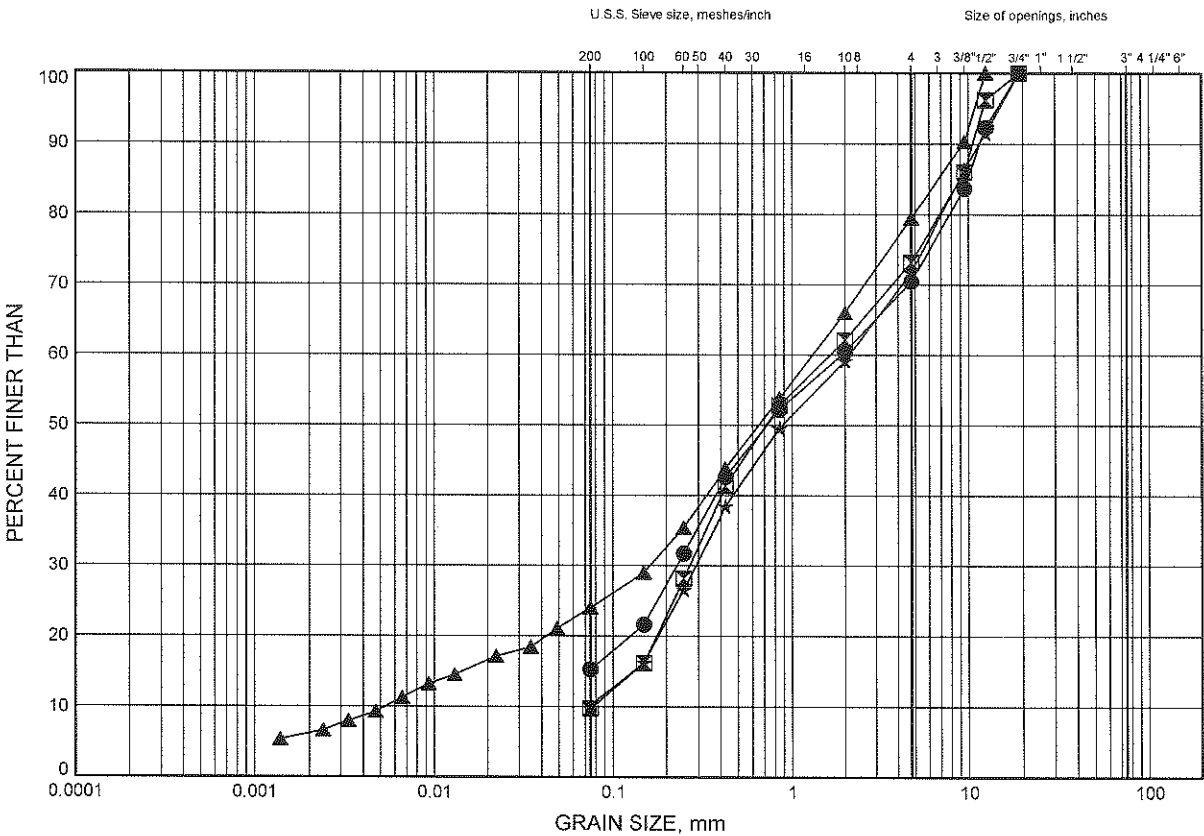
### **Laboratory Test Results**



# GRAIN SIZE DISTRIBUTION

FIGURE B1

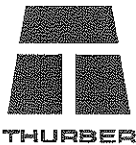
## GRAVELLY SAND FILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-SCH-12	0.28	123.32
⊠	08-SCH-15	0.30	125.90
▲	08-SCH-19	0.30	124.90
☆	08-SCH-24	0.30	125.40

