DOCUMENT MICROFILMING IDENTIFICATION

GEOCRES No. 316-214

DIST. 9 REGION

W.P. No. 187-89-03

CONT. No. 96-07

W. O. No.

STR. SITE No. 3-356/2

HWY. No. 416

LOCATION Hwy 416 & Steven Creek

No of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

G.I.-30 SEPT. 1976

STRATA ENGINEERING CORP.
RESEARCH . ENGINEERING . SCIENCE

Tel.: (416) 441-2560
Fax: (416) 441-4161

Suite ~~410~~ 122, 170 The Donway West,
Don Mills, Ontario, Canada M3C 2G3

FOUNDATION INVESTIGATION REPORT
for
Steven Creek Bridge

W.P. 187-89-03, District 9, Ottawa
Highway 416, Str. Site: 3-356/2

GEOCRES # 31G-21A

Strata Project: E-90-037A

Date of Submission: 1992 04 07

Report Distribution:

M.T.O.Foundations	13 copies
UMA Engineering	2 copies
McCormick Rankin	1 copy
Strata File E-90-037A	1 copy

Nature, to be commanded. must be obeyed

TABLE OF CONTENTS

FOUNDATION INVESTIGATION REPORT
for
Steven Creek Bridge

W.P. 187-89-03, District 9, Ottawa
Highway 416, Str. Site: 3-356/2

1.0 INTRODUCTION

Strata Engineering Corp. has been retained by UMA Engineering to carry out a foundation investigation for the crossing of the proposed southbound lanes of Highway 416 and Steven 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 in Rideau Township, some 35 km south of Ottawa along Highway 16. The location is shown in the key plan on Drawing 1878903-A, appended. The proposed bridge centreline is approximately 30 m west of the existing 20 m single span structure on Highway 16. At this location Steven Creek is approximately 12 m wide and 3 m deep. The flow is in an easterly direction towards the Rideau River. The south approach to this site is flat and clear of vegetation. The north approach is bush covered. A tributary stream flows from the northwest to join Steven Creek to the west of the existing bridge.

The site lies within the physiographic area known as the North Gower Drumlin Field. The drumlins have a north-south orientation. The area has been inundated by the Champlain Sea which has caused the drumlins to be covered with a mantle of marine soil, predominantly silt and Leda clay.

Bedrock in this area has been mapped as magnesium limestone to dolostone of the Oxford Formation, Lower Ordovician age.

Due to the undulating nature of the topography there are springs within the area. Water enters the soil in high ground, usually a glacial landform where the mantle of marine soil is relatively thin. Springs are frequently found where erosion has removed much of the cohesive overburden material. Artesian pressures exist at depth.

3.0 FIELD AND LABORATORY WORK

The field work, carried out between 1990 10 22 and 25, 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 other two holes were drilled for the north and south approach fills. The borehole elevations, referenced to Geodetic datum, were supplied by UMA Engineering. The locations of the boreholes are shown on Drawing 1878903-A.

Drilling was performed with bombardier mounted CME 55 drill rigs. Hollow stem augers were used to advance the boreholes. Boreholes 1 and 6 for the approaches were terminated within the highest competent stratum. Boreholes 3 and 4 for the structure were terminated at auger refusal. Bedrock was proven in Borehole 5 by diamond coring. It was intended to prove bedrock in Borehole 2, however artesian conditions required its premature termination.

Standard Penetration Tests were used to sample very dense or non-cohesive strata. 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 carried out to measure the undrained shear strength. Remoulded strengths were also determined to assess the sensitivity of the soil.

Upon completion of each borehole, water levels were measured in the uncased hole. Boreholes 1, 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 boreholes was monitored over a period of a week.

Borehole 2, in which high artesian pressures were present, was sealed with a polymer additive to stop the flow. Considerable difficulties were encountered in stemming the flow of water. Initial attempts resulted in the water finding a new path to the nearby cone test location, and upwards of two days were required to effect proper closure of all artesian conditions near this borehole.

Recovered soil samples were transported to our Don Mills Laboratory where they were visually examined and classified. Tests for index properties such as moisture contents, Atterberg Limits, and grain size analyses were performed on selected samples. Unconfined compression tests were conducted on seven of the thin walled samples. One consolidation test was also performed. The test results are given on the Record of Boreholes and on Figures 1 to 4 in the Appendix.

4.0 SUBSURFACE CONDITIONS

4.1 General

The soil stratigraphy consists of silt with trace organics overlying a sensitive silty clay to clay deposit above a silt stratum. The silt is underlain by a very dense sand and gravel glacial till. Limestone bedrock is fractured.

Details are provided below.

4.2 Silt, Trace Organics

Where present, there is some 400 mm of topsoil. Closer to the banks of the creek there is up to 1.4 m of brown silt with trace of organics. The moisture content ranged from 22 to 36 per cent. N values ranged from 2 to 17 blows/0.3 m indicating the consistency to range between soft and stiff.

4.3 Silty Clay to Clay

A silty clay to clay deposit was found below the topsoil or surficial silt with trace of organics. Its thickness varied from 6.2 m to 9.1 m, with its base between 76 m and 78 m. The silt content increases with depth.

The moisture content of this material generally increases with depth down to elev. 81±m below which the moisture content decreases. A desiccated crust is present in Boreholes 4, 5 and 6. Atterberg limit tests (Figure 1) indicate a medium to high plasticity for this soil. Below the desiccated crust, the moisture content is generally higher than the liquid limit, resulting in a liquidity index of 1 or greater.

N values ranged from 0 to 10 blows/0.3 m. The higher values being in the upper desiccated crust which has a lower moisture content.

Field vane tests indicate undrained shear strengths of 15 kPa to 48 kPa, generally increasing with depth at a c_u/p_o ratio of about 0.28. The sensitivity of the silty clay was found to be between 5 and 9 with a couple extreme values of 3 and 22. Unconfined compression test values ranged from 12 kPa to 30 kPa. Based on the measured undrained shear strengths, the deposit has an overall consistency ranging from soft to firm.

The result of one consolidation test carried out on a 75 mm sized thin walled tube sample is shown on Figure 2. The preconsolidation pressure, p_c, is 160 kPa±. The recompression index, C_r is 0.04 and the compression index, C_c, is 1.7.

4.4 Silt

Silt, ranging in thickness from 1.4 m to 3.0 m, is present below the silty clay to clay stratum. This deposit is non homogenous and contains inclusions of silty clay which diminish with depth. The sand content increases with depth.

The moisture content of the silt ranged from 20 to 38 per cent, the higher values being associated with the presence of the clay inclusions. Atterberg limit tests show the soil to be non-plastic. One grain size curve is shown on Figure 3.

Vane tests were attempted in this deposit in the belief that it was a plastic soil. However the thin walled tube samples taken in this stratum reveal the soil to be silt. Therefore, the reported vane shear strength values are not an appropriate indicator of strength for this deposit. N values of 0 to 13 blows/0.3 m indicate the soil to be very loose to compact.

4.5 Sand and Gravel (Glacial Till)

Below elev. ±75 m the silt deposit is underlain by a glacial till consisting of a mixture of sand and gravel with traces of silt and clay. The moisture content ranged from 5 to 20 per cent, with an average of 10 per cent. Grain size distribution curves are shown on Figure 4 and indicate a composition ranging from uniform fine to medium sand to well graded sand and gravel. N values in this glacial till deposit ranged from 10 to 59 blows/0.3 m indicating it to be compact to very dense.

