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W. O. No.

STR. SITE No. 3-358/2

HWY. No. 416

LOCATION Hwy 416 @ Mud Creek Bridge

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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FOUNDATION INVESTIGATION REPORT
for
Mud Creek Bridge

W.P. 187-89-04, District 9, Ottawa
Highway 416, Str. Site: 3-358/2

GEOCRES # 31G-215

Strata Project: E-90-037B

Date of Submission: 1992 04 07

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Nature, to be commanded. must be obeyed

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W.P. 187-89-04, District 9, Ottawa
Highway 416, Str. Site: 3-358/2

1.0 INTRODUCTION

Strata Engineering Corp. has been retained by UMA Engineering Ltd. to carry out a foundation investigation for the crossing of the proposed southbound lanes of Highway 416 and Mud Creek. The terms of reference were to investigate the site by means of sampled boreholes and dynamic cone penetration tests and to provide a full geotechnical report.

This report, which follows a letter report dated 1990 12 20, is submitted in compliance with these terms of reference.

2.0 SITE AND GEOLOGY

The site is located within Rideau Township approximately 30 km south of Ottawa along Highway 16. The location of the site is shown on the key plan in Drawing 1878904-A, appended. The proposed bridge centreline is approximately 30 m to the west of centreline of the existing structure at Highway 16.

The topography of the immediate area is flat. With the exception of a small wooded area to the west of the site, the land use is primarily agricultural. The creek flows within a channel some 4 m deep. The creek is approximately 10 m wide and 2 m deep in the vicinity of this site.

The site lies in the physiographic region known as the North Gower Drumlin field. The drumlins are oriented more or less north-south. A mantle of marine soils is draped over the drumlins and other glacial landforms. The marine soils are the result of inundation by the Champlain Sea. Therefore, silt and Leda clay are common in this area.

3.0 FIELD AND LABORATORY WORK

The field work, carried out from 1990 10 26 to 30, consisted of the drilling of six boreholes, each accompanied by a dynamic cone penetration test. Four boreholes were drilled at the corners of the proposed structure. The remaining two boreholes were drilled along centreline away from the structure to provide information for the approach fills. The borehole elevations, referenced to Geodetic datum, were supplied by UMA Engineering. The locations of the boreholes are shown on Drawing 1878904-A.

Drilling was conducted with two bombardier mounted CME 55 drill rigs. Hollow stem augers were used to advance the boreholes. Boreholes 1 and 6 for the approach embankments were terminated within the highest competent stratum. Boreholes 2 and 5 were terminated at auger refusal. Bedrock was cored in Boreholes 3 and 4.

Standard Penetration Tests were used to sample very dense materials as well as non-cohesive deposits, the accompanying N values being noted in blows/0.3 m. In cohesive strata, relatively undisturbed samples were obtained by pushing thin walled Shelby tubes either manually or hydraulically into the soil.

After the recovery of each thin walled tube sample, standard MTO A size vane tests were conducted to determine the undrained shear strength of the deposit. Remoulded shear strengths were also measured to determine the sensitivity of the soil.

Upon completion of each borehole the water levels were measured in the uncased holes. Boreholes 1, 2, 5 and 6 were backfilled with native soil cuttings. Bentonite sealed perforated standpipes were installed in Boreholes 3 and 4. The water level in these instrumented holes was monitored over a period of time. The site was restored to its original condition.

Recovered samples were transported to our Don Mills Laboratory for further visual examination, classification and index property testing such as moisture content, grain size distribution and Atterberg limits. Unconfined compression tests were performed on six thin walled tube samples. The results are shown on the Record of Boreholes and on Figures 1, 2A and 2B.

4.0 SUBSURFACE CONDITIONS

4.1 General

The soil stratigraphy consists of a silty clay to clay deposit overlying loose silt above a silty sand glacial till. Fractured limestone bedrock lies 11 m to 14.2 m below prevailing ground surface.

4.2 Surficial Organics

Topsoil (200 mm to 400 mm) was present at all borehole locations.

4.3 Silty Clay to Clay

A 4.2 m to 5.6 m thick deposit of silty clay to clay occurs below the topsoil.
The upper 1.5 m to 2.0 m of this deposit is desiccated. This upper desiccated crust is mottled brown and fissured. The moisture content in the crust ranged from 25 to 50 per cent, and lies between the liquid and plastic limits of the soil. One field vane test within the crust gave an undrained shear strength value of 68 kPa.

Below the desiccated zone the silty clay to clay is grey. The moisture content ranged from 70 to 40 per cent, generally decreasing with depth. Atterberg limits (Figure 1) indicate medium to high plasticity.

Field vane test undrained shear strength values ranged from 24 kPa to 58 kPa generally increasing with depth and decreasing moisture content, indicating a soft to firm consistency. The sensitivity of the soil is about 6 with extreme values of 2 and 11.

4.4 Silt

At about elevation 85 m to 86 m the silty clay to clay deposit is underlain by a grey silt deposit with thin clay seams. This stratum was 2.9 m to 4.6 m in total thickness at the drilled locations.

Field vane tests were carried out in this deposit in the belief that the soil was cohesive. However, when the recovered samples were examined, it was seen that the deposit was predominantly silt. Hence, any field vane values shown for this deposit have been discounted in stability analyses. The natural moisture content of the silt ranged from 20 to 50 per cent, the average being about 30 per cent. N values of 0 to 10 blows/0.3 m indicate the silt is very loose to compact.

4.5 Silty Sand (Glacial Till)

The silt stratum is underlain at a depth of about 9m below the prevailing ground surface by a silty sand with some gravel (glacial till). This deposit was fully penetrated in Borehole 3 where the thickness was 4.7 m and in Borehole 4 where it was 6.9 m.

Grain size curves are shown in envelope form in Figure 2A. A sandy zone is plotted on Figure 2B. N values in this deposit were between and 2 and 114 blows/0.3 m, generally increasing with depth. The lower N values were observed within the upper zones of the deposit and may be due to local re-working of the till. The dynamic cone penetration tests all terminated within this deposit. Based on these N values, the deposit is considered to be very dense with localized loose to compact zones near its surface. Cobbles are suspected to be present on the basis of observations in the field during drilling.

4.6 Limestone Bedrock

Limestone bedrock was proven in Boreholes 3 and 4. It is badly fractured with core recoveries of between 37% and 90%. The maximum RQD value was 30%, most values being 0% for each core run.

5.0 GROUNDWATER CONDITIONS

The phreatic level at the site corresponds more or less to the creek level. Observations are listed below:

Borehole	Ground Elev. (m)	W.L. Elev. (m)	Date
1	89.8	88.5	1990 10 30
2	90.4	88.3	1990 10 29
3	89.9	89.9	1990 10 29
4	90.7	90.3	1990 10 30
5	90.6	88.2	1990 10 30
6	90.8	88.5	1990 10 30

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct southbound lanes 30 m west of the existing Highway 16 which will be upgraded to a 4 lane freeway standard between Highway 401 and Ottawa. This will entail construction of a bridge across Mud Creek. The proposed structure is likely to be similar to the existing single span structure. The proposed embankment fill heights will be in the order of 3 m in height.

This investigation indicates the presence of topsoil overlying silty clay to clay above loose to compact silt. The silt overlies very dense silty sand glacial till above fractured limestone bedrock.

6.2 Structure Foundations

The presence of the silty clay stratum precludes the use of conventional spread footings for the proposed structure. Hence, a deep foundation is recommended.

Sub-artesian pressures within a competent lower bearing stratum preclude the use of caissons, due to difficulties associated with installation under such conditions. Therefore, steel H piles are recommended as the most appropriate deep foundation alternative for this site.

A minimum earth cover of 1.8 m should be provided to the underside of pile caps to protect against frost action.

Wing walls should be supported on end bearing piles unless they can be adequately cantilevered from the abutments. Due to the likely presence of cobbles at depth within the sand and gravel glacial till deposit it is recommended that the pile toes be reinforced.

The piles should be driven to bedrock. However if refusal is encountered above bedrock, the Hiley Dynamic Pile Driving formula should be used to determine the final founding elevation.

Steel H piles such as HP 310x110 are normally designed for the following axial load capacities:

Factored Axial Capacity in ULS	1600 kN
Axial Capacity at SLS Type II	1150 kN

However, the clay deposit which these piles will penetrate is sensitive and therefore subject to loss of strength after pile driving. The disturbed and softened clay surrounding the pile shafts will reconsolidate with time, causing negative skin friction loading on the piles. Therefore, it is recommended that the HP 310x110 steel H Piles be designed for the following axial capacities, to allow for downdrag loading:

Factored Axial Capacity in ULS	1400 kN
Axial Capacity at SLS Type II	950 kN

The piles should be driven with an energy not less than 50 kJ to achieve the intended capacities.

For pile length estimation, assume the pile toes to reach bedrock at about elevation 76.5 m. Some piles may go deeper where the bedrock is slightly below this elevation and some piles may hang up above this level within the very dense glacial till deposit. However, on average, a pile toe elevation of 76.5 m is adequate for pile length estimation. Should piles hang up in the glacial till, they can be easily cut off, after confirmation of their axial capacities by using the Hiley formula in accordance with MTO policy and practice.

6.3 Earth Pressures

Earth pressures should be computed as per sub-section 6-6.1.2.2 of the OHBD Code. A yielding foundation condition may be assumed. The granular A or B backfill should be in accordance with MTO Special Provision No. 109F03 (latest revision). The following parameters are recommended for granular backfill:

	Granular A	Granular B
Angle of Internal Friction, ϕ'	35.0°	30.0
Unit Weight (kN/m^3), γ	22.8	21.2

Surcharge effects, if any, should be computed as per Clause 6-6.1.2.4 of the OHBD Code.

6.4 Approach Embankments

The proposed profile grade at elev. 92.5 m results in a maximum fill height of 2.5 m. For fills of no more than 4 m, built with 2:1 slopes, no deep seated stability problems are anticipated.

All organic materials should be stripped before the placement of fill for the approaches. Total short and long term settlements under such embankment loading are estimated to be in the order of 25 mm - 30 mm.

6.5 Construction Considerations

The steel H piles may constitute a travel path for artesian flow. To prevent uncontrolled flow and consequent erosion and undermining, it is recommended that a 600 mm thick granular "A" filter-drainage blanket be provided below the pile cap, prior to pile driving, with suitable rip-rap cover to protect against surface erosion by high water.

Temporary excavations with side slopes of 1:1 may be made by open cut methods to maximum depths of 3 m within the silty clay stratum. Such side slopes will remain stable if (1) they are not surcharged with excavation spoil and (2) they are left open no longer than 24 hours. For longer exposure than 24 hours, the side slopes should be flattened to 1.5H : 1.0V.

Seepage into excavations made within the silty clay is expected to be minimal, and capable of being handled by pumping from sumps located within the excavation.

7.0 CLOSURE

The drilling was supervised by A. C. Abel. Drill rigs were rented from F. E. Johnston and Marathon Drilling companies, Ottawa.

Respectfully submitted:
STRATA ENGINEERING CORP.

A. C. Abel, M. Sc.
Project Engineer

REGISTERED PROFESSIONAL ENGINEER C. MIRZA PROVINCE OF ONTARIO

C. Mirza, P. Eng.
Senior Principal

ACA/lr

Report Distribution:

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APPENDIX

Explanation of Terms used in this Report

Records of Boreholes 1 to 6

Figures 1, 2A and 2B

Drawing 1878904-A

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/0.3m)	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 (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	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

SS	SPLIT SPOON	TP	THINWALL PISTON
WS	WASH SAMPLE	OS	OSTERBERG SAMPLE
ST	SLOTTED TUBE SAMPLE	RC	ROCK CORE
BS	BLOCK SAMPLE	PH	TW ADVANCED HYDRAULICALLY
CS	CHUNK SAMPLE	PM	TW ADVANCED MANUALLY
TW	THINWALL OPEN	FS	FOIL SAMPLE

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

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 $= \frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No1

METRIC

W P 187-89-04 LOCATION N: 5 005 065 ; E: 366 407.5 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 26 CHECKED BY C.M.