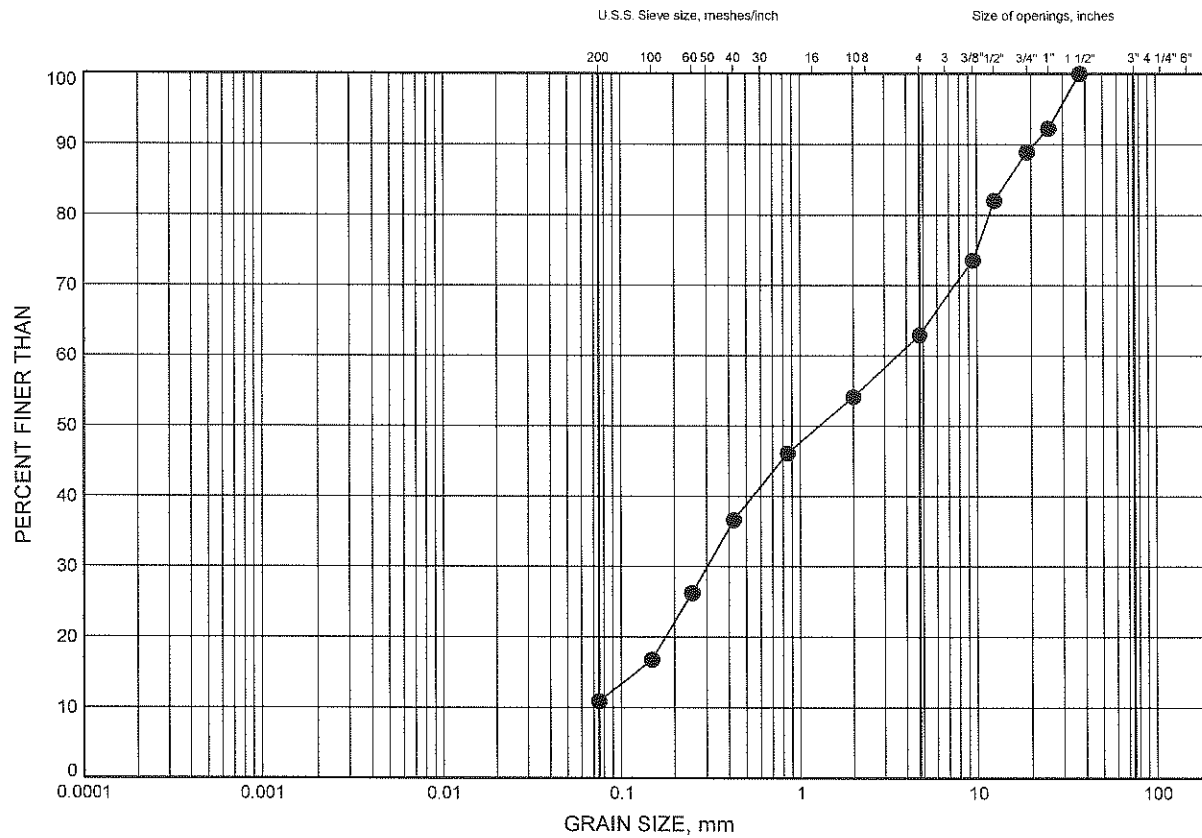


W.P.# 4067-03-00.....  
 Prepared By MFA.....  
 Checked By SKP.....

# GRAIN SIZE DISTRIBUTION

FIGURE B2

## SAND AND GRAVEL FILL



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-SCH-21	0.30	126.10

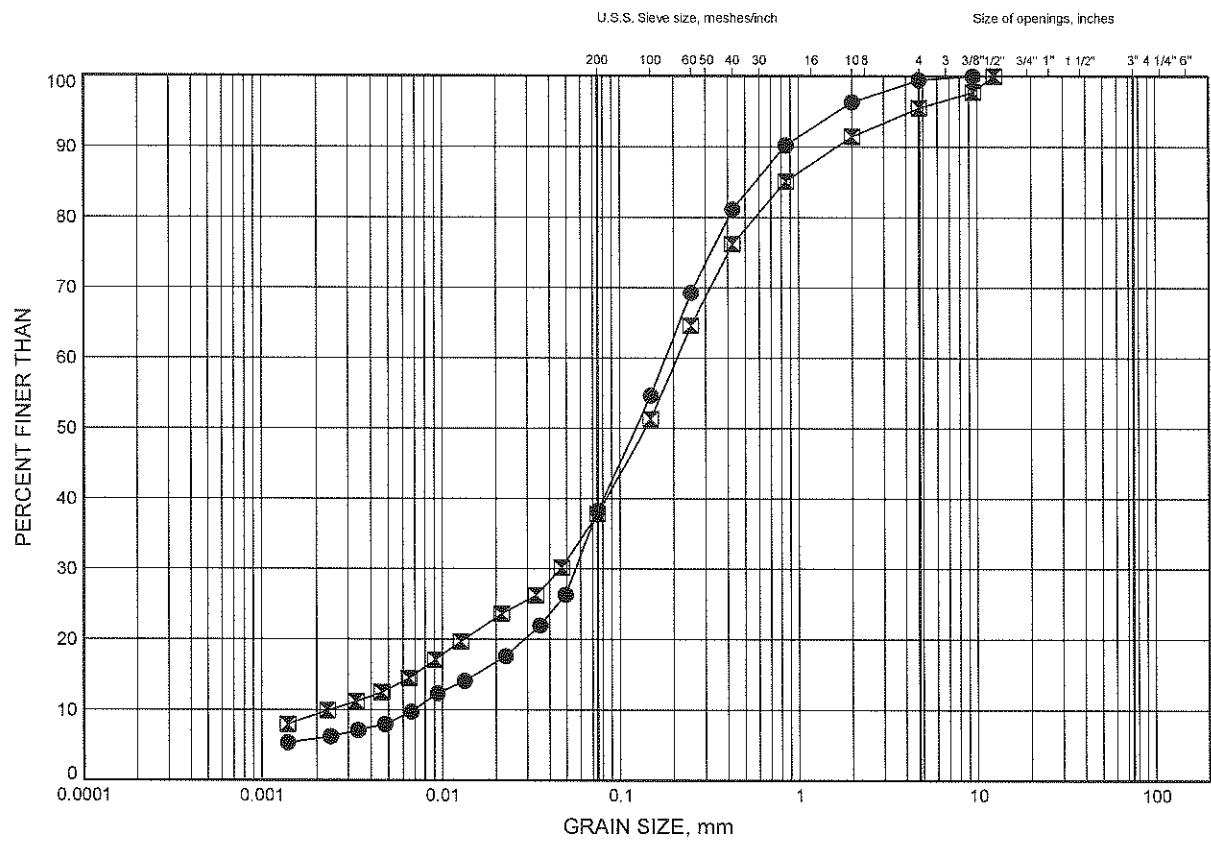


W.P.# 4067-03-00  
 Prepared By MFA  
 Checked By SKP

# GRAIN SIZE DISTRIBUTION

FIGURE B3

## SILTY SAND



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-SCH-03	0.30	126.10
■	08-SCH-07	0.30	122.60