4.6 Limestone Bedrock

Limestone bedrock was encountered at elevations of 71 m to 72 m and was proven by coring in Borehole 5. It is thinly bedded with recoveries ranging from 77 % to 100 %, the RQD values were all below 18 % indicating very poor quality.

5.0 GROUNDWATER CONDITIONS

In boreholes close to the stream, the water levels were the same as those of the stream, which was at elev. 86.1 m on 1991 10 24.

The sand and gravel deposit above the bedrock is under artesian pressure, with the water level rising to elev. 87.0 m, some 1+m above ground surface.

Water level observations are summarized below:

Borehole	**W.L. Elev.** (m)	**Art. W.L.** (m)	**Date**
1	86.2	-	1990 10 22
2	86.0	87.0	1990 10 23
3	86.1	87.0	1990 10 24
4	86.2	-	1990 10 26
5	86.0	87.0	1990 10 26
6	86.0	-	1990 10 26

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct southbound lanes 30 m to the west of the existing Highway 16 which will be upgraded to 4 lane freeway standards between Highway 401 and Ottawa. This will entail the construction of a bridge across Steven Creek.

The proposed structure is expected to be similar to the existing single span structure below the present highway. Approach fill heights are proposed to be in the order of 4 to 5 m.

This investigation indicates the presence of a surficial organic layer overlying a soft silty clay to clay above a loose silt. The silt overlies a compact to very dense sand and gravel glacial till stratum in contact with a fractured limestone bedrock. Groundwater in the sand and gravel deposit is under artesian pressure.

6.2 Structure Foundations

The presence of weak and relatively compressible soils near the surface precludes the use of conventional spread footings for the structure. A deep foundation is therefore required.

Due to artesian conditions at depth, caissons seated within the bedrock may not be feasible, owing to potential dewatering and artesian flow control problems. Therefore, steel H piles driven to bedrock or within the glacial till stratum are recommended.

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.

Normally, steel H piles such as HP 310 x 110 are 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 of 50 kJ or more to achieve the required capacities.

For pile length estimation, assume the pile toes to reach bedrock at about elevation 72 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 72 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 Provisions No. 109F03 (latest revision). The following parameters are recommended for the 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 Fills

Organic materials at the shoreline should be excavated from below the limits of the approach fills down to the silty clay to clayey silt stratum. Subexcavated areas should be backfilled with Granular B or other non-cohesive granular materials.

Fills no higher than 6 m may be built with 2:1 side slopes. For such fills, the undrained shear strength (Figure 5) profile shows no danger of deep-seated instability. The estimated total settlement of the final embankment is estimated to be in the order of 30 mm after construction.

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 stratum is expected to be minimal and capable of being handled by pumping from sumps located within the excavation.

7.0 CLOSURE

The field work was supervised by A. C. Abel. The drilling equipment was rented from F. E. Johnston and Marathon Drilling companies, Ottawa.

Respectfully Submitted:
STRATA ENGINEERING CORP.

ac abel
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:

M.T.O.Foundations	13 copies
UMA Engineering	2 copies
McCormick Rankin	1 copy
Strata File E-90-037A	1 copy

APPENDIX

Explanation of Terms used in this Report

Record of Boreholes 1 to 6

Figures 1 to 4

Drawing 1878903-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 (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

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

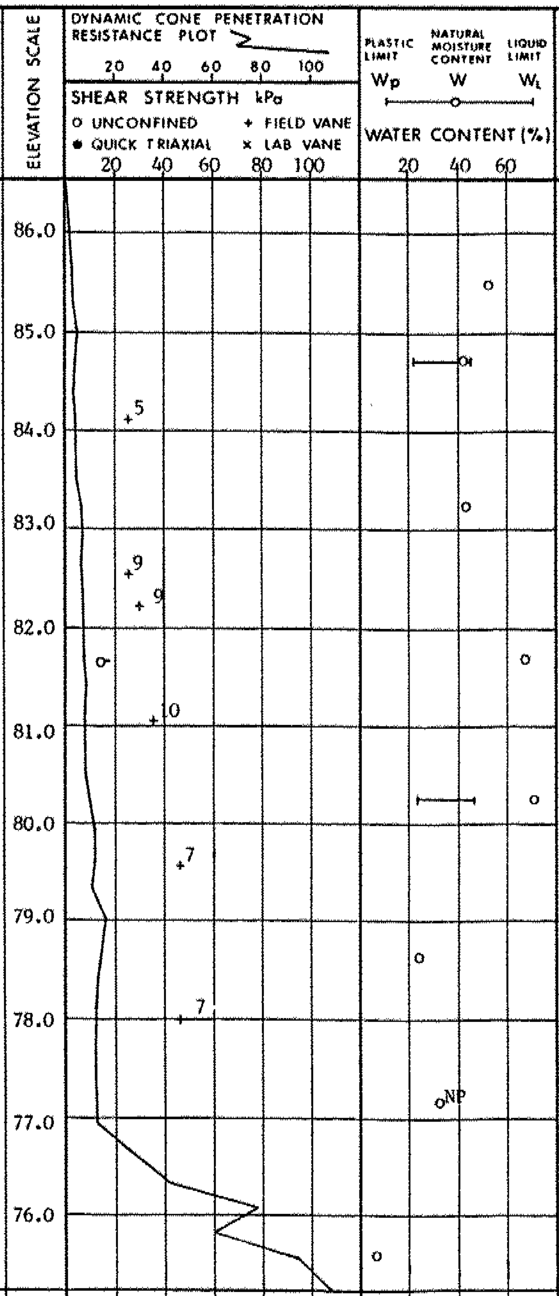
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No1

METRIC

W P 187-89-03
LOCATION N: 5 001 962.8 ; E: 368 833.0
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 22
CHECKED BY G.M.

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.5	Ground Surface						
0.0	350mm Topsoil				▽		W. L. on 1990 10 22
	Silty Clay to Clay	1	SS	2			
		2	SS	2			
	Soft to Firm	3	TW	PM			
		4	TW	PM		15.2	
	Grey	5	TW	PH			
		6	TW	PH			
77.4 9.1	Silt with Clay Inclusions V. Loose Grey	7	SS	*			
76.0 10.5	Sand and Gravel (Glacial Till) Dense Grey	8	SS	46			37 53 (10)
75.2 11.3	End of Borehole * Penertrated by weight of Hammer and Rods						



