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LOCATION LARONDE CREEK BRIDGE

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

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**REPORT ON**

**FOUNDATION INVESTIGATION  
LARONDE CREEK BRIDGE REPLACEMENT  
HIGHWAY 17, SITE 43-65, W.P. 812-76-02  
DISTRICT 54, SUDBURY  
G.W.P. 812-76-01**

FACTUAL ONLY

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June 2000

991-1164-1

GEORES NO. 31L-70

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## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (McCormick Rankin) to carry out a foundation investigation for the replacement of the Laronde Creek Bridge (Site 43-65) as part of the widening of Highway 17 between North Bay and Sturgeon Falls, Ontario. The proposed works consists of replacing the existing single span Laronde Creek Bridge structure with a wider three span structure.

The purpose of the investigation is to determine the subsurface conditions at the location of the proposed replacement bridge by drilling boreholes, carrying out in-situ tests and performing laboratory tests on selected samples. Based on our interpretation of the data obtained, recommendations on the geotechnical aspects of the foundation design and construction for the abutments and for the new bridge piers are provided.

McCormick Rankin provided the plan and profile of the proposed Highway 17 alignment at the Laronde Creek Bridge to Golder. The centreline and stations of the proposed alignment were surveyed by others prior to commencing the foundation field investigation program.

The terms of reference and scope of work for the investigation are outlined in Golder's proposal P91-1225, dated June 1999, that forms part of the Consultant's Agreement (Number P.O. 5005-A-000016) for this project. Changes to the original scope of work (as a result of proposed changes to the bridge structure) were described in Golder's letter to McCormick Rankin dated September 13, 1999. This additional work was subsequently authorized by MTO/McCormick Rankin. The work was carried out in accordance with the Quality Control Plan for this project.

A previous foundation investigation had been carried out at the site in 1998 under the supervision of Thurber Engineering Ltd. (Thurber). The results of the Thurber investigation are presented in their report titled *"Final Foundation Investigation and Design Report for Proposed Bridge over Laronde Creek, Site 43 - 65, Highway 17 from North Bay to Sturgeon Falls W.P. 812-76-00 & 398-91-00, District 54, Sudbury"* dated March 29, 1999 and submitted to Stantec Consulting Group Ltd. The Records of Boreholes from the Thurber investigation are provided in Appendix A of this report; the information has been used in the preparation of this report.

## **2.0 SITE DESCRIPTION**

### **2.1 Site Location**

The project area covered by this report extends along the proposed Highway 17 re-alignment, from approximately Stations 13+500 to 13+700 in the Township of Beaucage where Highway 17 crosses Laronde Creek. The site is situated approximately 20 km west of North Bay, Ontario between Highway 64 and Highway 11 (see Figure 1). The highway runs approximately east-west and the creek flows north to south towards Lake Nipissing.

The existing bridge deck is about 5 m above creek level. Based on available information provided to Golder, the existing bridge structure is a concrete rigid frame that is founded on timber piles. The ground surface at the existing abutment locations is at about Elevation 201.5 m and the Laronde Creek bed is at about Elevation 194.5 m. The water level in the creek is at about Elevation 196 m.

The bank on the east side of the creek is quite steep. On the west side, the bank is much flatter and a commercial operation including a lodge exists. An asphalt road (boat ramp) runs downslope to the creek about 20 m north (upstream) of the existing bridge. Heavy tree cover exists in the area north of the alignment on the east side of the creek.

The proposed centreline of the replacement bridge is located approximately 15 m north of the centreline of the existing bridge. It is understood that the proposed highway surface on the replacement bridge is at about Elevation 203 m.

### **2.2 Physiography**

The site lies within the Canadian Shield in an area where the bedrock is overlain by deep overburden. The regional area can be characterized as a flat plain that starts about 1 km to the east of Laronde Creek, extends many kilometers to the west, and stretches from Lake Nipissing to several kilometers north of the existing highway.

The bedrock in the vicinity of Laronde Creek is igneous and metamorphic rock of early Precambrian age. A former glacial lake basin existed in the area and, consequently, the site is underlain by extensive deposits of fine-grained lake sediments. The overburden typically consists of surficial sands and silts overlying thick clay deposits. Some of the clay deposits are varved. Overburden thickness is quite variable and can be as deep as 40 m or more.

On a more regional basis, the bedrock is exposed as low, rounded hills with a sporadic cover of thin glacial drift.

### 3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried between September 29 and October 3, 1999 at which time, three boreholes (Boreholes 99-43, 99-44 and 99-45) were advanced at the site of the proposed replacement bridge. The boreholes were drilled and sampled to depths ranging from about 20.1 m to 25.9 m. The bedrock surface and condition were proved in each borehole by rock coring. The borehole locations are shown in plan on Figure 2. It is noted that the Laronde Creek Bridge site is a part of the overall Highway 17 Widening Project of G.W.P. 812-76-01. In total 45 boreholes were drilled as part of this contract (i.e. 42 boreholes along the overall alignment and 3 boreholes at Laronde Creek).

The investigation was carried out using a bombardier mounted CME 55 drill rig supplied and operated by Marathon Drilling Co. Ltd. of Ottawa, Ontario. The boreholes were advanced using 208 mm outside diameter (O.D.) continuous flight hollow stem augers through overburden soils, and using NQ size casing for bedrock coring. Soil samples were obtained at regular intervals of depth using a 50 mm O.D. split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures, or a 80 mm O.D. thin walled open Shelby tube sampler. In-situ vane shear tests were also carried out at regular intervals in the clayey deposit. The cored length of bedrock in the boreholes ranged from 3.1 m to 4.6 m. Shallow and deep piezometers were installed in Boreholes 99-43 and 99-45 to measure the groundwater conditions at these locations. Water level in the piezometers were obtained on October 3, 1999 to determine stabilized levels at that time.

The field work was supervised throughout by a member of our engineering staff, who located the boreholes, cleared the borehole locations for underground services, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil and rock samples. The samples were identified in the field, placed in containers, labelled and transported to our Mississauga laboratory. Laboratory testing on selected samples included natural water content, Atterberg limits, grain size analyses, specific gravity and oedometer (consolidation) tests. The results of the laboratory testing are given on the Record of Borehole sheets and in Appendix B.

A substantial amount of classification testing, such as Atterberg limits and grain size, had been carried out by Thurber during their investigation in 1998. The number of soil tests carried out during the current investigation took into account the previous testing that had been performed to classify the soil deposits encountered.

The following table summarizes the proposed locations (at the time of drilling) of foundation units and boreholes, referenced to the proposed highway centreline stations.

<i>Foundation Unit/ Borehole Number</i>	<i>Approximate Station (m)</i>
West Abutment	13+561
West Pier	13+587
East Pier	13+621
East Abutment	13+647
Borehole 99-43	13+647
Borehole 99-44	13+587
Borehole 99-45	13+561

It was not possible to drill a borehole at the proposed location of the east pier using the conventional drilling equipment that was on-site. The same experience and conclusion was drawn by Thurber in 1998. The tree cover and very steep east bank prevented access by the track mounted drill rig. In order to drill at the proposed east pier foundation unit, substantial site preparation, a special drill rig, and possibly a large crane would be needed. It was considered not to be cost-effective to expend such effort. The main reason for this was that deep deposits of clay exist at the site and a piled foundation would be necessary. Sufficient information can be obtained from: (i) the three detailed boreholes drilled under Golder supervision as part of the current investigation, and (ii) the boreholes previously drilled at the site under the supervision of Thurber.

The as-drilled location of Borehole 99-43 also had to change from that proposed to avoid overhead hydro lines as per Health and Safety requirements. It was not possible to locate the borehole north of the proposed location because of the heavy tree cover (bush) north of the centreline of the highway realignment.



The as drilled borehole locations were surveyed using the NAD 83 MTM (Zone 12) co-ordinate system and the geodetic datum for elevation. The surveying was carried out by MF Tulloch Inc. of Thessalon, Ontario.

#### **4.0 SUBSURFACE CONDITIONS**

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the Record of Borehole and Record of Drillhole sheets, and by the laboratory test results contained in Appendix B. It should be noted that the stratigraphic boundaries indicated on the borehole records are inferred from non-continuous sampling, observations of drilling progress, results of Standard Penetration Tests (SPTs) and in-situ vane shear tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The ground surface elevation at the borehole locations varied from about Elevation 197.0 m to 201.6 m. The boreholes were sampled to depths ranging from 20.1 m to 25.9 m.

#### **4.1 General Stratigraphy**

The general stratigraphy at the site consists primarily of a thick deposit of cohesive soils overlying a thin granular layer over granitic bedrock. At one borehole location (Borehole 99-44) a 1.5 m thick layer of granular fill overlies the cohesive deposits. The fill is associated with the boat ramp roadway mentioned earlier. At Borehole 99-45, a 1.5 m layer of silty sand to sandy silt overlies the primary cohesive deposit.

#### **4.2 Fill**

In Borehole 99-44, below about 130 mm of asphalt, brown gravelly sand fill material containing some silt and fragments of wood and asphalt was encountered to a depth of about 1.5 m. Two SPT 'N' values of 4 and 5 blows per 0.3 m of penetration were recorded in the fill, indicating a loose state of packing.

#### **4.3 Silty Sand to Sandy Silt**

In Borehole 99-45, below about 100 mm of topsoil, a deposit of brown to grey silty sand to sandy silt containing trace organics and rootlets was encountered to about depth 1.5 m. Two SPT 'N' values of 4 and 7 blows per 0.3 m of penetration were recorded, indicating a loose state of packing.

#### 4.4 Clayey Silt to Silty Clay

Below about 120 mm of topsoil in Borehole 99-43, and the sandy silt in Borehole 99-45, a deposit of grey clayey silt to silty clay containing trace sand was encountered. The top of this deposit is at Elevation 200.7 m and 200.1 m in Boreholes 99-43 and 99-45, respectively. SPT 'N' values ranging from 0 (weight of hammer) to 8 blows per 0.3 m of penetration and one in-situ vane shear test result of 38 kPa were recorded in the silty clay, indicating a soft to firm consistency. Measured water contents of two samples from this deposit are 33 percent and 34 percent. Representative liquid and plastic limits, based on two samples tested, are 30 percent and 20 percent, respectively (plasticity index of 10). Figure B1 in Appendix B shows gradation curves for two samples of this deposit.

Figure B3 in Appendix B shows the void ratio ( $e$ ) vs. log effective vertical pressure ( $\sigma'$ ) for a sample of the clayey silt to silty clay deposit that was obtained directly above the varved silty clay deposit. The soil sample was assessed to be undisturbed. The  $e$ -log  $\sigma'$  curve is considered to reflect the very silty nature of the soil, although it may also reflect that some degree of disturbance may have been imparted to the sample. The key consolidation parameters interpreted from the test results are:

- Initial void ratio = 0.91
- Estimated preconsolidation pressure,  $\sigma'_p = 200$  kPa
- Overconsolidation Ratio, OCR = 2.3
- Recompression Index,  $C_r = 0.03$  (based on rebound portion of curve)
- Compression Index,  $C_c = 0.12$

Compared to the underlying varved silty clay that is described below, the upper clayey deposit is more overconsolidated and not near as compressible or sensitive.

#### 4.5 Varved Silty Clay

A deposit of grey varved silty clay was encountered in all boreholes. The top of this deposit ranged from Elevation 195.6 m to 196.8 m. The varved silty clay deposit extends to depths ranging from 16.9 m to 20.3 m (about Elevation 180.1 m to 181.3 m). SPT 'N' values ranging from 0 (weight of hammer) to 2 blows per 0.3 m of penetration and in-situ vane shear test results

from 30 kPa to greater than 100 kPa were recorded, indicating a firm to very stiff consistency. Measured water contents of samples from this deposit range from 41 percent to 57 percent. Representative liquid and plastic limits, based on 3 samples tested, are 38 percent and 18 percent, respectively (plasticity index of 20). A grain size curve of one sample is shown on Figure B2 in Appendix B.

Figure 3 summarizes the measured field vane shear tests that were carried out as part of the current investigation. There is a definite trend of increasing vane (undrained) shear strength ( $s_u$ ) with depth ranging from a minimum value of 30 kPa at 4 m depth to greater than 100 kPa at a depth of about 19 m below existing ground surface. The results show that the varved silty clay does not have a 'crust' of higher strength in its upper zone. It is noted that the higher strength values above the 4 m depth shown on Figure 3 correspond to the overlying clayey silt to silty clay layer. From Figure 3 it can be assumed that  $s_u$  in the varved silty clay increases linearly with depth according to the following empirical relation:

$$s_u = 18 + 4d \text{ (units of kPa)}$$

where  $d$  = depth below ground surface.

The results of an oedometer (consolidation) test on a sample of the varved silty clay are summarized in Figure B4 in Appendix B. The void ratio ( $e$ ) vs. log effective vertical pressure ( $\sigma'$ ) curve reflects the classic shape of a soft, sensitive, slightly overconsolidated clay, and indicates that a high quality undisturbed sample was obtained. The key consolidation parameters interpreted from the test results are:

- Initial void ratio,  $e_0 = 2.25$
- Preconsolidation pressure,  $\sigma'_p = 160$  kPa
- Overconsolidation Ratio (OCR) = 1.2
- Recompression Index,  $C_r = 0.07$
- Compression Index,  $C_c = 1.4$  (pressure range of 200 kPa to 800 kPa)

#### **4.6 Sand to Silty Sand**

Below the varved silty clay, a thin deposit of grey sand to silty sand was encountered. SPT 'N' values ranged from 4 blows to greater than 100 blows per 0.3 m of penetration, indicating a loose to very dense state of packing. The thickness of this deposit was variable, ranging from about 0.15 m to about 1.6 m. The top of the deposit was generally encountered at about Elevation 181 m. The deposit directly overlies bedrock.

#### **4.7 Granitic Bedrock**

Granitic bedrock surface was encountered between Elevation 179.5 m and 180.7 m. In Boreholes 99-44 and 99-45, the granitic bedrock is fresh with RQD values ranging from about 62 percent to 84 percent. It is inferred that the rock is very to extremely strong. In Borehole 99-43, the upper 3 m of bedrock is weathered and highly fractured with RQD values ranging from 0 percent to 6 percent. Fresh bedrock (RQD 48 percent) was encountered in Borehole 99-43 at about Elevation 176.5 m.

Based on the available borehole information (Golder and Thurber) it appears that the bedrock surface slopes slightly towards Laronde Creek on both sides of the creek. The maximum difference in bedrock surface encountered in the boreholes is approximately 2 m. However, given the variable nature of the bedrock surface in the area, greater variations in the bedrock surface should be expected across the proposed bridge site.

#### **4.8 Groundwater Conditions**

Shallow and deep piezometers were installed in Boreholes 99-43 and 99-45. The water level measured in the piezometers are summarized in the following table. It should be noted that the groundwater level is subject to seasonal fluctuations.

Borehole Number	Borehole Depth (m)	Piezometer Tip		Date	Water Level in Piezometer	
		Depth (m)	Elevation (m)		Depth (m)	Elevation (m)
99-43	25.9	12.2	188.6	03/10/99	1.9	198.8
		25.8	175.0	03/10/99	2.8	198.0
99-45	24.0	10.7	190.9	29/09/99	1.0	200.6
		23.9	177.7	29/09/99	3.2	198.4
98-1	22.6	15.3	181.5	27/10/98	2.3	199.1
					above g.s.	
98-4	30.0	25.0	176.4	27/10/98	4.2	197.2

Figure 4 summarizes the measured levels. It shows a hydrostatic groundwater pressure condition in relation to the current creek level, and the groundwater pressures as measured in the piezometers. The measured groundwater levels indicate a condition of downward seepage. An artesian condition with respect to the creek level is also shown.

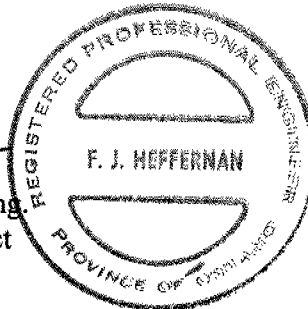
**GOLDER ASSOCIATES LTD.**



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Principal




Fintan J. Heffernan, P.Eng.  
Designated MTO Contact



BVB/DEB/FJH/clg

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## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II. PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.).

#### Dynamic Penetration Resistance; $N_d$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III. SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils

Consistency	$c_u, s_u$ kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
$w_p$	plastic limit
$w_l$	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
$D_R$	relative density (specific gravity, $G_s$ )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
$SO_4$	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane test (LV-laboratory vane test)
$\gamma$	unit weight

Note:

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I GENERAL

$\pi$	= 3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
$g$	acceleration due to gravity
$t$	time
$F$	factor of safety
$V$	volume
$W$	weight

### II STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
$u$	porewater pressure
$E$	modulus of deformation
$G$	shear modulus of deformation
$K$	bulk modulus of compressibility

### III SOIL PROPERTIES

#### (a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
$e$	void ratio
$n$	porosity
$S$	degree of saturation
*	Density symbol is $\rho$ . Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density $\times$ acceleration due to gravity)

#### (a) Index Properties (con't.)

$w$	water content
$w_l$	liquid limit
$w_p$	plastic limit
$I_p$	plasticity Index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (c) Hydraulic Properties

$h$	hydraulic head or potential
$q$	rate of flow
$v$	velocity of flow
$i$	hydraulic gradient
$k$	hydraulic conductivity (coefficient of permeability)
$j$	seepage force per unit volume

#### (d) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (overconsolidated range)
$C_s$	swelling index
$C_\alpha$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
$U$	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	Overconsolidation ratio = $\sigma'_p / \sigma'_{vo}$

#### (e) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
$p$	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
$q$	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

Notes: 1.  $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2



ON\_MOT 991-1164.GPJ ON\_MOT.GDT 27/6/00

+3, X3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 991-1164			RECORD OF BOREHOLE No 99-43			2 OF 2		METRIC						
W.P. 812-76-01			LOCATION N 5136761.07, E 288620.59 (Laronde Creek, Site 43-65)			ORIGINATED BY DRS								
DIST 54 HWY 17			BOREHOLE TYPE Bombardier CME-55			COMPILED BY BVB								
DATUM Geodetic			DATE 10/2/1999			CHECKED BY DEB								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID		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	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>					
— CONTINUED FROM PREVIOUS PAGE —														
181.12	Varved Silty Clay, sand seams Firm to stiff Grey to red		12	75 TO	PH		185							
			13	50 DO	WH		184							
			14	50 DO	WH		183	X						
							182							
181.66	Sand, some silt and gravel Compact Grey to red		15	50 DO	27		181							
179.50	Granitic Bedrock Weathered Strong to very strong becoming extremely strong with depth						180							
174.93	For bedrock coring details refer to Record of Drillhole 99-43.						179							
25.85	END OF BOREHOLE						178							
	Notes: Water levels in shallow and deep piezometers at Elev. 198.8m and Elev. 198.0m, respectively on Oct. 3/99.						177							
							176							
							175							

ON MOT 991-1164.GPJ ON MOT GDT 27/8/00

PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-43

SHEET 1 OF 1

LOCATION: N 5136761.07; E 288620.59


DRILLING DATE: 10/3/1999

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.	RUN No.	PENETRATION RATE (mm/min)	COLOUR FLUSH % RETURN	FR-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE	DIAMETER POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION	
				DEPTH (m)				CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH. BREAK			
				RECOVERY				SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING			
				TOTAL CORE %				SOLID CORE %	R.Q.D. %	FRACT. INDEX PER 0.3	DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION			HYDRAULIC CONDUCTIVITY k, cm/sec
				8 8 8 R				8 8 8 R	8 8 8 R	5 12 12 R	0 30 30 R				10 <sup>-2</sup> 10 <sup>-1</sup> 10 <sup>0</sup> 10 <sup>1</sup>
20		CONTINUED FROM PREVIOUS PAGE		180.78 20.00											
21															
22	NQ Core	Granitic Bedrock, weathered Strong to very strong		179.50 21.28	1	100									
23				2	100										
24															
25				3	100										
26		Granitic Bedrock, fresh Very to Extremely Strong		176.46 24.32											
27		END OF BOREHOLE		174.93 25.85											
28															
29															
30															

DEPTH SCALE

1 : 50



LOGGED: DRS

CHECKED: BVB

DRILLHOLE 1164 ROCK GPJ CLDR CAN GDT 8/2/00

PROJECT 991-1164			RECORD OF BOREHOLE No 99-44			1 OF 2			METRIC								
W.P. 812-76-01			LOCATION N 5136771.75; E 288563.47 (Laronde Creek, Site 43-65)			ORIGINATED BY DRS											
DIST 54 HWY 17			BOREHOLE TYPE Bombardier CME-55			COMPILED BY BVB											
DATUM Geodetic			DATE 9/29/1999			CHECKED BY DEB											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT WATER CONTENT (%)			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED			W <sub>p</sub> W W <sub>L</sub>			γ	GR SA SI CL		
197.04	GROUND SURFACE							20 40 60 80 100									
0.00	Asphalt		1	50 DO	4												
0.13	Gravelly Sand, some silt, wood fragments and asphalt		2	50 DO	5		196										
	Loose Brown (Fill)																
195.59	Varved Silty Clay, sand seams		3	50 DO	2		195										
1.45	Firm to stiff Grey to red		4	75 TO	PH		194										
			5	50 DO	WH		193										
			6	50 DO	WH		192										
							191										
			7	50 DO	WH		190										
			8	75 TO	PH		189										
							188										
			9	50 DO	WH		187										
							186										
			10	50 DO	WH		185										
							184										
			11	50 DO	WH		183										
			12	75 TO	PH												

ON\_MOT\_991-1164.GPJ ON\_MOT.GDT 27/6/00

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

PROJECT 991-1164			RECORD OF BOREHOLE No 99-44			2 OF 2			METRIC						
W.P. 812-76-01			LOCATION N 5136771.75; E 288563.47 (Laronde Creek, Site 43-65)			ORIGINATED BY DRS									
DIST 54 HWY 17			BOREHOLE TYPE Bombardier CME-55			COMPILED BY BVB									
DATUM Geodetic			DATE 9/29/1999			CHECKED BY DEB									
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 × REMOULDED							
--- CONTINUED FROM PREVIOUS PAGE ---															
	Varved Silty Clay, sand seams Firm to stiff Grey to red		13	50 DO	WH		181								
180.12			14	50 DO	4		180								
17.07	Sand, some silt, some gravel, trace clay Loose Grey Granitic Bedrock Fresh Very to extremely strong						179								
								178							
176.92	For bedrock coring details refer to Record of Drillhole 99-44.						177								
20.12	END OF BOREHOLE														

ON\_MOT 991-1164 GPJ ON\_MOT.GDT 27/6/00

PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-44

SHEET 1 OF 1

LOCATION: N 5136771.75; E 288563.47

DRILLING DATE: 10/30/1999

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	PENETRATION RATE (mm/min)	RUN No.	FLUSH	COLOUR % RETURN	FR-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE	DIAMETRAL INDEX (mm)	NOTES WATER LEVELS INSTRUMENTATION
									CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH. BREAK		
									SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING		
									VN-VEIN	S-SLICKENSIDED	PL-PLANAR	C-CURVED			
		CONTINUED FROM PREVIOUS PAGE		182.04 15.00											
15															
16															
17		Granitic Bedrock, fresh Very to Extremely Strong		179.97 17.07											
18															
19															
20				176.92 20.12											
21		END OF BOREHOLE													
22															
23															
24															
25															

DRILLHOLE 1164 ROCK GPJ GLDR CAN GDT 8/2/00

DEPTH SCALE

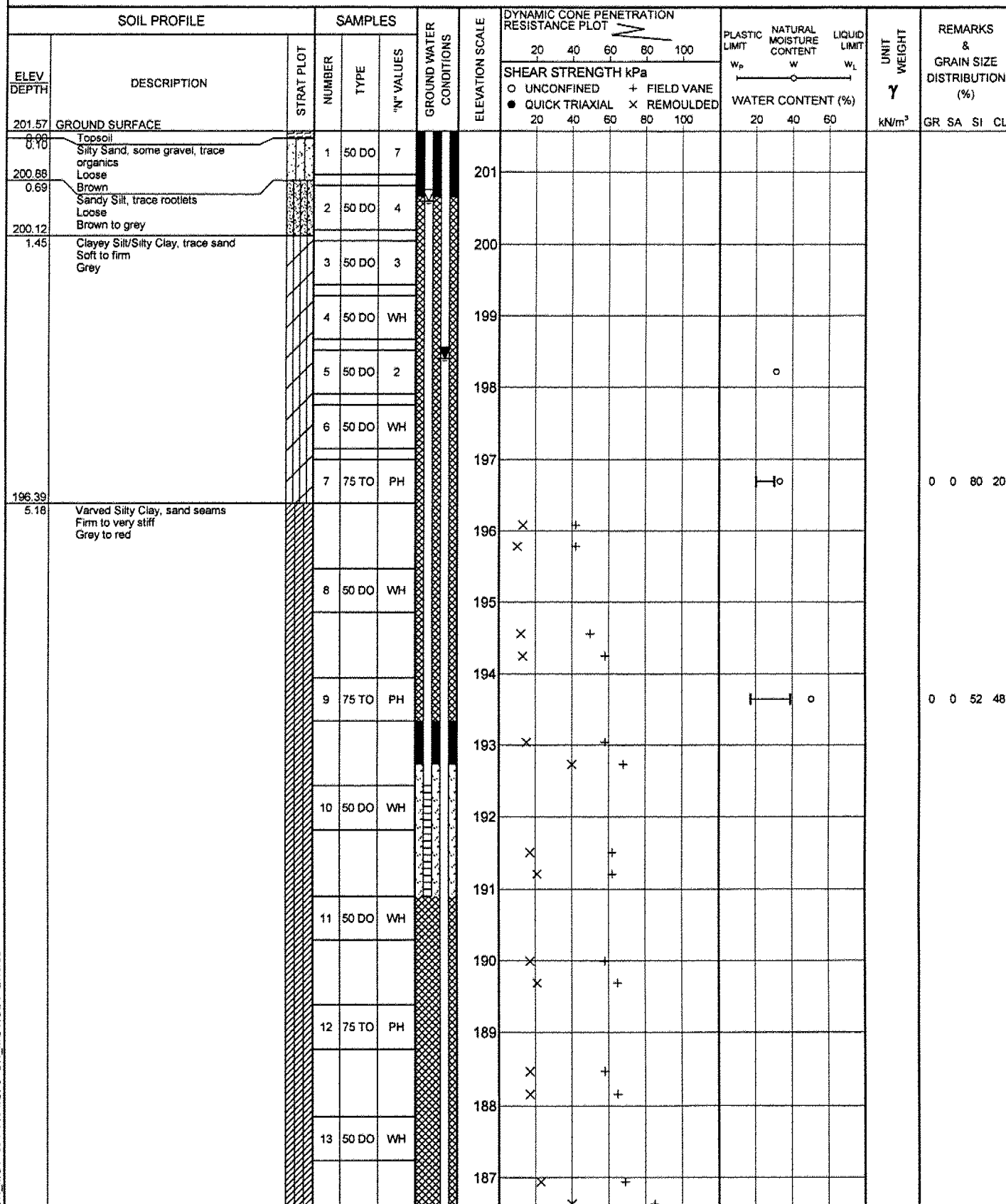
1 : 50



LOGGED: DRS

CHECKED: BVB

PROJECT <u>991-1164</u>		<b>RECORD OF BOREHOLE No 99-45</b>		1 OF 2	<b>METRIC</b>
W.P. <u>812-76-01</u>		LOCATION <u>N 5136770.75; E 288532.60 (Laronde Creek, Site 43-65)</u>		ORIGINATED BY <u>DRS</u>	
DIST <u>54</u> HWY <u>17</u>		BOREHOLE TYPE <u>Bombardier CME-55</u>		COMPILED BY <u>BVB</u>	
DATUM <u>Geodetic</u>		DATE <u>9/27/1999</u>		CHECKED BY <u>DEB</u>	



ON MOT 991-1164.GPJ ON MOT.GDT 27/6/00

Continued Next Page

+<sup>3</sup>, X<sup>3</sup>: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 991-1164

# RECORD OF BOREHOLE No 99-45

2 OF 2

METRIC

W.P. 812-76-01

LOCATION N 5136770.75; E 288532.60 (Laronde Creek, Site 43-65)

ORIGINATED BY DRS

DIST 54

HWY 17

BOREHOLE TYPE Bombardier CME-55

COMPILED BY BVV

DATUM Geodetic

DATE 9/27/1999

CHECKED BY DEB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT		UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa		W <sub>p</sub> W W <sub>L</sub>				
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x REMOULDED	WATER CONTENT (%)				
--- CONTINUED FROM PREVIOUS PAGE ---								20 40 60 80 100	20 40 60					
	Varved Silty Clay, sand seams Firm to very stiff Grey to red		14	50 DO	WH		186							
							185							
			15	50 DO	WH			184						
							183							
			16	50 DO	WH			182						
							181							
181.30			17	50 DO	WH		180							
20.27	Clayey Silt, trace sand						181							
180.84	Grey						180							
20.88	Silty Sand, some gravel, trace clay		18	50 DO	60/15		179							
	Grey						178							
	Granitic Bedrock													
	Fresh													
	Very to extremely strong													
	For bedrock coring details refer to Record of Drillhole 99-45.													
177.55														
24.02	END OF BOREHOLE													
	Note: Water levels in shallow and deep piezometers at Elev. 200.6m and Elev. 198.4m, respectively on Oct. 3/99.													