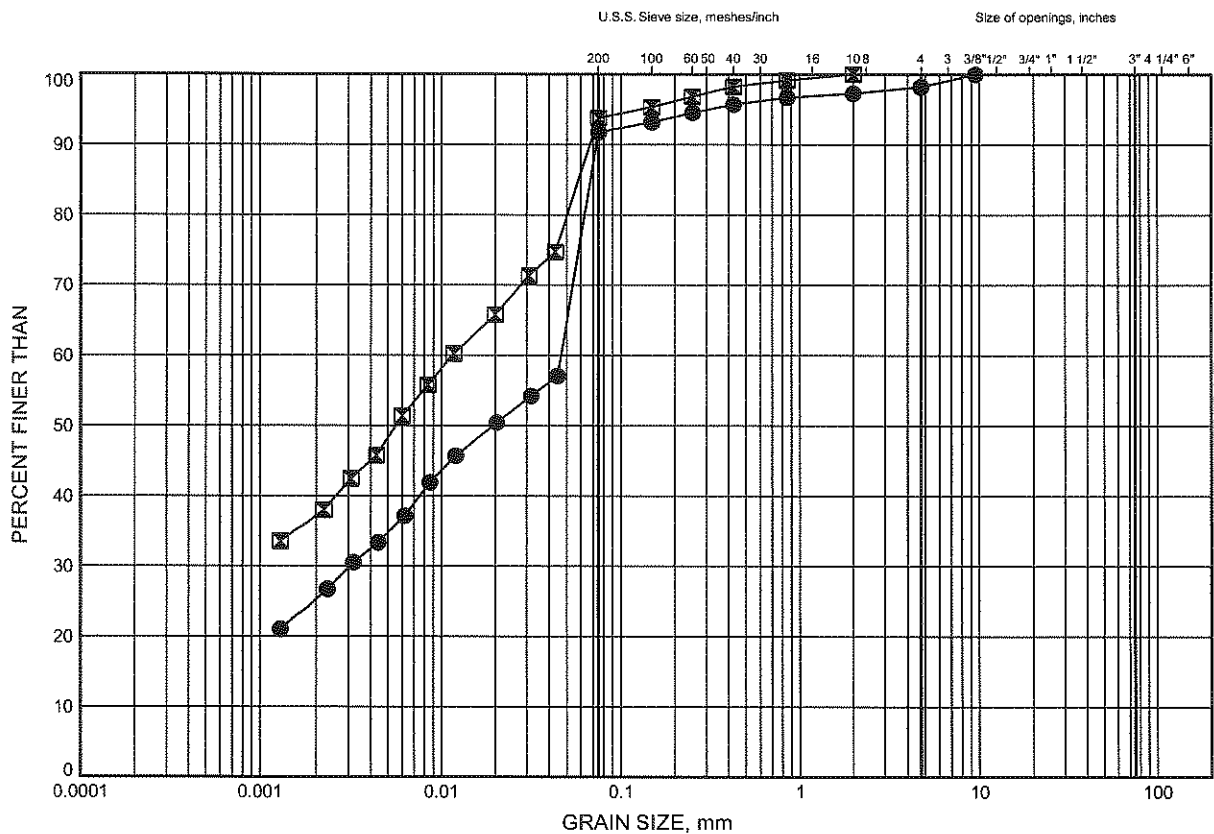


W.P.# .4067-03-00.....  
Prepared By MFA.....  
Checked By SKP.....

# GRAIN SIZE DISTRIBUTION

FIGURE B4

## CLAY



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

### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-SCH-01	1.07	121.33
⊠	08-SCH-02	1.07	122.33

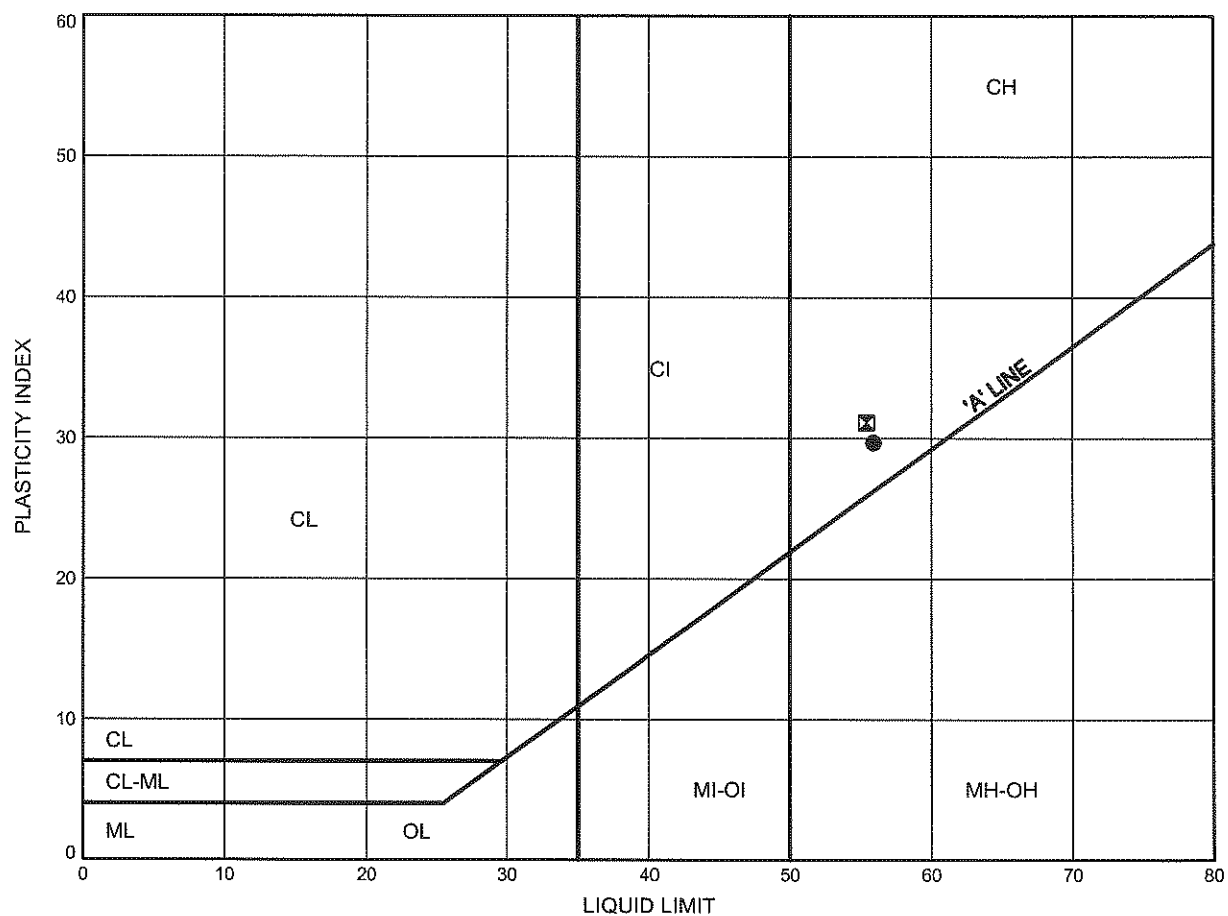


W.P.# .4067-03-00.....  
Prepared By .MFA.....  
Checked By .SKP.....