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

20
15 ⊕ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation
Ontario

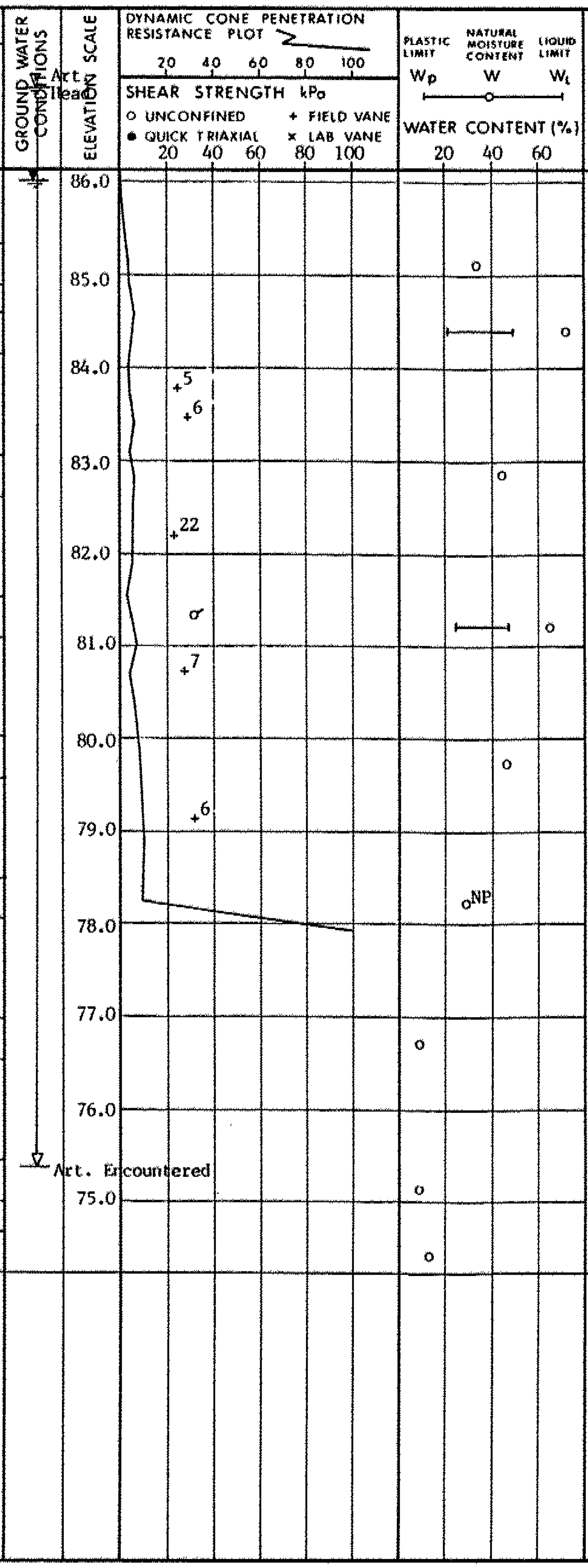
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 2

METRIC

W P 187-89-03
LOCATION N: 5 001 982.5 E: 368 832.5
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 23
CHECKED BY C.M.

SOIL PROFILE			SAMPLES			UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES		
86.1	Ground Surface						
0.0	Silt trace Organics Soft Brown		1	SS	2		W. L. on 1990 10 23
84.8 1.3	Silty Clay to Clay Firm Grey		2	SS	*		
			3	TW	PM		
			4	TW	PM	15.4	
			5	TW	PH		
78.6 7.5	Silt with Clay Inclusions Loose Grey		6	TW	PH		
77.2 8.9	Sand and Gravel trace Silt (Glacial Till) Occ. Cobbles Compact to V. Dense Grey		7	SS	30		
			8	SS	36		30 62 (8)
74.2			9	SS	59		
11.9	End of Borehole * Penetrated by weight of Hammer and Rods						



+3, ×5 : Numbers refer to Sensitivity

20 15 -○- 5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

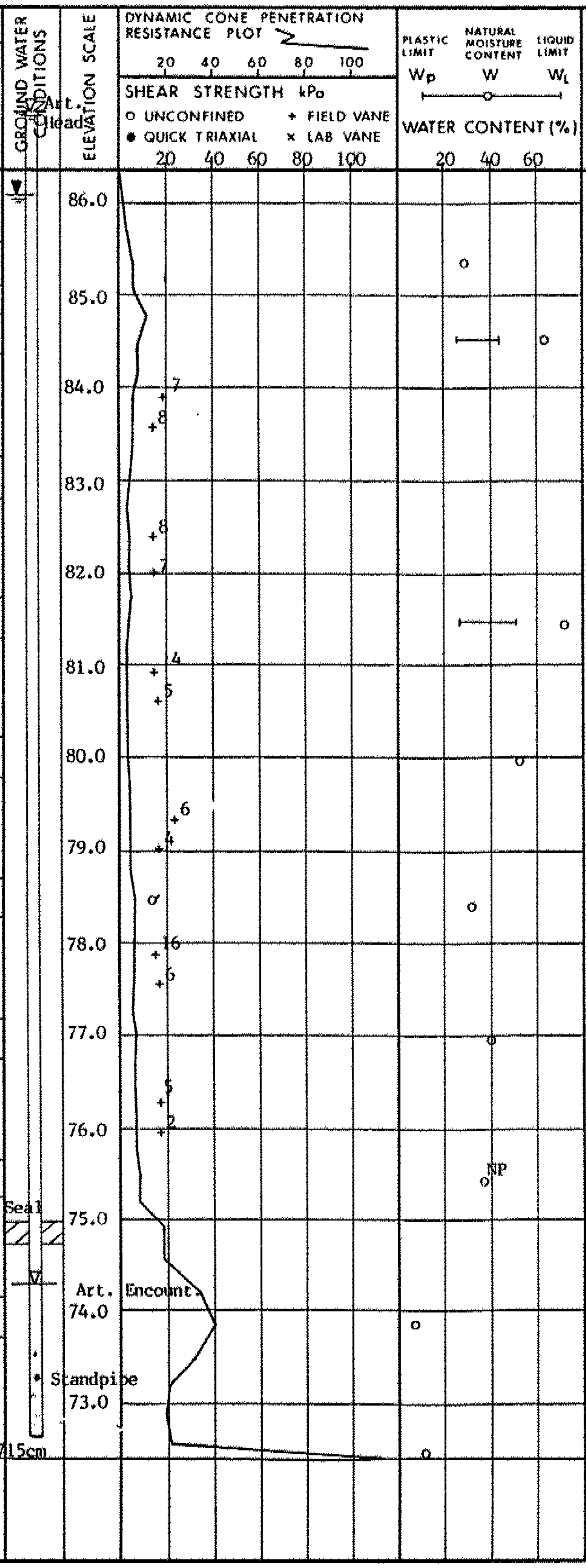
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No3

METRIC

W P 187-89-03
LOCATION N: 5 001 980.4 ; E: 368 820.4
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 23
CHECKED BY C.M.

SOIL PROFILE ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Ground Surface					
0.0	Silt trace Organics Firm Brown	1	SS	6		W.L. on 1990 10 24
85.0 1.3	Silty Clay to Clay	2	SS	1		
	Soft	3	TW	PM		
		4	TW	PM	15.5	Consol. Test Figure 2
	Grey	5	TW	PM		
		6	TW	PM	19.1	
		7	TW	PM		
76.1 10.2	Silt with Clay Inclusions Loose Grey	8	TW	PH		
74.7 11.6	Sand and Gravel some Silt (Glacial Till) Occ Cobbles Compact to Very Dense Grey	9	SS	22		
		10	SS	100/15cm		14 66 (20)
72.4 13.9	End of Borehole Probable Bedrock					



+3, x5 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

RECORD OF BOREHOLE No 4

METRIC

W P 187-89-03
DIST 9 HWY 416
DATUM Geodetic
LOCATION N: 5 002 012.5; E: 368 828.0
BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test
DATE 1990 10 24
ORIGINATED BY A.A.
COMPILED BY A.K.
CHECKED BY G.M.