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa (FIELD VANE / sensitivity)	WATER CONTENT (%)	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.8	Ground Surface									
0.0	200mm Topsoil Silty Clay to Clay Stiff Desiccated Mottled Brown	1	SS	10	▽	89.0		Wp–W–WL		W.L. on 1990 10 30
	Firm to Stiff	2	SS	5		88.0	+ 4			
	Grey	3	TW	PM		87.0	+ 5, + 5			
		4	TW	PM		86.0 / 85.0	+ 3		18.9	
84.2 5.6	Silt Occ. Clay Seams Loose	5	TW	PM		84.0 / 83.0	+ 1.2	NP		
	Grey	6	TW	PM		82.0 / 81.0	+ 3			
80.6 9.2	Silty Sand trace Gravel (Glacial Till) Compact to Very Dense	7	SS	12		80.0				
78.7	Grey	8	SS	101		79.0				1 92 (7)
11.1	End of Borehole									

DYNAMIC CONE PENETRATION RESISTANCE PLOT: 20 40 60 80 100

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

PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL — WATER CONTENT (%) 20 40 60

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No2

METRIC

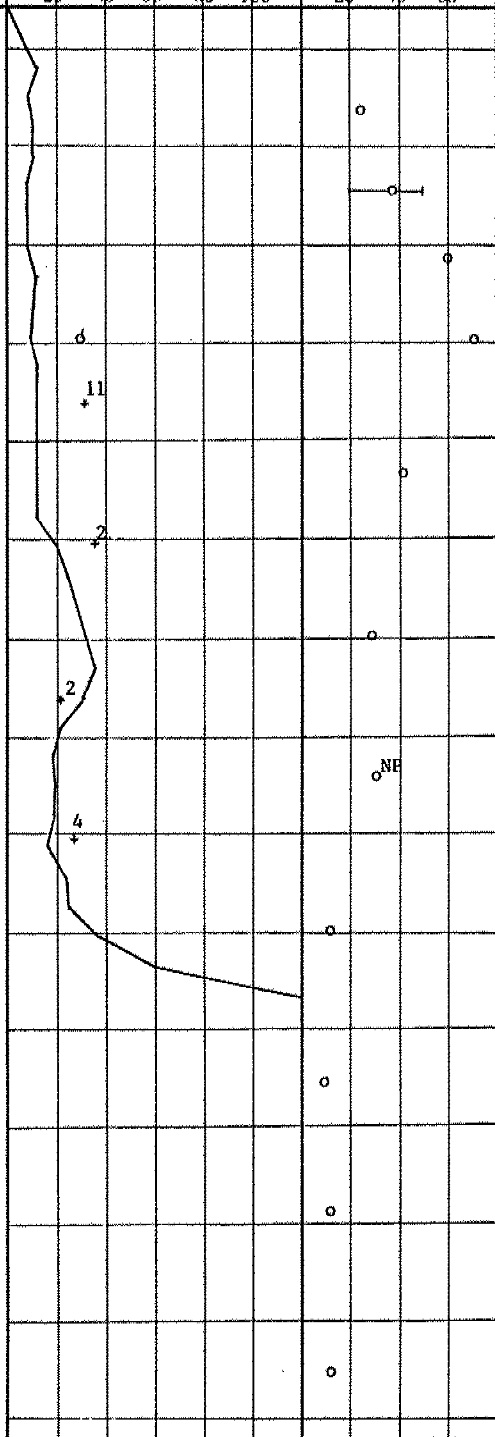
W P 187-89-04 LOCATION N: 5 005 086 ; E: 366 398 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 29 CHECKED BY C.M.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.4	Ground Surface								
0.0	250 mm Topsoil					90.0			
	Silty Clay to Clay Very Stiff to Stiff Desiccated Mottled Brown	1	SS	19					
		2	SS	11	▽	89.0			W.L. on 1990 10 29
	Firm	3	SS	4		88.0			
	Grey	4	TW	PM		87.0		15.1	
		5	TW	PM		86.0			
84.6						85.0			
5.8	Silt Occ.Clay Seams Loose	6	SS	4		84.0			
		7	SS	4		83.0	NP		
81.5	Grey					82.0			
8.9	Silty Sand with Gravel (Glacial Till)	8	SS	32		81.0			22 46 (32)
		9	SS	23		80.0			
	Compact to Very Dense	10	SS	100/17cm		79.0 / 78.0			
	Grey	11	SS	100/17cm		77.0 / 76.0			
75.7									
14.7	End of Borehole								

DYNAMIC CONE PENETRATION RESISTANCE PLOT / SHEAR STRENGTH kPa



PLASTIC LIMIT W_p — NATURAL MOISTURE CONTENT W — LIQUID LIMIT W_L

$+^3$, $\times^5$: Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3

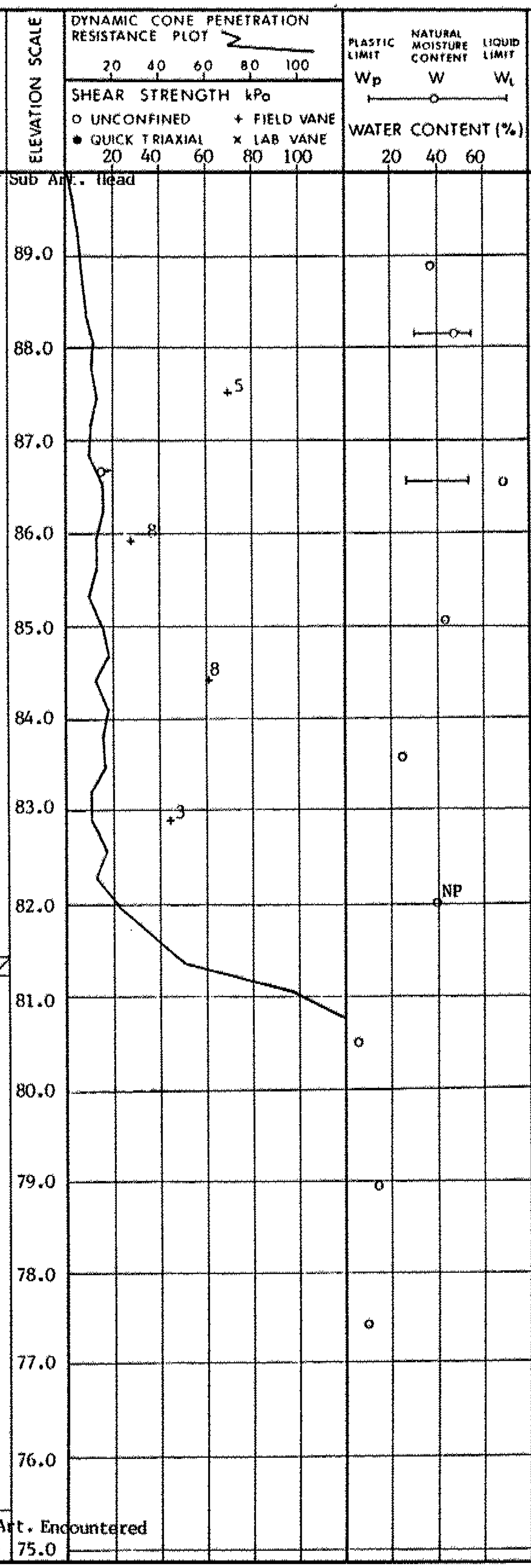
METRIC

W P 187-89-04 | LOCATION N: 5 005 061 ; E: 366 393 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 26 | CHECKED BY C.M.

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.9	Ground Surface						
0.0	250mm Topsoil Silty Clay to Clay Stiff to Firm Desiccated Mottled Brown	1	SS	10	Sub Art. Head		
		2	SS	4			W. L. on 1990 10 29
	Soft to Firm Grey	3	TW	PM		15.1	
85.4 4.5	Silt Occ. Clay Seams Loose to Compact Grey	4	TW	PH			
		5	TW	PH			
		6	SS	10	Seal		
81.0 8.9	Silty Sand some Gravel (Glacial Till) Very Dense Grey	7	SS	51			
		8	SS	100/10cm			14 45 (41)
		9	SS	100/20cm			
76.3 13.6	Limestone Bedrock Fractured	10	BX RC	Rec 75%	Sub Art. Encountered		RQD = 30%
74.9 15.0	Cont. on page 2	11	BX RC	Rec 90%			RQD = 22%



+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3 cont'd

METRIC

W P 187-89-04 | LOCATION N: 5 005 061 E: 366 393 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger ,Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 26 | CHECKED BY C.M.

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	PLASTIC LIMIT W_p NATURAL MOISTURE CONTENT W LIQUID LIMIT W_L / WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
74.9	Cont. from page 1										
15.0 / 74.1	Limestone Bedrock Fractured		12	BX RC	Rec 80%	Piezometer					RQD = 0%
15.8	End of Borehole										

$+^3, \times^5$: Numbers refer to Sensitivity

15 ⌖ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4 METRIC

W P 187-89-04 LOCATION N: 5 005 104 ; E: 366 380 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test COMPILED BY A. K.

DATUM Geodetic DATE 1990 10 30 CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.7	Ground Surface								
0.0	200mm Topsoil Silty Clay to Clay Firm Desiccated Mottled Brown				Sub Art. Head				W.L. on 1990 10 30
						90.0			
		1	SS	5					
	Soft to Firm	2	SS	6		89.0			
	Grey	3	SS	2		88.0			
		4	TW	PM				15.4	
						87.0			
86.3 / 4.4	Silt Occ. Clay Seams Very Loose Grey	5	TW	PM		86.0			
						85.0	NP		
		6	SS	1		84.0			
					Seal				
83.4 / 7.3	Silty Sand with Gravel (Glacial Till) V. Loose to V.Dense Grey					83.0			
		7	SS	2					22 41 (37)
						82.0			
		8	SS	36		81.0			
		9	SS	114/17cm		80.0			
						79.0			
		10	BX	Boulder		78.0			
		11	SS	58/23cm		77.0			
76.5 / 14.2	Limestone Bedrock Fractured	12	BX RC	Rec 37%	Sub Art. Encountered	76.0			RQD = 0 %
75.7 / 15.0									

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE (20 40 60 80 100). PLASTIC LIMIT W_p, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L (20 40 60). Field vane sensitivity values: 5, 5, 3, 2.

Continued on page 2

+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4 cont'd

METRIC

W P 187-89-04 LOCATION N: 5 005 104 ; E: 366 380 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 30 CHECKED BY C.M.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
75.7	Cont.from page 1										
15.0	Limestone Bedrock Fractured		12	BX RC	Rec 37%		75.0				RQD = 0%
							74.0				
			13	BX RC	Rec 48%		73.0				RQD = 0%
			14	BX RC	Rec 50%	Standpipe	72.0				RQD = 0 %
71.3 19.4	End of Borehole										

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 5

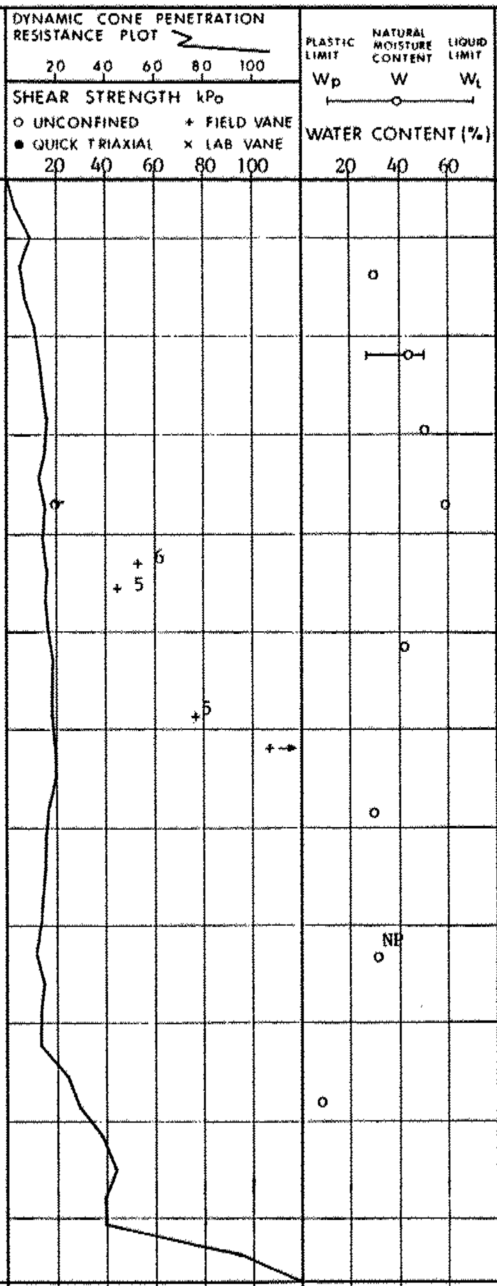
METRIC

W P 187-89-04 | LOCATION N: 5 005 094.5 ; E: 366 374 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetrarion Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 30 | CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	SAMPLES: NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.6	Ground Surface							
0.0	350mm Topsoil Silty Clay to Clay Firm Desiccated Mottled Brown					90.0		
		1	SS	6				
	Soft to Firm	2	SS	6		89.0		
	Grey	3	SS	2	▽	88.0		W.L. on 1990 10 30
		4	TW	PM		87.0	15.5	
86.2 / 4.4	Silt occ. Clay Seams Very Loose Grey	5	TW	PM		86.0		
						85.0		
		6	SS	2		84.0		
						83.0		
		7	SS	*		82.0		
81.6 / 9.0	Silty Sand some Gravel (Glacial Till) Compact Grey	8	SS	12		81.0		15 45 (40)
						80.0		
79.4 / 11.2	End of Borehole Probable Bedrock * Penetrated by weight of Hammer and Rods							