# ATTERBERG LIMITS TEST RESULTS

FIGURE B5

## CLAY



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-SCH-01	1.07	121.33
⊠	08-SCH-02	1.07	122.33

Date March 2009

Project 4067-03-00



Prep'd MFA

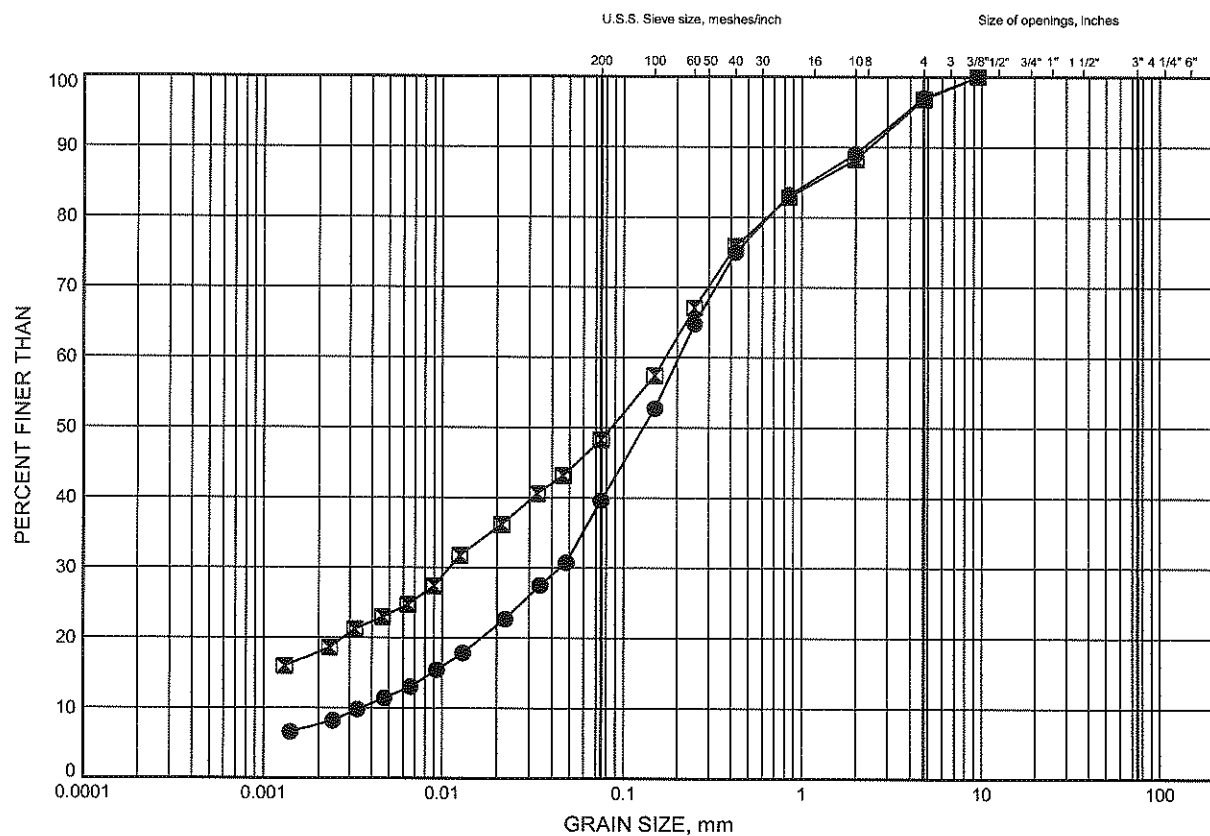
Chkd. SKP



# GRAIN SIZE DISTRIBUTION

FIGURE B6

## SILTY CLAY WITH SAND



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

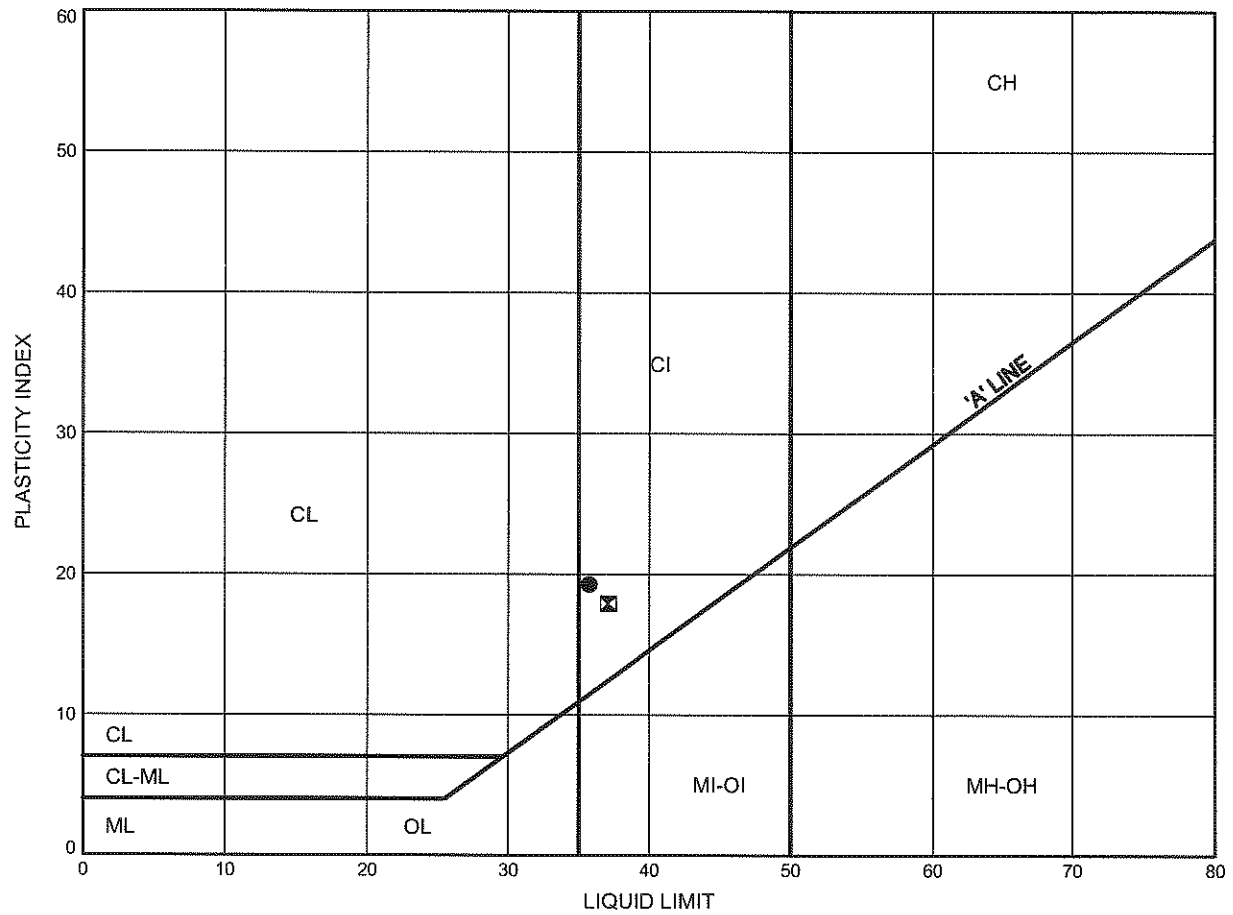
### LEGEND

SYMBOL	BOREHOLE	DEPTH (m)	ELEV. (m)