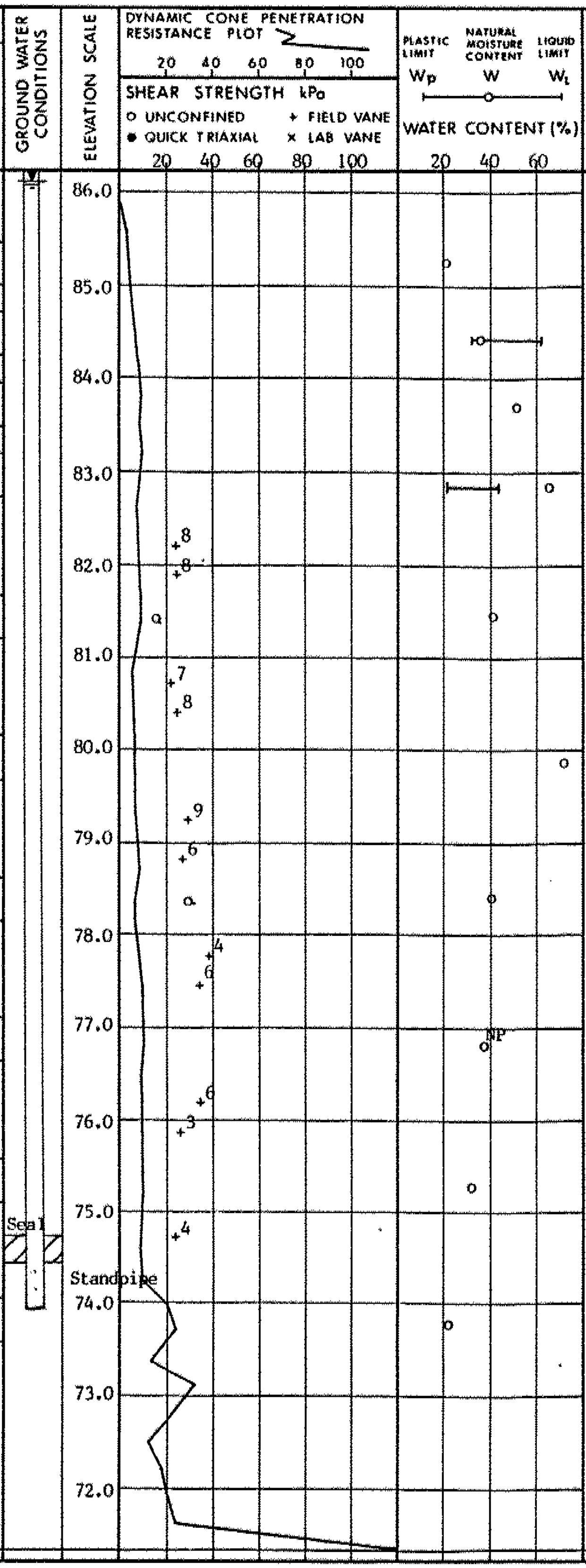
OFFICE REPORT ON SOIL EXPLORATION

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
86.2	Ground Surface
0.0	Silt trace Organics Stiff Brown
84.8 1.4	Silty Clay to Clay Desiccated Soft to Firm Grey
77.4 8.8	Silt with Clay Inclusions V. Loose to Compact Grey
74.4 11.8	Sandy Zone Sand and Gravel (Glacial Till) Occ. Cobbles Dense Grey
71.3 14.9	End of Borehole Probable Bedrock

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
				W.L. on 1990 10 26
1	SS	11		
2	SS	5		
3	SS	1		
4	TW	PM		
5	TW	PM	17.3	
6	TW	PM		
7	TW	PM	17.6	
8	TW	PM		
9	SS	13		
10	SS	32		0 99 (1)



+3, x5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation Ontario

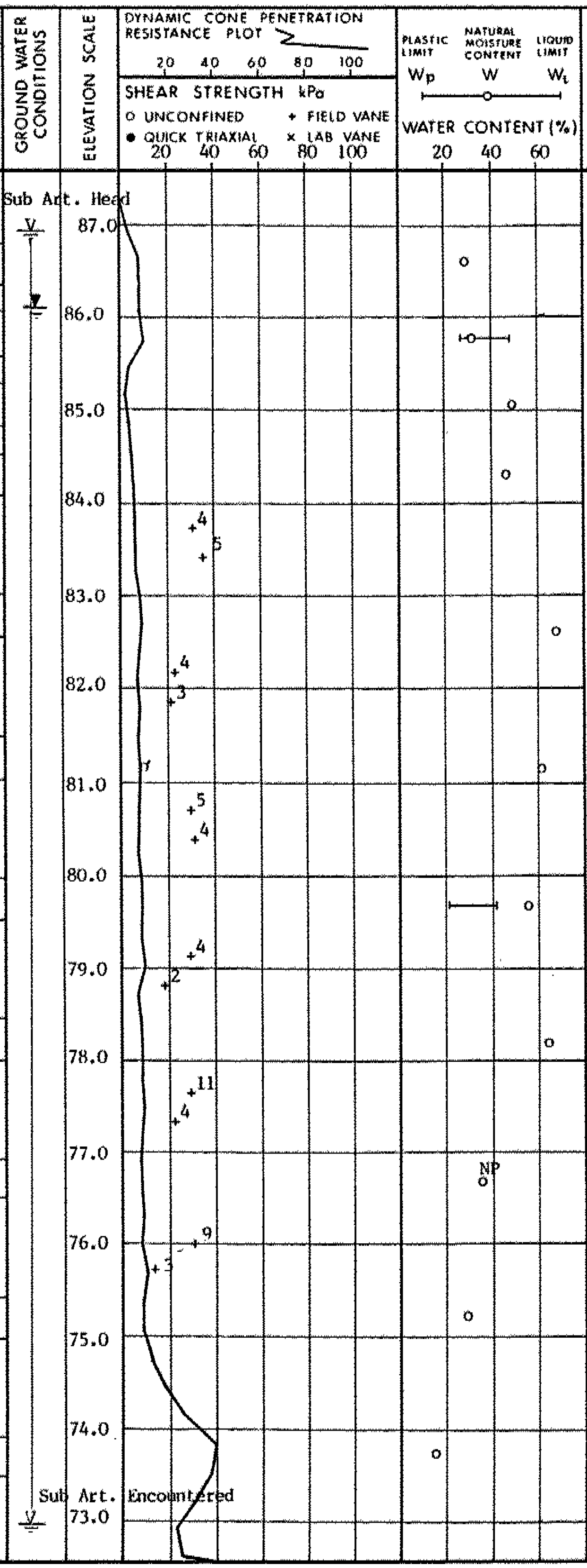
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 5

METRIC

W P 187-89-03
LOCATION N: 5 002 011.0; E: 368 812.0
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 25
CHECKED BY C.M.