ON MOT 991-1164.GPJ ON MOT.GDT 27/6/00



PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-45

SHEET 1 OF 1

LOCATION: N 5136770.75; E 288532.60

DRILLING DATE: 9/28/1999

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV.																NOTES					
				DEPTH (m)																WATER LEVELS					
				PENETRATION RATE (mm/min)	FLUSH % RETURN	FR-FRACTURE				F-FAULT				SM-SMOOTH				FL-FLEXURED				BC-BROKEN CORE			
						CL-CLEAVAGE		J-JOINT		R-ROUGH		UE-UNEVEN		MB-MECH. BREAK		B-BEDDING		DIAMETRAL POINT LOAD INDEX (MPa)		INSTRUMENTATION					
						SH-SHEAR		P-POLISHED		ST-STEPPED		W-WAVY													
VN-VEIN		S-SLICKENSIDED		PL-PLANAR		C-CURVED																			
RECOVERY		R.Q.D. %		FRACT. INDEX PER 0.3		DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY k, cm/sec																	
TOTAL CORE %		SOLID CORE %				TYPE AND SURFACE DESCRIPTION																			
10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100		10 20 30 40 50 60 70 80 90 100											
20	CONTINUED FROM PREVIOUS PAGE			181.57																					
				20.00																					
21		Granitic Bedrock, fresh Very to Extremely Strong		180.89																					
				20.88																					
					1		100																		
22																									
					2		100																		
23																									
24																									
					3		100																		
24		END OF BOREHOLE		177.55																					
				24.02																					
25																									
26																									
27																									
28																									
29																									
30																									

DEPTH SCALE

1 : 50



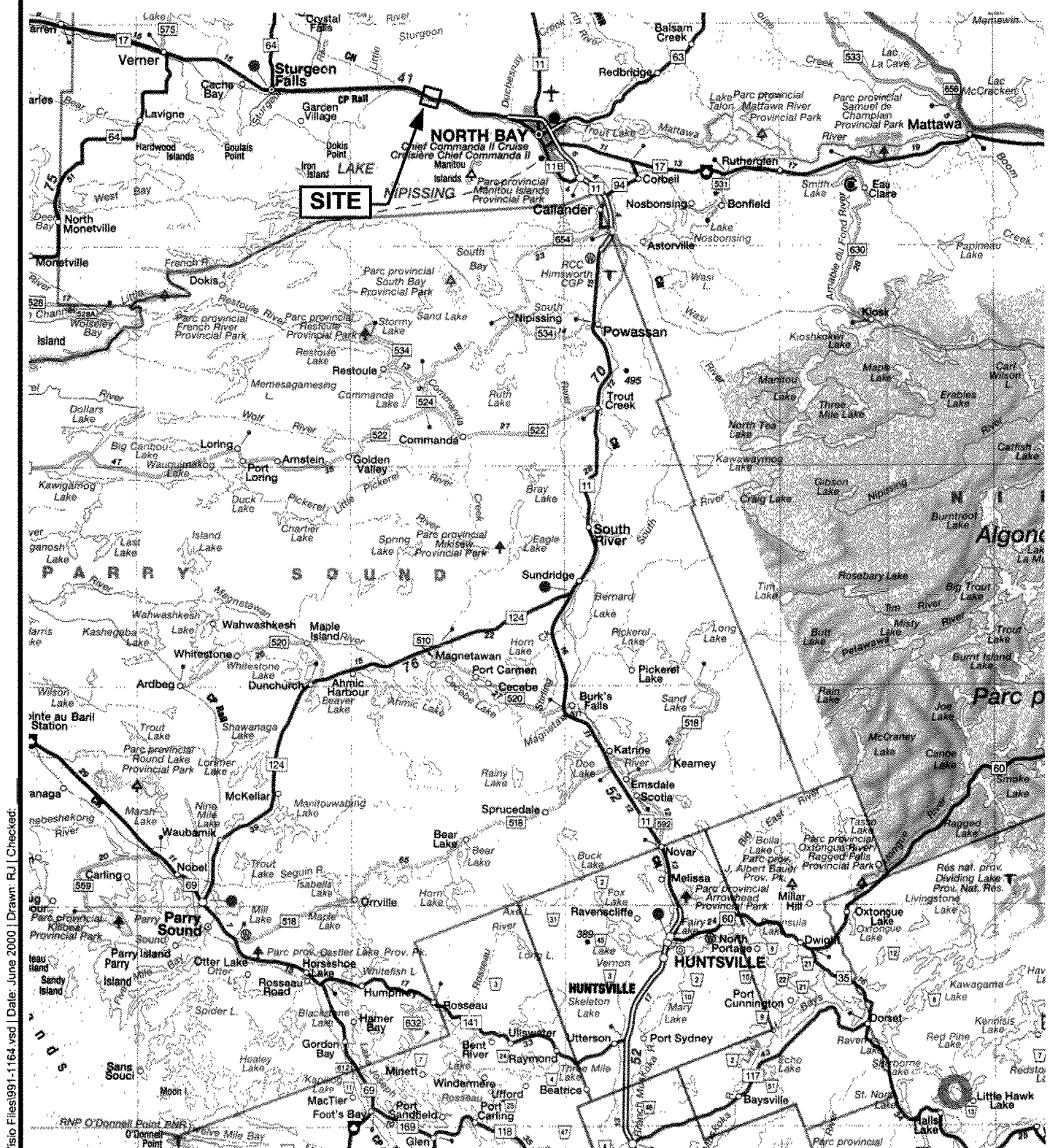
LOGGED: DRS

CHECKED: BVB

DRILLHOLE 1164 ROCK GPJ GLDR CAN.GDT 8/2/00

## SITE LOCATION MAP

## FIGURE 1



## REFERENCE

THIS FIGURE WAS CREATED FROM A MAPART PUBLISHING MAP TITLE "ONTARIO" WITH THE SCALE OF 1:750 000, 1997 EDITION.



**SCALE 1 : 750 000**

Date **FEBRUARY, 2000**

Project 991-1164

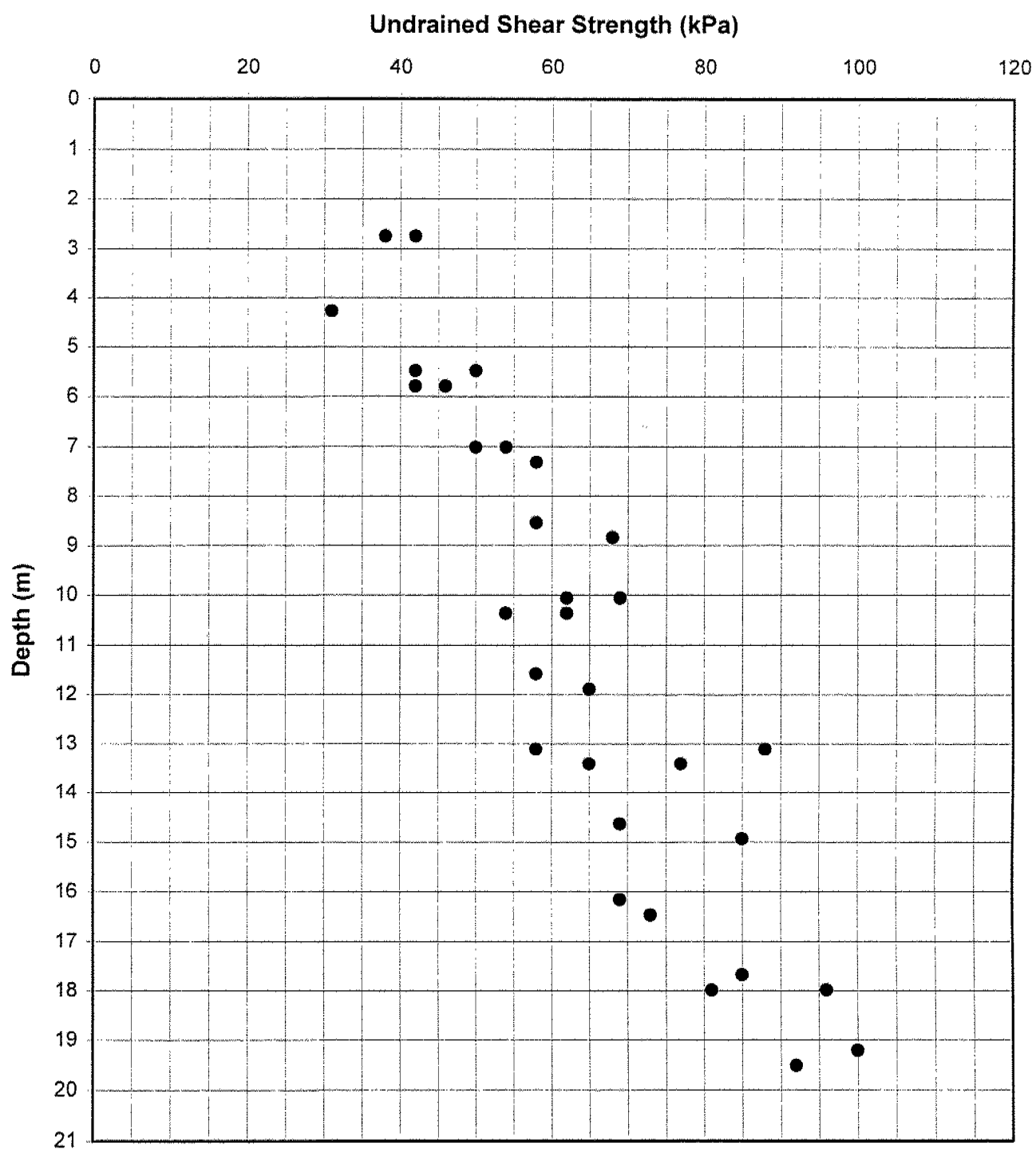
Drawn R.J.

Chkd.

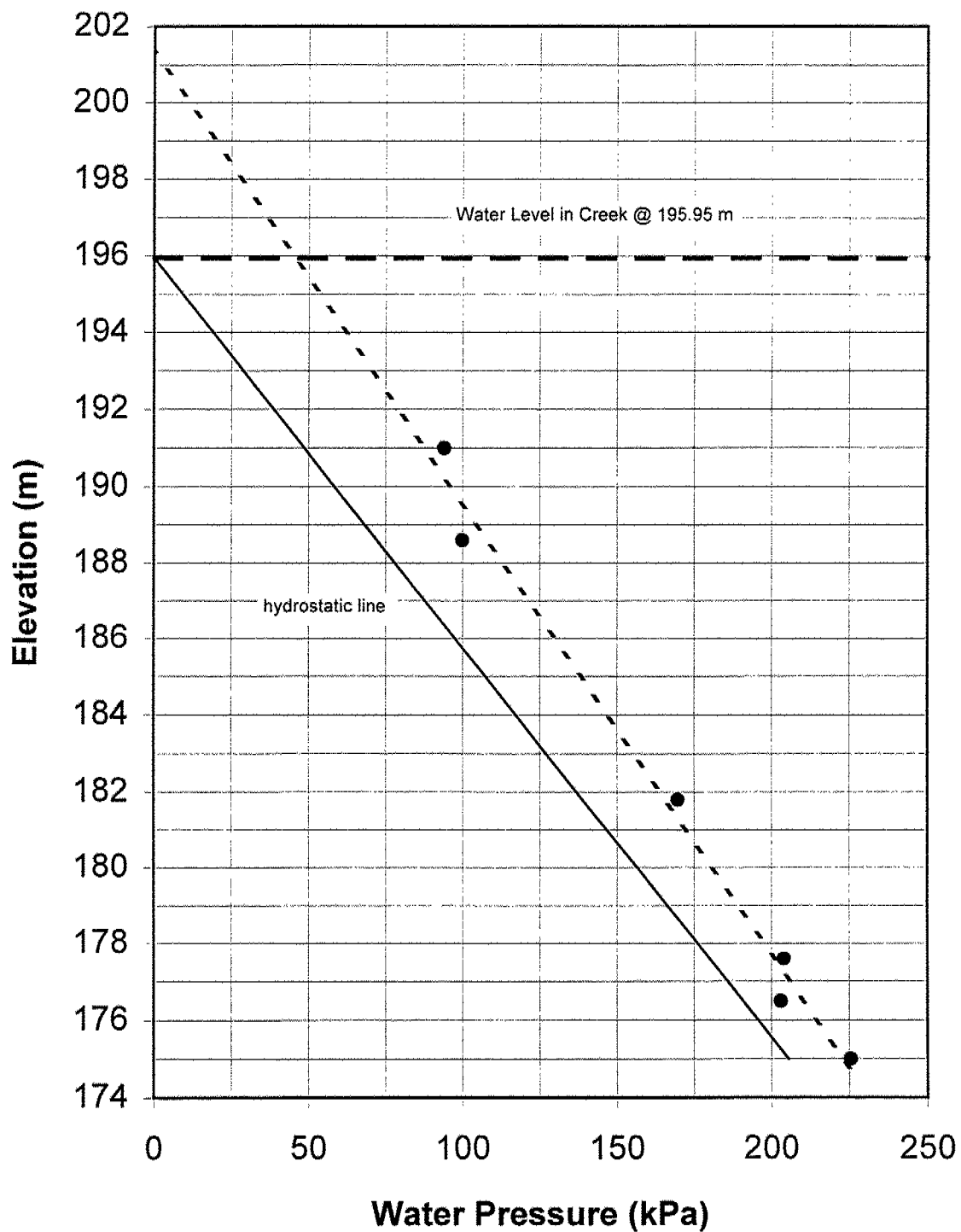
## **Golder Associates**

# OVERSIZE DRAWING

**FIGURE 3**  
**Vane Results vs. Depth**



**FIGURE 4**  
**Ground Water Pressure vs. Elevation**



June 2000

991-1164-1

## **APPENDIX A**

**RECORD OF BOREHOLE SHEETS FROM 1998 INVESTIGATION BY  
THURBER ENGINEERING LTD.**

# RECORD OF BOREHOLE No 98-1

1 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 763.6 E 288 575.3 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.15 - 98.10.15 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
196.8												
0.0	SILT, sandy, very loose, grey, wet		1	SS	2						80.820	
196.1							196					
0.8	CLAY, silty, medium plasticity, soft to firm, grey, wet (CI)		2	SS	2							
			3	SS	1		195				41.7	0 0 41 59
			4	SS	2		194				45.0	0 0 42 58
			5	SS	2							
	some varves evident		6	SS	2		193					
			7	SS	2		192				41.880	
			8	SS	1		191				46.480	
							190					
							189	+			46.480	0 0 43 57
109.3							188					
5	CLAY, silty, trace sand, low plasticity, firm to stiff, grey, wet (CU)		9	SS	1		187					
			10	SS	2		186	+			46.480	0 1 61 38
	some varves evident		11	SS	1		185					
			12	SS	1		184					
							183				50.980	
							182					

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

**METRIC**

ORIGINATED BY GA

COMPILED BY WM

CHECKED BY AEG

+ 3, x 3: Numbers refer to Sensitivity



# RECORD OF BOREHOLE No 98-2

1 OF 2

METRIC

W.P. 812-76-01.398-91-00 LOCATION Laronde Creek, N 5 136 763.4 E 288 612.7 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.20 - 98.10.20 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT Y 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					
199.6	SILT, trace clay, very loose to loose, grey to brown, wet (ML)		1	SS	5								
			2	SS	3								
			3	SS	2								
			4	SS	2								
196.5	CLAY, silty, trace sand, low to medium plasticity, firm to stiff, gray, wet (CL-CI)  some varves evident  (possibly CL between 10 & 12m)  (possibly CL between 13 & 15m)		5	SS	2								
			6	SS	2								
			7	SS	2								
			8	SS	2								
			9	SS	2								
			10	SS	1								
			11	SS	1								
			12	SS	1								

Continued Next Page

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

# RECORD OF BOREHOLE No 98-2

2 OF 2

METRIC

W.P. 812-76-01,398-91-00

LOCATION Laronde Creek, N 5 136 763.4 E 288 612.7

ORIGINATED BY GA

DIST 54

HWY 17

BOREHOLE TYPE Hollow Stem Augers, N Core

COMPILED BY WM

DATUM Geodetic

DATE 98.10.20 - 98.10.20

CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT  γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)  GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100		
							SHEAR STRENGTH kPa						
							○ UNCONFINED + FIELD VANE						
							● QUICK TRIAXIAL × LAB VANE						
							20	40	60	80	100		
							WATER CONTENT (%)						
							10	20	30				
							PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT						
							WP	W	WL				
181.0			13	SS	1	184							0 1 44 55
						183							
			14	SS	2							47.310	
						182							
						181							
18.6	SAND, trace silt, trace gravel, compact to dense, grey, wet		15	SS	2								
						180							
			16	SS	30								6 84 8 2
						179							
178.7													
20.9	BEDROCK undifferentiated granitic rock, very dense Core #1 REC = 100% RQD = 0%		1	CORE		178							
	Core #2 REC = 100% RQD = 51%		2	CORE		177							
	Core #3 REC = 100% RQD = 68%		3	CORE		176							
175.5													
24.0	END OF BOREHOLE AT 24.0m. BOREHOLE GROUTED TO SURFACE.												

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 98-3

1 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 733.6 E 288 573.7 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.24 - 98.10.24 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)							
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40						60	80	100	20	40	60	80
197.5 0.0	SILT and SAND, some clay, very loose to loose, dark brown: (FILL)		1	SS	2																
			2	SS	7																
			3	SS	3																
195.2	CLAY, silty, trace sand, low to medium plasticity, firm to stiff, grey, wet: (CL-CI)  some varves evident  (CL between 11 & 13m)		4	SS	1																
2.3			5	SS	1																
			6	SS	1																
			7	SS	1																
			8	SS	1																
			9	SS	1																
			10	SS	0																
			11	SS	1																
			12	SS	0																

Continued Next Page

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15  
10  
(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 98-3

2 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 733.6 E 288 573.7 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.24 - 98.10.24 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100		
181.3			13	SS	1		182							
16.2	CLAY, silty, medium plasticity, firm to stiff, grey, wet: (CI)		14	SS	2		181		+					
179.2							180							
18.3	SAND, some silt, some cobbles and boulders, very dense, grey, wet		15	SS	50/ .125		179							
176.5							178							
21.0	BEDROCK, undifferentiated granitic rock, very dense Core #1 REC = 100% RQD = 60%		1	CORE			177							
	Core #2 REC = 100% RQD = 75%		2	CORE			176							
	Core #3 REC = 100% RQD = 92%		3	CORE			175							
173.3							174							
24.2	END OF BOREHOLE AT 24.2m. BOREHOLE BACKFILLED AS FOLLOWS: 0-18m GROUT 18-21m BENTONITE & SAND 21-24.2m BENTONITE													

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

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 98-4

1 OF 3

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 743.1 E 288 611.5 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.22 - 98.10.22 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT Y kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES		20 40 60 80 100	PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	
201.4							SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE	WATER CONTENT (%) 10 20 30			GR SA SI CL
0.0	SAND and SILT, very loose to loose, brown: (FILL)		1	SS	3	201		○			
			2	SS	6				○		
			3	SS	4	200					
			4	SS	6	199			○		
198.4			5	SS	6	198			○		0 1 69 30
1.0	SILT, clayey, trace sand, low plasticity, soft to firm, grey, wet (CL-ML)										
197.6			6	SS	2	197			○		0 0 62 38
3.8	CLAY, silty, medium plasticity, soft to firm, grey, wet (CL-CI)		7	SS	1	196					
	some varves evident		8	SS	1	195					
			9	SS	1	194					
			10	SS	1	193					
			11	SS	1	192					
			12	SS	1	191					
						190					0 0 41 58
						189					
						188					
						187					0 0 45 54

Continued Next Page

+ 1, X 3: Numbers refer to Sensitivity 20 15 10 (% STRAIN AT FAILURE)

RECORD OF BOREHOLE No 98-4

2 OF 3

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 743.1 E 288 611.5 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.22 - 98.10.22 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100					
			13	SS	1		186								
							185								
			14	SS	2		184								
							183								
			15	SS	2		182								
							181								
			16	SS	1		180								
							179								
			17	SS	1		178								
							177								
178.7							176								
22.7	SAND, trace gravel, cobbles and boulders, compact to very dense, grey, wet		18	SS	27		175								
							174								
			19	SS	50/ .050		173								
							172								
174.5															
26.9	BEDROCK undifferentiated granitic rock Core #1 REC = 100% RQD = 61%		1	CORE											
	Core #2 REC = 100% RQD = 79%		2	CORE											
	Core #3 REC = 100% RQD = 61%		3	CORE											
171.5															

Continued Next Page

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

# RECORD OF BOREHOLE No 98-4

3 OF 3

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 743.1 E 288 611.5 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.22 - 98.10.22 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT Y 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									
30.0	<p>END OF BOREHOLE AT 29.97m.</p> <p>Piezometer installation consist of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>WATER LEVEL READINGS:</p> <table border="1"> <thead> <tr> <th>DATE</th> <th>DEPTH (m)</th> </tr> </thead> <tbody> <tr> <td>24/10/98</td> <td>4.1</td> </tr> <tr> <td>25/10/98</td> <td>4.1</td> </tr> <tr> <td>26/10/98</td> <td>4.3</td> </tr> <tr> <td>27/10/98</td> <td>4.2</td> </tr> </tbody> </table>	DATE	DEPTH (m)	24/10/98	4.1	25/10/98	4.1	26/10/98	4.3	27/10/98	4.2															
DATE	DEPTH (m)																									
24/10/98	4.1																									
25/10/98	4.1																									
26/10/98	4.3																									
27/10/98	4.2																									

# RECORD OF BOREHOLE No 98-5

1 OF 1

METRIC

W.P. 812-76-01,398-91-00

LOCATION Laronde Creek, N 5 136 767.7 E 288 557.3

ORIGINATED BY GA

DIST 54

HWY 17

BOREHOLE TYPE Hollow Stem Augers, N Coring

COMPILED BY WM

DATUM Geodetic

DATE 98.10.19 - 98.10.19

CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
0.0	SAND and SILT, loose to compact, brown, moist: (FILL)		1	SS	9												
			2	SS	4												
			3	SS	13												
1.9	CLAY, silty, low to medium plasticity, firm to stiff, grey, wet (CL)		4	SS	7												
			5	SS	4												
			6	SS	2												
5.2	END OF BOREHOLE AT 5.18m. BOREHOLE BACKFILLED WITH DRILL CUTTINGS.																