●	08-SCH-19	1.83	123.37
◻	08-SCH-24	2.55	123.15

# ATTERBERG LIMITS TEST RESULTS

FIGURE B7

## SILTY CLAY WITH SAND



SYMBOL	BH	DEPTH (m)	ELEV. (m)
●	08-SCH-19	1.83	123.37
⊠	08-SCH-24	2.55	123.15

Date March 2009  
 Project 4067-03-00



Prep'd MFA  
 Chkd. SKP

## Appendix C

### Foundation Alternatives



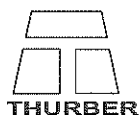
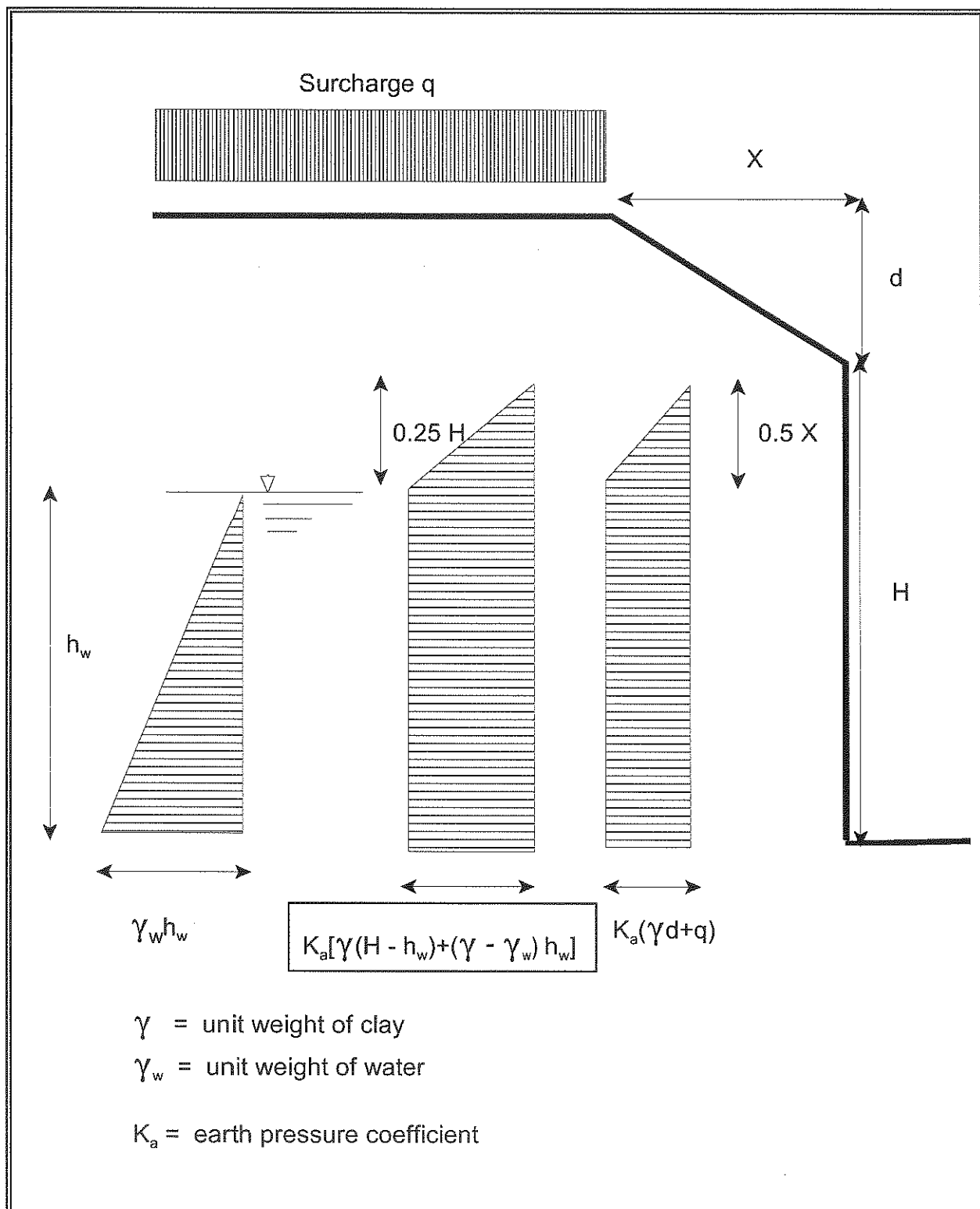
COMPARISON OF FOUNDATION ALTERNATIVES FOR EACH FOUNDATION ELEMENT