SOIL PROFILE		SAMPLES			UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES		
87.6	Ground Surface					
0.0	Silt trace Organics Very Stiff Brown	1	SS	17		W. L. on 1990 10 26
86.2 1.4	Silty Clay to Clay Stiff Desiccated	2	SS	10		
	Soft to Firm	3	SS	3		
		4	TW	PM		
	Grey	5	TW	PM		
		6	TW	PM	15.2	
		7	TW	PM		
		8	TW	PH		
77.1 10.5	Silt with Clay Incusions V. Loose Grey	9	TW	PM		
		10	SS	*		0 9 (91)
74.6 13.0	Sand and Gravel (Glacial Till) Occ. Cobbles Compact Grey	11	SS	10		
72.6 15.0	Cont. on Page 2					



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

20
15 ◊ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 5 cont'd

METRIC

W P 187-89-03	LOCATION N: 5 002 011.0 ; E: 368 812.0	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 25	CHECKED BY C.M.

SOIL PROFILE			SAMPLES								
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
72.6	Cont from Page 1										
72.4 15.2	Limestone Bedrock Thinly Bedded		12	BX RC	Rec 77		72.0				RQD = 0 %
			13	BX RC	Rec 71%						RQD = 0%
			14	BX RC	Rec 83%		71.0				RQD = 0 %
			15	BX RC	Rec 98%		70.0				RQD = 0 %
69.0			16	BX RC	Rec 100%						RQD = 18%
18.6	End of Borehole * Penetrated by weight of Hammer and Rods										

OFFICE REPORT ON SOIL EXPLORATION

+3, ×5 : Numbers refer to Sensitivity

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

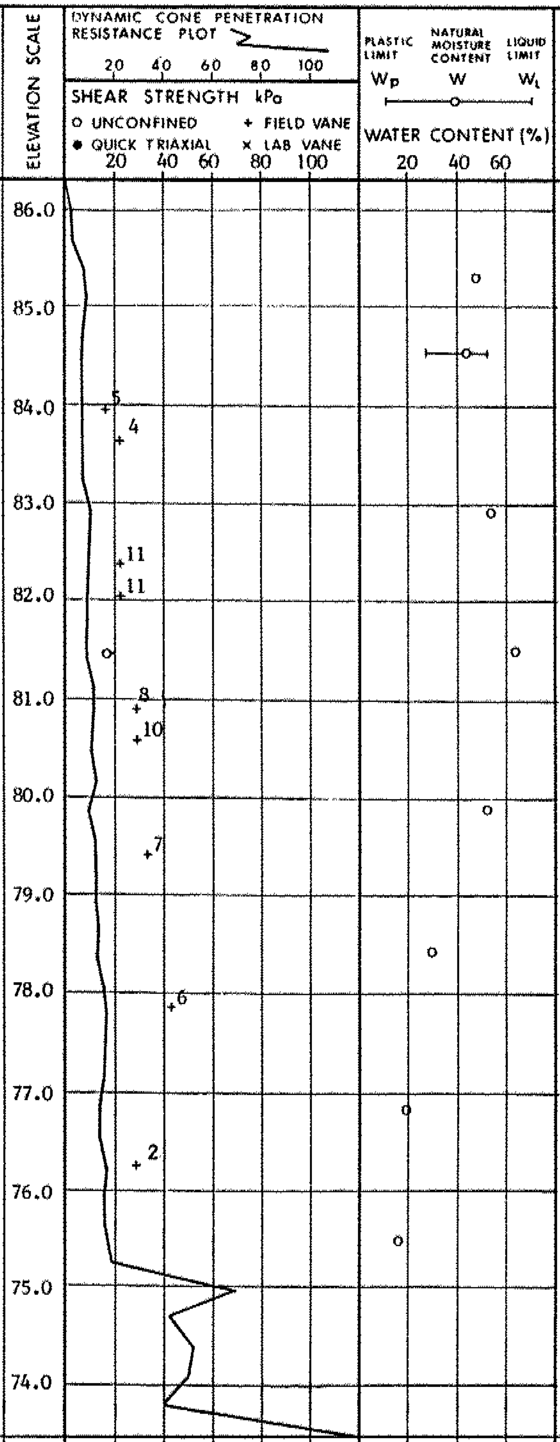
Ministry of Transportation
Ontario

RECORD OF BOREHOLE No6

METRIC

W P 167-89-03
LOCATION N: 5 002 037.8, E: 368 811.0
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 25
CHECKED BY C.M.

SOIL PROFILE		SAMPLES					
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Ground Surface						
0.0	400 mm Topsoil				▽		W.L. on 1990 10 26
	Silty Clay to Clay	1	SS	2			
	Desiccated						
		2	SS	1			
	Soft to Firm	3	TW	PM			
		4	TW	PM		15.1	
		5	TW	PM			
	Grey	6	TW	PM			
78.0 8.3	Silt with Clay Inclusions Loose Grey	7	TW	PH			
75.7 10.6	Sand and Gravel some Silt (Glacial Till) Occ. Cobbles Dense Grey	8	SS	40			10 76 (14)
73.5 12.8	End of Borehole						