# RECORD OF BOREHOLE No 98-6

1 OF 1

METRIC

W.P. 812-76-01,398-91-00

LOCATION Leronde Creek, N 5 136 733.4 E 288 556.5

ORIGINATED BY GA

DIST 54

HWY 17

BOREHOLE TYPE Hollow Stem Augers, N Coring

COMPILED BY WM

DATUM Geodetic

DATE 98.10.26 - 98.10.26

CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT	UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100					
0.0	SILT, sandy, trace gravel, very loose to loose, brown to black, moist to wet: (POSSIBLE FILL) (ML)		1	SS	4											
			2	SS	3											
			3	SS	4											
2.3	SILT, clayey, soft, grey, moist to wet: (ML)		4	SS	4											
			5	SS	2											
4.0	CLAY, silty, medium plasticity, grey, wet: (CI)		6	SS	1											
5.2	END OF BOREHOLE AT 5.18m. BOREHOLE BACKFILLED WITH DRILL CUTTINGS.															

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

20  
15-5  
10 (%) STRAIN AT FAILURE

**APPENDIX B**  
**LABORATORY TEST DATA**

TABLE B1

## SUMMARY OF WATER CONTENT, ATTERBERG LIMITS AND SPECIFIC GRAVITY DETERMINATIONS

PROJECT NUMBER		991-1164			
PROJECT NAME		McCormick Rankin / Highway 17 / North Bay			
DATE TESTED		October/November, 1999			
Borehole No.	Sample No.	Depth (m)	Water Content (%)	Atterberg Limits Wl, Wp, Ip	Specific Gravity
99-43	3	1.52-2.13	10.0		
99-43	5	3.05-3.66	30.2		
99-43	8	6.10-6.71	22.6		
99-44	6	4.57-5.18	55.4		
99-44	11	12.19-12.80	41.2	Wl=28.6, Wp=16.0, Ip=12.6	
99-45	5	3.05-3.51	31.1		
99-45	7	4.57-5.18	33.0	Wl=30.1, Wp=20.1, Ip=10.0	2.70
99-45	9	7.62-8.08	50.3	Wl=38.8, Wp=17.2, Ip=21.6	2.66
99-46	3	1.52-2.13	34.3	Wl=30.6, Wp=19.5, Ip=11.1	
99-46	7	7.62-8.23	56.9	Wl=47.7, Wp=21.4, Ip=26.3	
99-46	14	18.29-18.90	41.4		

Notes: Specific gravity test carried out using distilled water.

Wl = Liquid Limit

Wp = Plastic Limit

Ip = Plasticity Index

## FIGURE B1



SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
--------	----------	--------	----------

## Golder Associates

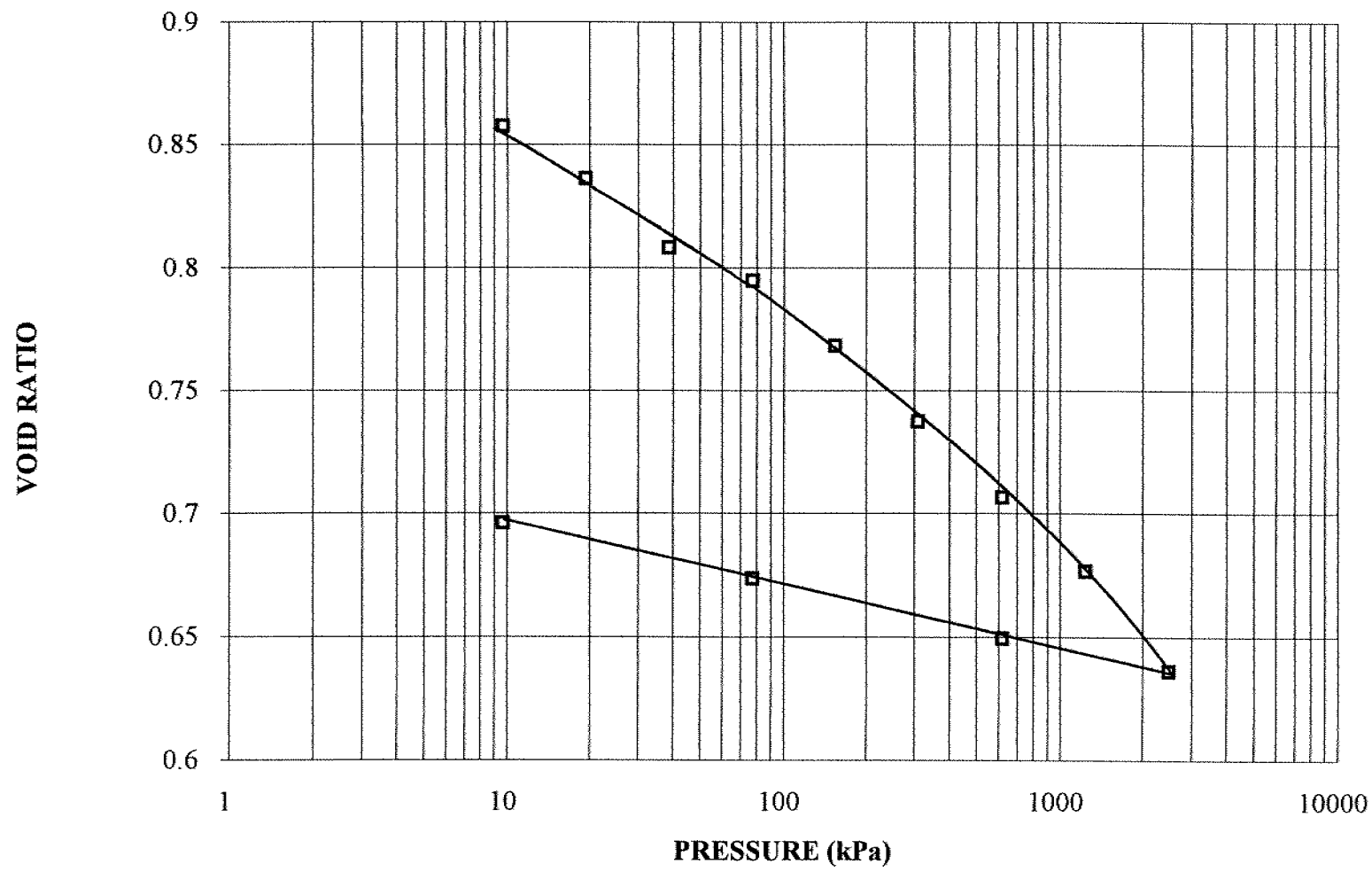
## FIGURE B2



SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
--------	----------	--------	----------

9

CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-45 SA 7



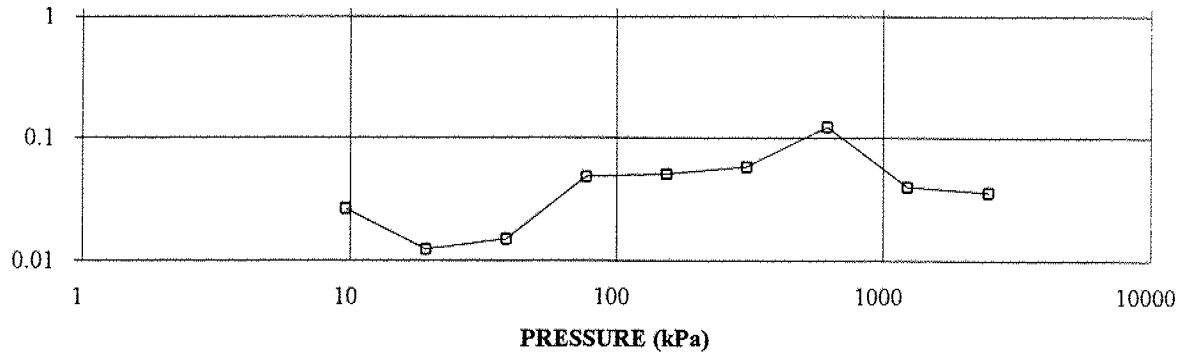
CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE B3

# OEDOMETER CONSOLIDATION SUMMARY

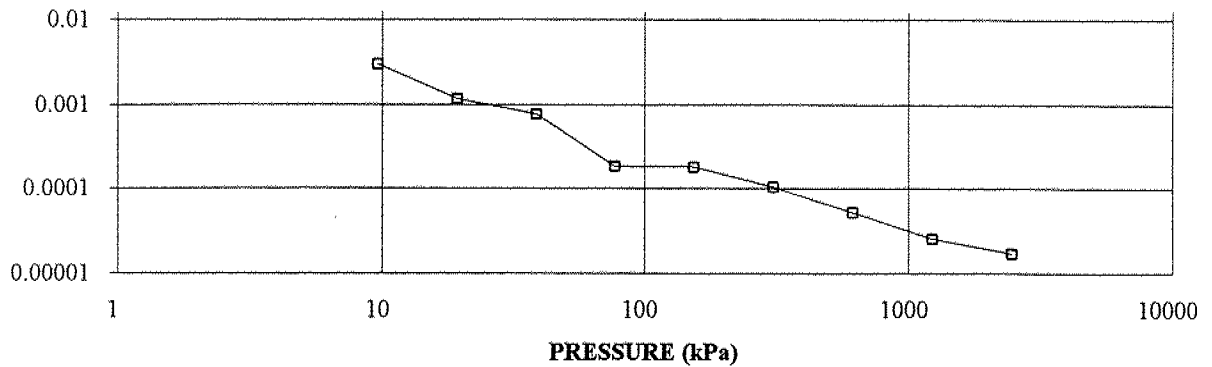
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $\text{cv cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 7



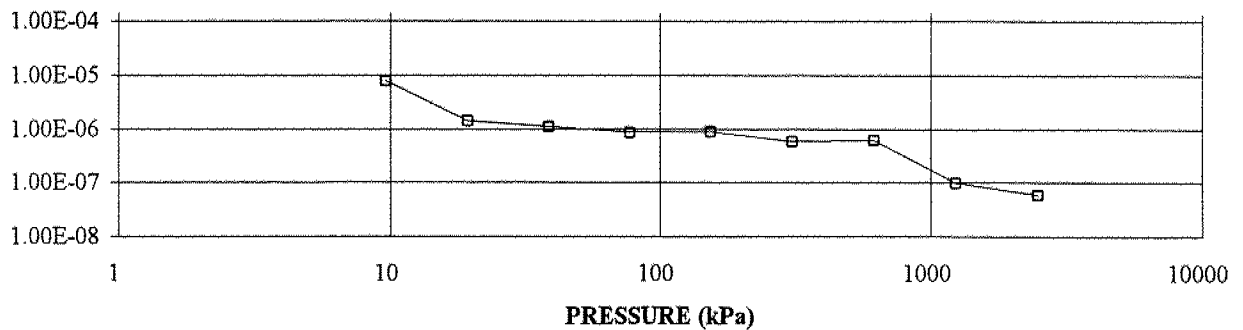
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $\text{mv, m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 7



HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-45 SA 7



## OEDOMETER CONSOLIDATION SUMMARY

### SAMPLE IDENTIFICATION

Project Number	991-1164	Sample Number	7
Borehole Number	99-45	Sample Depth, m	4.6-5.2

### TEST CONDITIONS

Test Type	Quick /Standard	Load Duration, hr	(0.10 - 22)
Oedometer Number	7		
Date Started	99-10-08		
Date Completed	99-10-09		

### SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.88	Unit Weight, kN/m <sup>3</sup>	18.64
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	13.84
Area, cm <sup>2</sup>	31.67	Specific Gravity, measured	2.70
Volume, cm <sup>3</sup>	59.63	Solids Height, cm	0.984
Water Content, %	34.72	Volume of Solids, cm <sup>3</sup>	31.17
Wet Mass, g	113.37	Volume of Voids, cm <sup>3</sup>	28.47
Dry Mass, g	84.15	Degree of Saturation, %	102.6

### TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.883	0.913	1.883				
9.66	1.828	0.858	1.856	28	2.61E-02	3.02E-03	7.71E-06
19.31	1.807	0.836	1.818	57	1.23E-02	1.15E-03	1.39E-06
38.63	1.779	0.808	1.793	46	1.48E-02	7.62E-04	1.11E-06
77.25	1.766	0.795	1.773	14	4.76E-02	1.83E-04	8.53E-07
154.50	1.740	0.768	1.753	13	5.01E-02	1.79E-04	8.81E-07
309.00	1.710	0.737	1.725	11	5.73E-02	1.04E-04	5.85E-07
618.00	1.679	0.706	1.694	5	1.22E-01	5.24E-05	6.25E-07
1236.00	1.650	0.676	1.664	15	3.92E-02	2.54E-05	9.73E-08
2471.99	1.610	0.636	1.630	16	3.52E-02	1.70E-05	5.87E-08
618.00	1.623	0.649	1.617				
77.25	1.647	0.673	1.635				
9.66	1.669	0.696	1.658				

Notes:

k calculated using cv based on t<sub>90</sub> values.

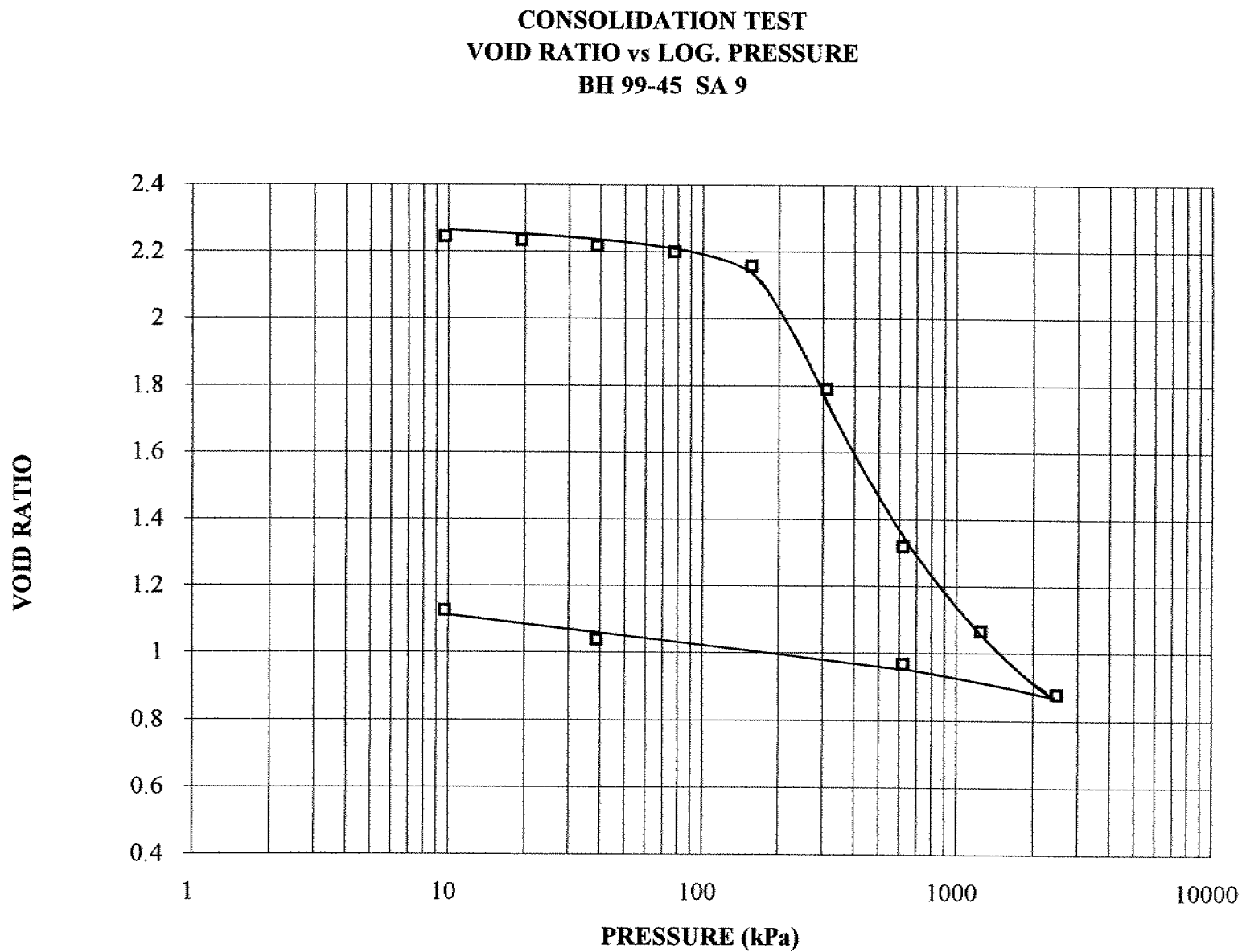
### SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.67	Unit Weight, kN/m <sup>3</sup>	19.84
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	15.61
Area, cm <sup>2</sup>	31.67	Specific Gravity, measured	2.70
Volume, cm <sup>3</sup>	52.86	Solids Height, cm	0.984
Water Content, %	27.11	Volume of Solids, cm <sup>3</sup>	31.17
Wet Mass, g	106.96	Volume of Voids, cm <sup>3</sup>	21.69
Dry Mass, g	84.15		



CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

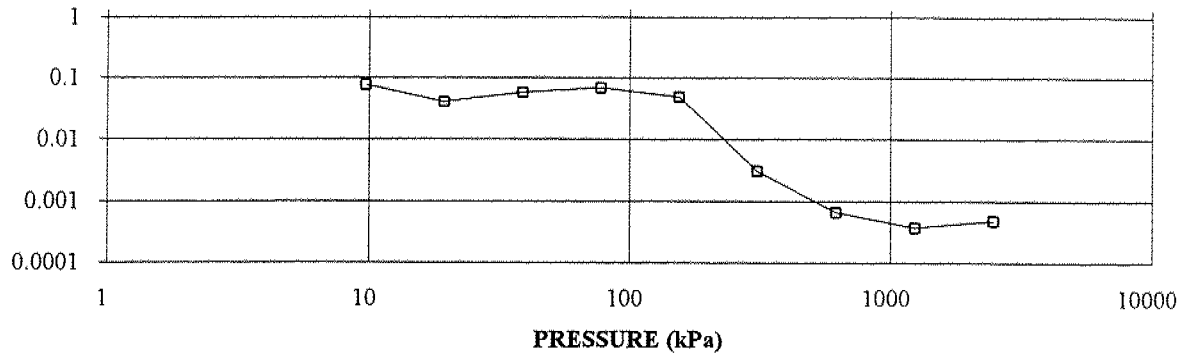
FIGURE B4



# OEDOMETER CONSOLIDATION SUMMARY

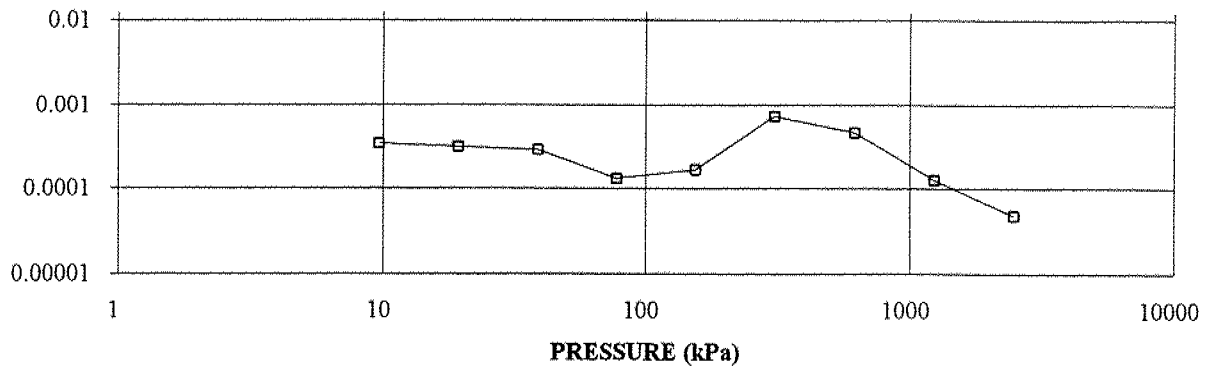
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $c_v$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 9



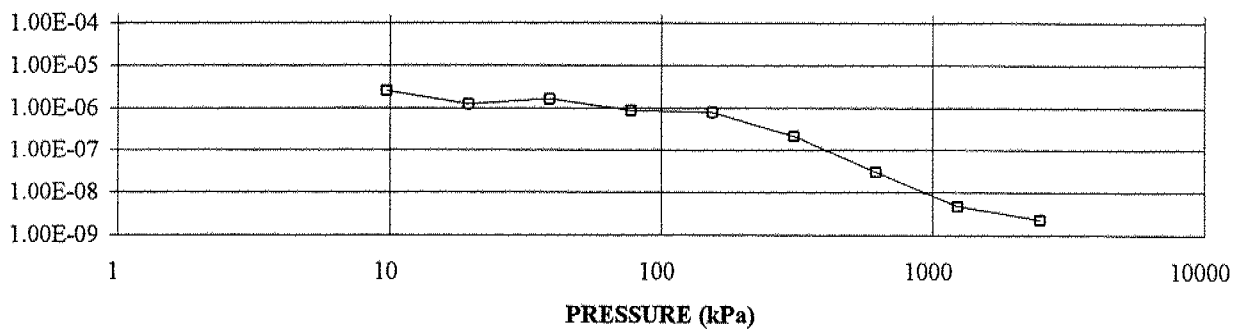
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $m_v$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 9



HYDRAULIC  
CONDUCTIVITY,  $\text{cm}/\text{s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-45 SA 9



# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-1164	Sample Number	9
Borehole Number	99-45	Sample Depth, m	7.9

## TEST CONDITIONS

Test Type	Quick /Standard	Load Duration, hr	(0.13 - 22)
Oedometer Number	6		
Date Started	99-10-07		
Date Completed	99-10-08		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m <sup>3</sup>	14.88
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	8.02
Area, cm <sup>2</sup>	31.52	Specific Gravity, measured	2.66
Volume, cm <sup>3</sup>	59.92	Solids Height, cm	0.584
Water Content, %	85.63	Volume of Solids, cm <sup>3</sup>	18.41
Wet Mass, g	90.92	Volume of Voids, cm <sup>3</sup>	41.51
Dry Mass, g	48.98	Degree of Saturation, %	101.0

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.901	2.254	1.901				
9.70	1.895	2.243	1.898	10	7.64E-02	3.42E-04	2.56E-06
19.40	1.889	2.233	1.892	19	3.99E-02	3.14E-04	1.23E-06
38.81	1.878	2.215	1.884	13	5.79E-02	2.90E-04	1.64E-06
77.62	1.869	2.199	1.873	11	6.76E-02	1.30E-04	8.63E-07
155.23	1.844	2.157	1.856	15	4.87E-02	1.67E-04	7.96E-07
310.46	1.629	1.788	1.736	211	3.03E-03	7.29E-04	2.17E-07
620.93	1.354	1.318	1.492	708	6.66E-04	4.65E-04	3.04E-08
1241.86	1.207	1.066	1.281	916	3.80E-04	1.25E-04	4.65E-09
2475.89	1.096	0.876	1.152	576	4.88E-04	4.72E-05	2.26E-09
620.93	1.149	0.966	1.122				
38.81	1.191	1.038	1.170				
9.70	1.241	1.124	1.216				

Notes:

k calculated using cv based on t<sub>90</sub> values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.24	Unit Weight, kN/m <sup>3</sup>	17.92
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	12.28
Area, cm <sup>2</sup>	31.52	Specific Gravity, measured	2.66
Volume, cm <sup>3</sup>	39.11	Solids Height, cm	0.584
Water Content, %	45.92	Volume of Solids, cm <sup>3</sup>	18.41
Wet Mass, g	71.47	Volume of Voids, cm <sup>3</sup>	20.70
Dry Mass, g	48.98		

**Golder Associates Ltd.**

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**REPORT ON**

**FOUNDATION INVESTIGATION AND DESIGN  
LARONDE CREEK BRIDGE REPLACEMENT  
HIGHWAY 17, SITE 43-65, W.P. 812-76-02  
DISTRICT 54, SUDBURY  
G.W.P. 812-76-01**

**Submitted to:**

McCormick Rankin Corporation  
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Mississauga, Ontario

June 2000

991-1164-1

GEOCRES NO. 31L-70

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List of Abbreviations and Symbols

## Record of Borehole and Drillhole Sheets (99-43, 99-44 and 99-45)

Figure 1	Site Location Map
Figure 2A	Borehole Location and Soil Strata
Figure 2B	Cross-Sections, Borehole Locations and Soil Strata
Figure 3	Field Vane Results vs. Depth
Figure 4	Groundwater Pressure vs. Elevation
Appendix A	Record of Borehole Sheets from 1998 Investigation by Thurber Engineering Ltd.
Appendix B	Laboratory Test Data



**PART A – FIELD INVESTIGATION**

**FOUNDATION INVESTIGATION AND DESIGN  
LARONDE CREEK BRIDGE REPLACEMENT  
HIGHWAY 17, SITE 43-65, W.P. 812-76-02  
DISTRICT 54, SUDBURY  
G.W.P. 812-76-01**



## 1.0 INTRODUCTION

Golder Associates Ltd. (Golder) has been retained by McCormick Rankin Corporation (McCormick Rankin) to carry out a foundation investigation for the replacement of the Laronde Creek Bridge (Site 43-65) as part of the widening of Highway 17 between North Bay and Sturgeon Falls, Ontario. The proposed works consists of replacing the existing single span Laronde Creek Bridge structure with a wider three span structure.

