

**MATERIALS ENGINEERING AND
RESEARCH OFFICE
FOUNDATION GROUP**

GWP 199-00-00
HWY QEW

REGION Central
SITE 18-138-104

Henley River Bridge Widening
over Twelve Mile Creek

GEOCRES No: 30M03-224

Date: May 13, 2003

FOUNDATION INVESTIGATION REPORT

for

Henley River Bridge Widening over Twelve Mile Creek

St. Catharines

W.P. 199-00-00

Site 18-138-104

Central Region

Introduction

This report summarizes the factual information obtained from a previous foundation investigation conducted for the widening of the proposed Henley River Bridge in 1986 under WP 8-86-00. The report was updated to include additional information. The work was carried out at the request of Central Region, Structural Section.

Site Description

The site is located at the crossing of QEW and Twelve Mile Creek in the City of St.Catharines.

The creek lies in a preglacial valley with slopes dissecting beds of sand, silt and glacial till. The rising lake level has drowned the valley and created the lagoon known as Martindale Pond. Outside the valley, the terrain is relatively flat. The elevation of the QEW in the area of investigation varies from El 90.0 to 92.0 m. The valley is approximately 18 m deep and 135m wide. Based on the boreholes advanced in the creek, the creek bed elevation is estimated at 73.5m. The creek is approximately 82 m wide at the bridge and the water level measured in October 2002 was El 78.9.

The existing Henley Bridge is a 6-span twin concrete arch structure. Originally constructed in 1938, the structures and substructures were widened on both north and south sides in 1988.

Slopes beyond the bridges are stable and vegetated. The forward slopes beneath the structures are scarred by erosion gullies, some of which are over 1m in depth and width.

Physiographically, the site falls within the Iroquois Plain and consists largely of thin deposits of sand overlying extensive cohesive deposits (after Putnam and Chapman, 1984, The Physiography of Southern Ontario, 3rd Edition). Land use is primarily commercial and recreational.

Investigation Procedures

i) Field

A foundation investigation was carried out by the Foundations Group for the existing structure widenings between 86 02 12 and 86 04 17. The fieldwork consisted of fourteen boreholes. Eight

boreholes (BH's 1, 2, 9, 10, 11, 12, 13 and 14) were advanced using a track-mounted auger machine equipped with hollow stem augers. A diamond drill equipped with BX and NX casings was used to advance the remaining boreholes (BH's 3, 4, 5, 6, 7 and 8).

One boring was carried out at each of the proposed footing widening locations. The boreholes at the footings were advanced to depths of between 13.4 and 29.3 m. Disturbed samples were recovered by means of a 50 mm O.D. split spoon sampler driven into the ground according to the specifications of the Standard Penetration Test (ASTM D 1586-8). The samples were retrieved at 0.76 m intervals for depths of up to 10 m, followed by a sampling interval of 1.5 m to the borehole termination depth. Vane tests were carried out at representative locations when soft cohesive soils were encountered. The boreholes were backfilled upon completion.

Groundwater elevations were obtained by measuring the water levels in the open boreholes prior to backfilling.

MTO Central Region Surveys and Plans Section provided survey information for the boreholes.

ii) Laboratory

Laboratory testing was carried out on representative samples to identify and determine the physical properties of the subsurface deposits including:

- Natural Moisture Content
- Atterburg Limits
- Grain Size Distribution
- Bulk Unit Weight
- Unconfined Uniaxial Compression

The results of the laboratory tests are plotted on the Record of Borehole sheets and on Plasticity Charts, Figures 1 and 2.

Subsurface Conditions

General

The definitions of the soil types and boundaries were developed as part of the original foundation report for the 1988 structure widening. Subsequent to that foundation investigation, the classification of cohesive soils at MTO was revised. The silty clay deposit encountered across much of the site is a low plasticity material and would currently be identified as a clayey silt deposit. However, for the ease of presenting the data, the original classifications have been maintained for this report.

The Twelve Mile Creek crossing extends for approximately 225 m. The depth of the valley is in the order of 12 m deep. The subsoil encountered at the site consists of an extensive deposit of silty clay within the valley slopes and a variety of alluvial deposits within the valley floor. The overburden at the crest of the west slope extends for a depth of 27.3m and overlies shale bedrock encountered at El.63.9. At the top of the east slope, the overburden is 28.8 m, overlying the shale

bedrock encountered at El. 62.6.

Within the valley, an organic silt to clay deposit extends below the silty clay deposit on the west side of the creek. On the east side coarser granular deposits were encountered. Cobbles and boulders were encountered at varying elevations across the site. Within the valley they were present within the non-cohesive fluvial deposits. BH 10 was terminated in a deposit of gravel, cobbles and boulders encountered at El. 67.1.

Shale bedrock of the Queenston Formation was encountered in all but three boreholes. The surface of the bedrock across the site varies from El. 62.5 and 66.8.

The groundwater level was measured in the open boreholes and was present at depths varying from 14.8 m at the top of the valley slopes to 0 within the valley. Generally, the ground water levels were consistent with the elevation of the creek.