+³, ×⁵ : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

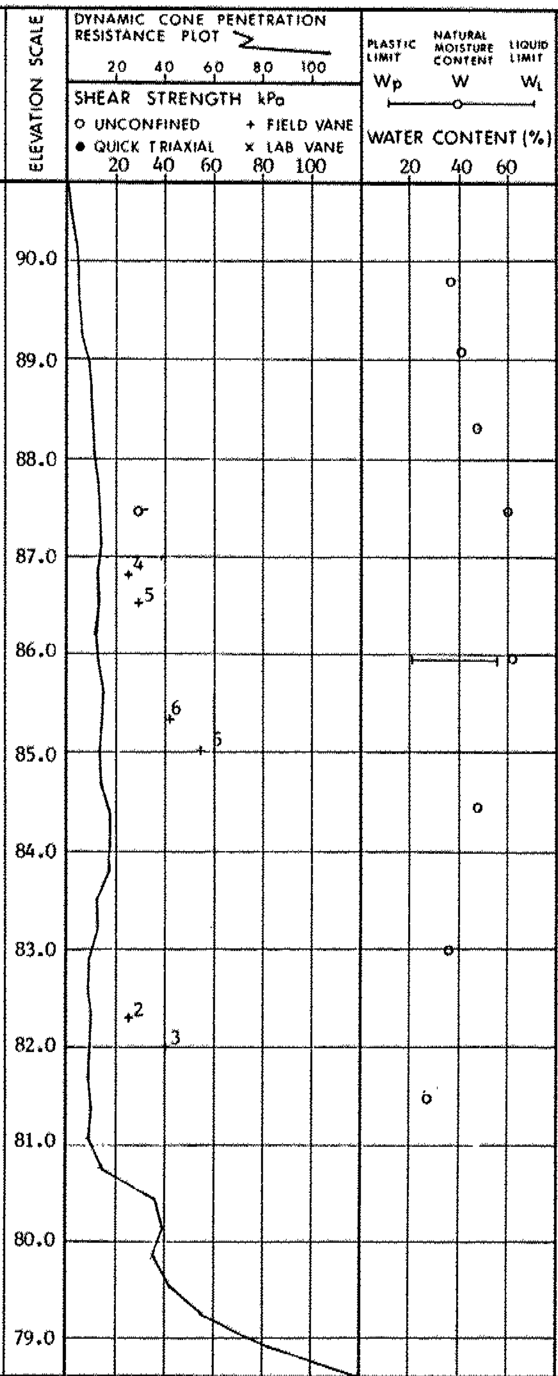
RECORD OF BOREHOLE No 6 — METRIC

W P 187-89-04 | LOCATION N: 5 005 111 : E: 366 366 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 26 | CHECKED BY G.M.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.8	Ground Surface						
0.0	300mm Topsoil; Silty Clay to Clay, Firm, Desiccated, Mottled Brown	1	SS	6			
		2	SS	6			
	Firm	3	SS	4	▽		W.L. on 1990 10 30
	Grey	4	TW	PM		15.8	
85.6		5	SS	4			
5.2	Silt, Occ. Clay Seams, Loose, Grey	6	TW	PM			
81.9		7	SS	5			
8.9	Silty Sand some Gravel (Glacial Till), Compact, Grey	8	SS	18			10 53 (37)
78.6 / 12.2	End of Borehole						