The purpose of the investigation is to determine the subsurface conditions at the location of the proposed replacement bridge by drilling boreholes, carrying out in-situ tests and performing laboratory tests on selected samples. Based on our interpretation of the data obtained, recommendations on the geotechnical aspects of the foundation design and construction for the abutments and for the new bridge piers are provided.

McCormick Rankin provided the plan and profile of the proposed Highway 17 alignment at the Laronde Creek Bridge to Golder. The centreline and stations of the proposed alignment were surveyed by others prior to commencing the foundation field investigation program.

The terms of reference and scope of work for the investigation are outlined in Golder's proposal P91-1225, dated June 1999, that forms part of the Consultant's Agreement (Number P.O. 5005-A-000016) for this project. Changes to the original scope of work (as a result of proposed changes to the bridge structure) were described in Golder's letter to McCormick Rankin dated September 13, 1999. This additional work was subsequently authorized by MTO/McCormick Rankin. The work was carried out in accordance with the Quality Control Plan for this project.

A previous foundation investigation had been carried out at the site in 1998 under the supervision of Thurber Engineering Ltd. (Thurber). The results of the Thurber investigation are presented in their report titled *"Final Foundation Investigation and Design Report for Proposed Bridge over Laronde Creek, Site 43 - 65, Highway 17 from North Bay to Sturgeon Falls W.P. 812-76-00 & 398-91-00, District 54, Sudbury"* dated March 29, 1999 and submitted to Stantec Consulting Group Ltd. The Records of Boreholes from the Thurber investigation are provided in Appendix A of this report; the information has been used in the preparation of this report.

## **2.0 SITE DESCRIPTION**

### **2.1 Site Location**

The project area covered by this report extends along the proposed Highway 17 re-alignment, from approximately Stations 13+500 to 13+700 in the Township of Beaucage where Highway 17 crosses Laronde Creek. The site is situated approximately 20 km west of North Bay, Ontario between Highway 64 and Highway 11 (see Figure 1). The highway runs approximately east-west and the creek flows north to south towards Lake Nipissing.

The existing bridge deck is about 5 m above creek level. Based on available information provided to Golder, the existing bridge structure is a concrete rigid frame that is founded on timber piles. The ground surface at the existing abutment locations is at about Elevation 201.5 m and the Laronde Creek bed is at about Elevation 194.5 m. The water level in the creek is at about Elevation 196 m.

The bank on the east side of the creek is quite steep. On the west side, the bank is much flatter and a commercial operation including a lodge exists. An asphalt road (boat ramp) runs downslope to the creek about 20 m north (upstream) of the existing bridge. Heavy tree cover exists in the area north of the alignment on the east side of the creek.

The proposed centreline of the replacement bridge is located approximately 15 m north of the centreline of the existing bridge. It is understood that the proposed highway surface on the replacement bridge is at about Elevation 203 m.

### **2.2 Physiography**

The site lies within the Canadian Shield in an area where the bedrock is overlain by deep overburden. The regional area can be characterized as a flat plain that starts about 1 km to the east of Laronde Creek, extends many kilometers to the west, and stretches from Lake Nipissing to several kilometers north of the existing highway.

The bedrock in the vicinity of Laronde Creek is igneous and metamorphic rock of early Precambrian age. A former glacial lake basin existed in the area and, consequently, the site is underlain by extensive deposits of fine-grained lake sediments. The overburden typically consists of surficial sands and silts overlying thick clay deposits. Some of the clay deposits are varved. Overburden thickness is quite variable and can be as deep as 40 m or more.

On a more regional basis, the bedrock is exposed as low, rounded hills with a sporadic cover of thin glacial drift.

### 3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried between September 29 and October 3, 1999 at which time, three boreholes (Boreholes 99-43, 99-44 and 99-45) were advanced at the site of the proposed replacement bridge. The boreholes were drilled and sampled to depths ranging from about 20.1 m to 25.9 m. The bedrock surface and condition were proved in each borehole by rock coring. The borehole locations are shown in plan on Figure 2. It is noted that the Laronde Creek Bridge site is a part of the overall Highway 17 Widening Project of G.W.P. 812-76-01. In total 45 boreholes were drilled as part of this contract (i.e. 42 boreholes along the overall alignment and 3 boreholes at Laronde Creek).

The investigation was carried out using a bombardier mounted CME 55 drill rig supplied and operated by Marathon Drilling Co. Ltd. of Ottawa, Ontario. The boreholes were advanced using 208 mm outside diameter (O.D.) continuous flight hollow stem augers through overburden soils, and using NQ size casing for bedrock coring. Soil samples were obtained at regular intervals of depth using a 50 mm O.D. split-spoon sampler in accordance with Standard Penetration Test (SPT) procedures, or a 80 mm O.D. thin walled open Shelby tube sampler. In-situ vane shear tests were also carried out at regular intervals in the clayey deposit. The cored length of bedrock in the boreholes ranged from 3.1 m to 4.6 m. Shallow and deep piezometers were installed in Boreholes 99-43 and 99-45 to measure the groundwater conditions at these locations. Water level in the piezometers were obtained on October 3, 1999 to determine stabilized levels at that time.

The field work was supervised throughout by a member of our engineering staff, who located the boreholes, cleared the borehole locations for underground services, supervised the drilling, sampling and in-situ testing operations, logged the boreholes, and examined and cared for the soil and rock samples. The samples were identified in the field, placed in containers, labelled and transported to our Mississauga laboratory. Laboratory testing on selected samples included natural water content, Atterberg limits, grain size analyses, specific gravity and oedometer (consolidation) tests. The results of the laboratory testing are given on the Record of Borehole sheets and in Appendix B.

A substantial amount of classification testing, such as Atterberg limits and grain size, had been carried out by Thurber during their investigation in 1998. The number of soil tests carried out during the current investigation took into account the previous testing that had been performed to classify the soil deposits encountered.

The following table summarizes the proposed locations (at the time of drilling) of foundation units and boreholes, referenced to the proposed highway centreline stations.

<i>Foundation Unit/ Borehole Number</i>	<i>Approximate Station (m)</i>
West Abutment	13+561
West Pier	13+587
East Pier	13+621
East Abutment	13+647
Borehole 99-43	13+647
Borehole 99-44	13+587
Borehole 99-45	13+561

It was not possible to drill a borehole at the proposed location of the east pier using the conventional drilling equipment that was on-site. The same experience and conclusion was drawn by Thurber in 1998. The tree cover and very steep east bank prevented access by the track mounted drill rig. In order to drill at the proposed east pier foundation unit, substantial site preparation, a special drill rig, and possibly a large crane would be needed. It was considered not to be cost-effective to expend such effort. The main reason for this was that deep deposits of clay exist at the site and a piled foundation would be necessary. Sufficient information can be obtained from: (i) the three detailed boreholes drilled under Golder supervision as part of the current investigation, and (ii) the boreholes previously drilled at the site under the supervision of Thurber.

The as-drilled location of Borehole 99-43 also had to change from that proposed to avoid overhead hydro lines as per Health and Safety requirements. It was not possible to locate the borehole north of the proposed location because of the heavy tree cover (bush) north of the centreline of the highway realignment.

The as drilled borehole locations were surveyed using the NAD 83 MTM (Zone 12) co-ordinate system and the geodetic datum for elevation. The surveying was carried out by MF Tulloch Inc. of Thessalon, Ontario.

#### **4.0 SUBSURFACE CONDITIONS**

The detailed subsurface conditions encountered in the boreholes advanced during this investigation are presented on the Record of Borehole and Record of Drillhole sheets, and by the laboratory test results contained in Appendix B. It should be noted that the stratigraphic boundaries indicated on the borehole records are inferred from non-continuous sampling, observations of drilling progress, results of Standard Penetration Tests (SPTs) and in-situ vane shear tests. These boundaries typically represent transitions from one soil type to another and should not be regarded as exact planes of geological change. Further, subsurface conditions will vary between and beyond the borehole locations.

The ground surface elevation at the borehole locations varied from about Elevation 197.0 m to 201.6 m. The boreholes were sampled to depths ranging from 20.1 m to 25.9 m.

#### **4.1 General Stratigraphy**

The general stratigraphy at the site consists primarily of a thick deposit of cohesive soils overlying a thin granular layer over granitic bedrock. At one borehole location (Borehole 99-44) a 1.5 m thick layer of granular fill overlies the cohesive deposits. The fill is associated with the boat ramp roadway mentioned earlier. At Borehole 99-45, a 1.5 m layer of silty sand to sandy silt overlies the primary cohesive deposit.

#### **4.2 Fill**

In Borehole 99-44, below about 130 mm of asphalt, brown gravelly sand fill material containing some silt and fragments of wood and asphalt was encountered to a depth of about 1.5 m. Two SPT 'N' values of 4 and 5 blows per 0.3 m of penetration were recorded in the fill, indicating a loose state of packing.

#### **4.3 Silty Sand to Sandy Silt**

In Borehole 99-45, below about 100 mm of topsoil, a deposit of brown to grey silty sand to sandy silt containing trace organics and rootlets was encountered to about depth 1.5 m. Two SPT 'N' values of 4 and 7 blows per 0.3 m of penetration were recorded, indicating a loose state of packing.

#### 4.4 Clayey Silt to Silty Clay

Below about 120 mm of topsoil in Borehole 99-43, and the sandy silt in Borehole 99-45, a deposit of grey clayey silt to silty clay containing trace sand was encountered. The top of this deposit is at Elevation 200.7 m and 200.1 m in Boreholes 99-43 and 99-45, respectively. SPT 'N' values ranging from 0 (weight of hammer) to 8 blows per 0.3 m of penetration and one in-situ vane shear test result of 38 kPa were recorded in the silty clay, indicating a soft to firm consistency. Measured water contents of two samples from this deposit are 33 percent and 34 percent. Representative liquid and plastic limits, based on two samples tested, are 30 percent and 20 percent, respectively (plasticity index of 10). Figure B1 in Appendix B shows gradation curves for two samples of this deposit.

Figure B3 in Appendix B shows the void ratio ( $e$ ) vs. log effective vertical pressure ( $\sigma'$ ) for a sample of the clayey silt to silty clay deposit that was obtained directly above the varved silty clay deposit. The soil sample was assessed to be undisturbed. The  $e$ -log  $\sigma'$  curve is considered to reflect the very silty nature of the soil, although it may also reflect that some degree of disturbance may have been imparted to the sample. The key consolidation parameters interpreted from the test results are:

- Initial void ratio = 0.91
- Estimated preconsolidation pressure,  $\sigma'_{p'}$  = 200 kPa
- Overconsolidation Ratio, OCR = 2.3
- Recompression Index,  $C_r$  = 0.03 (based on rebound portion of curve)
- Compression Index,  $C_c$  = 0.12

Compared to the underlying varved silty clay that is described below, the upper clayey deposit is more overconsolidated and not near as compressible or sensitive.

#### 4.5 Varved Silty Clay

A deposit of grey varved silty clay was encountered in all boreholes. The top of this deposit ranged from Elevation 195.6 m to 196.8 m. The varved silty clay deposit extends to depths ranging from 16.9 m to 20.3 m (about Elevation 180.1 m to 181.3 m). SPT 'N' values ranging from 0 (weight of hammer) to 2 blows per 0.3 m of penetration and in-situ vane shear test results



from 30 kPa to greater than 100 kPa were recorded, indicating a firm to very stiff consistency. Measured water contents of samples from this deposit range from 41 percent to 57 percent. Representative liquid and plastic limits, based on 3 samples tested, are 38 percent and 18 percent, respectively (plasticity index of 20). A grain size curve of one sample is shown on Figure B2 in Appendix B.

Figure 3 summarizes the measured field vane shear tests that were carried out as part of the current investigation. There is a definite trend of increasing vane (undrained) shear strength ( $s_u$ ) with depth ranging from a minimum value of 30 kPa at 4 m depth to greater than 100 kPa at a depth of about 19 m below existing ground surface. The results show that the varved silty clay does not have a 'crust' of higher strength in its upper zone. It is noted that the higher strength values above the 4 m depth shown on Figure 3 correspond to the overlying clayey silt to silty clay layer. From Figure 3 it can be assumed that  $s_u$  in the varved silty clay increases linearly with depth according to the following empirical relation:

$$s_u = 18 + 4d \text{ (units of kPa)}$$

where  $d$  = depth below ground surface.

The results of an oedometer (consolidation) test on a sample of the varved silty clay are summarized in Figure B4 in Appendix B. The void ratio ( $e$ ) vs. log effective vertical pressure ( $\sigma'$ ) curve reflects the classic shape of a soft, sensitive, slightly overconsolidated clay, and indicates that a high quality undisturbed sample was obtained. The key consolidation parameters interpreted from the test results are:

- Initial void ratio,  $e_0 = 2.25$
- Preconsolidation pressure,  $\sigma'_p = 160$  kPa
- Overconsolidation Ratio (OCR) = 1.2
- Recompression Index,  $C_r = 0.07$
- Compression Index,  $C_c = 1.4$  (pressure range of 200 kPa to 800 kPa)

#### **4.6 Sand to Silty Sand**

Below the varved silty clay, a thin deposit of grey sand to silty sand was encountered. SPT 'N' values ranged from 4 blows to greater than 100 blows per 0.3 m of penetration, indicating a loose to very dense state of packing. The thickness of this deposit was variable, ranging from about 0.15 m to about 1.6 m. The top of the deposit was generally encountered at about Elevation 181 m. The deposit directly overlies bedrock.

#### **4.7 Granitic Bedrock**

Granitic bedrock surface was encountered between Elevation 179.5 m and 180.7 m. In Boreholes 99-44 and 99-45, the granitic bedrock is fresh with RQD values ranging from about 62 percent to 84 percent. It is inferred that the rock is very to extremely strong. In Borehole 99-43, the upper 3 m of bedrock is weathered and highly fractured with RQD values ranging from 0 percent to 6 percent. Fresh bedrock (RQD 48 percent) was encountered in Borehole 99-43 at about Elevation 176.5 m.

Based on the available borehole information (Golder and Thurber) it appears that the bedrock surface slopes slightly towards Laronde Creek on both sides of the creek. The maximum difference in bedrock surface encountered in the boreholes is approximately 2 m. However, given the variable nature of the bedrock surface in the area, greater variations in the bedrock surface should be expected across the proposed bridge site.

#### **4.8 Groundwater Conditions**

Shallow and deep piezometers were installed in Boreholes 99-43 and 99-45. The water level measured in the piezometers are summarized in the following table. It should be noted that the groundwater level is subject to seasonal fluctuations.

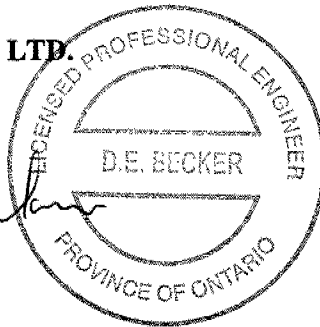
Borehole Number	Borehole Depth (m)	Piezometer Tip		Date	Water Level in Piezometer	
		Depth (m)	Elevation (m)		Depth (m)	Elevation (m)
99-43	25.9	12.2	188.6	03/10/99	1.9	198.8
		25.8	175.0	03/10/99	2.8	198.0
99-45	24.0	10.7	190.9	29/09/99	1.0	200.6
		23.9	177.7	29/09/99	3.2	198.4
98-1	22.6	15.3	181.5	27/10/98	2.3	199.1
					above g.s.	
98-4	30.0	25.0	176.4	27/10/98	4.2	197.2

Figure 4 summarizes the measured levels. It shows a hydrostatic groundwater pressure condition in relation to the current creek level, and the groundwater pressures as measured in the piezometers. The measured groundwater levels indicate a condition of downward seepage. An artesian condition with respect to the creek level is also shown.

**GOLDER ASSOCIATES LTD.**



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BVB/DEB/FJH/clg

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**PART B –FOUNDATION DESIGN**

**FOUNDATION INVESTIGATION AND DESIGN  
LARONDE CREEK BRIDGE REPLACEMENT  
HIGHWAY 17, SITE 43-65, W.P. 812-76-02  
DISTRICT 54, SUDBURY  
G.W.P. 812-76-01**

## **5.0 ENGINEERING RECOMMENDATIONS**

This section of the report provides our interpretation of the factual geotechnical data obtained during the investigation. The recommendations provided are intended for the guidance of the design engineer. The data may not be sufficient for construction and where comments are made on construction, they are provided to highlight aspects of construction that could affect the design of the project. Contractors bidding on or undertaking the works must make their own interpretation of the subsurface information provided as it affects their proposed construction methods, costs, equipment selection, scheduling and the like.

The proposed work consists of a three span bridge structure (see Figure 2). It is understood that this structure will replace the existing Laronde Creek bridge located to the south of the proposed replacement structure. The road surface on the new bridge deck will be at about Elevation 203 m.

The three span structure has been proposed to avoid large time-dependent consolidation settlement (of the thick clay deposit at the site) that would be induced by the approach fills. The performance and construction schedule desired by MTO did not permit the use of pre-load and other techniques to minimize settlement and ensure stability of the approach embankments. Therefore, based on discussions between MTO, McCormick Rankin and Golder, the abutments have been shifted farther away from the creek so as to minimize approach embankment height and settlement.

### **5.1 Bridge Foundations**

The subsoils (i.e. thick deposits of compressible varved silty clay) encountered at the proposed bridge location are not considered suitable to support shallow spread footings. Deep foundations are recommended for support of the abutments and piers, such as steel H-piles driven to practical refusal on bedrock. H-piles are recommended because they will easily penetrate the clay deposit and minimize the amount of disturbance imparted to the clay given their shape and small cross-sectional area.

For frost action protection, the base of pile caps and other footings should be provided with a minimum soil cover of 2.0 m.

### **5.1.1 Pile Axial Resistance**

For HP 310 x 110 piles driven to refusal in the granitic bedrock, a factored axial resistance at Ultimate Limit States (ULS) of 2,000 kN may be assumed for design. This value takes into account the structural capacity limitation of the pile, and potential difficulties that the pile may have seating into the bedrock surface that may be variable and inclined. The pile tips should be suitably reinforced with rock points to ensure penetration and adequate seating as per current MTO practice (Standard OPSD 3301.00 and OPSS 903.07.02.05).

A Serviceability Limit States (SLS) value is not provided because the granitic bedrock is considered to be an unyielding material. Under such conditions, SLS values (for 25 mm of settlement) do not govern design because the SLS value is much higher than the ULS value.

#### **5.1.1.1 Downdrag Load (Negative Skin Friction)**

As will be discussed in a later section, the height of the approach embankments is minimal. Nevertheless, some consolidation settlement of the underlying thick clay deposits will take place as a result of increased vertical grades due to approach embankments to the abutments and regrading in the vicinity of the piers. The consolidation settlement is time-dependent and will not completely occur during the construction period. That is, post-construction settlement of the clay deposit will take place. Because the piles are end-bearing on bedrock, a small amount of settlement of the clay relative to the pile will result in the development of negative skin friction acting on the piles. Therefore, negative skin friction or downdrag loads will need to be taken into account during design of the piles supporting the piers and abutments.

The magnitude of the downdrag load acting on a pile is a function of the adhesion (skin friction) that develops between the pile and the clay, and the surface area of the pile within the clay deposit.

The unit negative skin friction acting on a unit area along a single pile can be calculated using the following equation:

$$f_{ns} = \beta \sigma_v'$$

where  $f_{ns}$  = unit negative skin friction  
 $\beta$  = shaft resistance factor = 0.25  
 $\sigma_v'$  = Effective vertical (overburden) pressure

For this site  $\sigma_v'$  Can be calculated (approximately) for design purposes as  
 $\sigma_v' = \gamma' z$

where  $\gamma'$  = buoyant unit weight of soil (assume 9 kN/m<sup>3</sup>)  
 $z$  = depth below final road surface (m)

The total downdrag load is a function of the surface area of the pile within the cohesive soil. The load calculated in this manner is a nominal (unfactored) load. The structural engineer needs to multiply this load by a load factor of 1.25, as defined in OHBDC, and include it as part of the load effects acting on the pile as described in OHBDC.

As an example, it is calculated that the nominal (unfactored) downdrag load acting on a HP 310 x 110 pile, embedded 18 m in clay, is approximately 700 kN.

#### 5.1.1.2 Set Criteria

Set criteria are highly dependent on pile driving hammer type and selected pile. The set criteria can be determined through a variety of methods, including empirical correlations and wave equation analyses, at the time of construction once the hammer and pile types are known. The choice of set criteria is dependent on the experience of the engineer, and traditional use where a substantial database has been developed over the years. An example would be the use of the Hiley formulae that is commonly used by MTO. The criteria also needs to be set to avoid overdriving and possible damage to the piles. Pile driving should be in conformance with OPSS 903.

#### 5.1.1.3 Pile Driving Note

The pile driving note to be added to the drawings is Note 4 in Clause 2.5.11 of the Structural Manual – “Piles to be driven to bedrock”.



#### 5.1.1.4 Effect of Artesian Groundwater Pressure

Artesian groundwater pressure relative to the Laronde Creek level was measured by the deep piezometers installed in or near the bedrock. The clayey soils are considered to be sufficiently cohesive to seal against the shafts of driven piles, thereby minimizing potential for continual upward seepage of water along the pile shaft. The piles derive their resistance from end-bearing on bedrock. Therefore, minor upward seepage along the pile shaft would not reduce axial resistance.

#### 5.1.2 Horizontal Resistance

The design of pile subjected to lateral loads should take into account such factors as relative rigidity of the pile to the surrounding soil, the fixity condition at the head of the pile (pile cap level), the structural capacity of the pile to withstand bending moments, the soil resistance that can be mobilized, the maximum tolerable lateral deflection at the head of the pile and pile group effects. For a longer, more flexible pile, its maximum yield moment may be reached prior to mobilization of the lateral geotechnical resistance. For design purposes, both the structural and geotechnical resistances should be determined to establish the governing case.

It is understood that integral abutments are being considered for this bridge. An integral abutment consists of the use of the double pipe liner that allows the H-pile to flex more freely. This double pipe liner involves the use of corrugated steel pipe (CSP) 600 mm and 800 mm diameter pipes placed around the H-piles. The space between the H-pile and the inner pipe is filled with uniform grained uncompacted sand. The space between the two pipes is left unfilled and the H-pile / sand / inner CSP is free to deflect within the outer CSP. The passive resistance over the length of the double pipe liner may be neglected in design. ✓

The horizontal soil reaction to a vertical pile can be estimated using a vertical following formula:

$$k_h = \frac{67 s_u}{b}$$

where:

- $k_h$  = coefficient of horizontal subgrade reaction (kPa/m)
- $s_u$  = undrained shear strength of the soil (kPa)
- $b$  = pile width or diameter (m)

In-situ vane shear test results indicate that the undrained shear strength of the clay deposit increases with depth (see Figure 3). For the purpose of design, it may be assume that  $s_u$  increases linearly with depth according to the following relation:

$$s_u = 18 + 4d \text{ (units of kPa)}$$

where:  $d$  = depth below ground surface (m)

Group action for lateral loading should be considered when the pile spacing in the direction of loading is less than six to eight pile diameters. Group action can be evaluated by reducing the coefficient of horizontal subgrade reaction in the direction of loading by a reduction factor  $R$  as follows:

**Subgrade Reduction Factors**

<i>Pile Spacing in Direction of Loading <math>d</math> = Pile Diameter</i>	<i>Subgrade Reaction Reduction Factor <math>R</math></i>
8d	1.00
6d	0.70
4d	0.40
3d	0.25

## 5.2 Lateral Earth Pressure

The lateral pressures acting on the bridge abutments will depend on the type and method of placement of the backfill materials, on the nature of the soils behind the backfill and on the subsequent lateral movement of the structure. The following recommendations are made concerning the design of the abutments and the retaining walls in accordance with OHBDC 6-7.

- Select free-draining granular fill meeting the specifications of OPSS Granular A or Granular B, Type II but with less than 5 percent passing the 200 sieve should be used as backfill behind the walls. All granular fill should be compacted in lifts of loose thickness not greater than 200 mm to 95 percent of the material's Standard Proctor maximum dry density.
- Longitudinal drains and weep holes should be installed to provide positive drainage of the granular backfill.

- The granular fill may be placed either in a zone with width equal to at least 2.0 m behind the back of the stem (Case I – OHBDC, Figure 6-7.4.1) or within the wedge-shaped zone defined by a 1.5 horizontal to 1 vertical line extending up and back from the bottom of the rear face of the footing as shown by OPSD-3501.000 (Case II).
- If the wall support allows lateral yielding of the stem (unrestrained structure), active earth pressures may be used in the geotechnical design of the structure. If the abutment support does not allow lateral yielding (restrained structure), at-rest pressures should be assumed for geotechnical design.
- A compaction surcharge equal to 16 kPa should be included in the lateral earth pressures for the structural design of the abutment wall in accordance with OHBDC Figure 6-7.4.3. Compaction equipment should be restricted as per OPSS 501.06.
- For Case I, the pressures will be based on the in-situ soil and proposed embankment fill. The following parameters (unfactored) may be assumed:

Soil unit weight	21 kN/m <sup>3</sup>
[assuming compacted clean earth fill such as Select Subgrade Material (OPSS 1010)]	

Coefficients of lateral earth pressure:	
‘active’	0.33
‘at rest’	0.50

- For Case II, the pressures are based on the granular fill as placed and the following parameters (unfactored) may be assumed:

	<b>Granular A</b>	<b>Granular B Type II</b>
Soil Unit Weight	22 kN/m <sup>3</sup>	21 kN/m <sup>3</sup>
Coefficient of Lateral Earth Pressure		
‘active’	0.27	0.31
‘at rest’	0.43	0.47

It should be noted that the above design parameters assume level backfill and ground surface behind the wall. Other aspects of the abutment granular backfill requirements with respect to sub-drains and frost taper should be in accordance with OPSD-3501.00.