The boundaries of the various strata, together with field and laboratory test results, appear on the Record of Borehole Sheets appended to this report. The locations of the borings in plan and the stratigraphical profile are shown on Drawing No. 88600-A. A detailed description of the subsurface conditions is given below.

Gravel, Sand, Clay and Asphalt (Fill)

A 1.4 m thick non-cohesive fill deposit containing varying amounts of gravel, sand, clay and asphalt was encountered only in BH 4 (East Pier). From standard penetration testing an N value of 34 was obtained, indicating that the fill is in a dense state.

Silty Clay

A surficial deposit of cohesive low plasticity silty clay was encountered in all but four boreholes. The clayey silt is the only deposit encountered in BH 13 advanced at the west end of the site and it extends for a depth of 27.3m to the top of bedrock (El. 63.9). At other locations, the thickness of the deposit ranges from 1.5 m within the valley to 26.5 m at the crest of the east slope. It is occasionally interbedded with granular seams. In BH 4, a zone of cobbles and boulders was encountered at approximate El. 80. The silty clay stratum contains trace/some sand and trace/some gravel. N values for this material range from 0, increasing with depth to greater than 120 blows per 15 cm. More typically N values range from 20 to 74, indicating that the clayey silt is very stiff to hard in consistency. The following soil properties were determined from laboratory testing carried out on representative samples:

	<u>Range</u>	<u>Average</u>
Moisture Content (w)	5 - 30 %	14.5%
Plastic Limit (w_p)	11 - 26%	16.1%
Liquid Limit (w_L)	17 - 44%	26.5%
Unit Weight (γ)	20.6 - 22.8 kN/m ³	21.7 kN/m ³
Shear Strength (kPa)	80 kPa	
Sensitivity	6	
Unconfined Compressive Strength	156 kPa	

The Atterburg limits test results are plotted on the plasticity chart in Figure 1.

Silty Sand to Sandy Silt

A non-cohesive deposit of silty sand to sandy silt was encountered beneath the clayey silt stratum in boreholes 1, 2, 3, 5, 6, and 14, and interbedded within the clayey silt stratum in BH's 11 and 12. The thickness of the silty sand to sandy silt ranges from 1.3 m thick in BH 11 to 8.3 m thick in BH 3, advanced on the east side of Twelve Mile Creek. The sand to silty sand deposit extends to bedrock in boreholes 1, 2, 3, 5, 6, and 14. N values ranging from 9 to in excess of 120 blows per 30 cm were obtained from Standard Penetration testing. More typically the N values exceeded 120 blows per 30 cm, revealing that the non-cohesive deposit is in a very dense state of compaction. The composition of the deposit makes it susceptible to disturbance under conditions of unbalanced hydrostatic head. Based on laboratory testing carried out on representative samples, the moisture content of this deposit ranges from 7% to 25%.

Organic Clay/Organic Silt/Peat

Organic deposits were encountered in BH's 9 and 10 advanced along west bank of Twelve Mile Creek. Organic pockets were also present within the upper silty clay deposit in BH's 5 and 6 located on the east bank of the creek. On the west bank, the organic material varied from 2.3 to 5.3 m in thickness. It was encountered between elevations 71.3 and 76.6. The N values ranged from 0 to 11, but were typically in the order of 2 to 4, revealing a consistency of very soft to soft.

	<u>Range</u>	<u>Average</u>
Moisture Content (w)	38 - 119 %	70%
Plastic Limit (w_p)	21 - 31%	26.2%
Liquid Limit (w_L)	17 - 44%	39.4%

The Atterburg limits test results are plotted on the plasticity chart in Figure 2.

Silty Clay to Silt

A cohesive deposit of low plasticity silty clay to silt was found in BH's 7, 10 and 12. The deposit was encountered between elevations 65.3 and 67.3 and varied in thickness from 2.5 to 4.9 m. It was composed predominantly of silt with the occasional sand seam. N values for this material ranged from 23 to greater than 120 blows per 30 cm. Generally the N values were greater than 100, indicating a hard consistency for the deposit. The following properties were obtained from laboratory testing:

	<u>Range</u>
Moisture Content (w)	16 - 24%
Plastic Limit (w_p)	14 - 15%
Liquid Limit (w_L)	22 - 23%

Bedrock

Bedrock was proven in all boreholes except BH's 2, 10 and 13. The bedrock is shale of the Queenston Formation. The following are bedrock elevations encountered at the borehole locations:

<u>Borehole</u>	<u>Bedrock Elevation</u>	
	<u>Weathered</u>	<u>Sound</u>
1	-	62.6
3	63.2	62.9
4	65.3	63.0
5	63.5	62.6
6	63.8	63.0
7	65.2	63.5
8	66.8	65.3
9	64.2	62.9
11	65.0	63.7
12	65.3	63.9
14	63.7	63.1

Groundwater Conditions

Water levels were measured in the open holes at the completion of each borehole.