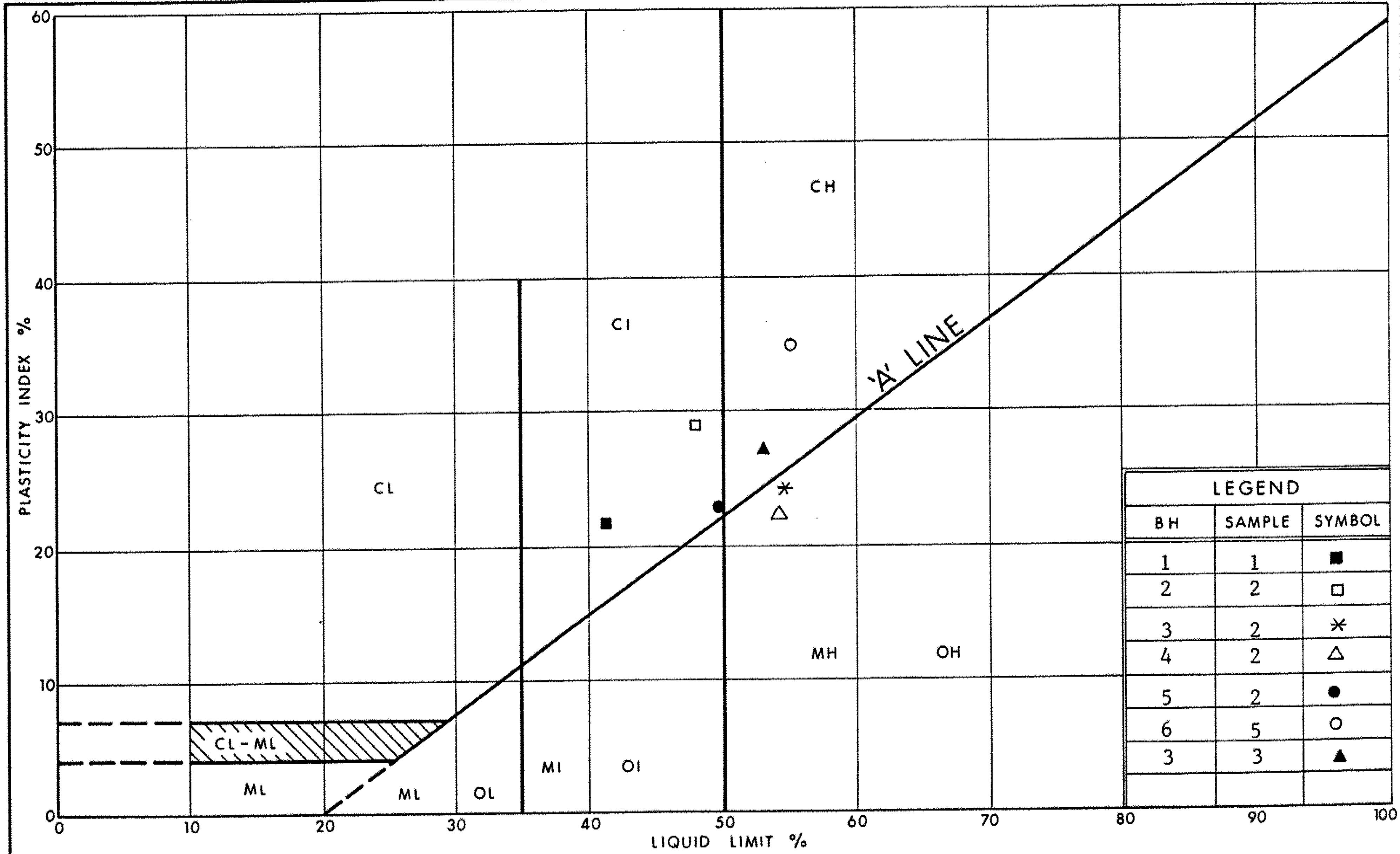


+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Oct 75, FF-S-21



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PLASTICITY CHART

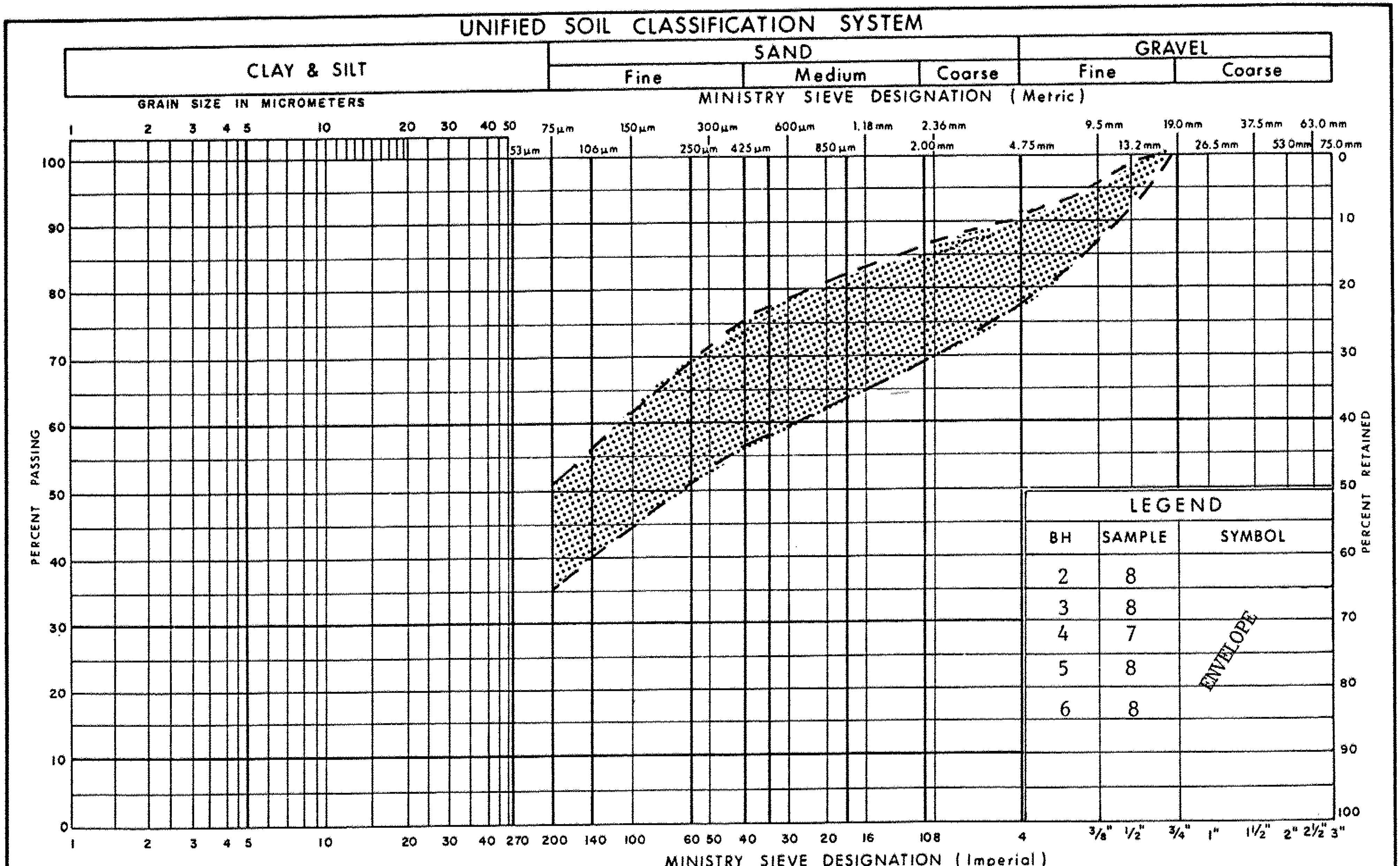
Silty Clay to Clay

FIG No 1

W P 187-89-04

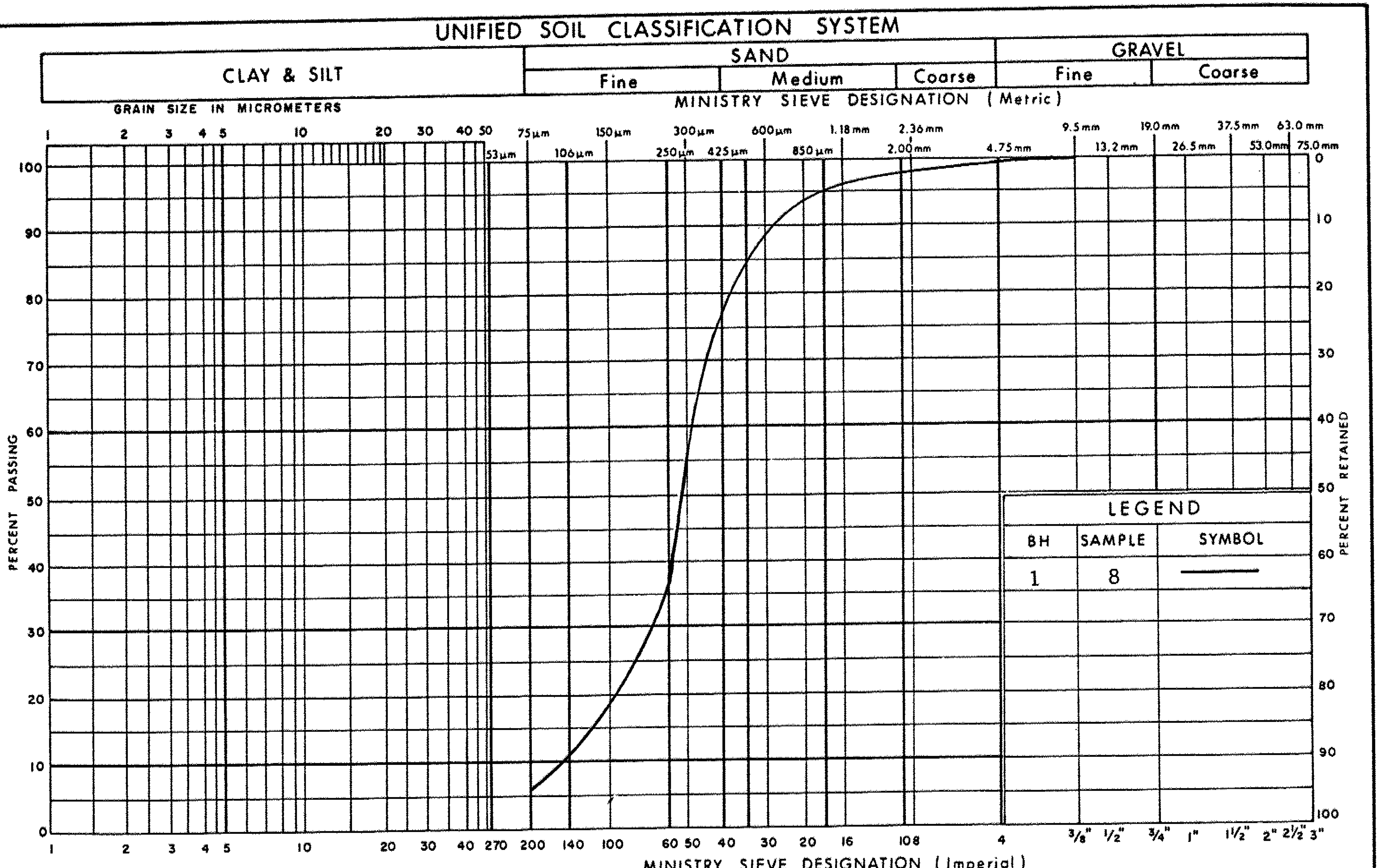
Mud Creek Bridge

78 12 M



Ministry of Transportation Ontario	GRAIN SIZE DISTRIBUTION	FIG No 2A
	Silty Sand with some Gravel (Glacial Till)	W P 187-89-04
		Mud Creek Bridge

78 12 M



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GRAIN SIZE DISTRIBUTION

Silty Sand trace Gravel
(Glacial Till)

FIG No	2B
W P	187-89-04
Mud Creek Bridge	

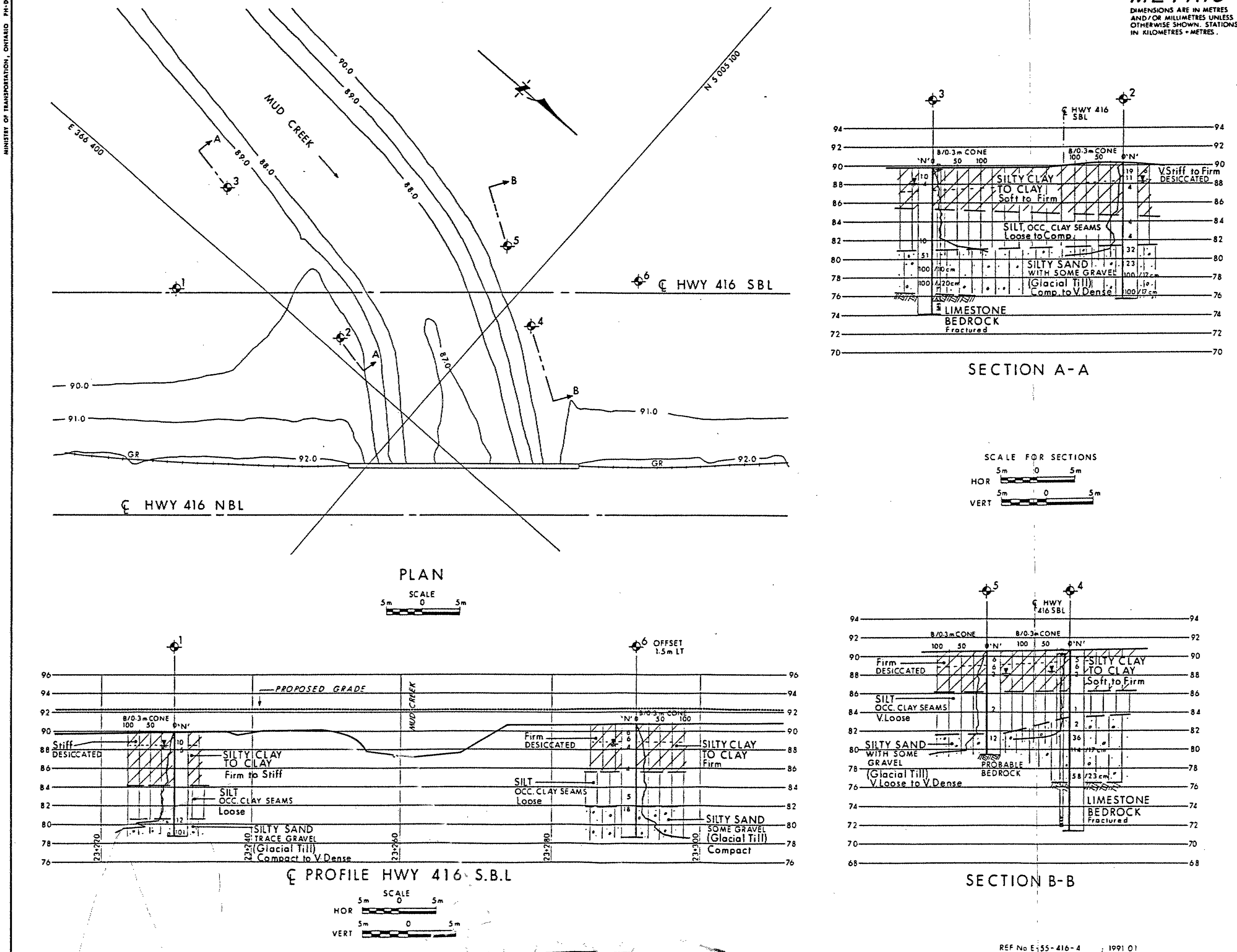
MUD CREEK
BORE HOLE LOCATIONS & SOIL STRATA

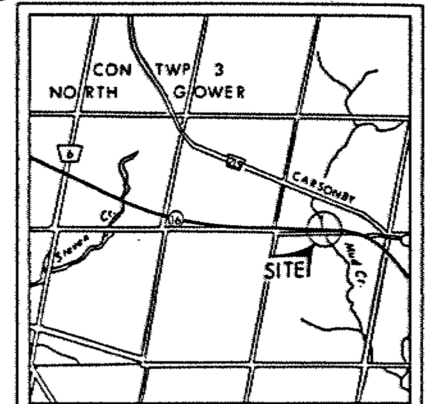
CONT No
WP No 187-89-04

SHEET

STRATA ENGINEERING CORP.

METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.





KEY PLAN
SCALE
1km 0 1 2km

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- WL at time of investigation Oct 1990
- Stand Pipe; Head; SUB ARTESIAN WATER Encountered

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	89.8	5 005 065.0	366 407.5
2	90.4	5 005 086.0	366 398.0
3	89.9	5 005 061.0	366 393.0
4	90.7	5 005 104.0	366 380.0
5	90.6	5 005 094.5	366 374.0
6	90.8	5 005 111.0	366 366.0

=NOTE=
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100

REV.	DATE	BY	DESCRIPTION

Geocres No 31G-215

HWY No 416			DIST 9
SUBM'D A A	CHECKED	DATE May 05 1991	SITE 3-358/2
DRAWN A K	CHECKED	APPROVED	DWG 1878934-A

DOCUMENT MICROFILMING IDENTIFICATION

G.I.-30 SEPT. 1976

GEOCRES No. 31G-215

DIST. 9 REGION

W.P. No. 187-89-04

CONT. No. 96-07

W. O. No.

STR. SITE No. 3-358/2

HWY. No. 416

LOCATION Hwy 416 @ Mud Creek Bridge

No of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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FOUNDATION INVESTIGATION REPORT
for
Mud Creek Bridge

W.P. 187-89-04, District 9, Ottawa
Highway 416, Str. Site: 3-358/2

GEOCRES # 31G-215

Strata Project: E-90-037B

Date of Submission: 1992 04 07

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Nature, to be commanded. must be obeyed

E-90-037B

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FOUNDATION INVESTIGATION REPORT
for
Mud Creek Bridge

W.P. 187-89-04, District 9, Ottawa
Highway 416, Str. Site: 3-358/2

1.0 INTRODUCTION

Strata Engineering Corp. has been retained by UMA Engineering Ltd. to carry out a foundation investigation for the crossing of the proposed southbound lanes of Highway 416 and Mud Creek. The terms of reference were to investigate the site by means of sampled boreholes and dynamic cone penetration tests and to provide a full geotechnical report.

This report, which follows a letter report dated 1990 12 20, is submitted in compliance with these terms of reference.

2.0 SITE AND GEOLOGY

The site is located within Rideau Township approximately 30 km south of Ottawa along Highway 16. The location of the site is shown on the key plan in Drawing 1878904-A, appended. The proposed bridge centreline is approximately 30 m to the west of centreline of the existing structure at Highway 16.

The topography of the immediate area is flat. With the exception of a small wooded area to the west of the site, the land use is primarily agricultural. The creek flows within a channel some 4 m deep. The creek is approximately 10 m wide and 2 m deep in the vicinity of this site.

The site lies in the physiographic region known as the North Gower Drumlin field. The drumlins are oriented more or less north-south. A mantle of marine soils is draped over the drumlins and other glacial landforms. The marine soils are the result of inundation by the Champlain Sea. Therefore, silt and Leda clay are common in this area.

3.0 FIELD AND LABORATORY WORK

The field work, carried out from 1990 10 26 to 30, consisted of the drilling of six boreholes, each accompanied by a dynamic cone penetration test. Four boreholes were drilled at the corners of the proposed structure. The remaining two boreholes were drilled along centreline away from the structure to provide information for the approach fills. The borehole elevations, referenced to Geodetic datum, were supplied by UMA Engineering. The locations of the boreholes are shown on Drawing 1878904-A.

Drilling was conducted with two bombardier mounted CME 55 drill rigs. Hollow stem augers were used to advance the boreholes. Boreholes 1 and 6 for the approach embankments were terminated within the highest competent stratum. Boreholes 2 and 5 were terminated at auger refusal. Bedrock was cored in Boreholes 3 and 4.

Standard Penetration Tests were used to sample very dense materials as well as non-cohesive deposits, the accompanying N values being noted in blows/0.3 m. In cohesive strata, relatively undisturbed samples were obtained by pushing thin walled Shelby tubes either manually or hydraulically into the soil.

After the recovery of each thin walled tube sample, standard MTO A size vane tests were conducted to determine the undrained shear strength of the deposit. Remoulded shear strengths were also measured to determine the sensitivity of the soil.

Upon completion of each borehole the water levels were measured in the uncased holes. Boreholes 1, 2, 5 and 6 were backfilled with native soil cuttings. Bentonite sealed perforated standpipes were installed in Boreholes 3 and 4. The water level in these instrumented holes was monitored over a period of time. The site was restored to its original condition.

Recovered samples were transported to our Don Mills Laboratory for further visual examination, classification and index property testing such as moisture content, grain size distribution and Atterberg limits. Unconfined compression tests were performed on six thin walled tube samples. The results are shown on the Record of Boreholes and on Figures 1, 2A and 2B.