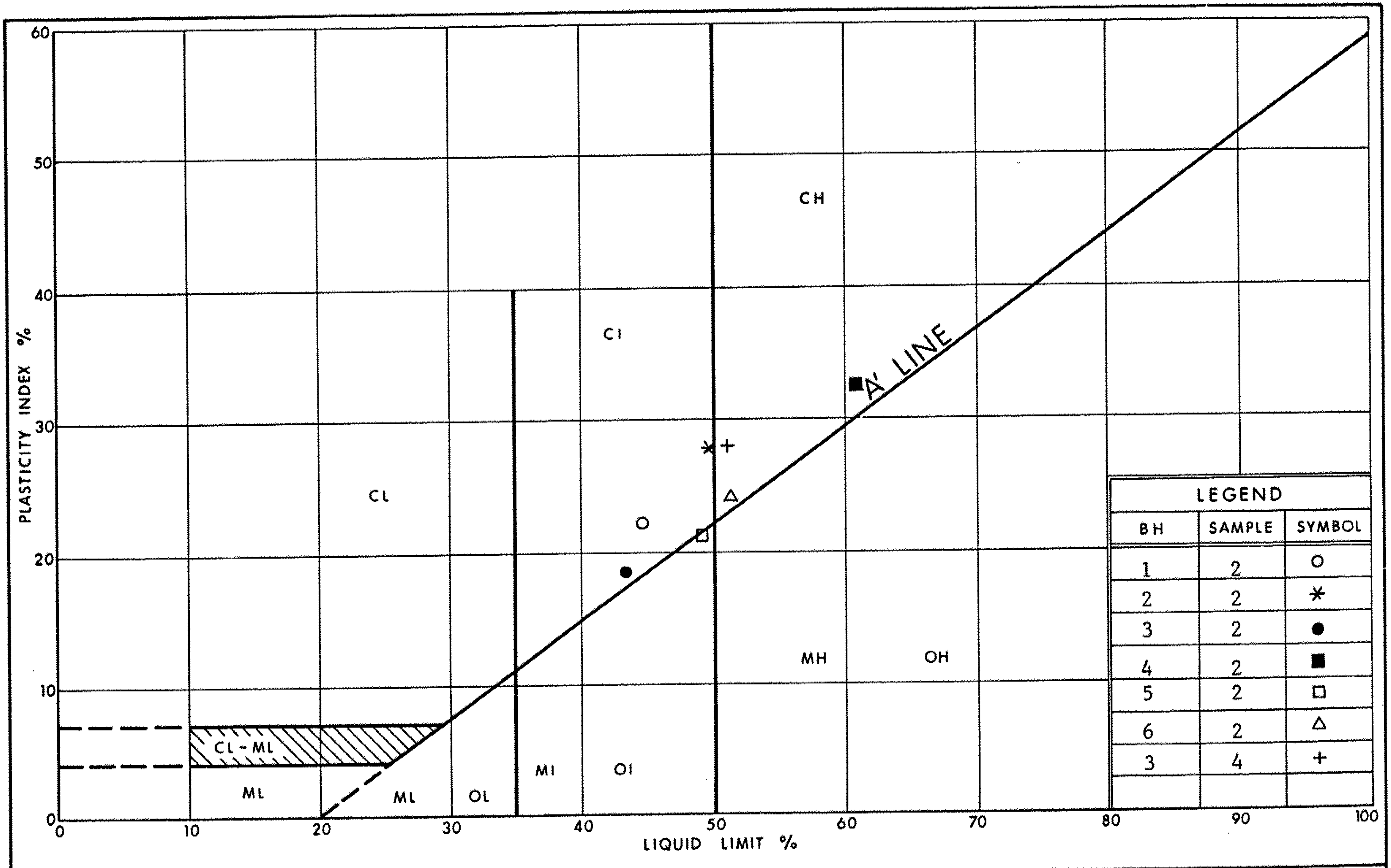


+3, ×5 : Numbers refer to Sensitivity

20
15 ⌖ 5 (%) STRAIN AT FAILURE
10

OFFICE REPORT ON SOIL EXPLORATION

Oct 75, FF-S-21



Ministry of Transportation
Ontario

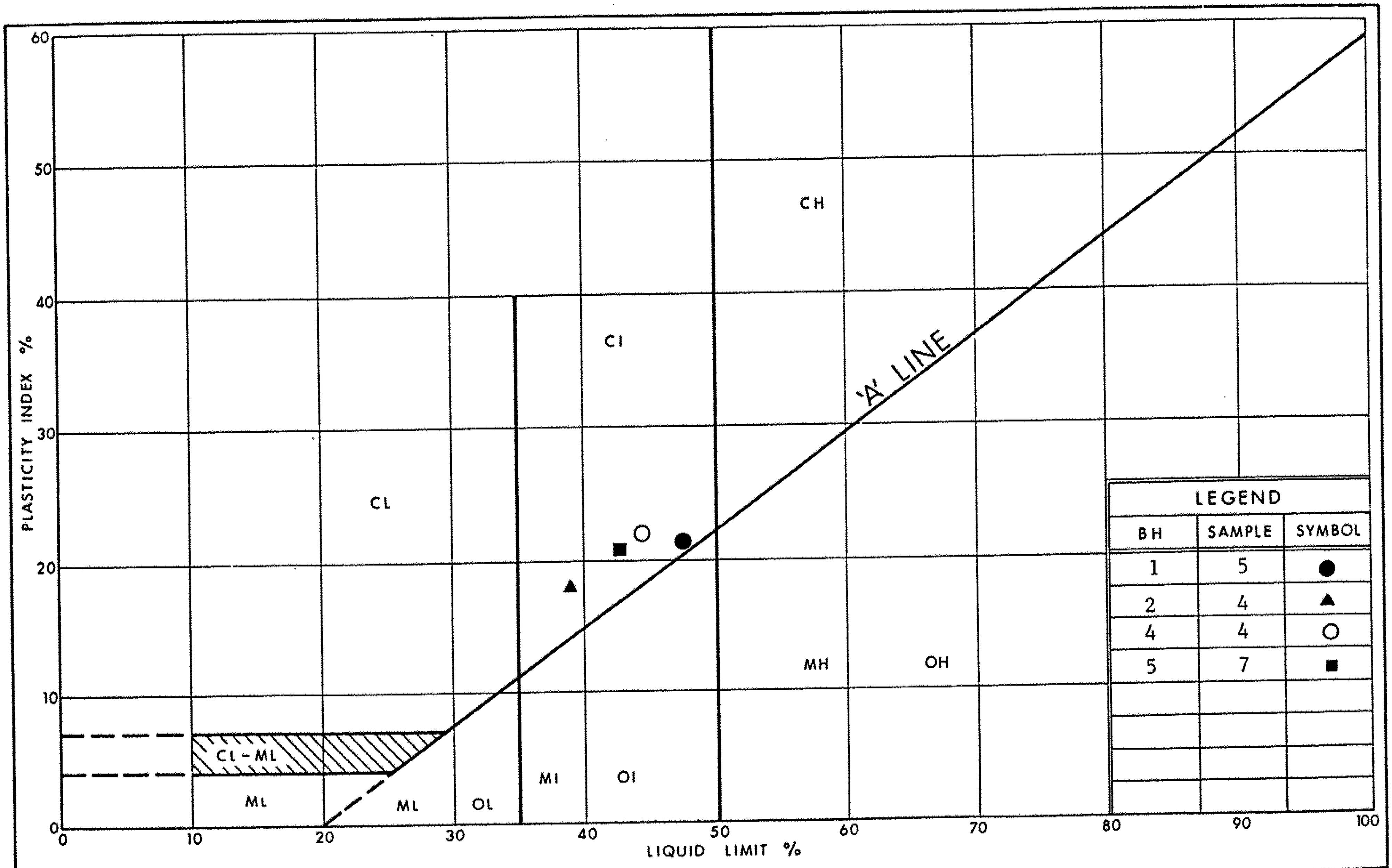
PLASTICITY CHART

Silty Clay to Clay

FIG No 1A