### 5.3 Approach Embankments

Assuming a finished road surface elevation of about 203 m on the new structure, and based on existing ground surface contours, it appears that as much as approximately 3.5 m of fill is

required locally for the west approach embankment and less than 1 m of fill is generally required for the east approach. The 3.5 m of fill is required to fill an existing ditch that is located to the north of the existing highway on the west side of the creek. On average, the proposed embankment height is about 1.9 m at the west abutment.

A settlement analysis was carried out for the Laronde Creek Bridge approach embankments. The analysis was based on the available borehole, oedometer and in-situ vane shear strength data. The overconsolidation ratio (OCR) profile in the clayey silt and silty clay was established using the oedometer data and the following correlation relating in-situ vane shear strength to preconsolidation pressure.

$$s_u = 0.22\sigma'_p$$

where  $\sigma'_p$  = preconsolidation pressure (kPa)  
 $s_u$  = in-situ vane shear strength (kPa)

The following parameters were used in the analysis:

<i>Soil Unit</i>	<i>Compression Index Cc</i>	<i>Recompression Index Cr</i>	<i>Initial void ratio e<sub>0</sub></i>
Clayey Silt to Silty Clay	0.12	0.03	0.9
Varved Silty Clay	1.4	0.1	2.2

The sandy silt to silty sand deposit was interpreted (based on SPT values) to have a modulus of deformation of about 10 MPa. The settlement analysis was carried out using the commercially available program UNISETTLE (v2.4). The additional fill added to the west abutment varies up to 3.5 m in depth, but is generally less than about 2 m. The west approach and abutment fill loading was modelled as a rectangular wedge of fill (unit weight = 17 kN/m<sup>3</sup>) measuring 25 m by 40 m, and varying from 2 m of fill at the abutment location to 0 m at a distance of 40 m back from the abutment. The fill on the east abutment was measured using a similar wedge configuration, but with a maximum depth of 0.8 m.

Based on the results of the analysis, the following conclusions are made:

- For the west approach at the abutment, the maximum total settlement is estimated to be in the range of 45 mm to 70 mm. Of this amount, about 15 mm to 45 mm is expected to occur during construction (assuming a construction duration of about 3 months). Post-construction long-term consolidation settlement is estimated to be about 30 mm over 10 years or so.
- For the east approach, the maximum total settlement is estimated to be about 30 mm to 40 mm, most of which should occur during construction. The long-term consolidation settlement is estimated to be about 15 mm over 10 years or so.

The amount of settlement can be reduced if lighter backfill material is used. However, given the anticipated relatively small amount of post-construction settlement, the use of special lightweight fill probably is not warranted or cost-effective. Consideration should be given to using rockfill because it is lighter than compacted earth or granular fill. The unit weight of rockfill is typically about 17 kN/m<sup>3</sup> to 19 kN/m<sup>3</sup>, whereas a well compacted earth / granular fill's unit weight would typically be in the range of 20 kN/m<sup>3</sup> to 22 kN/m<sup>3</sup>.

The approach fills should be built as soon as possible in the early stages of construction so as to minimize the amount of long-term post-construction consolidation settlement.

#### **5.4 Subgrade Preparation and Embankment Construction**

Topsoil and organic deposits should be stripped from within the plan limits of the proposed embankments. As mentioned earlier, the use of rockfill is recommended for the approach embankment in order to minimize consolidation settlement of the thick clay deposit. Rockfill is recommended because its unit weight is less than compacted clean earth or granular fill. Beyond the approaches, earth fill (in accordance with OPSS 212) or Select Subgrade Material (in accordance with OPSS 1010), depending on material availability, can be used. Benching into existing slopes should be carried out as per OPSD 208.010. All embankment soil fill should be placed in regular lifts with loose thickness not exceeding 300 mm, and be compacted to at least 95 percent of the materials' Standard Proctor maximum dry density. The final lift prior to placement of the granular subbase or base course should be placed and compacted to current MTO requirements for pavements.

For earth fill embankments permanent slopes should be maintained not steeper than 2 horizontal to 1 vertical. Vegetation cover should be established on all soil slopes to protect embankment fill against surficial erosion. For rockfill the side slopes will correspond to its angle of repose, typically in the range of 1.25H – 1.5 H to 1V.

Inspection and field density testing should be carried out by qualified geotechnical personnel during all fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved.

### **5.5 Temporary Excavations and Groundwater Control**

Depending on the final selected foundation types, local excavation at the locations of abutment and piers will be required. Based on drawings provided to us by McCormick Rankin, the founding level is at about Elevation 198 m at the proposed west abutment and at about Elevation 199 m at the proposed east abutment. The abutment excavations will fully penetrate the upper silty sand to sandy silt layers and its base will be in the upper clayey silt to silty clay deposit that overlie the varved clay stratum. These soils are classified as Type 3 according to the Occupational Health and Safety Act of Ontario. All excavations should be carried out according to the latest edition of the Occupational Health and Safety Act.

Cuts made no steeper than 2 horizontal to 1 vertical should be stable during normal construction duration, although some localized surficial sloughing may be experienced in areas of higher groundwater seepage. Conventional excavation equipment would be suitable for excavating the soils. All surface water must be directed away from the excavation and not permitted to enter the excavation.

The base of the abutment excavations may be below the groundwater table, depending on the groundwater level at the time of construction. For the piers, it is likely that the excavation will be in the lower part of the clayey silt to silty clay stratum or within the upper part of the varved clay deposit. Further, the founding level may be below the water level in Laronde Creek. Some water inflow is expected in the excavations for the abutments and piers. However, it is anticipated that adequate groundwater control can be effected through the use of pumping from properly filtered sumps in the excavation.

For the piers, the quantity of groundwater inflow will be dependent upon the presence of more permeable sandier / siltier seams and layers within the otherwise impermeable clayey soil. If significant inflow is encountered as a result of the excavation intersecting continuous, more permeable layers / seams, the use of steel sheet piling or other appropriate measures to cutoff the seepage may be required.

Provided that the excavations do not exceed 7 m depth below the existing ground, base heave of the soft to firm clayey soils should not occur. After the final foundation layout and construction procedures are known, the potential for base heave should be checked to confirm an adequate factor of safety.

The artesian groundwater head measured in Thurber Borehole 98-1 originated close to the bedrock surface at depth. It is not expected to have any influence on shallow excavations.

## **5.6 Temporary Shoring**

The construction of the new bridge structure will result in excavations that encroach upon the existing highway. Temporary support (shoring) would be locally required to permit the existing highway to remain in service as the new structure is being built. Protection to any underground service in the vicinity of the excavation would also need to be provided.

At the proposed west abutment, the encountered subsoils consist of up to 1.5 m of loose silty sand to sandy silt overlying the soft to firm clayey deposits. Similar subsoil conditions exist at the proposed east abutment, except that the upper soils are not as sandy as on the west side of the creek. The groundwater level was at about 2 m below the ground surface in the vicinity of the two abutments.

Given the very extensive deposit of soft to firm clay, it is considered that the use of cantilever shoring will not be feasible at this site. Some form of support would be required near the top of the shoring system. The use of rakers to provide support is hindered by the soil conditions and tight space restrictions. Although the use of anchors may be possible, it is probable that long anchors would be required to develop the required load within the thick clay deposit. An allowable adhesion between the clay and grout bond length of 40 kPa could be used for design of

soil anchors. Anchors to bedrock would be very long. Further, the vertical component of the inclined anchor load would tend to pull the shoring system down into the clay.

For the conditions at this site it is considered that the use of a deadman anchor system in conjunction with steel sheet piling or a soldier pile and lagging system would provide adequate temporary support. The deadman anchorage system (possibly steel sheeting as well) could be constructed on the south side of the existing highway and connected to the temporary shoring by horizontal anchors installed at sufficient depth below the existing road surface.

The shoring system should be embedded sufficiently below the base of excavation into the clay deposit to provide toe resistance. For calculation of toe resistance generated in the clay, an undrained shear strength of 40 kPa may be used. For deep penetration into the clay, the design could be based on the undrained shear strength profile shown on Figure 3. This design profile takes advantage of increasing shear strength with depth.

The shoring system should be designed to resist a rectangular lateral earth pressure distribution as given by the following equation:

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

where  $p_h$  = lateral earth pressure (kPa)  
 $K$  = lateral earth pressure coefficient = 0.3  
 $\gamma$  = unit weight of soil (assume 19 kN/m<sup>3</sup>)  
 $H$  = retained height (m)  
 $q$  = nominal uniform surcharge loading (kPa)

The design of the shoring system should be carried out by a professional engineer experienced in the design of such works.

## 5.7 Permanent Cuts

The final grading plan for the site is not known at the time of this report preparation. Permanent cut slopes that are no higher than 6 m should be formed no steeper than 2 horizontal to 1 vertical.

Perched water may exist with the silty sand to sandy silt strata that overlie the primary clay deposit at the site. Appropriate drainage measures will be required to effectively control and



adequately discharge water seepage from the face of the slope, and to maintain the integrity of the slope. This may be accomplished by placement of a suitably graded granular drainage blanket on the slope, and in conjunction with drainage trenches that discharge to the highway drainage works, as required. All granular blanket material should meet the specifications for fine aggregates in accordance with OPSS 1002. Erosion protection may also be required and achieved through the use of cobbles and boulders or rockfill armour (rip-rap).

### **5.8 Construction Considerations**

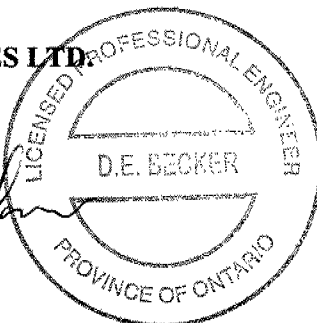
Depending on final founding elevations and grading, work will take place on the surface of the upper silty soils or the soft to firm clay. Some water inflow into excavations should be expected; however, pumping from well-filtered sumps should provide sufficient groundwater control during construction as discussed previously in the report.

The piles for the integral piers and abutments may need to be spaced very close together. If so, it will be important for the specifications to include stringent tolerances on pile driving to assure that the piles remain at specified spacing throughout their embedded length. Minimum pile spacing criteria set forth in OHBDC should be satisfied.

The soils at the site are sensitive to disturbance and softening due to water seepage and / or construction traffic. To preserve the integrity of the exposed subsoils, the use of a granular working platform or a mud coat (lean concrete mixture) is recommended. The mud coat should be used in foundation excavations and placed immediately after the founding level is reached, and inspected / approved by the geotechnical engineer.

**GOLDER ASSOCIATES LTD.**

Dennis E. Becker, P.Eng.  
Principal



Fintan J. Heffernan, P.Eng.  
Designated MTO Contact



BVB/DEB/FJH/clg

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## LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

### I SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
DO	Drive open
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

### II PENETRATION RESISTANCE

#### Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.).

#### Dynamic Penetration Resistance; $N_6$ :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

**PH:** Sampler advanced by hydraulic pressure

**PM:** Sampler advanced by manual pressure

**WH:** Sampler advanced by static weight of hammer

**WR:** Sampler advanced by weight of sampler and rod

#### Piezo-Cone Penetration Test (CPT):

An electronic cone penetrometer with a 60° conical tip and a projected end area of 10 cm<sup>2</sup> pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance ( $Q_t$ ), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

### III SOIL DESCRIPTION

#### (a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

#### (b) Cohesive Soils

Consistency	$c_u, s_u$ kPa	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

### IV. SOIL TESTS

w	water content
w <sub>p</sub>	plastic limit
w <sub>l</sub>	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test <sup>1</sup>
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement <sup>1</sup>
D <sub>R</sub>	relative density (specific gravity, G <sub>s</sub> )
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO <sub>4</sub>	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane test (LV-laboratory vane test)
γ	unit weight

Note:

1. Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

## LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

### I GENERAL

$\pi$	= 3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

### II STRESS AND STRAIN

$\gamma$	shear strain
$\Delta$	change in, e.g. in stress: $\Delta \sigma$
$\epsilon$	linear strain
$\epsilon_v$	volumetric strain
$\eta$	coefficient of viscosity
$\nu$	Poisson's ratio
$\sigma$	total stress
$\sigma'$	effective stress ( $\sigma' = \sigma - u$ )
$\sigma'_{vo}$	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses (major, intermediate, minor)
$\sigma_{oct}$	mean stress or octahedral stress $= (\sigma_1 + \sigma_2 + \sigma_3)/3$
$\tau$	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

### III SOIL PROPERTIES

#### (a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
$\gamma'$	unit weight of submerged soil ( $\gamma' = \gamma - \gamma_w$ )
$D_R$	relative density (specific gravity) of solid particles ( $D_R = \rho_s / \rho_w$ ) (formerly $G_s$ )
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is $\rho$ . Unit weight symbol is $\gamma$ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

#### (a) Index Properties (con't.)

w	water content
$w_l$	liquid limit
$w_p$	plastic limit
$I_p$	plasticity Index = $(w_l - w_p)$
$w_s$	shrinkage limit
$I_L$	liquidity index = $(w - w_p) / I_p$
$I_C$	consistency index = $(w_l - w) / I_p$
$e_{max}$	void ratio in loosest state
$e_{min}$	void ratio in densest state
$I_D$	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

#### (c) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

#### (d) Consolidation (one-dimensional)

$C_c$	compression index (normally consolidated range)
$C_r$	recompression index (overconsolidated range)
$C_s$	swelling index
$C_\alpha$	coefficient of secondary consolidation
$m_v$	coefficient of volume change
$c_v$	coefficient of consolidation
$T_v$	time factor (vertical direction)
U	degree of consolidation
$\sigma'_p$	pre-consolidation pressure
OCR	Overconsolidation ratio $= \sigma'_p / \sigma'_{vo}$

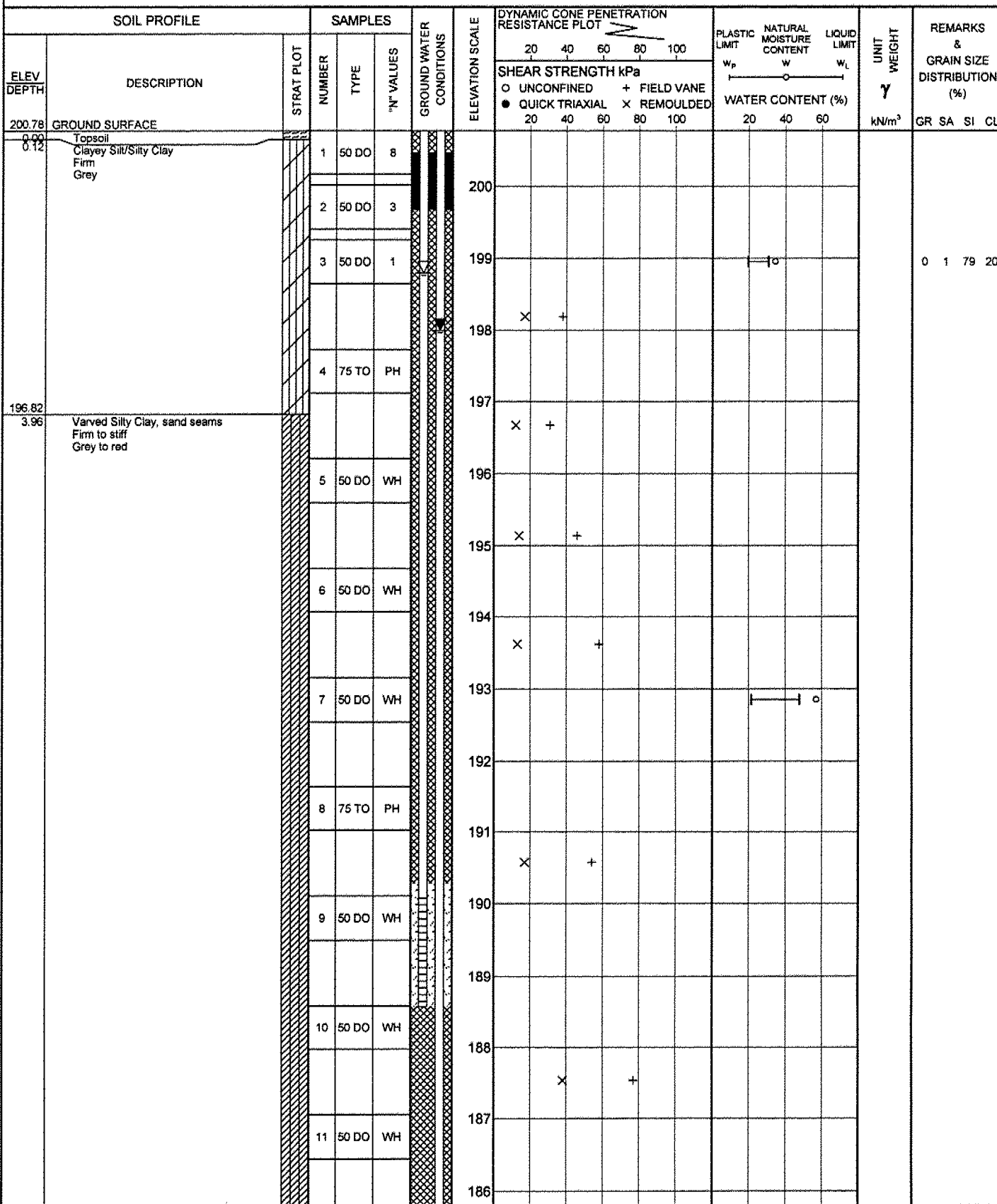
#### (e) Shear Strength

$\tau_p, \tau_r$	peak and residual shear strength
$\phi'$	effective angle of internal friction
$\delta$	angle of interface friction
$\mu$	coefficient of friction = $\tan \delta$
$c'$	effective cohesion
$c_u, s_u$	undrained shear strength ( $\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3)/2$
$p'$	mean effective stress $(\sigma'_1 + \sigma'_3)/2$
q	$(\sigma_1 - \sigma_3)/2$ or $(\sigma'_1 - \sigma'_3)/2$
$q_u$	compressive strength $(\sigma_1 - \sigma_3)$
$S_t$	sensitivity

Notes: 1.  $\tau = c' + \sigma' \tan \phi'$

2. Shear strength = (Compressive strength)/2

<b>PROJECT</b> 991-1164		<b>RECORD OF BOREHOLE No 99-43</b>		1 OF 2	<b>METRIC</b>
<b>W.P.</b> 812-76-01		<b>LOCATION</b> N 5136761.07; E 288620.59 (Laronde Creek, Site 43-65)		<b>ORIGINATED BY</b> DRS	
<b>DIST</b> 54 <b>HWY</b> 17		<b>BOREHOLE TYPE</b> Bombardier CME-55		<b>COMPILED BY</b> BVB	
<b>DATUM</b> Geodetic		<b>DATE</b> 10/2/1999		<b>CHECKED BY</b> DEB	



ON MOT 991-1164.GPJ ON MOT.GDT 27/6/00

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 991-1164			RECORD OF BOREHOLE No 99-43			2 OF 2			METRIC					
W.P. 812-76-01			LOCATION N 5136761.07; E 288620.59 (Laronde Creek, Site 43-65)			ORIGINATED BY DRS								
DIST 54 HWY 17			BOREHOLE TYPE Bombardier CME-55			COMPILED BY BVB								
DATUM Geodetic			DATE 10/2/1999			CHECKED BY DEB								
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT								
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED 20 40 60 80 100			PLASTIC LIMIT NATURAL MOISTURE CONTENT WATER CONTENT (%) 20 40 60	LIQUID LIMIT UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
--- CONTINUED FROM PREVIOUS PAGE ---														
181.12	Varved Silty Clay, sand seams Firm to stiff Grey to red		12	75 TO	PH		185							
			13	50 DO	WH		184							
			14	50 DO	WH		183	x						
19.66	Sand, some silt and gravel Compact Grey to red		15	50 DO	27		182							
179.50	Granitic Bedrock Weathered Strong to very strong becoming extremely strong with depth						181							
21.28							180							
174.93	For bedrock coring details refer to Record of Drillhole 99-43.						179							
25.85	END OF BOREHOLE						178							
	Note: Water levels in shallow and deep piezometers at Elev. 198.8m and Elev. 198.0m, respectively on Oct. 3/99.						177							
							176							
							175							

ON MOT 991-1164.GPJ ON MOT.GDT 27/6/00

PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-43

SHEET 1 OF 1

LOCATION: N 5136761.07; E 288620.59

DRILLING DATE: 10/3/1999

DATUM: Geodetic

INCLINATION: -90°

AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH % RETURN	COLOUR	FR-FRACTURE				F-FAULT				SM-SMOOTH				FL-FLEXURED				BC-BROKEN CORE				DIAMETER POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION	
									CL-CLEAVAGE				J-JOINT				R-ROUGH				UE-UNEVEN				MB-MECH. BREAK						
									SH-SHEAR				P-POLISHED				ST-STEPPED				W-WAVY				B-BEDDING						
									VN-VEIN				S-SLICKENSIDED				PL-PLANAR				C-CURVED										
				RECOVERY				R.Q.D. %				FRACT. INDEX PER 0.3				DISCONTINUITY DATA				HYDRAULIC CONDUCTIVITY k, cm/sec											
				TOTAL CORE %				SOLID CORE %								DIP w.r.t. CORE AXIS				TYPE AND SURFACE DESCRIPTION				10 <sup>-8</sup> 10 <sup>-7</sup> 10 <sup>-6</sup> 10 <sup>-5</sup>							
				0 20 40 60 80 100				0 20 40 60 80 100				0 20 40 60 80 100				0 20 40 60 80 100				0 20 40 60 80 100											
20		CONTINUED FROM PREVIOUS PAGE		180.78 20.00																											
21																															
22	NQ Core	Granitic Bedrock, weathered Strong to very strong		179.50 21.28	1		100																								
23				2		100																									
24																															
25				176.46 24.32	3		100																								
26		END OF BOREHOLE		174.93 25.85																											
27																															
28																															
29																															
30																															

DRILLHOLE 1164ROCK.GPJ GLDR CAN GDT 8/2/00

DEPTH SCALE

1 : 50



LOGGED: DRS

CHECKED: BVB

<b>PROJECT</b> 991-1164		<b>RECORD OF BOREHOLE No 99-44</b>		1 OF 2	<b>METRIC</b>
W.P. 812-76-01		LOCATION N 5136771.75; E 288563.47 (Laronde Creek, Site 43-65)		ORIGINATED BY DRS	
DIST 54 HWY 17		BOREHOLE TYPE Bombardier CME-55		COMPILED BY BVB	
DATUM Geodetic		DATE 9/29/1999		CHECKED BY DEB	

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						
197.04	GROUND SURFACE													
0.00	Asphalt													
0.13	Gravelly Sand, some silt, wood fragments and asphalt Loose Brown (Fill)		1	50 DO	4									
			2	50 DO	5									
195.59							196							
1.45	Varved Silty Clay, sand seams Firm to stiff Grey to red		3	50 DO	2									
							195							
								X	+					
			4	75 TO	PH		194							
			5	50 DO	WH									
							193							
			6	50 DO	WH									
							192							
								X	+					
			7	50 DO	WH		191							
							190	X	+					
			8	75 TO	PH		189							
							188							
			9	50 DO	WH									
							187							
								X	+					
			10	50 DO	WH		186							
							185							
			11	50 DO	WH									
							184							
								X	+					
			12	75 TO	PH		183							

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity ○ 3% STRAIN AT FAILURE

ON\_MOT 991-1164.GPJ ON\_MOT.GDT 276/00



PROJECT 991-1164			RECORD OF BOREHOLE No 99-44			2 OF 2			METRIC									
W.P. 812-76-01			LOCATION N 5136771.75: E 288563.47 (Laronde Creek, Site 43-65)			ORIGINATED BY DRS												
DIST 54 HWY 17			BOREHOLE TYPE Bombardier CME-55			COMPILED BY BVB												
DATUM Geodetic			DATE 9/29/1999			CHECKED BY DEB												
SOIL PROFILE			SAMPLES			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	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × REMOULDED					WATER CONTENT (%)			GR SA SI CL		
— CONTINUED FROM PREVIOUS PAGE —																		
180.12	Varved Silty Clay, sand seams Firm to stiff Grey to red		13	50 DO	WH		181											
17.07	Sand, some silt, some gravel, trace clay Loose Grey Granitic Bedrock Fresh Very to extremely strong		14	50 DO	4		180											
176.92	For bedrock coring details refer to Record of Drillhole 99-44.						179											
20.12	END OF BOREHOLE						178											
							177											

ON\_MOT\_991-1164.GPJ ON\_MOT.GDT 27/6/00

PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-44

SHEET 1 OF 1

LOCATION: N 5136771.75; E 288563.47

DRILLING DATE: 10/30/1999

DATUM: Geodetic

INCLINATION: -90°

AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH	COLOR % RETURN	FR-FRACTURE CL-CLEAVAGE SH-SHEAR VN-VEIN	F-FAULT J-JOINT P-POLISHED S-SLICKENSIDED	SM-SMOOTH R-ROUGH ST-STEPPED PL-PLANAR	FL-FLEXURED UE-UNEVEN W-WAVY C-CURVED	BC-BROKEN CORE MB-MECH. BREAK B-BEDDING	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION
		CONTINUED FROM PREVIOUS PAGE		182.04 15.00											
15															
16															
17		Granitic Bedrock, fresh Very to Extremely Strong		179.97 17.07											
18					1										
19															
20					2										
21		END OF BOREHOLE		176.92 20.12											
22															
23															
24															
25															