4.0 SUBSURFACE CONDITIONS

4.1 General

The soil stratigraphy consists of a silty clay to clay deposit overlying loose silt above a silty sand glacial till. Fractured limestone bedrock lies 11 m to 14.2 m below prevailing ground surface.

4.2 Surficial Organics

Topsoil (200 mm to 400 mm) was present at all borehole locations.

4.3 Silty Clay to Clay

A 4.2 m to 5.6 m thick deposit of silty clay to clay occurs below the topsoil.
The upper 1.5 m to 2.0 m of this deposit is desiccated. This upper desiccated crust is mottled brown and fissured. The moisture content in the crust ranged from 25 to 50 per cent, and lies between the liquid and plastic limits of the soil. One field vane test within the crust gave an undrained shear strength value of 68 kPa.

Below the desiccated zone the silty clay to clay is grey. The moisture content ranged from 70 to 40 per cent, generally decreasing with depth. Atterberg limits (Figure 1) indicate medium to high plasticity.

Field vane test undrained shear strength values ranged from 24 kPa to 58 kPa generally increasing with depth and decreasing moisture content, indicating a soft to firm consistency. The sensitivity of the soil is about 6 with extreme values of 2 and 11.

4.4 Silt

At about elevation 85 m to 86 m the silty clay to clay deposit is underlain by a grey silt deposit with thin clay seams. This stratum was 2.9 m to 4.6 m in total thickness at the drilled locations.

Field vane tests were carried out in this deposit in the belief that the soil was cohesive. However, when the recovered samples were examined, it was seen that the deposit was predominantly silt. Hence, any field vane values shown for this deposit have been discounted in stability analyses. The natural moisture content of the silt ranged from 20 to 50 per cent, the average being about 30 per cent. N values of 0 to 10 blows/0.3 m indicate the silt is very loose to compact.

4.5 Silty Sand (Glacial Till)

The silt stratum is underlain at a depth of about 9m below the prevailing ground surface by a silty sand with some gravel (glacial till). This deposit was fully penetrated in Borehole 3 where the thickness was 4.7 m and in Borehole 4 where it was 6.9 m.

Grain size curves are shown in envelope form in Figure 2A. A sandy zone is plotted on Figure 2B. N values in this deposit were between and 2 and 114 blows/0.3 m, generally increasing with depth. The lower N values were observed within the upper zones of the deposit and may be due to local re-working of the till. The dynamic cone penetration tests all terminated within this deposit. Based on these N values, the deposit is considered to be very dense with localized loose to compact zones near its surface. Cobbles are suspected to be present on the basis of observations in the field during drilling.

4.6 Limestone Bedrock

Limestone bedrock was proven in Boreholes 3 and 4. It is badly fractured with core recoveries of between 37% and 90%. The maximum RQD value was 30%, most values being 0% for each core run.

5.0 GROUNDWATER CONDITIONS

The phreatic level at the site corresponds more or less to the creek level. Observations are listed below:

Borehole	Ground Elev. (m)	W.L. Elev. (m)	Date
1	89.8	88.5	1990 10 30
2	90.4	88.3	1990 10 29
3	89.9	89.9	1990 10 29
4	90.7	90.3	1990 10 30
5	90.6	88.2	1990 10 30
6	90.8	88.5	1990 10 30

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct southbound lanes 30 m west of the existing Highway 16 which will be upgraded to a 4 lane freeway standard between Highway 401 and Ottawa. This will entail construction of a bridge across Mud Creek. The proposed structure is likely to be similar to the existing single span structure. The proposed embankment fill heights will be in the order of 3 m in height.

This investigation indicates the presence of topsoil overlying silty clay to clay above loose to compact silt. The silt overlies very dense silty sand glacial till above fractured limestone bedrock.

6.2 Structure Foundations

The presence of the silty clay stratum precludes the use of conventional spread footings for the proposed structure. Hence, a deep foundation is recommended.

Sub-artesian pressures within a competent lower bearing stratum preclude the use of caissons, due to difficulties associated with installation under such conditions. Therefore, steel H piles are recommended as the most appropriate deep foundation alternative for this site.

A minimum earth cover of 1.8 m should be provided to the underside of pile caps to protect against frost action.

Wing walls should be supported on end bearing piles unless they can be adequately cantilevered from the abutments. Due to the likely presence of cobbles at depth within the sand and gravel glacial till deposit it is recommended that the pile toes be reinforced.

The piles should be driven to bedrock. However if refusal is encountered above bedrock, the Hiley Dynamic Pile Driving formula should be used to determine the final founding elevation.

Steel H piles such as HP 310x110 are normally designed for the following axial load capacities:

Factored Axial Capacity in ULS	1600 kN
Axial Capacity at SLS Type II	1150 kN

However, the clay deposit which these piles will penetrate is sensitive and therefore subject to loss of strength after pile driving. The disturbed and softened clay surrounding the pile shafts will reconsolidate with time, causing negative skin friction loading on the piles. Therefore, it is recommended that the HP 310x110 steel H Piles be designed for the following axial capacities, to allow for downdrag loading:

Factored Axial Capacity in ULS	1400 kN
Axial Capacity at SLS Type II	950 kN

The piles should be driven with an energy not less than 50 kJ to achieve the intended capacities.

For pile length estimation, assume the pile toes to reach bedrock at about elevation 76.5 m. Some piles may go deeper where the bedrock is slightly below this elevation and some piles may hang up above this level within the very dense glacial till deposit. However, on average, a pile toe elevation of 76.5 m is adequate for pile length estimation. Should piles hang up in the glacial till, they can be easily cut off, after confirmation of their axial capacities by using the Hiley formula in accordance with MTO policy and practice.

6.3 Earth Pressures

Earth pressures should be computed as per sub-section 6-6.1.2.2 of the OHBD Code. A yielding foundation condition may be assumed. The granular A or B backfill should be in accordance with MTO Special Provision No. 109F03 (latest revision). The following parameters are recommended for granular backfill:

	Granular A	**Granular B**
Angle of Internal Friction, ϕ'	35.0°	30.0
Unit Weight (kN/m^3), γ	22.8	21.2

Surcharge effects, if any, should be computed as per Clause 6-6.1.2.4 of the OHBD Code.

6.4 Approach Embankments

The proposed profile grade at elev. 92.5 m results in a maximum fill height of 2.5 m. For fills of no more than 4 m, built with 2:1 slopes, no deep seated stability problems are anticipated.

All organic materials should be stripped before the placement of fill for the approaches. Total short and long term settlements under such embankment loading are estimated to be in the order of 25 mm - 30 mm.

6.5 Construction Considerations

The steel H piles may constitute a travel path for artesian flow. To prevent uncontrolled flow and consequent erosion and undermining, it is recommended that a 600 mm thick granular "A" filter-drainage blanket be provided below the pile cap, prior to pile driving, with suitable rip-rap cover to protect against surface erosion by high water.

Temporary excavations with side slopes of 1:1 may be made by open cut methods to maximum depths of 3 m within the silty clay stratum. Such side slopes will remain stable if (1) they are not surcharged with excavation spoil and (2) they are left open no longer than 24 hours. For longer exposure than 24 hours, the side slopes should be flattened to 1.5H : 1.0V.

Seepage into excavations made within the silty clay is expected to be minimal, and capable of being handled by pumping from sumps located within the excavation.

7.0 CLOSURE

The drilling was supervised by A. C. Abel. Drill rigs were rented from F. E. Johnston and Marathon Drilling companies, Ottawa.

Respectfully submitted:
STRATA ENGINEERING CORP.

A. C. Abel, M. Sc.
Project Engineer

REGISTERED PROFESSIONAL ENGINEER
C. MIRZA
PROVINCE OF ONTARIO

C. Mirza, P. Eng.
Senior Principal

ACA/lr

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APPENDIX

Explanation of Terms used in this Report

Records of Boreholes 1 to 6

Figures 1, 2A and 2B

Drawing 1878904-A

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 $\tilde{N}$.

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/0.3m)	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:

RQD (%)	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

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

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 $= \frac{c_u}{\tau_r}$

PHYSICAL PROPERTIES OF SOIL

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No1

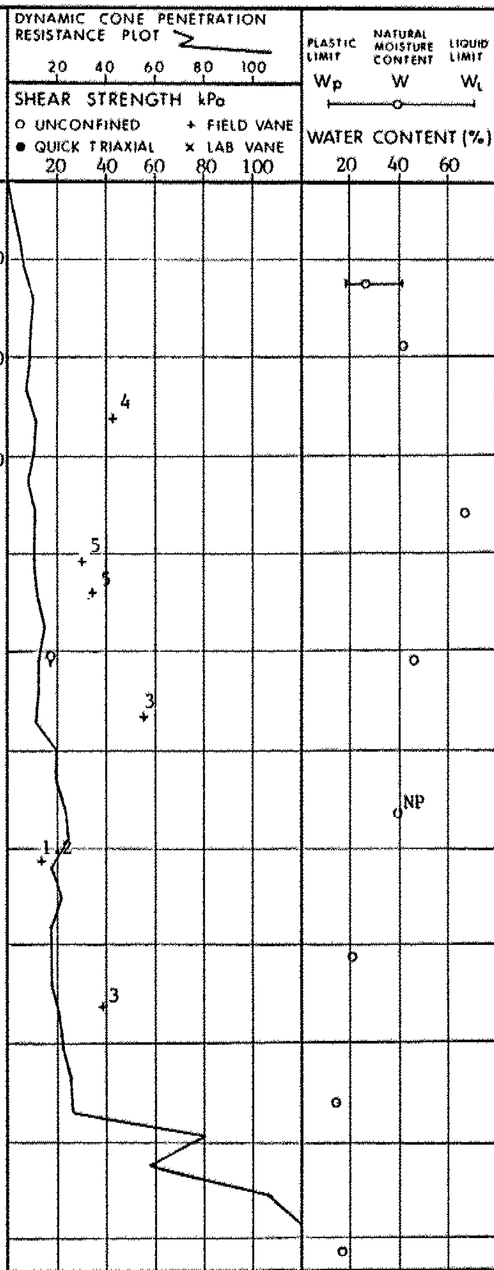
METRIC

W P 187-89-04 LOCATION N: 5 005 065 ; E: 366 407·5 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 26 CHECKED BY C.M.

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
89.8	Ground Surface								
0.0	200mm Topsoil; Silty Clay to Clay; Stiff; Desiccated; Mottled Brown	1	SS	10	▼	89.0			W.L. on 1990 10 30
	Firm to Stiff	2	SS	5		88.0			
	Grey	3	TW	PM		87.0 / 86.0			
84.2 / 5.6		4	TW	PM		85.0		18.9	
	Silt; Occ. Clay Seams; Loose	5	TW	PM		84.0 / 83.0	NP		
80.6	Grey	6	TW	PM		82.0 / 81.0			
9.2	Silty Sand trace Gravel (Glacial Till); Compact to Very Dense	7	SS	12		80.0			
78.7	Grey	8	SS	101		79.0			1 92 (7)
11.1	End of Borehole								