At the time of the investigation in 1986, the following groundwater elevations were measured:


<u>Borehole</u>	<u>Groundwater Elevation</u>
1	88.5
2	76.6
3	76.2
4	Not observed
5	78.7
6	78.7
7	78.7
8	78.7
9	79.3
10	78.4
11	80.9
12	80.0
13	89.0
14	82.0

The creek elevation recorded in October 2002 was 78.9.

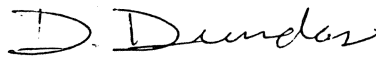
Miscellaneous

The original foundation investigation was carried out by Paul Payer, Sr. Foundation Engineer, in 1986. This updated report was prepared by B. Bennett, and was reviewed by D. Dundas, Senior Foundation Engineer.




Betty Bennett, P.Eng.
Foundation Engineer




David Dundas, P.Eng.
Sr. Foundation Engineer

A P P E N D I X

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D. SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS / 0.3 m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (R Q D), FOR MODIFIED RECOVERY, IS:

R Q D (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

S S	SPLIT SPOON	T P	THINWALL PISTON
W S	WASH SAMPLE	O S	OSTERBERG SAMPLE
S T	SLOTTED TUBE SAMPLE	R C	ROCK CORE
B S	BLOCK SAMPLE	P H	T W ADVANCED HYDRAULICALLY
C S	CHUNK SAMPLE	P M	T W ADVANCED MANUALLY
T W	THINWALL OPEN	F S	FOIL SAMPLE

MECHANICAL PROPERTIES OF SOIL

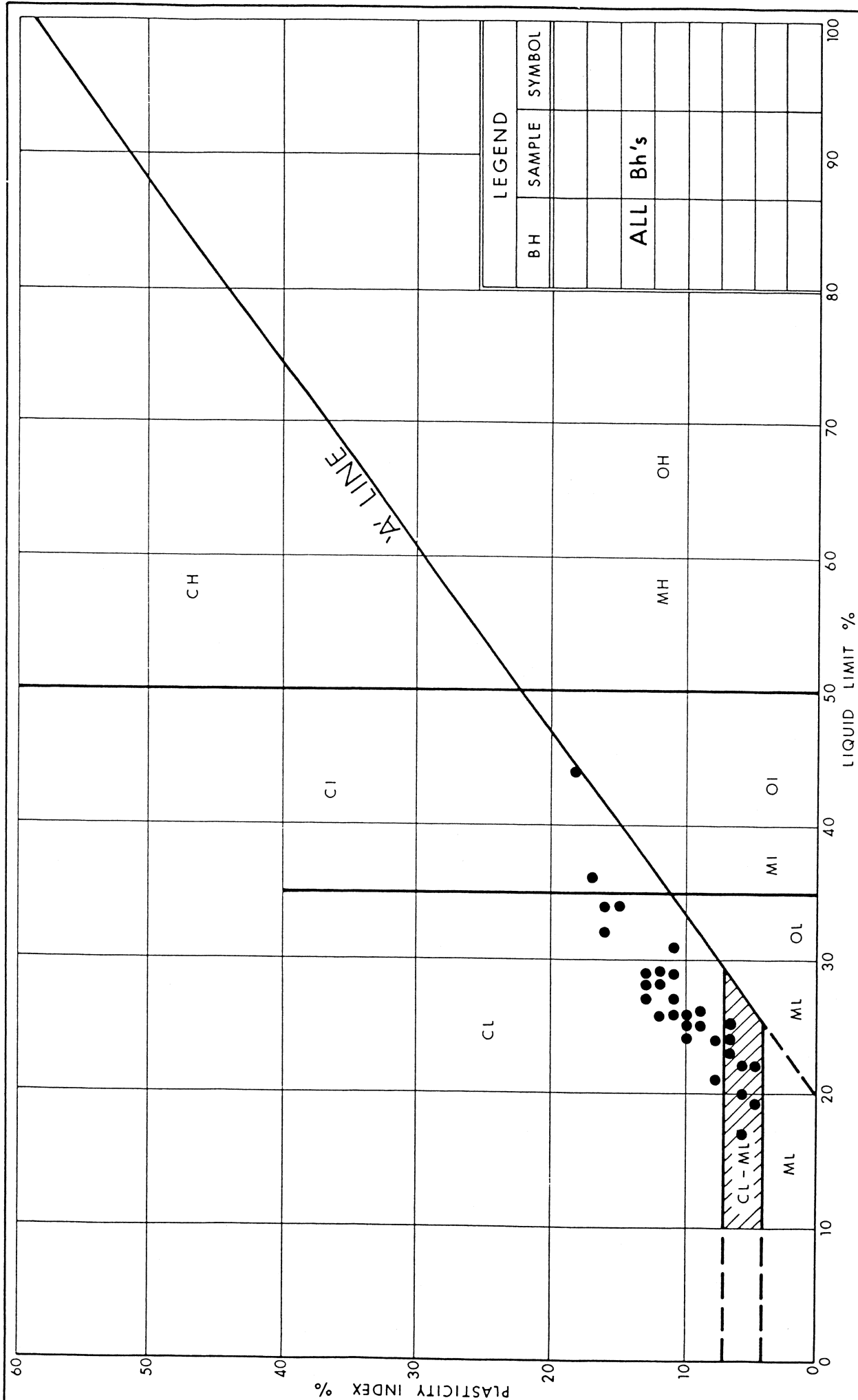
m_v	kPa ⁻¹	COEFFICIENT OF VOLUME CHANGE
C_c	1	COMPRESSION INDEX
C_s	1	SWELLING INDEX
C_α	1	RATE OF SECONDARY CONSOLIDATION
C_v	m ² /s	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
T_v	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
σ'_{VO}	kPa	EFFECTIVE OVERBURDEN PRESSURE
σ'_p	kPa	PRECONSOLIDATION PRESSURE
τ_f	kPa	SHEAR STRENGTH
c'	kPa	EFFECTIVE COHESION INTERCEPT
ϕ'	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
c_u	kPa	APPARENT COHESION INTERCEPT
ϕ_u	-°	APPARENT ANGLE OF INTERNAL FRICTION
τ_R	kPa	RESIDUAL SHEAR STRENGTH
τ_r	kPa	REMOULDED SHEAR STRENGTH
S_t	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