DRILLHOLE 1164ROCKGPJ GLDR CAN.GDT 8/2/00

DEPTH SCALE

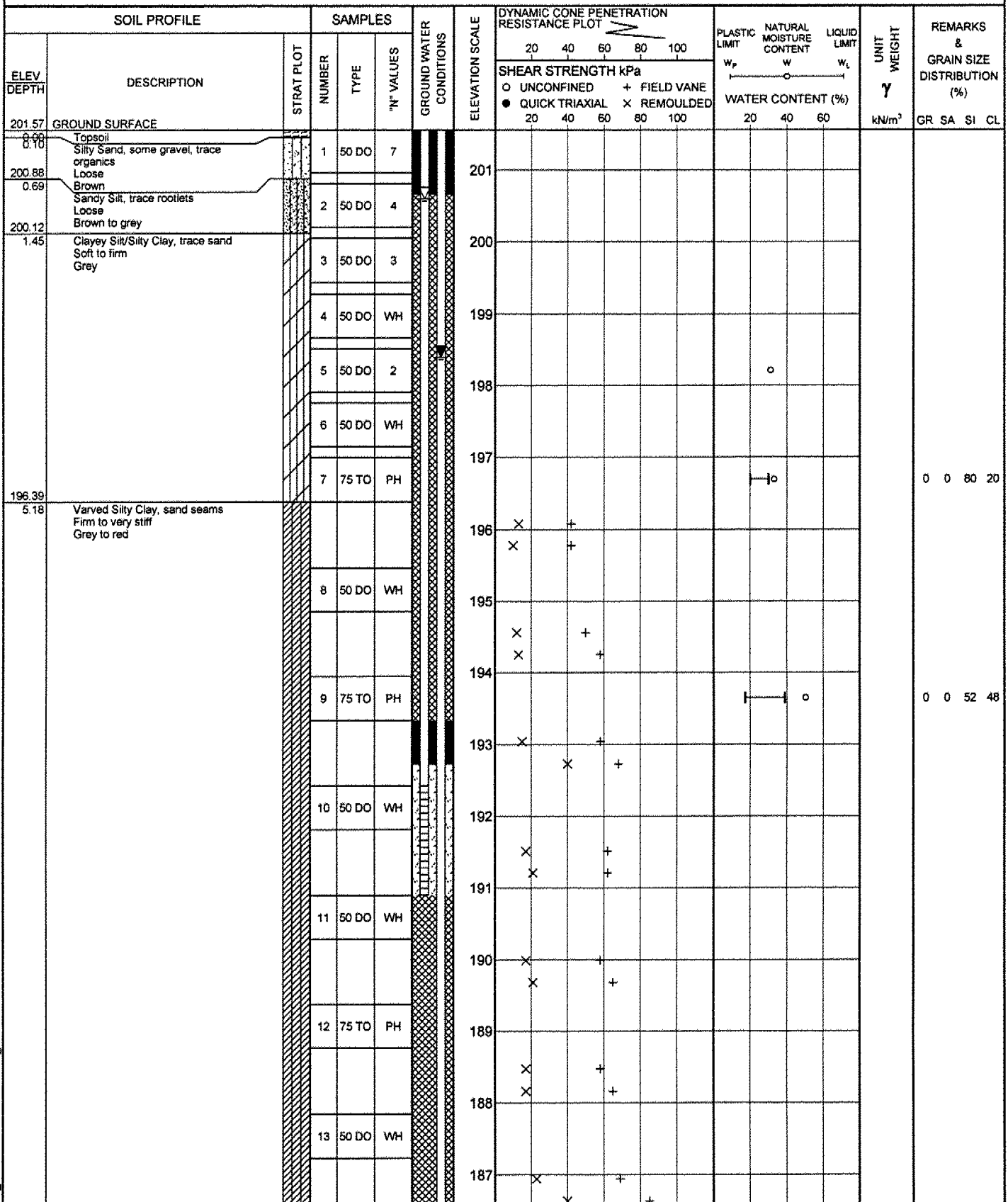
1 : 50



LOGGED: DRS

CHECKED: BVB

<b>PROJECT</b> 991-1164		<b>RECORD OF BOREHOLE No 99-45</b>		1 OF 2	<b>METRIC</b>
<b>W.P.</b> 812-76-01		<b>LOCATION</b> N 5136770.75; E 288532.60 (Laronde Creek, Site 43-65)		<b>ORIGINATED BY</b> DRS	
<b>DIST</b> 54 <b>HWY</b> 17		<b>BOREHOLE TYPE</b> Bombardier CME-55		<b>COMPILED BY</b> BVB	
<b>DATUM</b> Geodetic		<b>DATE</b> 9/27/1999		<b>CHECKED BY</b> DEB	



ON\_MOT 991-1164.GPJ ON\_MOT.GDT 27/6/00

Continued Next Page

+ 3, X 3: Numbers refer to Sensitivity      ○ 3% STRAIN AT FAILURE

PROJECT 991-1164				RECORD OF BOREHOLE No 99-45				2 OF 2		METRIC				
W.P. 812-76-01		LOCATION N 5136770.75; E 288532.60 (Laronde Creek, Site 43-65)				ORIGINATED BY DRS								
DIST 54 HWY 17		BOREHOLE TYPE Bombardier CME-55				COMPILED BY BVB								
DATUM Geodetic		DATE 9/27/1999				CHECKED BY DEB								
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 × REMOULDED						
--- CONTINUED FROM PREVIOUS PAGE ---														
	Varved Silty Clay, sand seams Firm to very stiff Grey to red		14	50 DO	WH		186							
							185	×						
			15	50 DO	WH									
							184							
			16	50 DO	WH									
							183							
							182							
181.30			17	50 DO	WH									
20.27	Clayey Silt, trace sand Grey						181							
180.84														
20.88	Silty Sand, some gravel, trace clay Grey Granitic Bedrock Fresh Very to extremely strong		18	50 DO	60/15									
							180							
							179							
							178							
177.55	For bedrock coring details refer to Record of Drillhole 99-45.													
24.02	END OF BOREHOLE  Note: Water levels in shallow and deep piezometers at Elev. 200.6m and Elev. 198.4m, respectively on Oct. 3/99.													

ON MOT 991-1164.GPJ ON MOT.GDT 27/6/00

PROJECT: 991-1164

## RECORD OF DRILLHOLE: 99-45

SHEET 1 OF 1

LOCATION: N 5136770.75; E 288532.60


DRILLING DATE: 9/28/1999

DATUM: Geodetic

INCLINATION: -90° AZIMUTH: —

DRILL RIG: Bombardier CME-55

DRILLING CONTRACTOR:

DEPTH SCALE METRES	DRILLING RECORD	DESCRIPTION	SYMBOLIC LOG	ELEV. DEPTH (m)	RUN No.	PENETRATION RATE (mm/min)	FLUSH	COLOUR % RETURN	FR-FRACTURE	F-FAULT	SM-SMOOTH	FL-FLEXURED	BC-BROKEN CORE	DIAMETRAL POINT LOAD INDEX (MPa)	NOTES WATER LEVELS INSTRUMENTATION	
									CL-CLEAVAGE	J-JOINT	R-ROUGH	UE-UNEVEN	MB-MECH. BREAK			
									SH-SHEAR	P-POLISHED	ST-STEPPED	W-WAVY	B-BEDDING			
									VN-VEIN	S-SUCKENSIDED	PL-PLANAR	C-CURVED				
RECOVERY		R.Q.D. %	FRACT. INDEX PER 0.3	DISCONTINUITY DATA		HYDRAULIC CONDUCTIVITY K, cm/sec										
TOTAL CORE %	SOLID CORE %			DIP w.r.t. CORE AXIS	TYPE AND SURFACE DESCRIPTION	1	2	3	4							
20		CONTINUED FROM PREVIOUS PAGE		181.57 20.00												
21	NQ Core	Granitic Bedrock, fresh Very to Extremely Strong		180.69 20.88	1		100									
22				2		100										
23				3		100										
24		END OF BOREHOLE		177.55 24.02												
25																
26																
27																
28																
29																
30																

DEPTH SCALE

1 : 50



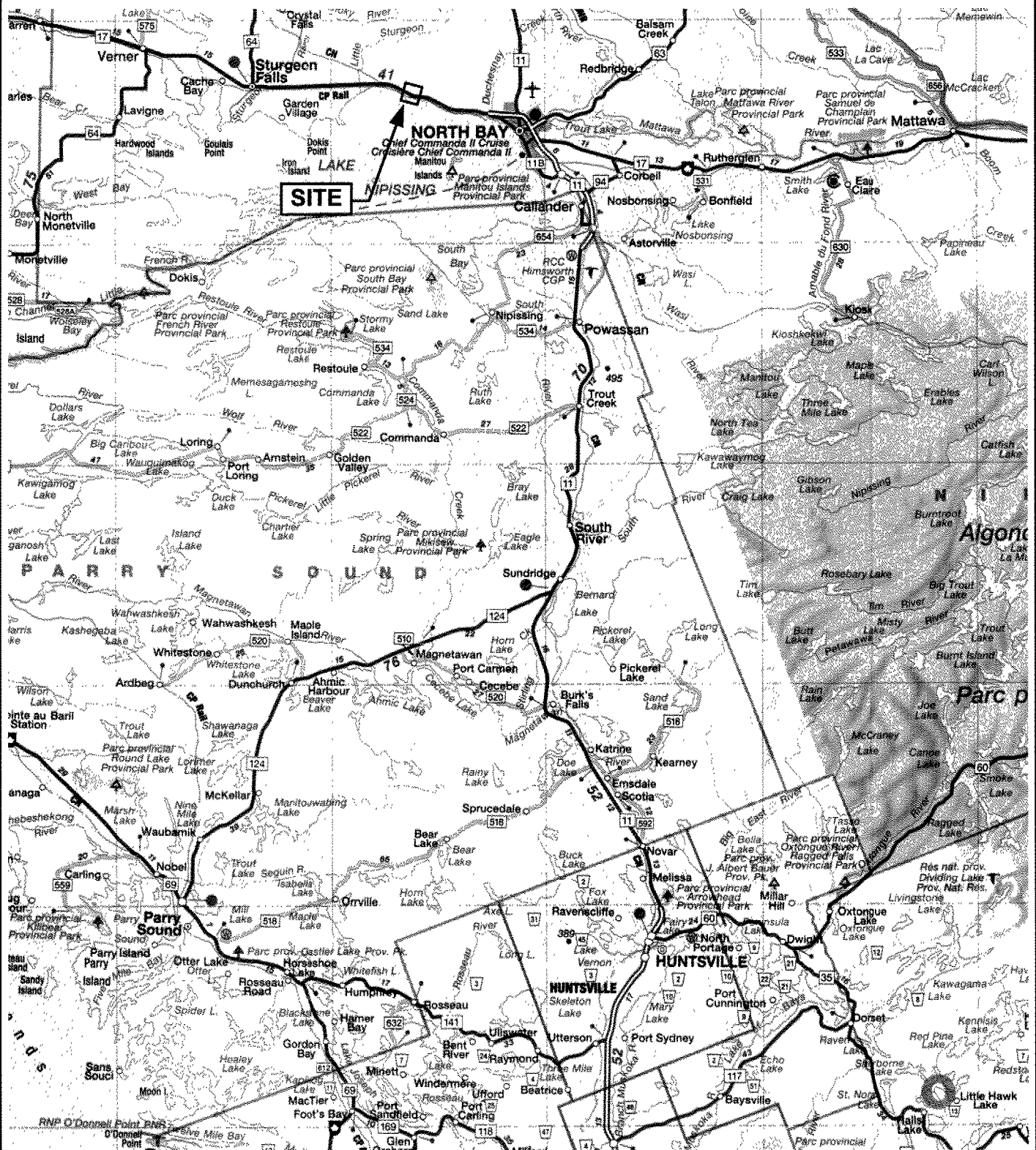
LOGGED: DRS

CHECKED: BVB

DRILLHOLE 1164ROCKGPJ GLDR CAN.GDT 8/2/00

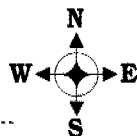
# SITE LOCATION MAP

FIGURE 1



## REFERENCE

THIS FIGURE WAS CREATED FROM A MAPART PUBLISHING MAP TITLE "ONTARIO" WITH THE SCALE OF 1:750 000, 1997 EDITION.



SCALE 1 : 750 000

Date FEBRUARY, 2000

Project 991-1164

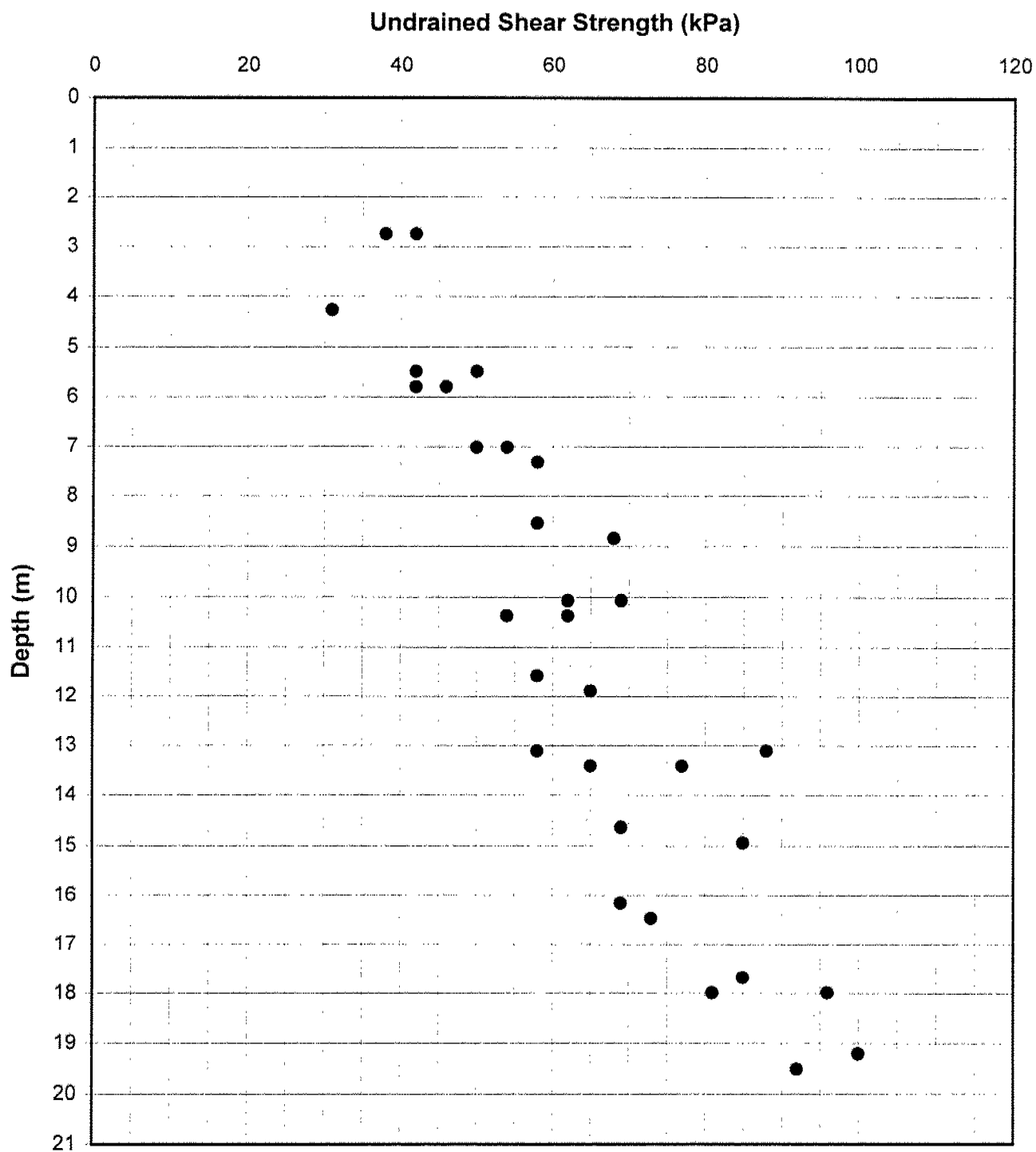
**Golder Associates**

Drawn R.J.

Chkd.

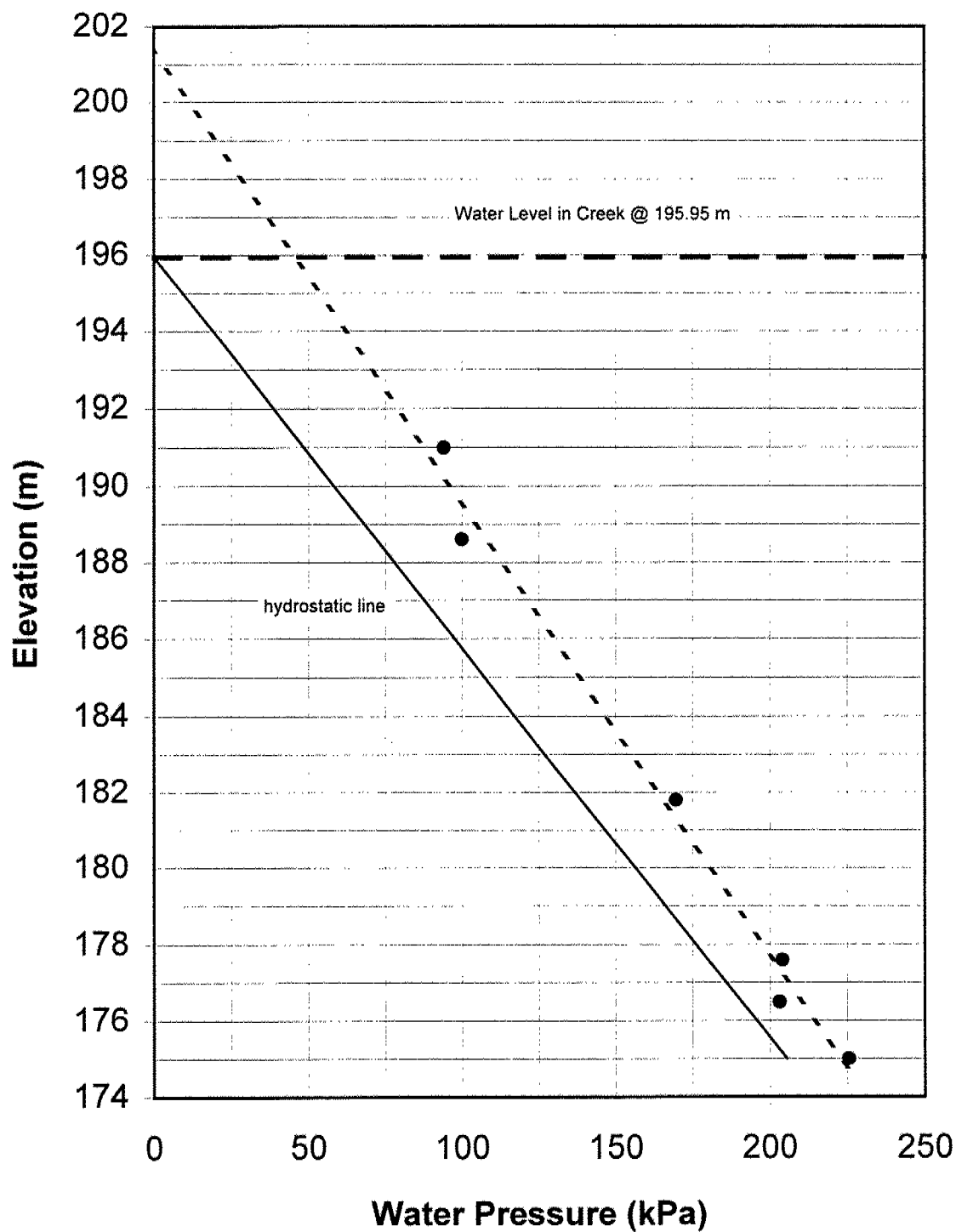
# OVERSIZE DRAWING

**FIGURE 3**  
**Vane Results vs. Depth**





**FIGURE 4**  
**Ground Water Pressure vs. Elevation**



June 2000

991-1164-1

## **APPENDIX A**

**RECORD OF BOREHOLE SHEETS FROM 1998 INVESTIGATION BY  
THURBER ENGINEERING LTD.**

## 1 OF 2

**METRIC**

ORIGINATED BY GA

COMPILED BY WM

CHECKED BY AEC

Continued Next Page

+ 3, x 3: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 98-1

2 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 763.6 E 288 575.3 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.15 - 98.10.15 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20	40	60	80	100					
			13	SS	1		181	+								82.850	
			14	SS	3		180									42.840	0 1 63 36
178.5							179										
18.3	BEDROCK undifferentiated granitic rock, very dense		15	SS	50/ .0		178										
	Core #1 REC = 100% RQD = 79%		1	CORE			177										
	Core #2 REC = 100% RQD = 92%		2	CORE			176										
174.2							175										
22.6	END OF BOREHOLE AT 22.6m. Piezometer installation consist of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.  WATER LEVEL READINGS: DATE DEPTH (m) 21/10/98 2.44(above surface) 22/10/98 2.44(above surface) 23/10/98 2.29(above surface) 24/10/98 2.29(above surface) 25/10/98 2.29(above surface) 26/10/98 2.29(above surface) 27/10/98 2.31(above surface)																

+ 3, x 3, 20  
Sensitivity 15 5  
10 (%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 98-2

1 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 763.4 E 288 612.7 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.20 - 98.10.20 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	PLASTIC LIMIT	NATURAL MOISTURE CONTENT	LIQUID LIMIT		
199.6 0.0	SILT, trace clay, very loose to loose, grey to brown, wet (ML)		1	SS	5		199						
			2	SS	3		198						0 0 93 7
			3	SS	2		197						
196.5			4	SS	2		196						
3.0	CLAY, silty, trace sand, low to medium plasticity, firm to stiff, grey, wet (CL-CI)		5	SS	2		195						0 2 54 44
			6	SS	2		194						
			7	SS	2		193						
			8	SS	2		192						
			9	SS	2		191						
	some varves evident		10	SS	1		190						0 0 40 60
	(possibly CL between 10 & 12m)		11	SS	1		189						
			12	SS	1		188						
	(possibly CL between 13 & 15m)						187						
							186						
							185						

Continued Next Page

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

# RECORD OF BOREHOLE No 98-2

2 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 763.4 E 288 612.7 ORIGINATED BY GA  
DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
DATUM Geodetic DATE 98.10.20 - 98.10.20 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			20	40	60	80	100		
							SHEAR STRENGTH kPa						
							○ UNCONFINED + FIELD VANE						
							● QUICK TRIAXIAL × LAB VANE						
							20	40	60	80	100		
							WATER CONTENT (%)						
							WP W WL						
							10	20	30				
181.0			13	SS	1	184							0 1 44 55
						183							
			14	SS	2	182							
						181							
18.6	SAND, trace silt, trace gravel, compact to dense, grey, wet		15	SS	2	180							
						179							
178.7			16	SS	30	178							6 84 8 2
						177							
20.9	BEDROCK undifferentiated granitic rock, very dense Core #1 REC = 100% RQD = 0%		1	CORE		176							
			2	CORE									
			3	CORE									
175.5	Core #2 REC = 100% RQD = 51%												
24.0	Core #3 REC = 100% RQD = 68%												
	END OF BOREHOLE AT 24.0m. BOREHOLE GROUTED TO SURFACE.												