W P 187-89-03

Steven Creek Bridge



LEGEND

BH	SAMPLE	SYMBOL
1	5	●
2	4	▲
4	4	○
5	7	■

Ministry of Transportation
Ontario

PLASTICITY CHART
Silty Clay

FIG No 1B
W P 187-89-03
Steven Creek Bridge

VOID RATIO - PRESSURE CURVES

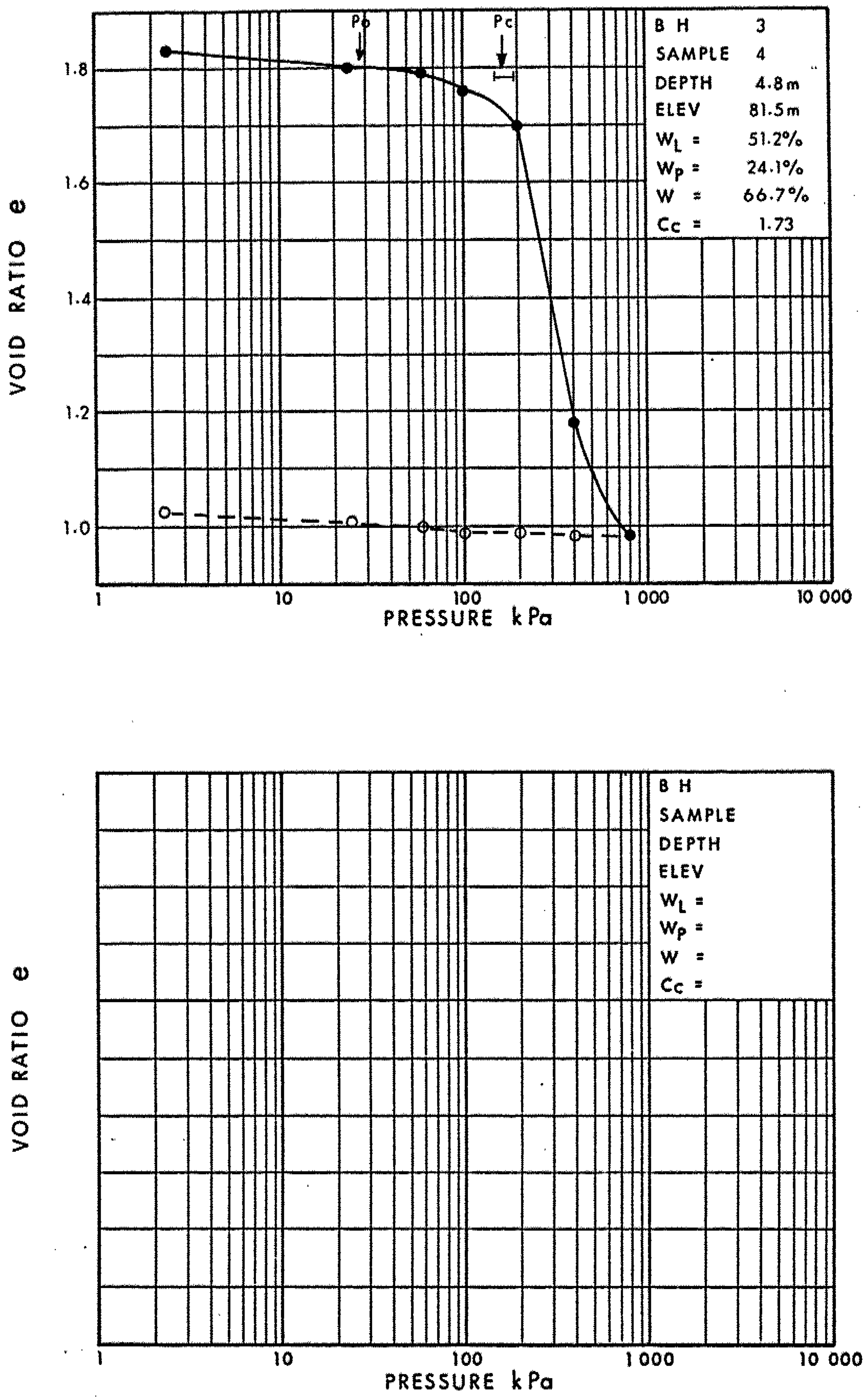
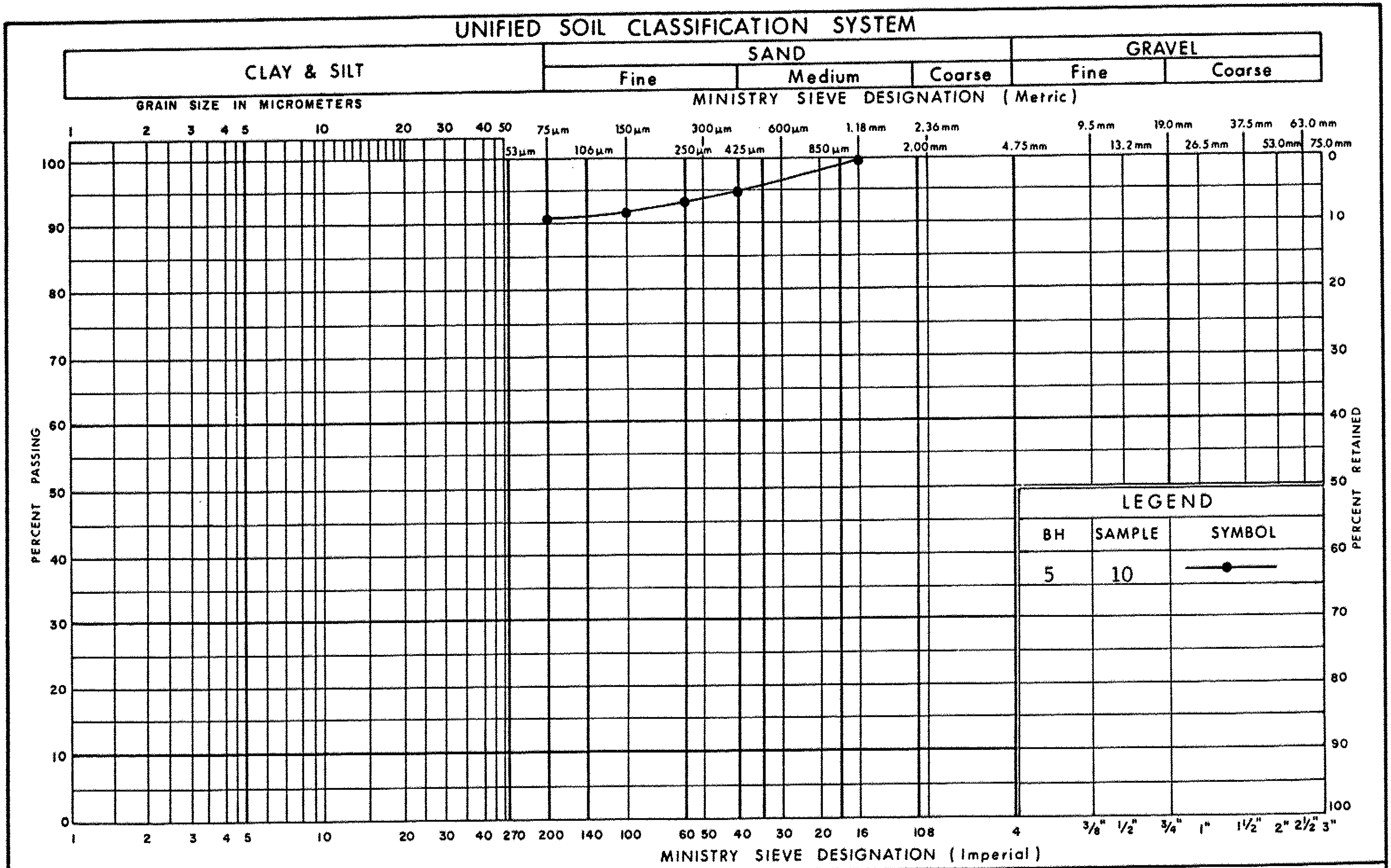