STRESS AND STRAIN

u_w	kPa	PORE WATER PRESSURE
r_u	1	PORE PRESSURE RATIO
σ	kPa	TOTAL NORMAL STRESS
σ'	kPa	EFFECTIVE NORMAL STRESS
τ	kPa	SHEAR STRESS
$\sigma_1, \sigma_2, \sigma_3$	kPa	PRINCIPAL STRESSES
ϵ	%	LINEAR STRAIN
$\epsilon_1, \epsilon_2, \epsilon_3$	%	PRINCIPAL STRAINS
E	kPa	MODULUS OF LINEAR DEFORMATION
G	kPa	MODULUS OF SHEAR DEFORMATION
μ	1	COEFFICIENT OF FRICTION

PHYSICAL PROPERTIES OF SOIL

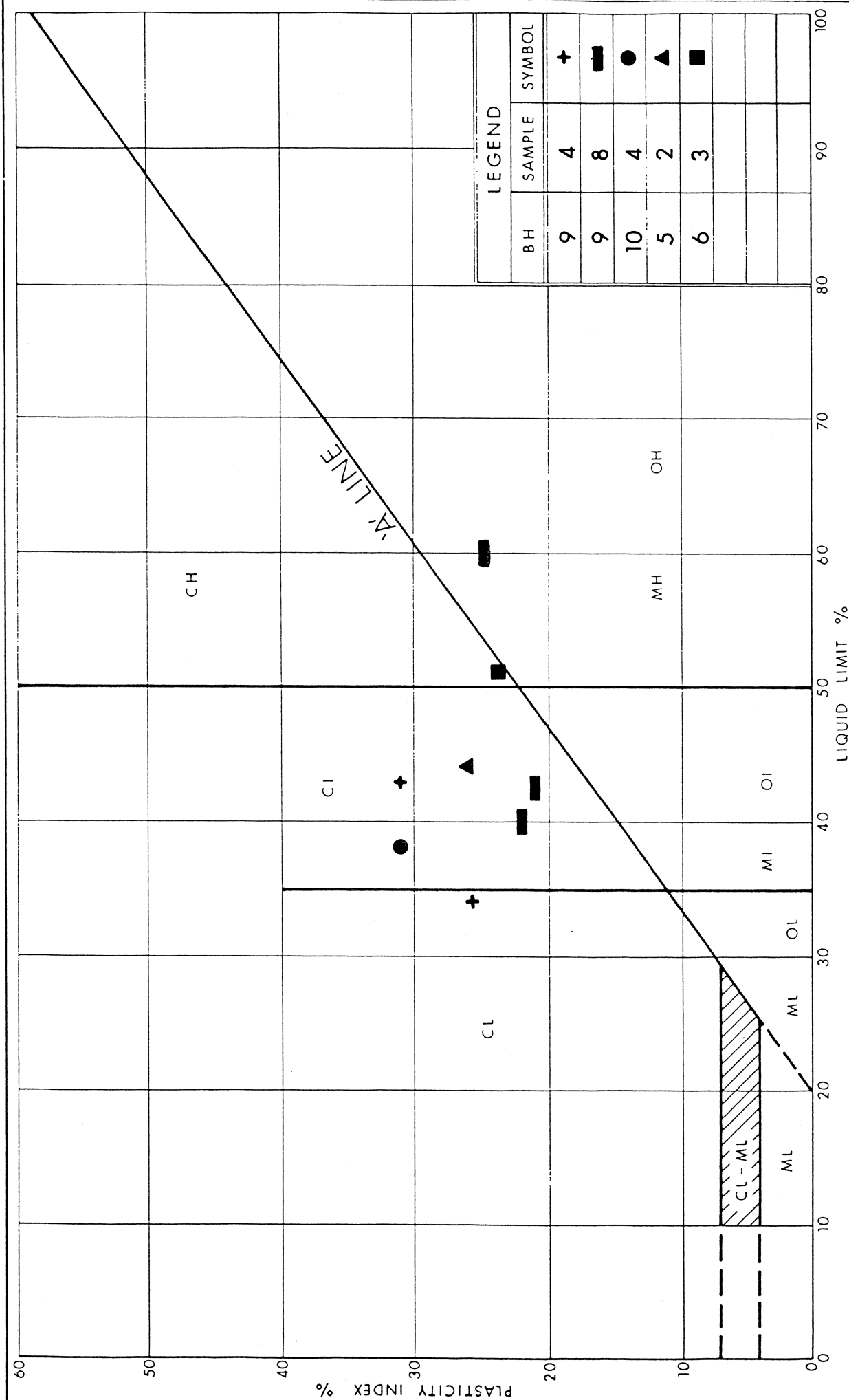
ρ_s	kg/m ³	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	kn/m ³	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m ³	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	kn/m ³	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m ³	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	kn/m ³	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m ³	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m ³ /s	RATE OF DISCHARGE
γ_d	kn/m ³	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m ³	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	kn/m ³	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m ³	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	kn/m ³	SEEPAGE FORCE
γ'	kn/m ³	UNIT WEIGHT OF SUBMERGED SOIL						