Foundation Element	Steel H-Piles	Footings on Bedrock	Augered Caisson
<p><b>North and South Abutments</b></p> <p><b>WBL and EBL Structures</b></p>	<p><i><b>Advantages:</b></i></p> <ul style="list-style-type: none"> <li>i. Foundation construction requires less volume of excavation than footings after the rock cut is formed.</li> </ul> <p><i><b>Disadvantages:</b></i></p> <ul style="list-style-type: none"> <li>i. Presence of bedrock at design grade of the cut; impractical to install piles through strong bedrock.</li> </ul>	<p><i><b>Advantages:</b></i></p> <ul style="list-style-type: none"> <li>i. Presence of bedrock at design grade of the cut.</li> <li>ii. High values of geotechnical resistance are available on the bedrock.</li> </ul> <p><i><b>Disadvantages:</b></i></p> <ul style="list-style-type: none"> <li>i. Higher cost of excavation into bedrock.</li> </ul> <p>ii. Mass concrete fill and removal of loose rock fragments may be required to prepare the founding subgrade.</p>	<p><i><b>Advantages:</b></i></p> <ul style="list-style-type: none"> <li>i. High values of geotechnical resistance are available on the bedrock.</li> </ul> <p><i><b>Disadvantages:</b></i></p> <ul style="list-style-type: none"> <li>i. Presence of bedrock at design grade of the cut; impractical to form caisson holes into bedrock.</li> <li>ii. Higher cost of excavation into bedrock.</li> <li>iii. Dewatering may be required.</li> <li>iv. Inspection by geotechnical personnel may be required.</li> </ul>

## Appendix D

### Figures





LATERAL PRESSURE DISTRIBUTION FOR  
BRACED SHORING DESIGN

FIGURE D1

## **Appendix E**

### **Special Provisions**



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

- SP 110F13
- SP 206S03
- SP 539S01
- SP 572S01
- SP 902S01
- OPSS 201.010
- OPSS 201.020
- OPSS 206
- OPSS 501.06
- OPSD 3101.150
- OPSD 3101.200
- OPSD 3102.100

**2. Suggested Text for NSSP on “Mass Concrete”**

The purpose of the mass concrete pad is to provide a level surface for the construction of the footing on the irregular founding rock surface as per the contract drawings and documents. The surface of the pier or abutment footing founding rock shall be exposed, cleaned and any loose or fractured parts removed so that sound rock is exposed. The mass concrete shall be placed on the exposed, cleaned, sound founding rock surface as per the contract drawings and documents. The thickness of the mass concrete pad depends on the slope and irregularities in the exposed founding rock surface, but a nominal minimum thickness of 200 mm shall be assumed. The extent of the mass concrete in plan, which shall extend 300mm beyond the edge of the footing, shall be shown on the contract drawings.

**3. Suggested Text for NSSP on “Rock Dowel Installation and Testing”**

Rock dowels shall be installed in accordance with OPSS 904. All reinforcing steel supplied shall be in accordance with OPSS 1440. If the hole contains water, the Contractor shall either remove the water or use a tremie procedure to fill the hole with grout.

All rock dowel testing procedures shall be in general accordance with ASTM D 3689-90 and ASTM D 114381 (Re-approved 1994). Field testing must be carried out in the presence of, and the results reviewed by, the Contract Administrator (CA). For each abutment, a minimum of 2 dowels to be selected by the CA shall be performance tested. Performance tests shall be carried out by axial tensioning using a hydraulic jack with a capacity of at least 1.5 times the ultimate strength of the dowels. Acceptance criteria for the rock dowels will be in accordance with the Post-Tensioning Institute (2004) Recommendations for Prestressed Rock and Soil Anchors. If a rock dowel fails, 3 additional rock dowels at the same abutment shall be tested as directed by the CA. Rock dowels which fail to meet the acceptance criteria shall be replaced at the Contractor’s expense and re-tested for conformance.

**4. Suggested Text for NSSP on “Rock Cut Inspection”**

After blasting and foundation excavation of the rock cut is completed, the Contractor shall scale all loosened rock from the exposed rock faces. The Contract Administrator shall retain a rock slope stability specialist to examine the cut and provide recommendations for stabilizing the slopes if required. Where the faces of the rock cut at and beyond the foundation develop potentially unstable wedges or where over-breaking occurs, the Contractor shall implement remedial stabilization measures including the placement of mass concrete fill or installation of rock bolts as required. The remedial work shall be designed by and carried out under the direction of the rock slope stability specialist.