+³, ×⁵ : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No2

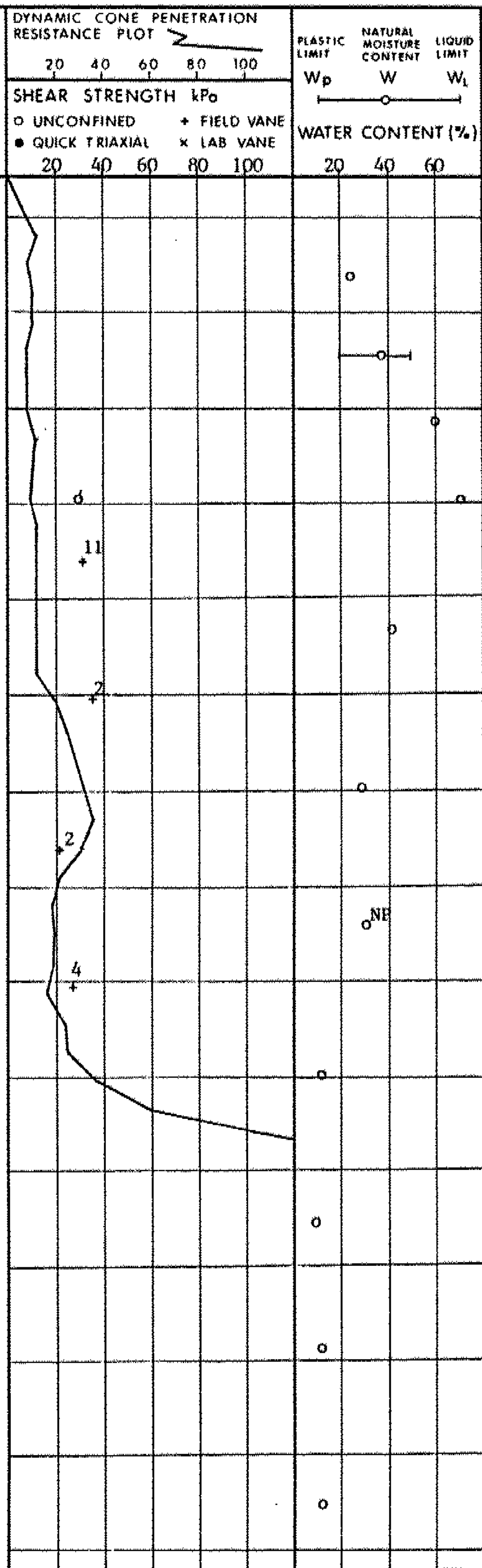
METRIC

W P 187-89-04 LOCATION N: 5 005 086 ; E: 366 398 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 29 CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.4	Ground Surface							
0.0	250 mm Topsoil					90.0		
	Silty Clay to Clay, Very Stiff to Stiff, Desiccated, Mottled Brown	1	SS	19		89.0		
		2	SS	11	▼			W.L. on 1990 10 29
	Firm	3	SS	4		88.0		
	Grey	4	TW	PM		87.0	15.1	
		5	TW	PM		86.0		
84.6 / 5.8	Silt, Occ.Clay Seams, Loose	6	SS	4		85.0 / 84.0		
81.5 / 8.9	Grey	7	SS	4		83.0 / 82.0		
	Silty Sand with Gravel (Glacial Till)	8	SS	32		81.0		22 46 (32)
	Compact to Very Dense	9	SS	23		80.0 / 79.0		
		10	SS	100/17cm		78.0		
	Grey	11	SS	100/17cm		77.0 / 76.0		
75.7 / 14.7	End of Borehole							



+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3

METRIC

W P 187-89-04 LOCATION N: 5 005 061 ; E: 366 393 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 26 CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	UNIT WEIGHT γ kN/m³
89.9	Ground Surface				Sub Art. Head			
0.0	250mm Topsoil; Silty Clay to Clay, Stiff to Firm, Desiccated, Mottled Brown	1	SS	10		89.0		
		2	SS	4		88.0	W. L. on 1990 10 29	
	Soft to Firm, Grey	3	TW	PM		87.0		15.1
85.4						86.0		
4.5	Silt, Occ. Clay Seams, Loose to Compact, Grey	4	TW	PH		85.0		
		5	TW	PH		84.0 / 83.0		
		6	SS	10	Seal	82.0		
81.0								
8.9	Silty Sand some Gravel (Glacial Till), Very Dense, Grey	7	SS	51		81.0 / 80.0		
		8	SS	100/10cm		79.0	14 45 (41)	
		9	SS	100/20cm		78.0 / 77.0		
76.3								
13.6	Limestone Bedrock, Fractured	10	BX RC	Rec 75%		76.0	RQD = 30%	
74.9 / 15.0	Cont. on page 2	11	BX RC	Rec 90%	Sub Art. Encountered	75.0	RQD = 22%	

Cont. on page 2

DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa: ○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE (20 40 60 80 100); PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL; WATER CONTENT (%) (20 40 60). Field vane sensitivities: +5 (approx. 87.6), +8 (approx. 86.0), +8 (approx. 84.5), +3 (approx. 82.9); sample 6: NP.

$+^3$, $\times^5$: Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 3 cont'd

METRIC

W P 187-89-04 | LOCATION N: 5 005 061 E: 366 393 | ORIGINATED BY A.A.

DIST 9 HWY 416 | BOREHOLE TYPE Hollow Stem Auger ,Dynamic Cone Penetration Test | COMPILED BY A.K.

DATUM Geodetic | DATE 1990 10 26 | CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE)	PLASTIC LIMIT W_p / NATURAL MOISTURE CONTENT W / LIQUID LIMIT W_L; WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
74.9	Cont. from page 1										
15.0 / 74.1	Limestone Bedrock Fractured		12	BX RC	Rec 80%	Piezometer					RQD = 0%
15.8	End of Borehole										

OFFICE REPORT ON SOIL EXPLORATION

$+^3$, $\times^5$: Numbers refer to Sensitivity

15 -○- 5 (20 above, 10 below) (%) STRAIN AT FAILURE

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4

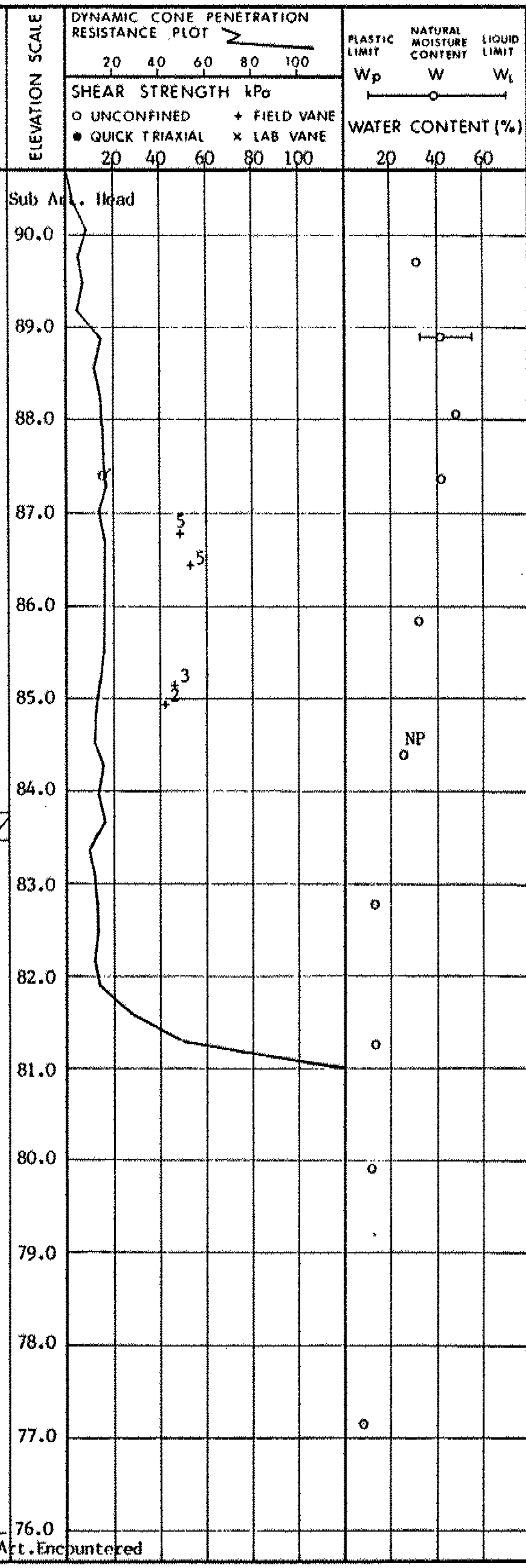
METRIC

W P 187-89-04 — LOCATION N: 5 005 104 ; E: 366 380 — ORIGINATED BY A.A.

DIST 9 HWY 416 — BOREHOLE TYPE Hollow Stem Auger , Dynamic Cone Penetration Test — COMPILED BY A. K.

DATUM Geodetic — DATE 1990 10 30 — CHECKED BY C.M.

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.7	Ground Surface						
0.0	200mm Topsoil Silty Clay to Clay Firm Desiccated Mottled Brown	1	SS	5	Sub Art. Head		W.L. on 1990 10 30
	Soft to Firm	2	SS	6			
		3	SS	2			
	Grey	4	TW	PM		15.4	
86.3 / 4.4	Silt Occ. Clay Seams Very Loose Grey	5	TW	PM			
		6	SS	1	Seal		
83.4 / 7.3	Silty Sand with Gravel (Glacial Till)	7	SS	2			22 41 (37)
	V. Loose to V.Dense	8	SS	36			
	Grey	9	SS	114/17cm			
		10	BX	Boulder			
76.5		11	SS	58/23cm			
14.2	Limestone Bedrock Fractured	12	BX RC	Rec 37%	Sub Art. Encountered		RQD = 0 %
75.7 / 15.0	Continued on page 2						



+3, ×5 : Numbers refer to Sensitivity

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

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4 cont'd — METRIC

W P 187-89-04 — LOCATION N: 5 005 104 ; E: 366 380 — ORIGINATED BY A.A.

DIST 9 HWY 416 — BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test — COMPILED BY A.K.

DATUM Geodetic — DATE 1990 10 30 — CHECKED BY C.M.

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100) / SHEAR STRENGTH kPa (○ UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × LAB VANE)	PLASTIC LIMIT Wp, NATURAL MOISTURE CONTENT W, LIQUID LIMIT WL — WATER CONTENT (%)	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
75.7	Cont. from page 1										
15.0	Limestone Bedrock Fractured		12	BX RC	Rec 37%	Standpipe	75.0				RQD = 0%
							74.0				
			13	BX RC	Rec 48%						RQD = 0%
							73.0				
			14	BX RC	Rec 50%		72.0				RQD = 0 %
71.3 / 19.4	End of Borehole										

$+^3$, $\times^5$: Numbers refer to Sensitivity — 20 / 15 ⌖ 5 / 10 (%) STRAIN AT FAILURE

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 5

METRIC

W P 187-89-04 LOCATION N: 5 005 094.5 ; E: 366 374 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 30 CHECKED BY C.M.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.6	Ground Surface								
0.0	350mm Topsoil; Silty Clay to Clay; Firm Desiccated Mottled Brown	1	SS	6		90.0			
	Soft to Firm	2	SS	6		89.0			
	Grey	3	SS	2	▽	88.0			W.L. on 1990 10 30
		4	TW	PM		87.0		15.5	
86.2 / 4.4	Silt occ. Clay Seams Very Loose Grey	5	TW	PM		86.0			
						85.0			
		6	SS	2		84.0			
		7	SS	*		83.0	NP		
81.6 / 9.0	Silty Sand some Gravel (Glacial Till) Compact Grey	8	SS	12		81.0			15 45 (40)
79.4 / 11.2	End of Borehole Probable Bedrock					80.0			

* Penetrated by weight of Hammer and Rods

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)

Field vane values with sensitivity: +6, +5, +5

Plastic Limit W_P — Natural Moisture Content W — Liquid Limit W_L (20 40 60)

$+^3$, $\times^5$: Numbers refer to Sensitivity

15 ⌖ 5 (%) STRAIN AT FAILURE (20 above, 10 below)

OFFICE REPORT ON SOIL EXPLORATION

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 6

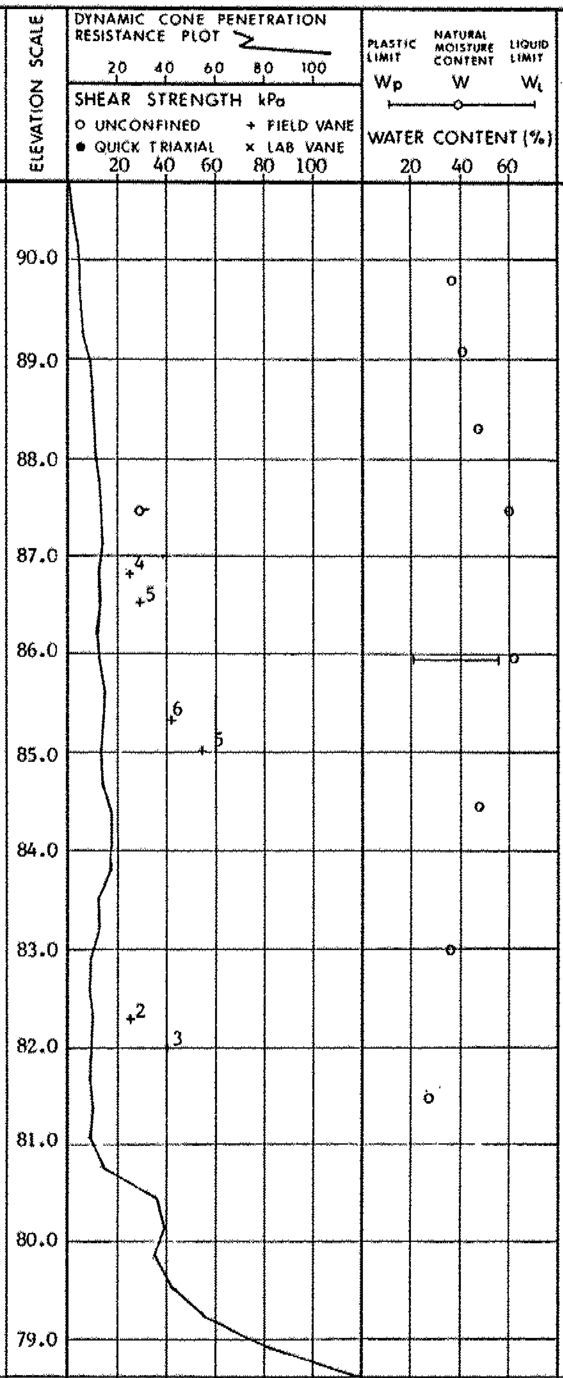
METRIC

W P 187-89-04 LOCATION N: 5 005 111 : E: 366 366 ORIGINATED BY A.A.