Ministry of
Transportation

PLASTICITY CHART SILTY CLAY

FIG No 1

WP 199-00-00



PLASTICITY CHART
ORGANIC SILT/CLAY

FIG No 2

W P 199-00-00

RECORD OF BOREHOLE No 1

METRIC

W P 8-86-00 LOCATION Co-ords. N 4781898.0 E 323379.7 ORIGINATED BY WD
 DIST 4 HWY Q.E.W. BOREHOLE TYPE 'Cont' Flight Auger (H.S.) COMPILED BY DG
 DATUM Geodetic DATE 86 02 27 CHECKED BY LD

SOIL PROFILE		SAMPLES		GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L	WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER TYPE 'N' VALUES								
91.4 0.0	Ground Surface										
	Silty Clay trace/some sand trace of gravel		1 SS 6								
			2 SS 12								
			3 SS 20								
			4 SS 23								
			5 SS 43								
			6 SS 53								
			7 SS 62								
			8 SS 59								
			9 SS 43								
			10 SS 50								
			11 SS 48								
		Occ. Silt Layers		12 SS 83							
				13 SS 43							
				14 SS 45							
		Firm to Hard		15 SS 53							
			16 SS 20								
			17 SS 100	23 cm							
			18 SS 108								
64.9 26.5	Sandy Silt Trace of Clay some gravel Very Dense		19 SS 100								
62.6 28.8			21 RC REC NQ 96%								
60.5 30.9	Shale Sound Bedrock		22 RC REC NQ 98%								

OFFICE REPORT, ON SOIL EXPLORATION

RECORD OF BOREHOLE No 2

METRIC

W P 8-86-00 LOCATION Co-ords. N 4781931.6 E 323366.8 ORIGINATED BY WD
DIST 4 HWY Q.E.W BOREHOLE TYPE Cont. Flight Auger (H.S.) COMPILED BY PP
DATUM Geodetic DATE 86 02 12 & 13 CHECKED BY *ab*

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 x LAB VANE	NATURAL MOISTURE CONTENT Wp W WL WATER CONTENT (%) 20 40 60	UNIT WEIGHT γ kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
91.4 0.0	Ground Level										
	Silty Clay trace/some sand trace/some gravel Occ. silt layers Firm to Hard		1	SS	22						
			2	SS	24						
			3	SS	38						
			4	SS	33						
			5	SS	19						
			6	SS	18						
			7	SS	16						
			8	TW	PH						
			9	TW	PH						
			10	SS	23						
			11	SS	29						
			12	SS	32						
			13	SS	36						
			14	SS	44						
			15	SS	34						
			16	SS	18						
			17	SS	150						
67.6 23.8	Silty Sand some clay Very Dense		18	SS	95	15cm					
			19	SS	83						
62.7 28.7	Refusal										
	End of Borehole										

+3, x5: Numbers refer to 20
Sensitivity 15 (5%) STRAIN AT FAILURE



RECORD OF BOREHOLE No 3

METRIC

W P 8-86-00 LOCATION Co-ords N 4 781 891.4 E 323 360.8 ORIGINATED BY WD
DIST 4 HWY Q.E.W. BOREHOLE TYPE Wash Boring (NW Casing) COMPILED BY WD
DATUM Geodetic DATE 86 04 09 CHECKED BY LB