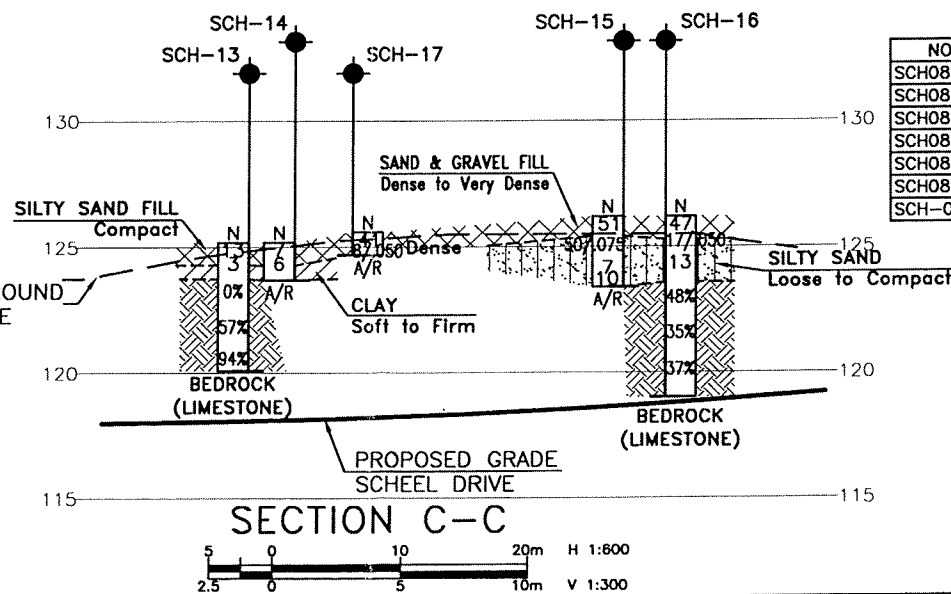
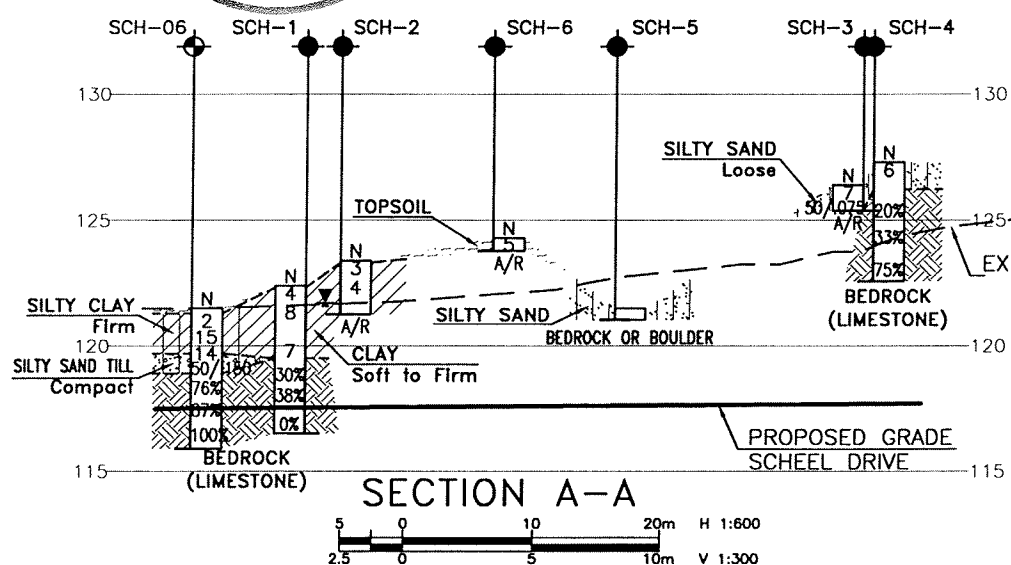
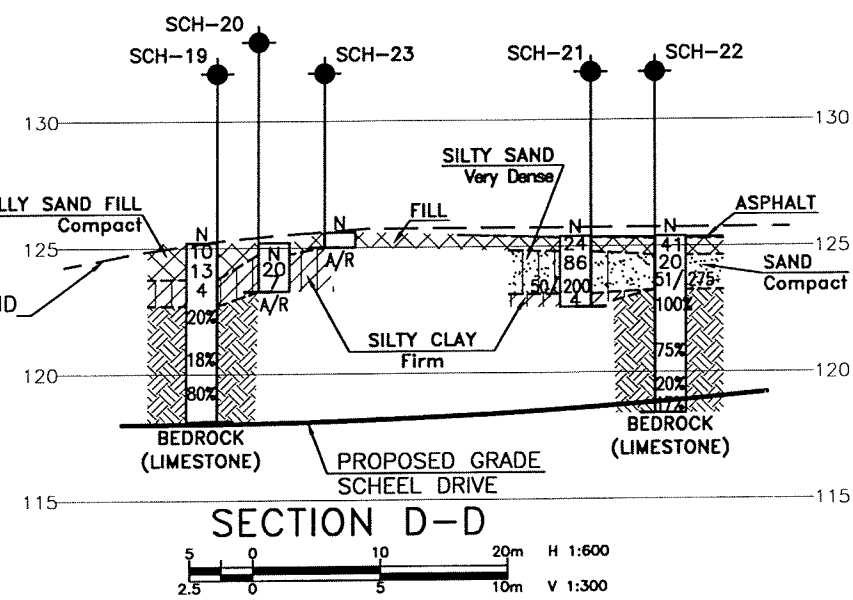
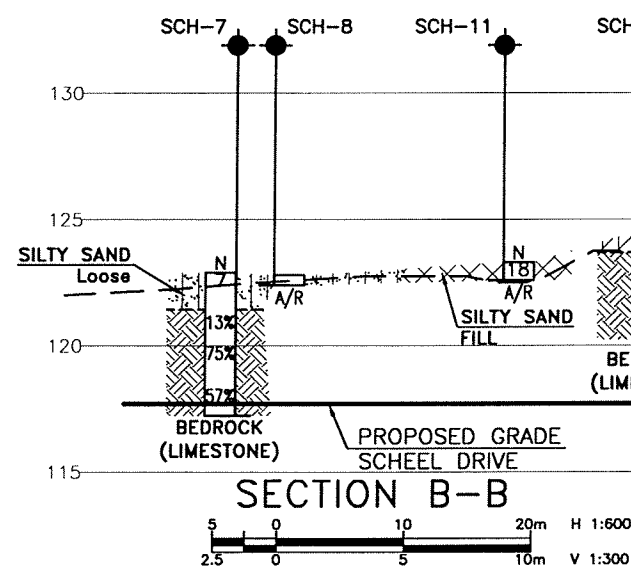
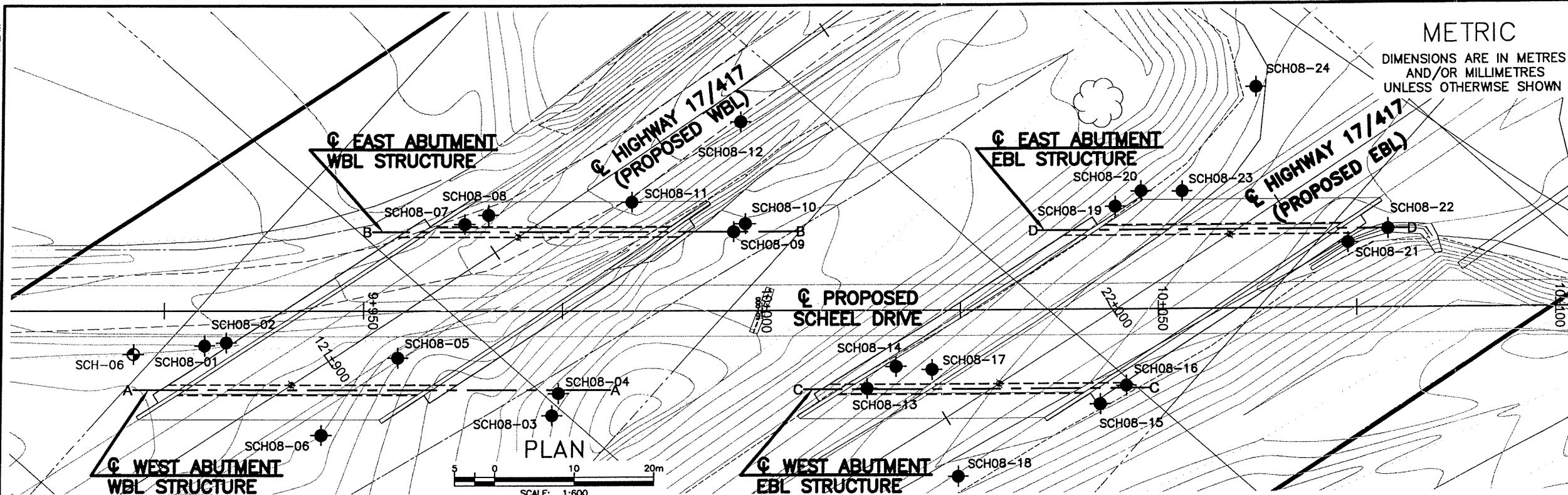
**5. Suggested Text for NSSP on "Earth Excavation"**