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test COMPILED BY A.K.

DATUM Geodetic DATE 1990 10 26 CHECKED BY C.M.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
90.8	Ground Surface						
0.0	300mm Topsoil Silty Clay to Clay Firm Desiccated Mottled Brown	1	SS	6			
		2	SS	6			
	Firm	3	SS	4	▽		W.L. on 1990 10 30
	Grey	4	TW	PM		15.8	
85.6		5	SS	4			
5.2	Silt Occ. Clay Seams Loose Grey	6	TW	PM			
81.9		7	SS	5			
8.9	Silty Sand some Gravel (Glacial Till) Compact Grey	8	SS	18			10 53 (37)
78.6 12.2	End of Borehole						

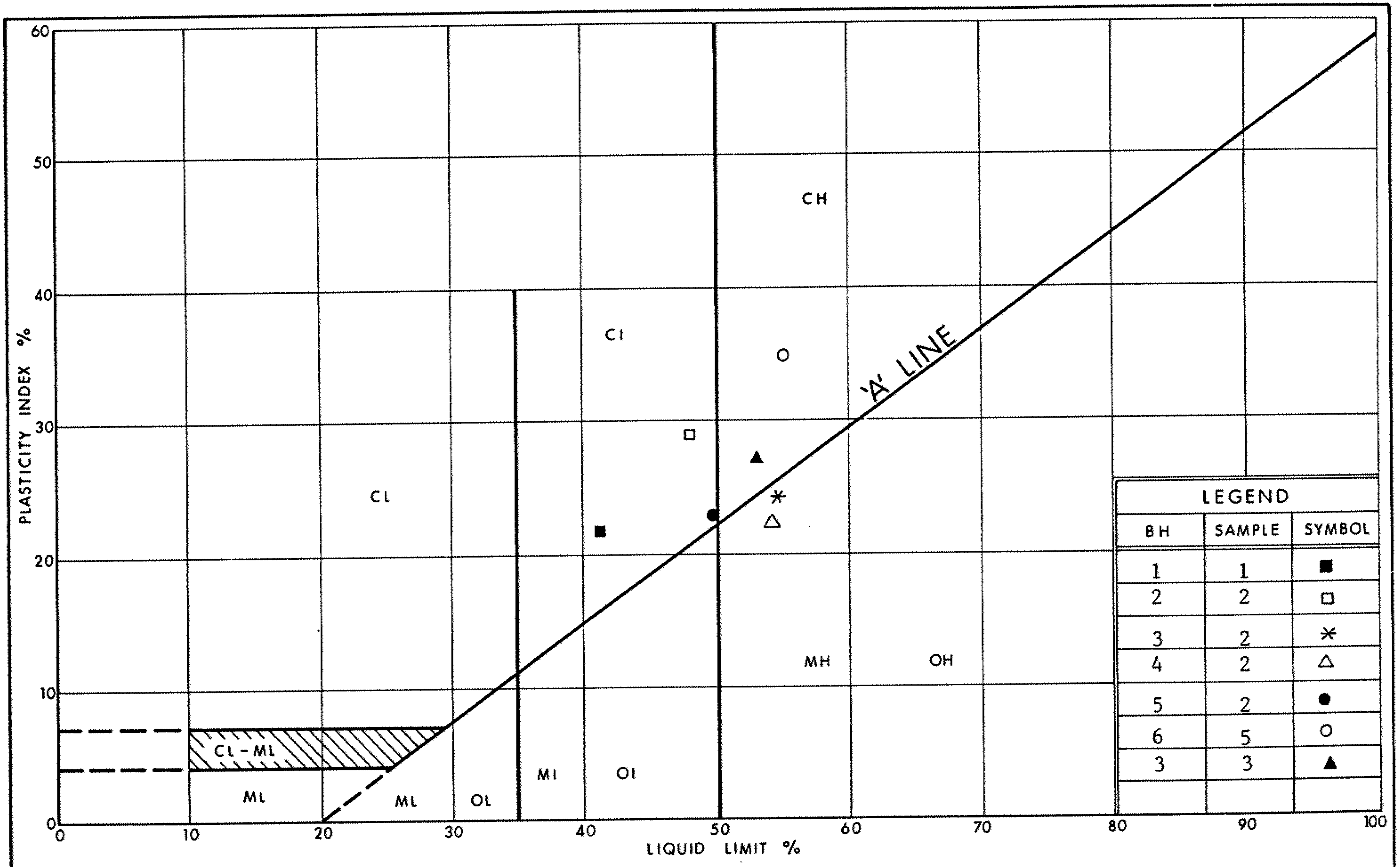


OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

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

Oct 75, FF-S-21



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Ontario

PLASTICITY CHART

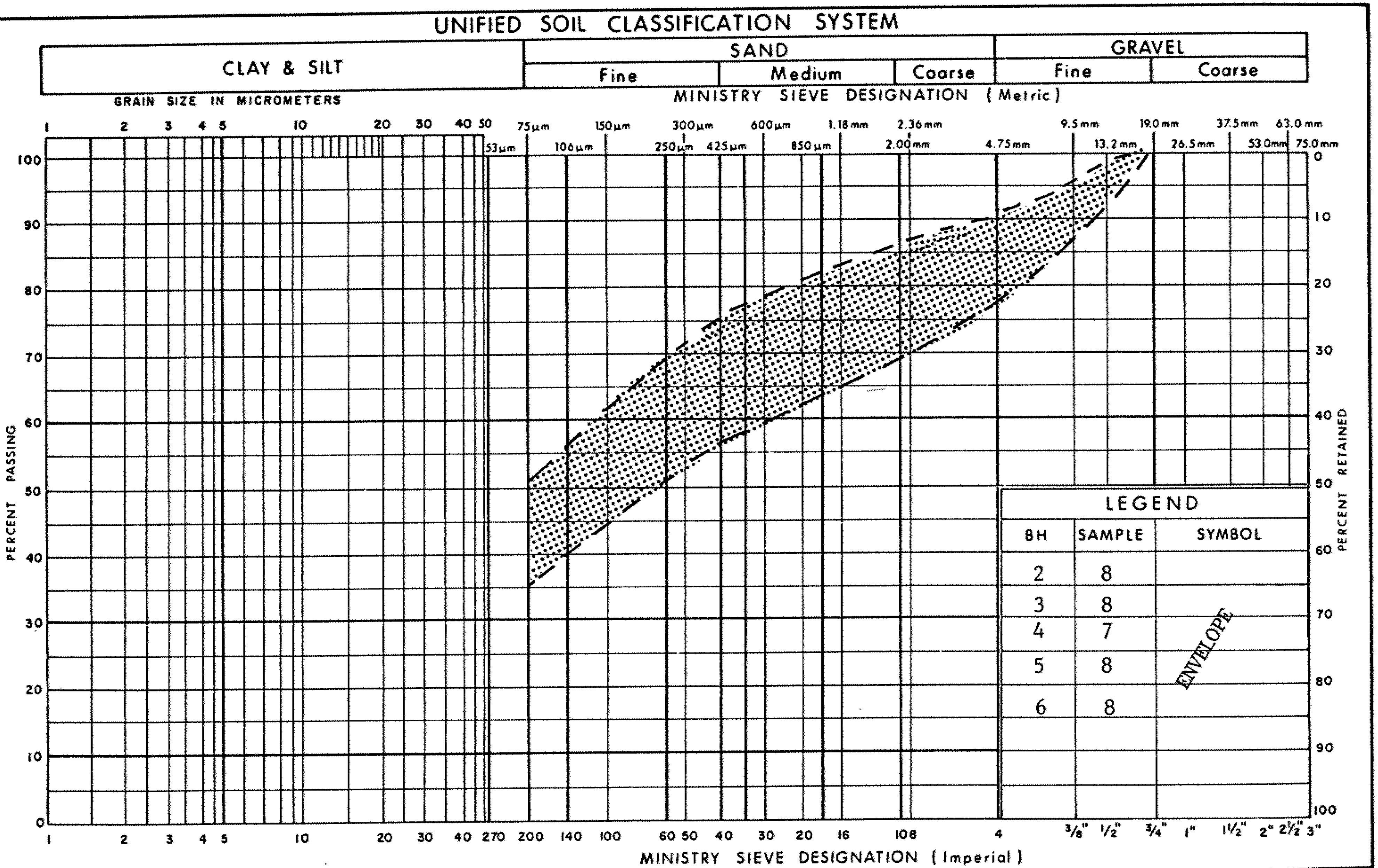
Silty Clay to Clay

FIG No 1

W P 187-89-04

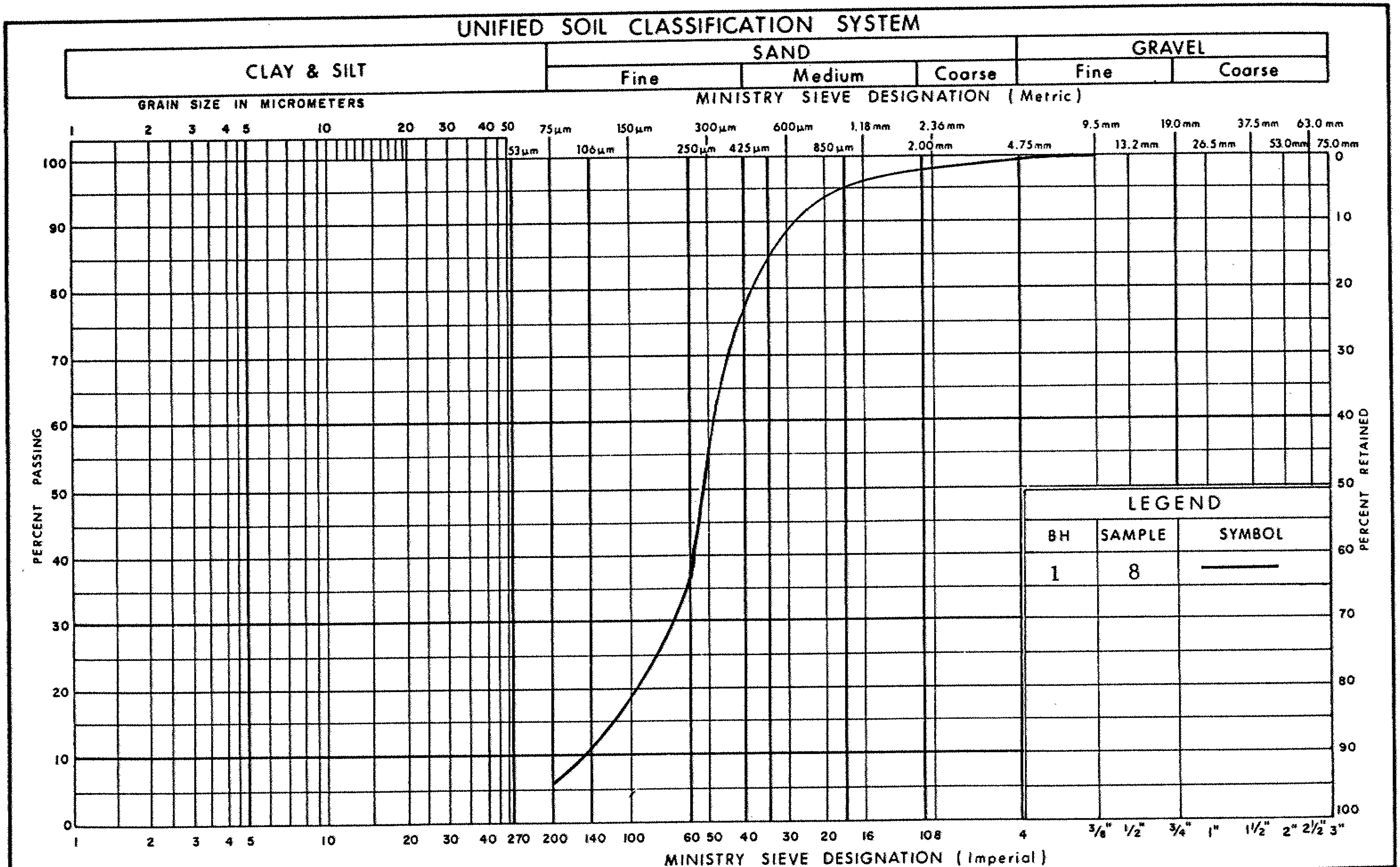
Mud Creek Bridge

78 12 M



Ministry of Transportation Ontario	**GRAIN SIZE DISTRIBUTION** Silty Sand with some Gravel (Glacial Till)	FIG No 2A W P 187-89-04 Mud Creek Bridge