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT Wp	NATURAL MOISTURE CONTENT W	LIQUID LIMIT Wl	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES								
86.1 0.0	Ground Surface												
	Silty Clay trace/some sand trace of gravel Occ. silt Layers Stiff to Hard		1	SS	10								1 14 56 29
			2	SS	8								
			3	SS	12								
			4	SS	12								
			5	SS	41								
			6	SS	82	23 cm							
			7	SS	86								
			8	SS	84	23 cm							1 4 69 26
			9	SS	83								
			10	SS	58								
			11	SS	43								
			12	SS	11								
			13	SS	48								
			14	SS	33								0 12 60 28
71.5 14.6	Silty Sand trace of clay trace of gravel Very Dense		15	SS	100	13 cm							
			16	SS	98	15 cm							
			17	SS	100	20 cm							0 64 26 10
			18	SS	73	20 cm							
63.2 22.9	Shale Bedrock		19	RC BQ	REC 92%								
61.7 24.4	End of Borehole												

RECORD OF BOREHOLE No 4

METRIC

W P 8-86-00 LOCATION Co-ords. N 4 781 923.4 E 323 349.7
 DIST 4 HWY O.E.W. BOREHOLE TYPE Wash Boring (NW Casing)
 DATUM Geodetic DATE 86 04 17
 ORIGINATED BY WD
 COMPILED BY WD
 CHECKED BY *LB*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	5 10 15 20 25	20 40 60					
87.5	Ground Surface														
0.0	Gravel, Sand, Clay and Asphalt					*									
86.1	Fill Material		1	SS	34										
1.4	Silty Clay trace/some sand trace of gravel		2	SS	39										
			3	SS	90										
			4	SS	67										
			5	SS	99										
			6	SS	69	20 cm									
			7	SS	81	25 cm									
			8	SS	81										
		cobbles and boulders		9	SS	59	10 cm								
				10	SS	81	25 cm								
				11	SS	74									
		Occ. Silt Layers		12	SS	84									
		Hard		13	SS	47									
				14	SS	28									
72.7				15	SS	41	10 cm								
14.8	Sand and Gravel trace of silt Very Dense		16	SS	30	8 cm									
70.5	Silty Clay some gravel some sand occ. sand layers Hard		17	SS	103	15 cm									
17.0			18	RC BQ	REC 22%										
			19	RC BQ	REC 72%										
65.3	Shale														
22.2	Bedrock Weathered														
62.2	Sound														
25.3	End of Borehole														
	* Water Level Not Observed														

+3, x5: Numbers refer to
Sensitivity

20
15 x 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 5

METRIC

W P 8-86-00 LOCATION Co-ords N 4 781 878.5 E 323 325.5 ORIGINATED BY WD
 DIST 4 HWY Q.E.W. BOREHOLE TYPE Wash Boring - NX Casing COMPILED BY DC
 DATUM Geodetic DATE 86 03 25 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40						60	80	100	WATER CONTENT (%)
								SHEAR STRENGTH kPa										
78.7	Creek Water Level																	
0.0	Water Creek Bed																	
77.2																		
1.5	Silty Clay trace of sand Occ. organic layers and pockets Very Soft to Soft		1	SS	1													
74.9			2	TW	PM													
3.8	Sand and Gravel trace/some silt trace/some clay Occ. silty clay layers		3	SS	5													
			4	SS	16													
			5	SS	10													
			6	SS	48													
	cobbles and boulders		7	SS	90	15 cm												
			8	SS	100	18 cm												
68.9	Loose to Very Dense																	
9.8	Silty Clay trace of sand Hard		9	SS	81	23 cm												
67.4																		
11.3	Sandy Silt some clay occ. silty clay layers		10	SS	51	10 cm												
			11	SS	100	10 cm												
	Very Dense																	
63.5			12	SS	100	13 cm												
15.2	Weathered Shale Sound		13	RC BX	REC 56%													
	Bedrock		14	RC BX	REC 80%													
60.4																		
18.3	End of Borehole																	

*3, *5: Numbers refer to
Sensitivity

20
15 *5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 6

METRIC

W P 8 -86-00 LOCATION Co-ords N 4 781 909.5 E 323 313.6
 DIST 4 HWY Q.E.W. BOREHOLE TYPE Wash Boring - NX Casing
 DATUM Geodetic DATE 86 03 20
 ORIGINATED BY WD
 COMPILED BY DC
 CHECKED BY *so*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			UNIT WEIGHT Y kN/m ³	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	
78.7	Water Surface											
0.0	Water											
77.2	Creek Bed											
1.3	Sand & Gravel		1	SS	0							
76.5	Very Loose											
2.2	Silty Clay		2	SS	0							
	to Clay											
	Occ. Organic Seams		3	TW	PM							
74.1	Very Soft to Firm		4	SS	0							
4.6	Silty Sand with											
	Gravel											
	trace of clay		5	SS	43							
72.3	Compact to Dense											
6.4	Silty Clay		6	SS	45							
	trace of sand											
	Hard											
70.5												
8.5												
	Sandy Silt											
	trace/some gravel											
	trace of clay											
	Occasional silty											
	clay layers											
	Very Dense											
63.8												
14.9	Shale		13	RC	REC							
	Weathered											
	Sound											
	Bedrock		14	RC	REC							
60.7												
18.0	End of Borehole											