+ 3, × 3: Numbers refer to  
Sensitivity

20  
15  
10

(%) STRAIN AT FAILURE

# RECORD OF BOREHOLE No 98-3

1 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 733.6 E 288 573.7 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.24 - 98.10.24 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE						
197.5							20 40 60 80 100	20 40 60 80 100	10 20 30					
0.0	SILT and SAND, some clay, very loose to loose, dark brown: (FILL)		1	SS	2								88.030	
			2	SS	7						○			0 36 53 11
			3	SS	3						○			
195.2														
2.3	CLAY, silty, trace sand, low to medium plasticity, firm to stiff, grey, wet: (CL-CI)		4	SS	1								88.890	0 0 46 54
			5	SS	1								81.250	
			6	SS	1			+					48.060	
			7	SS	1								82.420	0 1 38 61
								+						
			8	SS	1								82.430	
	some varves evident													
			9	SS	1								80.060	
			10	SS	0								82.540	
	(CL between 11 & 13m)													
			11	SS	1								87.70	0 0 64 36
			12	SS	0			+					80.580	

Continued Next Page

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



# RECORD OF BOREHOLE No 98-3

2 OF 2

METRIC

W.P. 812-76-01,398-91-00 LOCATION Laronde Creek, N 5 136 733.6 E 288 573.7 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.24 - 98.10.24 CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
181.3			13	SS	1		182							
16.2	CLAY, silty, medium plasticity, firm to stiff, grey, wet: (CI)		14	SS	2		181		+					
179.2							180							
18.3	SAND, some silt, some cobbles and boulders, very dense, grey, wet		15	SS	50/ .125		179							
176.5							178							
21.0	BEDROCK, undifferentiated granitic rock, very dense Core #1 REC = 100% RQD = 60%  Core #2 REC = 100% ROD = 75%  Core #3 REC = 100% RQD = 92%		1	CORE			176							
			2	CORE			175							
173.3			3	CORE			174							
24.2	END OF BOREHOLE AT 24.2m. BOREHOLE BACKFILLED AS FOLLOWS: 0-18m GROUT 18-21m BENTONITE & SAND 21-24.2m BENTONITE													

+ 3, x 3: Numbers refer to  
Sensitivity

20  
15 5  
10 (%) STRAIN AT FAILURE



## METRIC

ORIGINATED BY GA

COMPILED BY WM

CHECKED BY AEG

Continued Next Page

+ 3. x 3: Numbers refer to Sensitivity

# RECORD OF BOREHOLE No 98-4

2 OF 3

METRIC

W.P. 812-76-01.398-91-00

LOCATION Laronde Creek, N 5 136 743.1 E 288 611.5

ORIGINATED BY GA

DIST 54 HWY 17

BOREHOLE TYPE Hollow Stem Augers, N Core

COMPILED BY WM

DATUM Geodetic

DATE 98.10.22 - 98.10.22

CHECKED BY AEG

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w <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									
			13	SS	1		186							
			14	SS	2		185							
			15	SS	2		184							
			16	SS	1		183							
			17	SS	1		182							
	some varves evident		18	SS	27		181							
178.7			19	SS	50/ .050		180							
22.7	SAND, trace gravel, cobbles and boulders, compact to very dense, gray, wet						179							
							178							
							177							
							176							
174.5							175							
26.9	BEDROCK undifferentiated granitic rock Core #1 REC = 100% RQD = 61%		1	CORE			174							
	Core #2 REC = 100% RQD = 79%		2	CORE			173							
	Core #3 REC = 100% RQD = 61%		3	CORE			172							
171.5														

Continued Next Page

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

# RECORD OF BOREHOLE No 98-4

3 OF 3

METRIC

W.P. 812-76-01.398-91-00 LOCATION Laronde Creek, N 5 136 743.1 E 288 611.5 ORIGINATED BY GA  
 DIST 54 HWY 17 BOREHOLE TYPE Hollow Stem Augers, N Core COMPILED BY WM  
 DATUM Geodetic DATE 98.10.22 - 98.10.22 CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT $\gamma$ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT NUMBER	TYPE	"N" VALUES			20	40	60	80	100	W P	W	W L		
30.0	<p>END OF BOREHOLE AT 29.97m. Piezometer installation consist of 19mm diameter Schedule 40 PVC pipe with a 1.52m slotted screen.</p> <p>WATER LEVEL READINGS: DATE DEPTH (m)</p> <p>24/10/98 4.1 25/10/98 4.1 26/10/98 4.3 27/10/98 4.2</p>															

# RECORD OF BOREHOLE No 98-5

1 OF 1

METRIC

W.P. 812-76-01,398-91-00

LOCATION Laronde Creek, N 5 136 767.7 E 288 557.3

ORIGINATED BY GA

DIST 54 HWY 17

BOREHOLE TYPE Hollow Stem Augers, N Coring

COMPILED BY WM

DATUM Geodetic

DATE 98.10.19 - 98.10.19

CHECKED BY AEG

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			"N" VALUES	SHEAR STRENGTH kPa						WATER CONTENT (%)
						20	40	60	80	100				
0.0	SAND and SILT, loose to compact, brown, moist: (FILL)		1	SS	9							o		
			2	SS	4									
			3	SS	13								o	
1.9	CLAY, silty, low to medium plasticity, firm to stiff, grey, wet (CL)		4	SS	7									
			5	SS	4									
			6	SS	2									
5.2	END OF BOREHOLE AT 5.18m. BOREHOLE BACKFILLED WITH DRILL CUTTINGS.													

+ 3, x 3: Numbers refer to Sensitivity

(%) STRAIN AT FAILURE

**APPENDIX B**  
**LABORATORY TEST DATA**

TABLE B1

## SUMMARY OF WATER CONTENT, ATTERBERG LIMITS AND SPECIFIC GRAVITY DETERMINATIONS

PROJECT NUMBER		991-1164			
PROJECT NAME		McCormick Rankin / Highway 17 / North Bay			
DATE TESTED		October/November, 1999			
Borehole No.	Sample No.	Depth (m)	Water Content (%)	Atterberg Limits Wl,Wp,Ip	Specific Gravity
99-43	3	1.52-2.13	10.0		
99-43	5	3.05-3.66	30.2		
99-43	8	6.10-6.71	22.6		
99-44	6	4.57-5.18	55.4		
99-44	11	12.19-12.80	41.2	Wl=28.6, Wp=16.0, Ip=12.6	
99-45	5	3.05-3.51	31.1		
99-45	7	4.57-5.18	33.0	Wl=30.1, Wp=20.1, Ip=10.0	2.70
99-45	9	7.62-8.08	50.3	Wl=38.8, Wp=17.2, Ip=21.6	2.66
99-46	3	1.52-2.13	34.3	Wl=30.6, Wp=19.5, Ip=11.1	
99-46	7	7.62-8.23	56.9	Wl=47.7, Wp=21.4, Ip=26.3	
99-46	14	18.29-18.90	41.4		

Notes: Specific gravity test carried out using distilled water.

Wl = Liquid Limit

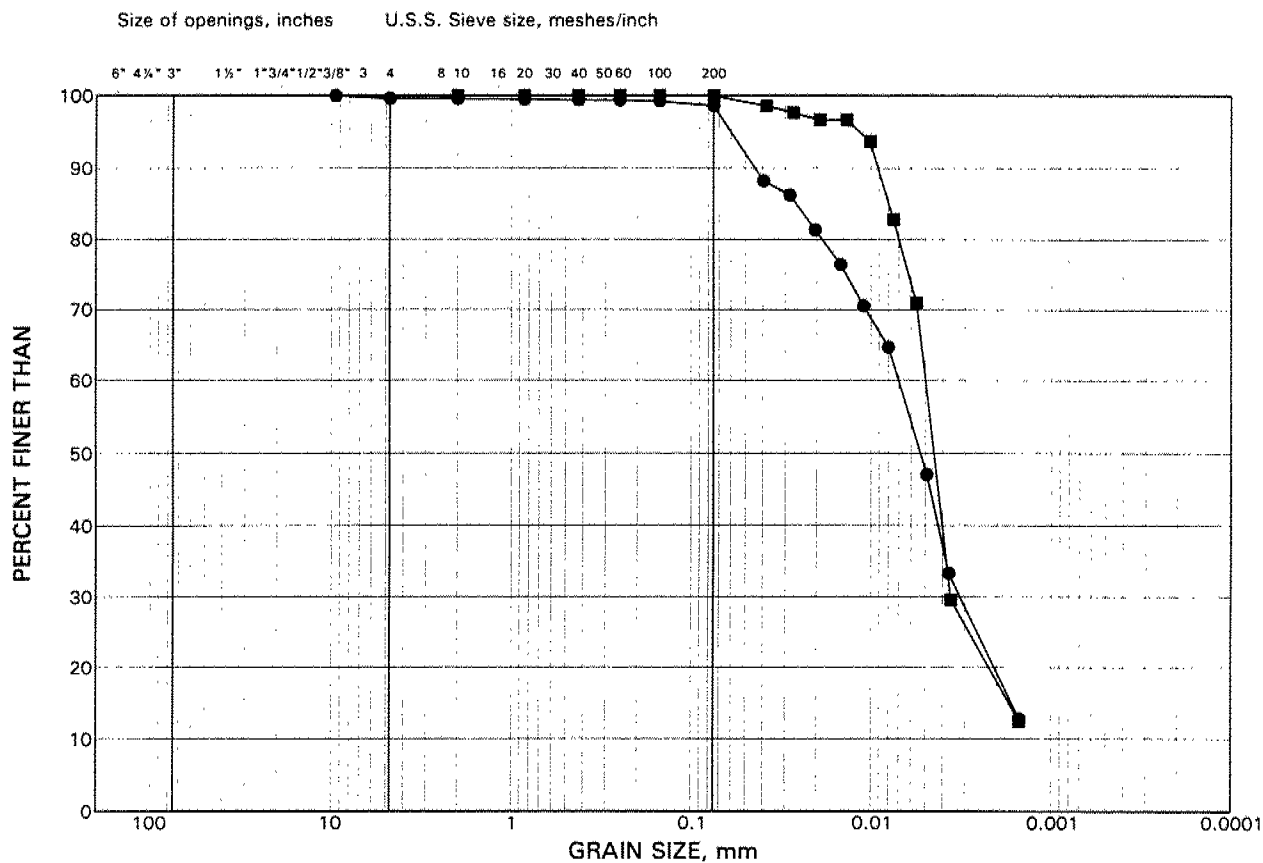
Wp = Plastic Limit

Ip = Plasticity Index

# GRAIN SIZE DISTRIBUTION

Clayey Silt / Silty Clay trace sand

FIGURE B1



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

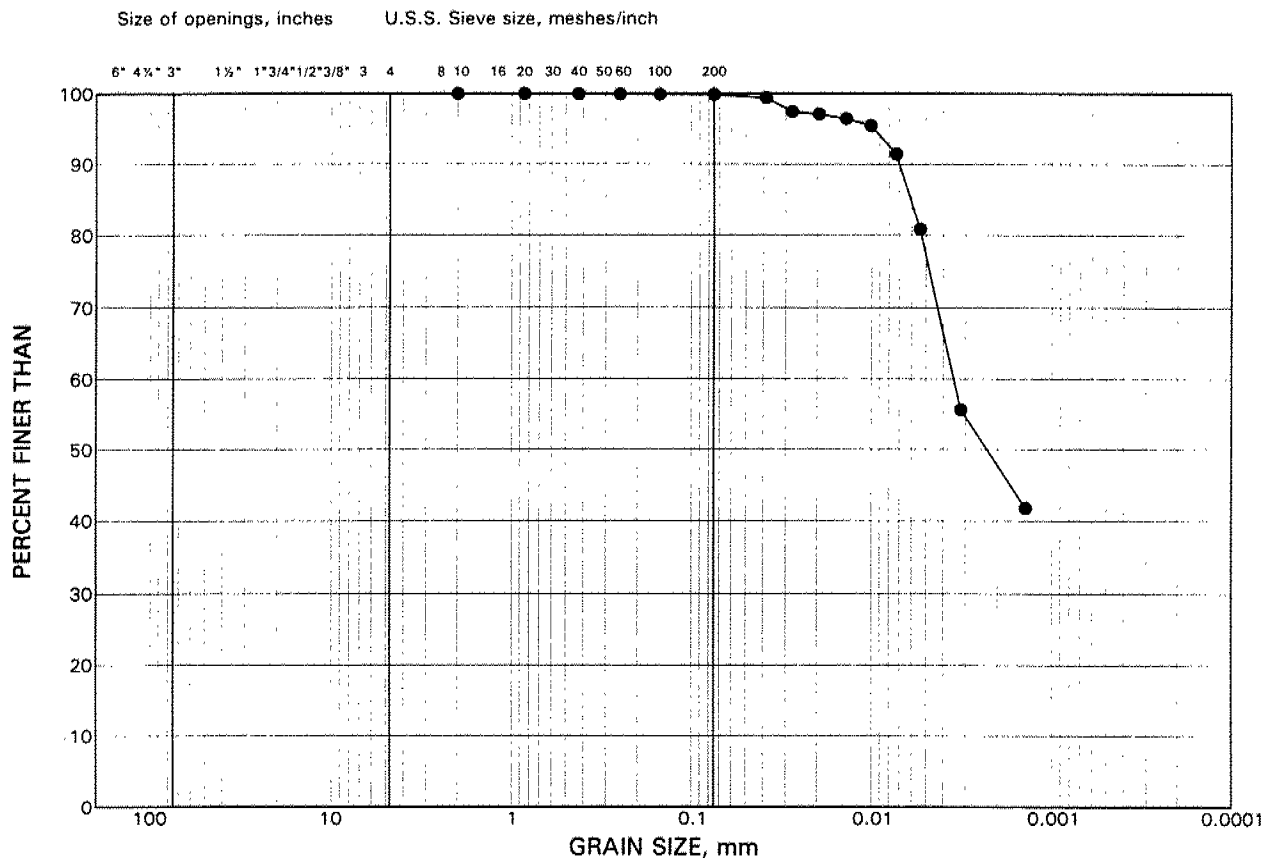
## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	99-43	3	2.1
■	99-45	7	-

# GRAIN SIZE DISTRIBUTION

Varved Silty Clay

FIGURE B2



COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

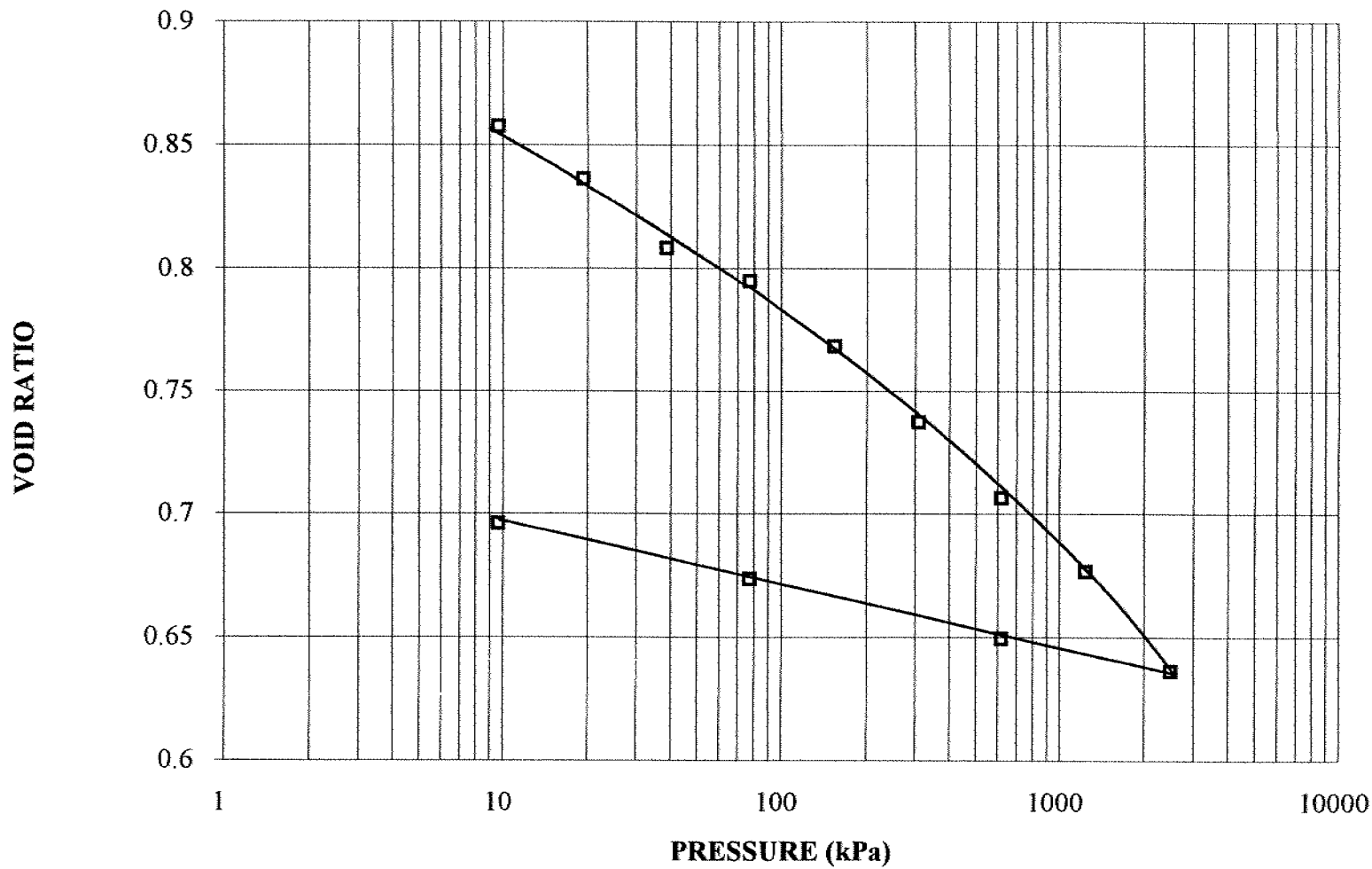
## LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
--------	----------	--------	----------

•	99-45	9	-
---	-------	---	---



CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-45 SA 7



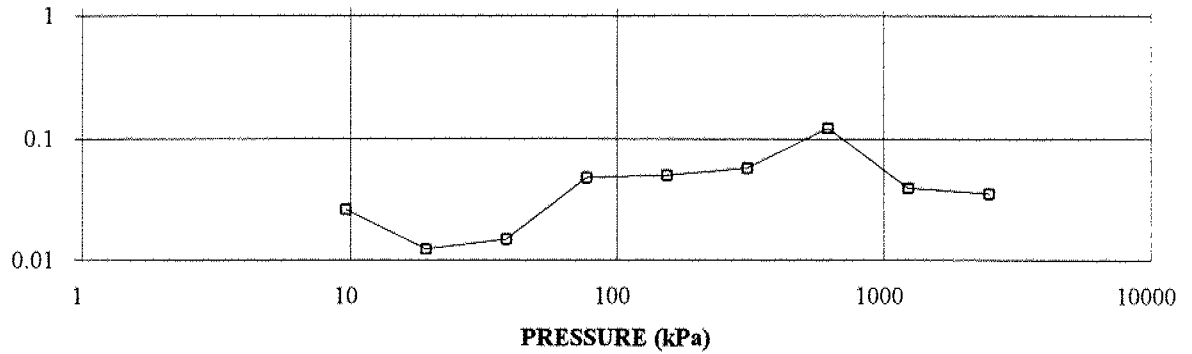
CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE B3

# OEDOMETER CONSOLIDATION SUMMARY

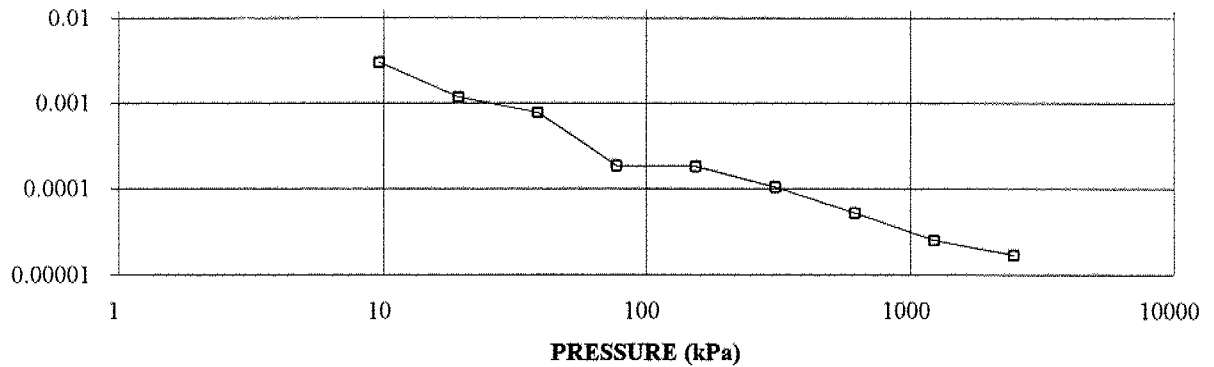
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $c_v$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 7



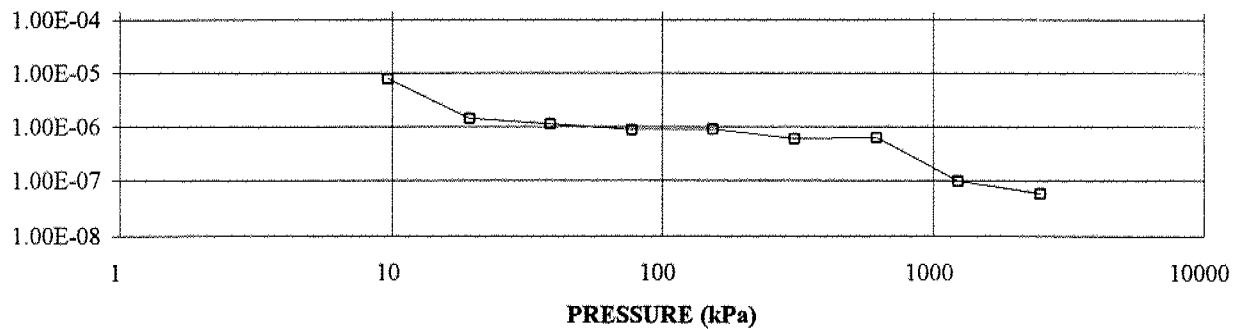
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $m_v$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 7



HYDRAULIC  
CONDUCTIVITY,  $\text{cm/s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-45 SA 7



# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-1164	Sample Number	7
Borehole Number	99-45	Sample Depth, m	4.6-5.2

## TEST CONDITIONS

Test Type	Quick /Standard	Load Duration, hr	(0.10 - 22)
Oedometer Number	7		
Date Started	99-10-08		
Date Completed	99-10-09		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.88	Unit Weight, kN/m <sup>3</sup>	18.64
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	13.84
Area, cm <sup>2</sup>	31.67	Specific Gravity, measured	2.70
Volume, cm <sup>3</sup>	59.63	Solids Height, cm	0.984
Water Content, %	34.72	Volume of Solids, cm <sup>3</sup>	31.17
Wet Mass, g	113.37	Volume of Voids, cm <sup>3</sup>	28.47
Dry Mass, g	84.15	Degree of Saturation, %	102.6

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv. cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.883	0.913	1.883				
9.66	1.828	0.858	1.856	28	2.61E-02	3.02E-03	7.71E-06
19.31	1.807	0.836	1.818	57	1.23E-02	1.15E-03	1.39E-06
38.63	1.779	0.808	1.793	46	1.48E-02	7.62E-04	1.11E-06
77.25	1.766	0.795	1.773	14	4.76E-02	1.83E-04	8.53E-07
154.50	1.740	0.768	1.753	13	5.01E-02	1.79E-04	8.81E-07
309.00	1.710	0.737	1.725	11	5.73E-02	1.04E-04	5.85E-07
618.00	1.679	0.706	1.694	5	1.22E-01	5.24E-05	6.25E-07
1236.00	1.650	0.676	1.664	15	3.92E-02	2.54E-05	9.73E-08
2471.99	1.610	0.636	1.630	16	3.52E-02	1.70E-05	5.87E-08
618.00	1.623	0.649	1.617				
77.25	1.647	0.673	1.635				
9.66	1.669	0.696	1.658				

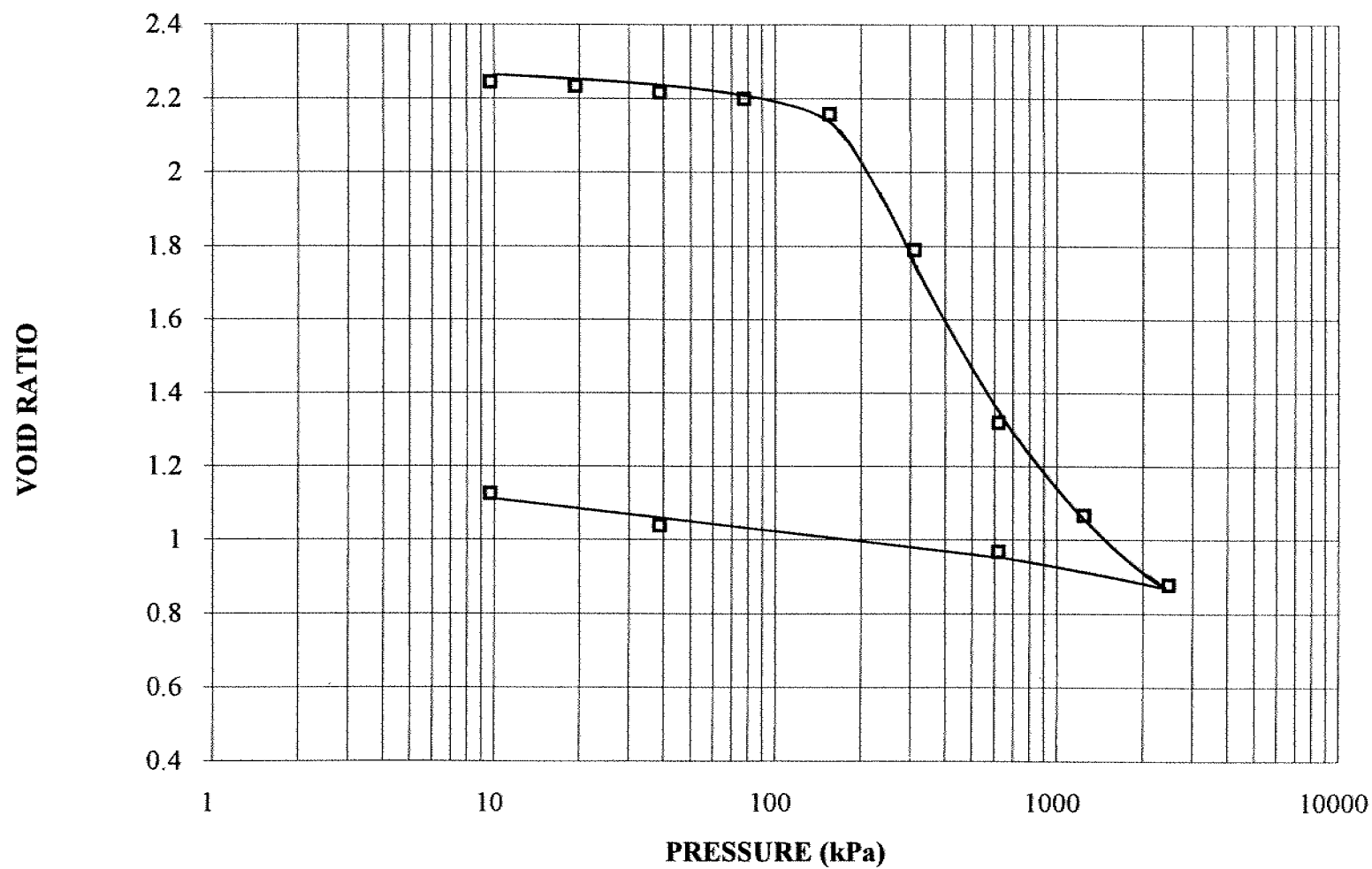
Notes:

k calculated using cv based on t<sub>90</sub> values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.67	Unit Weight, kN/m <sup>3</sup>	19.84
Sample Diameter, cm	6.35	Dry Unit Weight, kN/m <sup>3</sup>	15.61
Area, cm <sup>2</sup>	31.67	Specific Gravity, measured	2.70
Volume, cm <sup>3</sup>	52.86	Solids Height, cm	0.984
Water Content, %	27.11	Volume of Solids, cm <sup>3</sup>	31.17
Wet Mass, g	106.96	Volume of Voids, cm <sup>3</sup>	21.69
Dry Mass, g	84.15		