78 12 M



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Ontario

GRAIN SIZE DISTRIBUTION

Silty Sand trace Gravel
(Glacial Till)

FIG No 2B

W P 187-89-04

Mud Creek Bridge

METRIC

DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

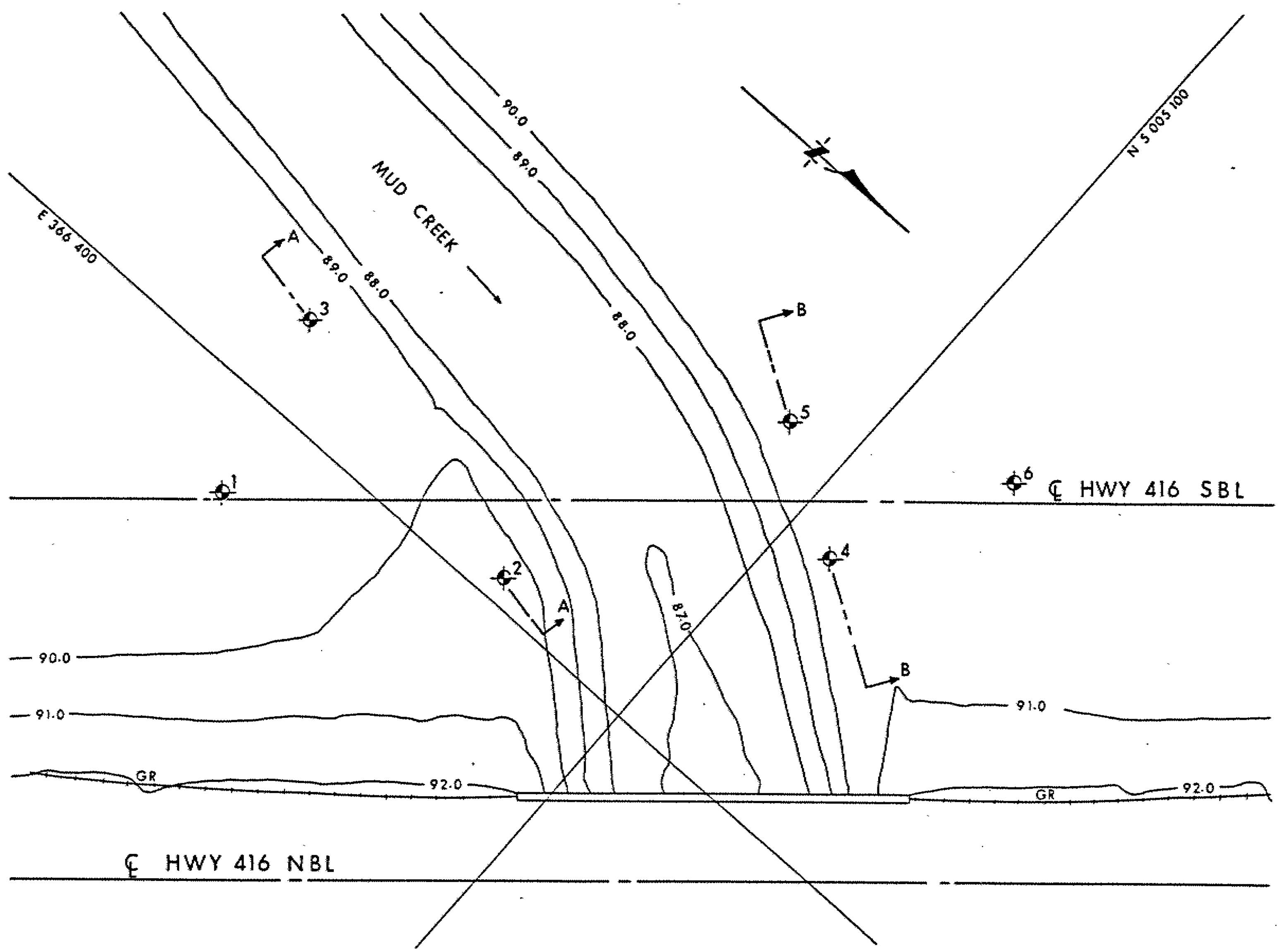
CONT No
WP No 187-89-04

SHEET

MUD CREEK

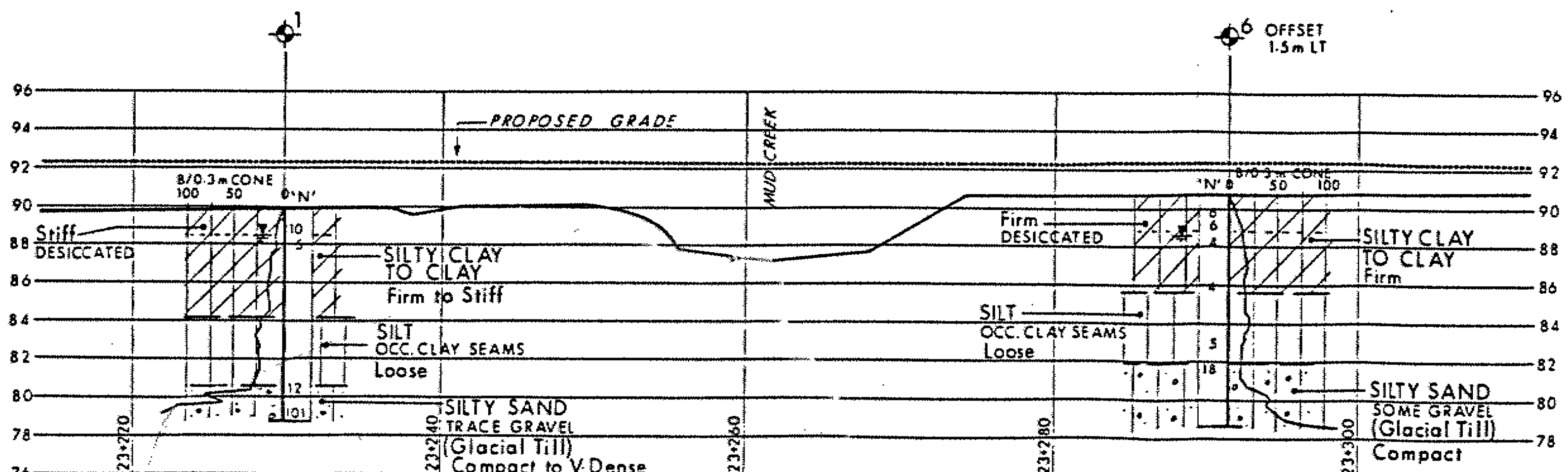
BORE HOLE LOCATIONS & SOIL STRATA

STRATA ENGINEERING CORP.



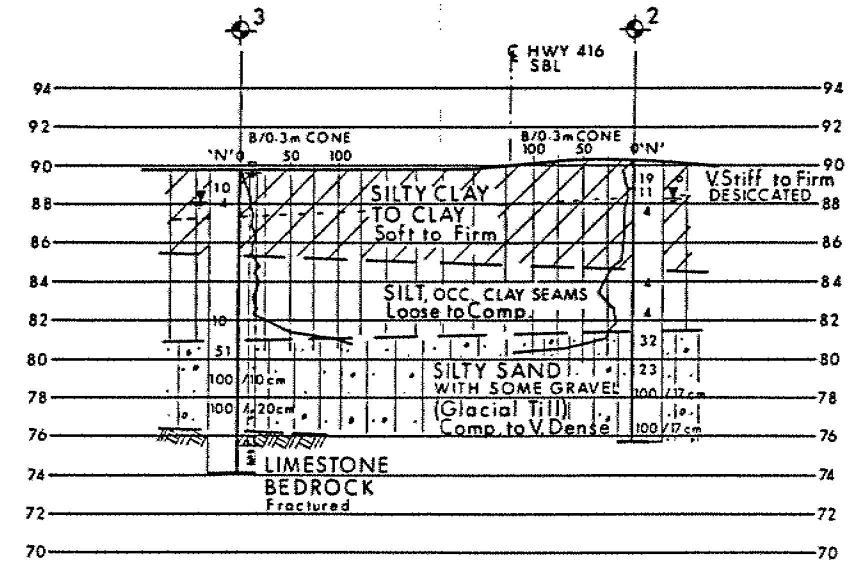
PLAN

SCALE 5m 0 5m



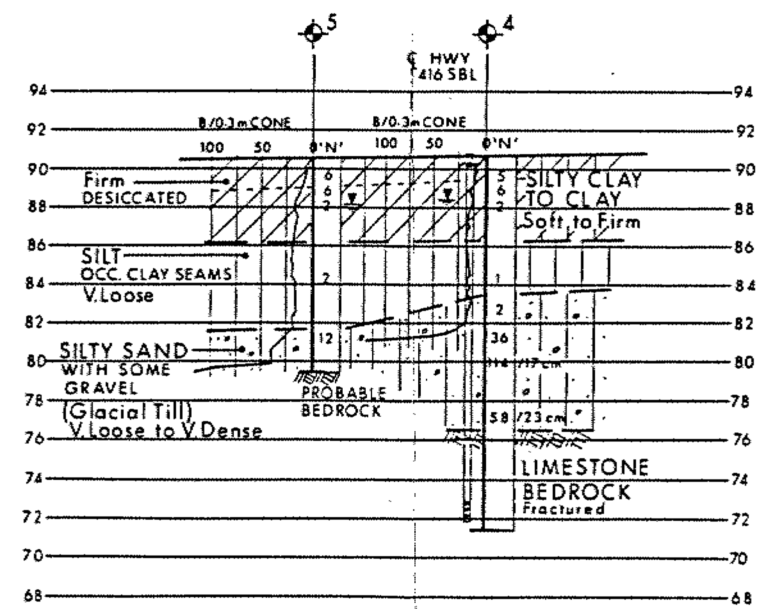
℄ PROFILE HWY 416 S.B.L

SCALE
HOR 5m 0 5m
VERT 5m 0 5m

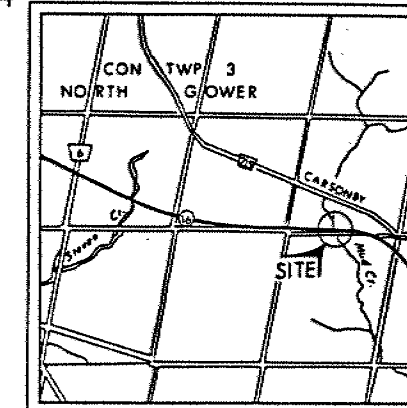


SECTION A-A

SCALE FOR SECTIONS
HOR 5m 0 5m
VERT 5m 0 5m



SECTION B-B



KEY PLAN

SCALE 1km 0 1 2km

LEGEND

- Bore Hole
- Dynamic Cone Penetration Test (Cone)
- Bore Hole & Cone
- N — Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE — Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation Oct 1990
- Stand Pipe — Head — SUB ARTESIAN WATER Encountered

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	89.8	5 005 065.0	366 407.5
2	90.4	5 005 086.0	366 398.0
3	89.9	5 005 061.0	366 393.0
4	90.7	5 005 104.0	366 380.0
5	90.6	5 005 094.5	366 374.0
6	90.8	5 005 111.0	366 366.0

NOTE

The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

NOTE: The complete foundation investigation and design report for this project and other related documents may be examined at the Engineering Materials Office, Downsview. Information contained in this report and related documents is specifically excluded in accordance with the conditions of Section 102-2 of Form 100.

REV.	DATE	BY	DESCRIPTION

Geocres No 31G-215

HWY No 416			DIST 9
SUBM'D A A	CHECKED	DATE May 05 1991	SITE 3-358/2
DRAWN A K	CHECKED	APPROVED	DWG 1878904-A

REF No E 55-416-4 1991 01