+3, x5: Numbers refer to
Sensitivity

20
15 \div 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 7

METRIC

W P B-86-00 LOCATION Co-ords. N 4 781 867.0 E 323 280.0 ORIGINATED BY WD
 DIST 4 HWY Q.E.W. BOREHOLE TYPE Wash Boring NW Casing COMPILED BY WD
 DATUM Geodetic DATE 86 04 01 CHECKED BY WD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100				
78.7	Creek Water Level															
0.0																
73.2	Creek Bed															
5.5	Heterogenous Mixture of gravel, sand silt, clay		1	SS	7											21 48 21 10
			2	SS	38											
			3	SS	74	8 cm										
			4	SS	38	5 cm										
	Firm to Hard		5	SS	100	8 cm										42 17 34 7
67.9			6	SS	100	15 cm										
10.8			7	SS	100	18 cm										
65.2	Silty Clay to Silt		8	SS	79	20 cm										
			9	SS	75	15 cm										0 0 84 16
13.5	Hard		10	SS	100	8 cm										
	Shale Weathered		11	RC	REC											
				BQ	75%											
	Bedrock Sound		12	RC	REC											
				BQ	88%											
62.2																
16.5	End of Borehole															

+3, x5 : Numbers refer to
Sensitivity

20
15
10
5
(%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 8

METRIC

W P 8-86-00 LOCATION Co-ords. N 4 781 894.5 E 323 273.0
DIST 4 HWY Q.E.W. BOREHOLE TYPE Wash Boring (NW Casing)
DATUM Geodetic DATE 86 04 03
ORIGINATED BY WD
COMPILED BY WD
CHECKED BY *so*

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
78.7	Creek Water Level																
74.3	Water																
4.3	Creek Bed																
4.3	Sandy Silt some gravel trace of clay Loose to Compact		1	SS	8												
72.6			2	SS	20												
6.1			3	SS	28												
			4	SS	49												
	Silty Clay some sand trace gravel Very Stiff to Hard		5	SS	100/	15 cm											
			6	SS	15/	10 cm											
			7	SS	100/	5 cm											
			8	SS	100/	8 cm											
			9	SS	100/	2 cm											
66.8			10	SS	93/	15 cm											
11.9			11	SS	100/	0 cm											
	Shale - Weathered Sound		12	SS	100/	0 cm											
	Bedrock		13	RC BQ	REC 82%												
62.3			14	RC BQ	REC 92%												
16.4	End of Borehole																

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 9

METRIC

W P 8-86-00 LOCATION N 4 781 846.3 E 323 240.9 ORIGINATED BY WD
 DIST 4 HWY O.E.W. BOREHOLE TYPE Cont. Flight Auger (H.S.) COMPILED BY PP
 DATUM Geodetic DATE 86 03 18 & 19 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	0 UNCONFINED • QUICK TRIAXIAL					
79.5 0.0	Ground Level													
	Silty Clay with sand trace of gravel Firm		1	SS	4									2 35 (63)
			2	SS	5									
76.6			3	SS	4									
2.9	Organic Clay and Peat Layers Very Soft to Soft		4	SS	4									
			5	SS	4									
			6	SS	11									
			7	SS	2									
			8	SS	1									0 6 (94)
			9	SS	4									
71.3			10	TW	PH									14 78 (8) 0 88 (12)
8.2	Heterogenous Mixture of gravel, sand, silt, clay		11	SS	100	15 cm								
			12	SS	100	15 cm								
			13	SS	100	15 cm								
			14	SS	100	10 cm								
	Hard		15	SS	150									20 35 (45)
			16	SS	100	5 cm								
64.2			17	SS	100	10 cm								
15.3	Shale <u>Weathered</u> Sound		18	RC NQ	REC 53%									
	Bedrock		19	RC NQ	REC 100%									
			20	RC NQ	REC 100%									
59.7	End of Borehole													
19.8														

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 10

METRIC

W P 8-86-00 LOCATION Co-ords. N 4 781 877.5 E 323 228.6 ORIGINATED BY WD
 DIST 4 HWY Q.E.W. BOREHOLE TYPE Cont. Flight Auger H.S. COMPILED BY DC
 DATUM Geodetic DATE 86 02 14 CHECKED BY SD

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
79.0	Ground Level																
0.0	Silty Clay some sand trace of gravel Soft to Firm		1	SS	6		78										
76.6			2	SS	4												
2.4			3	SS	6		76										2 17 (81)
	Organic Silt trace sand Soft to Very Soft		4	TW	PH												
			5	SS	2												
			6	TW	PH		74										
			7	SS	2												
72.0			8	SS	0		72										
7.0	Silty Clay to Silt trace/some sand trace of gravel		9	SS	23												
			10	SS	105												
			11	SS	74												
			12	SS	37		70										
	Very Stiff to Hard		13	SS	111/30 cm												
67.1			14	SS	100/23 cm		68										
11.9	Gravel, Cobbles and Boulders		15	RC NQ	REC 13%		66										
65.6																	
13.4	End of Borehole						64										