CONSOLIDATION TEST  
VOID RATIO vs LOG. PRESSURE  
BH 99-45 SA 9



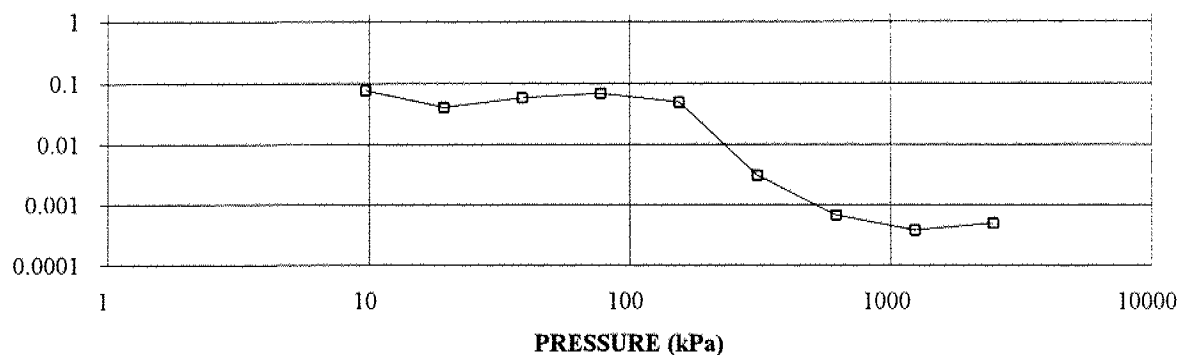
CONSOLIDATION TEST  
VOID RATIO VS. LOG PRESSURE

FIGURE B4

# OEDOMETER CONSOLIDATION SUMMARY

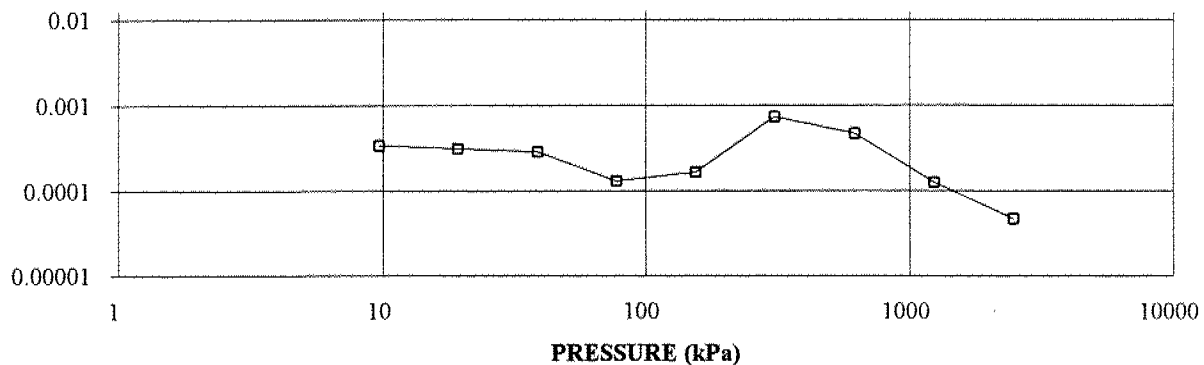
COEFFICIENT OF CONSOLIDATION,  $\text{cm}^2/\text{s}$

CONSOLIDATION TEST  
LOG.  $c_v$   $\text{cm}^2/\text{s}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 9



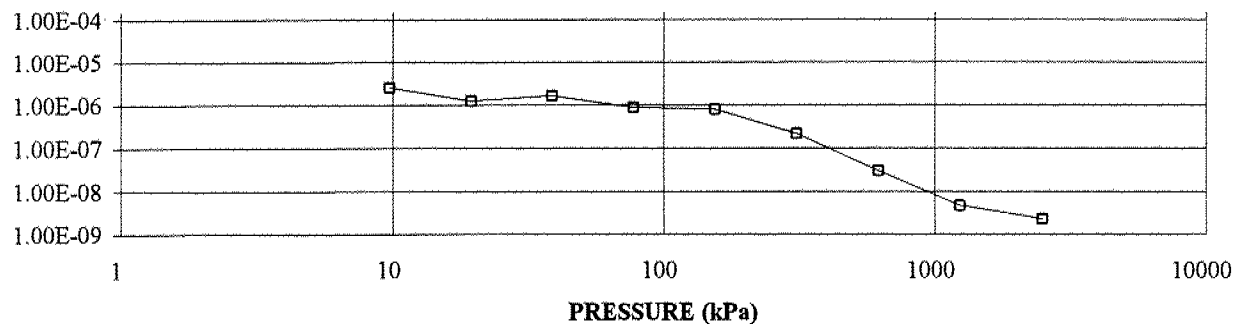
VOLUME  
COMPRESSIBILITY,  
 $\text{m}^2/\text{kN}$

CONSOLIDATION TEST  
LOG.  $m_v$ ,  $\text{m}^2/\text{kN}$  vs LOG. PRESSURE (kPa)  
BH 99-45 SA 9



HYDRAULIC  
CONDUCTIVITY,  $\text{cm}/\text{s}$

CONSOLIDATION TEST  
HYDRAULIC CONDUCTIVITY vs LOG. PRESSURE  
BH 99-45 SA 9



# OEDOMETER CONSOLIDATION SUMMARY

## SAMPLE IDENTIFICATION

Project Number	991-1164	Sample Number	9
Borehole Number	99-45	Sample Depth, m	7.9

## TEST CONDITIONS

Test Type	Quick /Standard	Load Duration, hr	(0.13 - 22)
Oedometer Number	6		
Date Started	99-10-07		
Date Completed	99-10-08		

## SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.90	Unit Weight, kN/m <sup>3</sup>	14.88
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	8.02
Area, cm <sup>2</sup>	31.52	Specific Gravity, measured	2.66
Volume, cm <sup>3</sup>	59.92	Solids Height, cm	0.584
Water Content, %	85.63	Volume of Solids, cm <sup>3</sup>	18.41
Wet Mass, g	90.92	Volume of Voids, cm <sup>3</sup>	41.51
Dry Mass, g	48.98	Degree of Saturation, %	101.0

## TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t <sub>90</sub> sec	cv, cm <sup>2</sup> /s	mv m <sup>2</sup> /kN	k cm/s
0.00	1.901	2.254	1.901				
9.70	1.895	2.243	1.898	10	7.64E-02	3.42E-04	2.56E-06
19.40	1.889	2.233	1.892	19	3.99E-02	3.14E-04	1.23E-06
38.81	1.878	2.215	1.884	13	5.79E-02	2.90E-04	1.64E-06
77.62	1.869	2.199	1.873	11	6.76E-02	1.30E-04	8.63E-07
155.23	1.844	2.157	1.856	15	4.87E-02	1.67E-04	7.96E-07
310.46	1.629	1.788	1.736	211	3.03E-03	7.29E-04	2.17E-07
620.93	1.354	1.318	1.492	708	6.66E-04	4.65E-04	3.04E-08
1241.86	1.207	1.066	1.281	916	3.80E-04	1.25E-04	4.65E-09
2475.89	1.096	0.876	1.152	576	4.88E-04	4.72E-05	2.26E-09
620.93	1.149	0.966	1.122				
38.81	1.191	1.038	1.170				
9.70	1.241	1.124	1.216				

Notes:

k calculated using cv based on t<sub>90</sub> values.

## SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.24	Unit Weight, kN/m <sup>3</sup>	17.92
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m <sup>3</sup>	12.28
Area, cm <sup>2</sup>	31.52	Specific Gravity, measured	2.66
Volume, cm <sup>3</sup>	39.11	Solids Height, cm	0.584
Water Content, %	45.92	Volume of Solids, cm <sup>3</sup>	18.41
Wet Mass, g	71.47	Volume of Voids, cm <sup>3</sup>	20.70
Dry Mass, g	48.98		



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

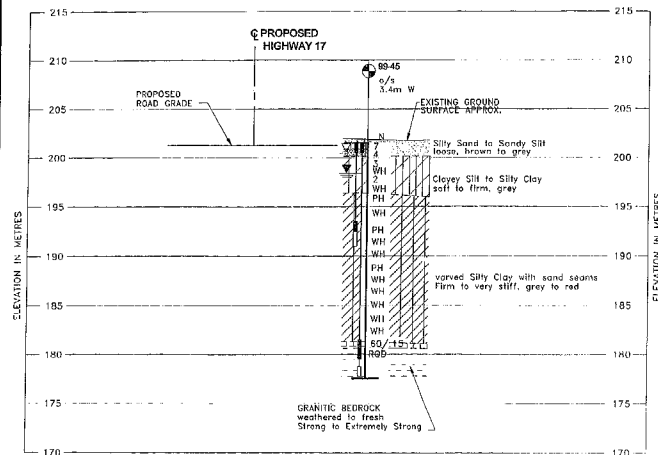
CONT. No.  
WP No. 812-76-02

LARONDE CREEK BRIDGE  
CROSS-SECTIONS  
BOREHOLE LOCATIONS & SOIL STRATA



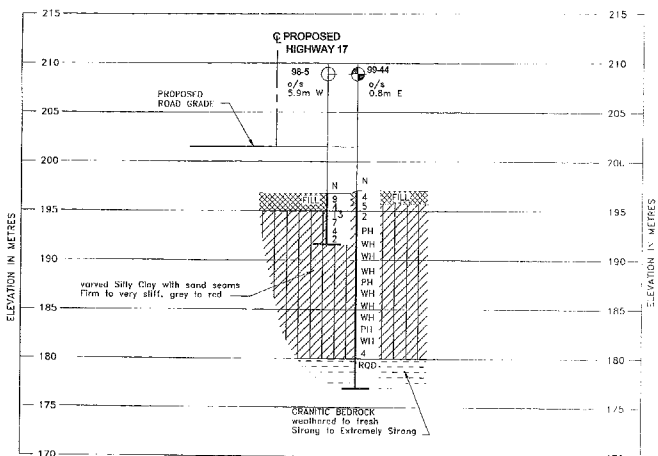
Golden Associates Ltd.  
MISSISSAUGA, ONTARIO, CANADA

SHEET



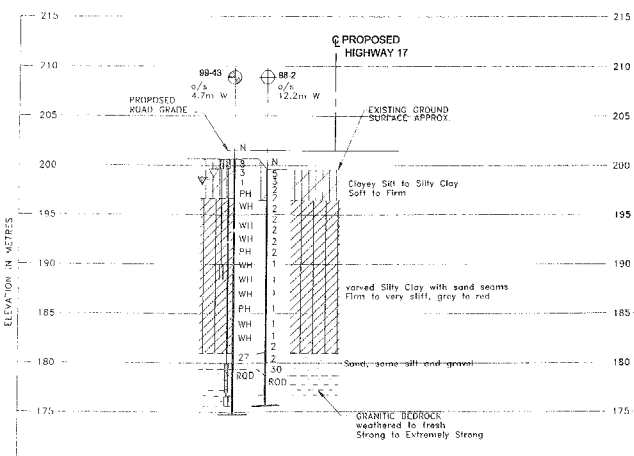
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WEST INTEGRAL ABUT.

SCALE  
0 5 10 15 20 25 30 METRES



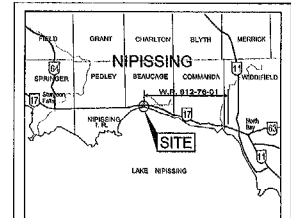
SECTION B-B  
WEST PIER

SCALE  
0 5 10 15 20 25 30 METRES



SECTION C-C  
EAST INTEGRAL ABUT.

SCALE  
0 5 10 15 20 25 30 METRES



KEY PLAN

#### LEGEND

- 88-43 Borehole by Golden Associates (current investigation)
- 88-1 Borehole by Thurber Engineering Ltd. (Report Dated March 1999)
- Seal
- Plazometer
- N Standard Penetration Test value
- 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 lb/blow)
- 100% Rock Quality Designation (RQD)
- WL in deep piezometer on Oct. 3, 1999
- WL in shallow piezometer on Oct. 3, 1999

No.	ELEVATION	LOCATION	NORTHING	EASTING
88-43	700.78		5136761	288262.6
88-44	187.04		5136772	288562.5
88-45	201.57		5136771	288552.6
88-1	186.80		5136764	288675.3
88-2	199.60		5136763	288612.7
88-3	197.50		5136734	288551.7
88-4	201.40		5136734	288551.7
88-5	N/A		5136768	288551.3
88-6	N/A		5136733	288556.5

#### REFERENCE

This drawing was created from digital files provided by McCormick Rankin Corp.

#### NOTES

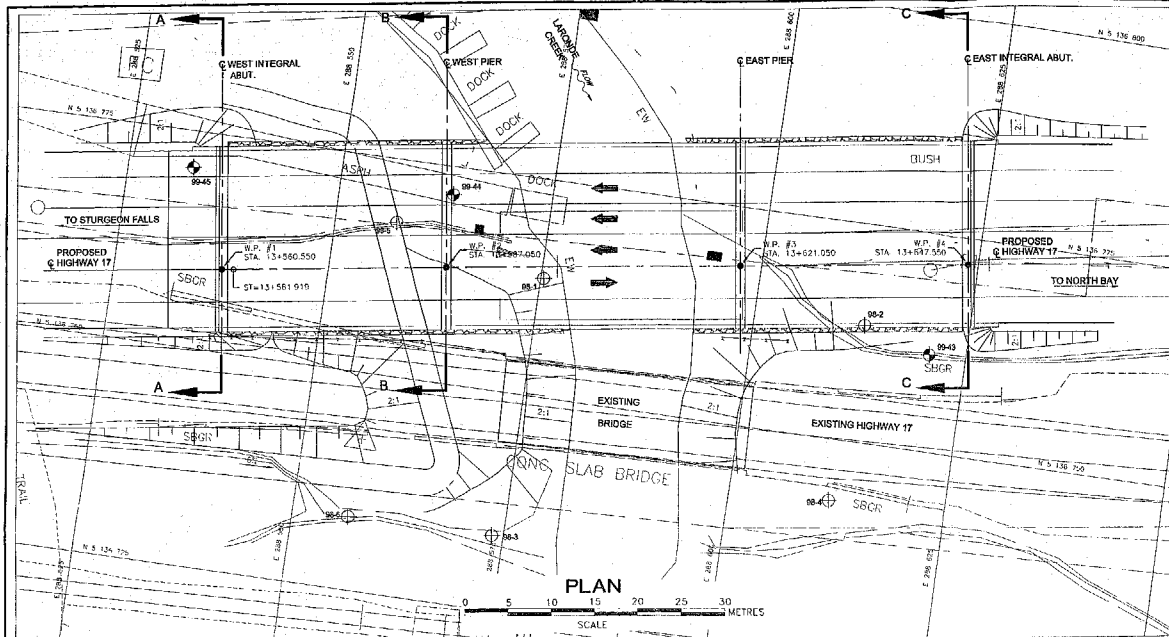
- The boundaries between soil strata have been established with all Borehole locations. Between strata the boundaries are assumed from geological evidence.
- For detailed Stratigraphy at Borehole locations refer to Record of Borehole Logs.

NO.	DATE	BY	REVISION
1			

Geocres No. 311 - 70

HWY. No. 17	PROJECT NO. 931-1164	INS. 54
SUB'D. RVS	CHKD. UBR	DATE: 2000 OR 27
DRAWN: JTC	CHKD. BVR	APPRO. SHE. 43 - 65
		FIGURE 2B





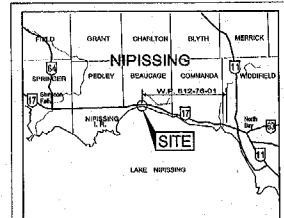
**METRIC**  
DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

CONT. No.  
WP No. 812-76-02

LARONDE CREEK BRIDGE  
BOREHOLE LOCATIONS & SOIL STRATA



Golder Associates Ltd.  
MISSISSAUGA, ONTARIO, CANADA



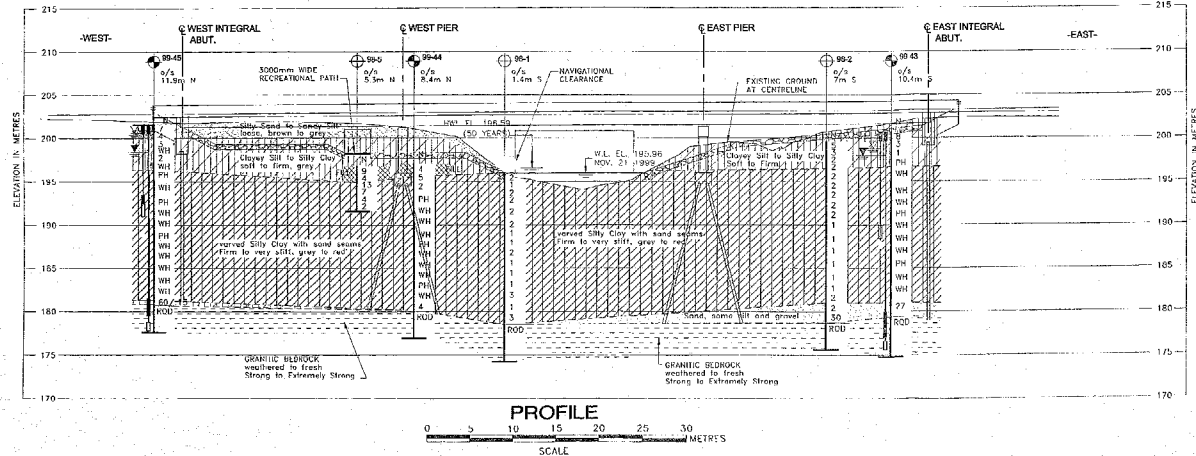
- LEGEND**
- 99-43 Borehole by Golder Associates (current investigation)
  - 99-51 Borehole by Thurber Engineering Ltd. (Report Dated March 1988)
  - Seal
  - Piezometer
  - N Standard Penetration Test value
  - 16 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 l/blow)
  - 100% Rock Quality Designation (RQD)
  - WL in deep piezometer on Oct. 3, 1989
  - WL in shallow piezometer on Oct. 3, 1989

No.	ELEVATION	NORTHING	EASTING
99-43	200.78	5156761	288620.6
99-44	187.04	5136772	288563.5
99-45	201.57	5136771	288532.6
98-1	196.80	5136764	288575.3
98-2	199.80	5136763	288612.7
98-3	197.50	5136754	288575.7
98-4	201.40	5136754	288611.5
98-5	N/A	5136768	288557.3
98-6	N/A	5136733	288556.5

**REFERENCE**  
This drawing was created from digital files provided by McCarrick Barker Corp.

**NOTES**

1. the boundaries between soil strata have been established only at Borehole locations. Between Boreholes the boundaries are assumed from geological evidence.
2. For detailed Stratigraphy of Borehole locations refer to Record of Borehole Sheets.



NO.	DATE	BY	REVISION
1	1991-11-04	RY	1
2	1991-11-04	RY	2
3	1991-11-04	RY	3
4	1991-11-04	RY	4
5	1991-11-04	RY	5
6	1991-11-04	RY	6
7	1991-11-04	RY	7
8	1991-11-04	RY	8
9	1991-11-04	RY	9
10	1991-11-04	RY	10
11	1991-11-04	RY	11
12	1991-11-04	RY	12
13	1991-11-04	RY	13
14	1991-11-04	RY	14
15	1991-11-04	RY	15
16	1991-11-04	RY	16
17	1991-11-04	RY	17
18	1991-11-04	RY	18
19	1991-11-04	RY	19
20	1991-11-04	RY	20
21	1991-11-04	RY	21
22	1991-11-04	RY	22
23	1991-11-04	RY	23
24	1991-11-04	RY	24
25	1991-11-04	RY	25
26	1991-11-04	RY	26
27	1991-11-04	RY	27
28	1991-11-04	RY	28
29	1991-11-04	RY	29
30	1991-11-04	RY	30

**METRIC**

DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES  
UNLESS OTHERWISE SHOWN

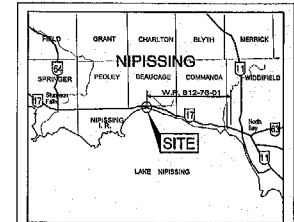
CONT. No.  
WP No. 812-76-02

LARONDE CREEK BRIDGE  
CROSS-SECTIONS  
BOREHOLE LOCATIONS & SOIL STRATA

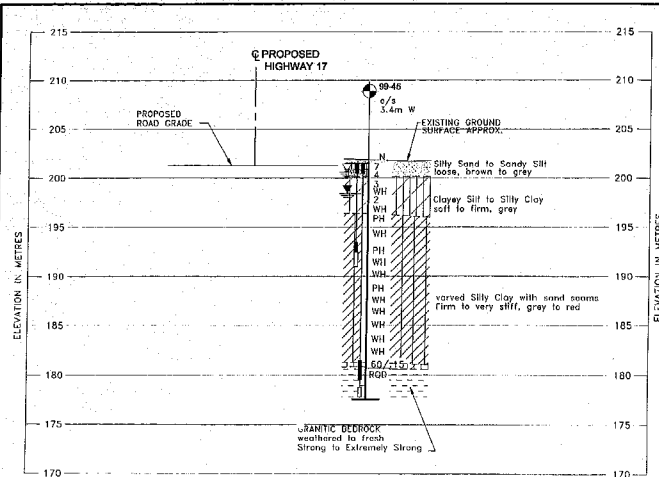
SHEET



Golden Associates Ltd.  
MISSISSAUGA, ONTARIO, CANADA

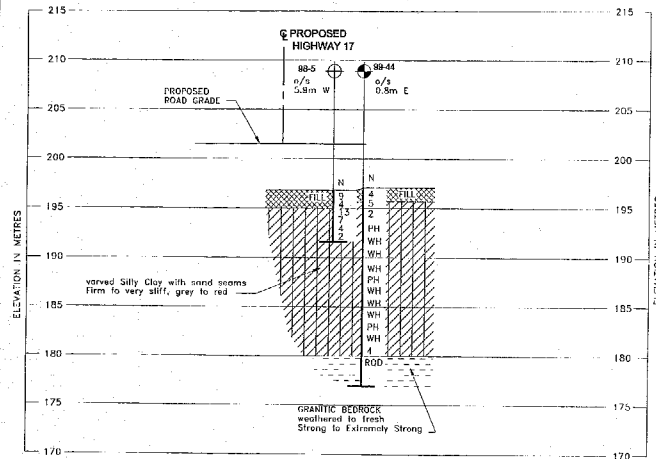


KEY PLAN



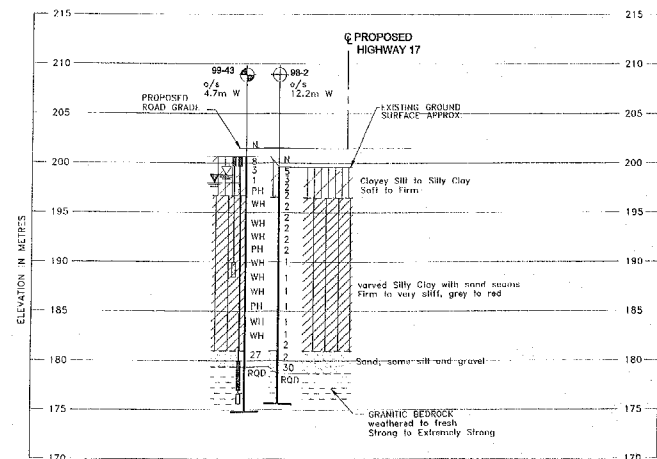
SECTION A-A  
WEST INTEGRAL ABUT.

SCALE  
0 5 10 15 20 25 30 METRES



SECTION B-B  
WEST PIER

SCALE  
0 5 10 15 20 25 30 METRES



SECTION C-C  
EAST INTEGRAL ABUT.

SCALE  
0 5 10 15 20 25 30 METRES

LEGEND

- 99-43 Borehole by Golden Associates (current investigation)
- 88-1 Borehole by Thwyler Engineering Ltd. (Report Dated March 1999)
- Seal
- Piezometer
- N Standard Penetration Test value
- 15 Blows/0.3m unless otherwise stated (Std. Pen. Test, 475 1/3blows)
- 100% Rock Quality Designation (ROD)
- WL in deep piezometer on Oct. 3, 1999
- WL in shallow piezometer on Oct. 3, 1999

LOCATION			
No.	ELEVATION	NORTHING	EASTING
99-43	200.70	5136761	288520.6
99-44	197.04	5136772	288563.5
99-45	201.57	5136771	288532.6
98-1	196.80	5136764	288575.3
88-2	199.60	5136763	288612.7
98-3	197.50	5136734	288573.7
98-4	201.40	5136734	288611.5
98-5	N/A	5136760	288557.3
98-6	N/A	5136733	288556.5

REFERENCE

This drawing was created from digital files provided by McConnell South Corp.

NOTES

1. The boundaries between soil strata have been established only at Borehole locations. Between Borehole the boundaries are assumed from geological evidence.
2. For detailed Stratigraphy at Borehole locations refer to Record of Borehole Sheets.

REVISION			
NO.	DATE	BY	REVISION
Geocres No. 31L - 70			
HWY. No. 17	PROJECT NO. 99-1154	DIST. 54	
SUBV'D. BYB	CHKD. DES	DATE: 2000 08 27	SITE 43 - 65
DRAWN: JFC	CHKD. EWB	APPD.	FIGURE 2N