Cobbles, boulders, rock fragments and rock slabs may be encountered within the overburden soils during excavation. The soil matrix is anticipated to become harder or denser with depth. The Contractor's excavating equipment must be able to dislodge, handle, remove or otherwise penetrate these obstructions and hard/very dense layers.

## **Appendix F**

### **Borehole Locations and Soil Strata Drawing**





NO	ELEVATION	NORTHING	EASTING
SCH08-19	125.2	5 033 122.2	308 215.4
SCH08-20	125.2	5 033 121.0	308 219.0
SCH08-21	126.4	5 033 097.0	308 231.3
SCH08-22	126.4	5 033 094.4	308 235.9
SCH08-23	125.6	5 033 117.1	308 222.4
SCH08-24	125.7	5 033 119.0	308 238.5
SCH-06	121.5	5 033 202.2	308 119.7

HWY 17/417  
SITE No  
GWP No 4067-03-00



SCHEEL DRIVE UNDERPASS  
TWIN OVERPASS BRIDGES  
HIGHWAY 17/417 TWINNING  
BOREHOLE LOCATIONS AND SOIL STRATA

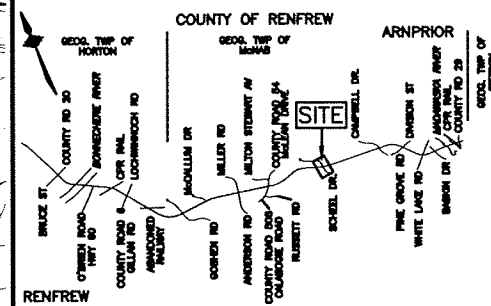
SHEET



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## KEYPLAN

## LEGEND

- |   |   |
|---|---|
|  | Borehole (Present Investigation, 2008)  |
|  | Borehole (Previous Investigation, 2006) |
| 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
SCH08-01	122.4	5 033 196.3	308 126.4
SCH08-02	123.4	5 033 194.4	308 128.5
SCH08-03	126.4	5 033 157.7	308 148.7
SCH08-04	127.3	5 033 159.0	308 151.4
SCH08-05	121.5	5 033 177.1	308 141.3
SCH08-06	124.3	5 033 177.7	308 127.7
SCH08-07	122.9	5 033 182.2	308 159.6
SCH08-08	122.8	5 033 180.7	308 162.4
SCH08-09	124.5	5 033 156.2	308 181.3
SCH08-10	124.7	5 033 155.8	308 183.0
SCH08-11	123.3	5 033 168.3	308 175.6
SCH08-12	123.6	5 033 164.9	308 192.3
SCH08-13	125.2	5 033 130.3	308 177.5
SCH08-14	125.2	5 033 129.4	308 182.0
SCH08-15	126.2	5 033 106.9	308 195.4
SCH08-16	126.2	5 033 106.0	308 199.3
SCH08-17	125.6	5 033 125.8	308 184.6
SCH08-18	126.1	5 033 114.3	308 176.7

**-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. 31F-167**

[illegible]