+3, x5: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 11

METRIC

W P 8-86-00 LOCATION Co-ords. N 4 781 830.2 E 323 197.6 ORIGINATED BY WD
 DIST 4 HWY Q.E.W. BOREHOLE TYPE Cont. Flight Auger (H.S.) COMPILED BY DC
 DATUM Geodetic DATE 86 02 19 CHECKED BY 10

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT	PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'IN' VALUES			20 40 60 80 100		WATER CONTENT (%) 20 40 60			
81.8 0.0	Ground Surface												
	Silty Clay trace sand Firm to Very Stiff Some Gravel		1	SS	5	↓							14 7 (79)
			2	SS	22								
			3	SS	27								
			4	SS	25								
			5	SS	21								
			6	SS	16								
			7	SS	17								
75.6 6.2	Silt to Sandy Silt trace clay Dense		8	TW	PH								0 10 87 3
74.3 7.5	Silty Clay Some Sand Some Gravel Hard		9	SS	45								15 28 (57)
			10	SS	76								
			11	SS	41								
			12	SS	59								
			13	SS	63								
			14	SS	100	10 cm							
			15	SS	100	15 cm							
			16	SS	144	25 cm							
			17	SS	100	7 cm							
			18	RC	NQ	REC 40%							
65.0 16.8	Shale - Weathered Sound		19	RC	NQ REC 50%								
62.0 19.8	Bedrock		20	RC	NQ REC 100%								
	End of Borehole												

*3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 12

METRIC

W P 8-86-00 LOCATION Co-ords. N 4 781 860.5 E 323 186.5
DIST 4 HWY Q.E.W. BOREHOLE TYPE Cont. Flight Auger (H.S.)
DATUM Geodetic DATE 86 02 20
ORIGINATED BY WD
COMPILED BY DC
CHECKED BY

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80					
81.0	Ground Surface															
0.0	Silty Clay trace/some sand Soft to Stiff		1	SS	9		80									0 14 (86)
			2	SS	7											
			3	SS	2											
			4	SS	4											
			5	SS	6											
75.8			6	SS	5											
5.2	Sandy Silt to Silt Loose to Dense		7	SS	0											0 3 (97)
			8	SS	0											
73.5			9	SS	38											
7.5	Silty Clay trace of sand Occ. Silt Layers Hard		10	SS	4											
			11	SS	46											
			12	SS	85											
			13	SS	14											
			14	SS	165											
			15	SS	75											
67.8																0 10 (90)
13.2	Silty Clay to Silt Occ. Sand Layers Hard		16	SS	103/20 cm											
			17	SS	83/15 cm											
65.3																
15.7	Shale -- Weathered Sound		18	RC NQ	REC 80%											
			19	RC NQ	REC 95%											
62.2	Bedrock															
18.8	End of Borehole															

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

METRIC

[illegible]

		GR SA ST CL	
0.0		1 SS 12	90
		2 SS 26	
		3 SS 38	120 (28 cm)
		4 SS 57	O I
		5 SS 32	
		6 SS 33	
		7 TW PH	O I
		8 SS 30	
		9 SS 31	
		10 SS 31	
		11 SS 40	O I
		12 SS 89	
		13 SS 42	
		14 SS 49	
		15 SS 45	O I
		16 SS 59	
		17 SS 100/ 18 cm	
		18 SS 100/ 18 cm	O I
63.9		19 SS 100/ 8 cm	
27.3	Refusal Probable Bedrock End of Borehole		
			62

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RECORD OF BOREHOLE No 14

METRIC

W P 8-86-00 LOCATION N 4 781 852.7 E 323 154.5
DIST 4 HWY Q.E.W. BOREHOLE TYPE Cont. Flight Auger (H.S.)
DATUM Geodetic DATE 86 02 25
ORIGINATED BY WD
COMPILED BY DC
CHECKED BY

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x LAB VANE	PLASTIC LIMIT W _p NATURAL MOISTURE CONTENT W LIQUID LIMIT W _L WATER CONTENT (%) 20 40 60	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE						
90.9	Ground Level									
0.0			1	SS	39					0 4 (96)
			2	SS	41					
			3	SS	43					
			4	SS	46					
			5	SS	28					
			6	SS	36					
			7	SS	25					
			8	TW	PH					
			9	SS	33					
			10	SS	34					
	Silty Clay some to trace sand Very Stiff to Hard trace of gravel		11	SS	35					0 7 (93)
			12	SS	38					
			13	SS	36					
			15	SS	24					
			16	TW	PH					
			17	SS	121					
			18	SS	146/	28 cm				
67.7										
23.2	Silty Sand trace of gravel trace of clay Very Dense		19	SS	166/	23 cm				
63.7										
27.2	Shale Bedrock Weathered Sound		21	RC	54%	5 cm				6 28 (66)
			22	RC	REC NQ 100%					
61.6										
29.3	End of Borehole									

+3, x5: Numbers refer to
Sensitivity

20
15 + 5 (%) STRAIN AT FAILURE
10