Fig 2

WP 187-89-03

78 12 M

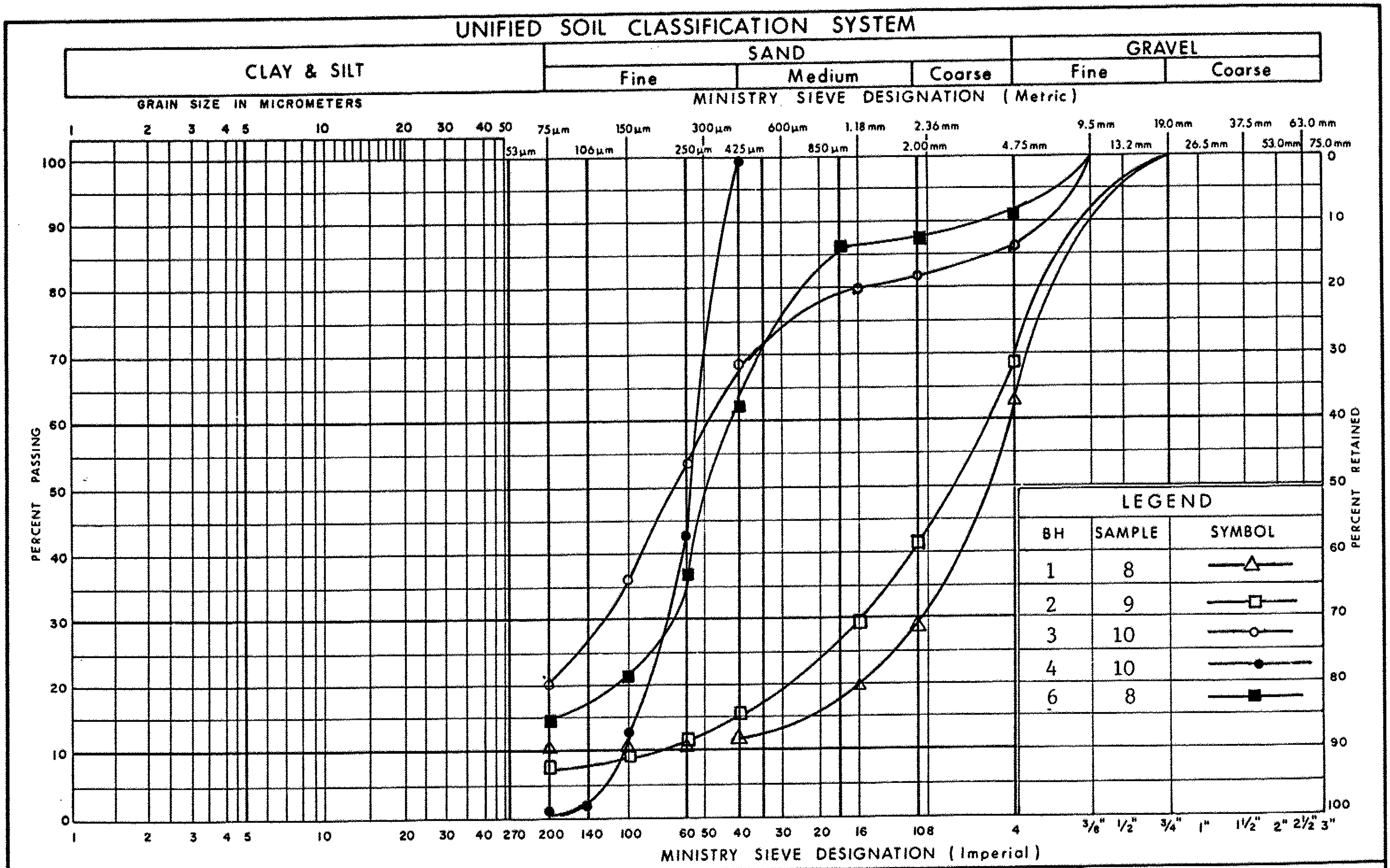


Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

Silt

FIG No	3
W P	187-89-03
Steven Creek Bridge	



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

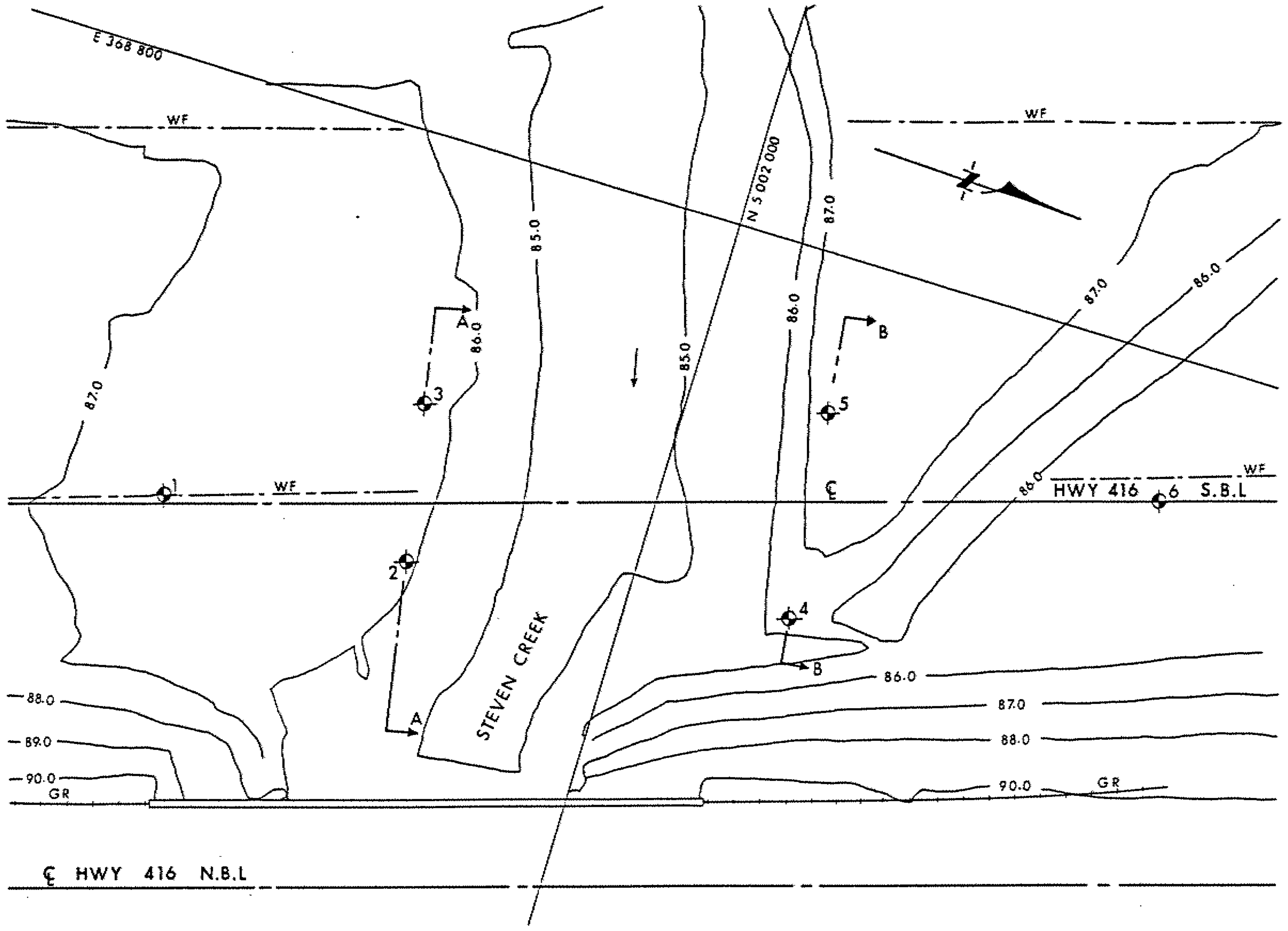
Sand and Gravel (Glacial Till)

FIG No 4

W P 187-89-03

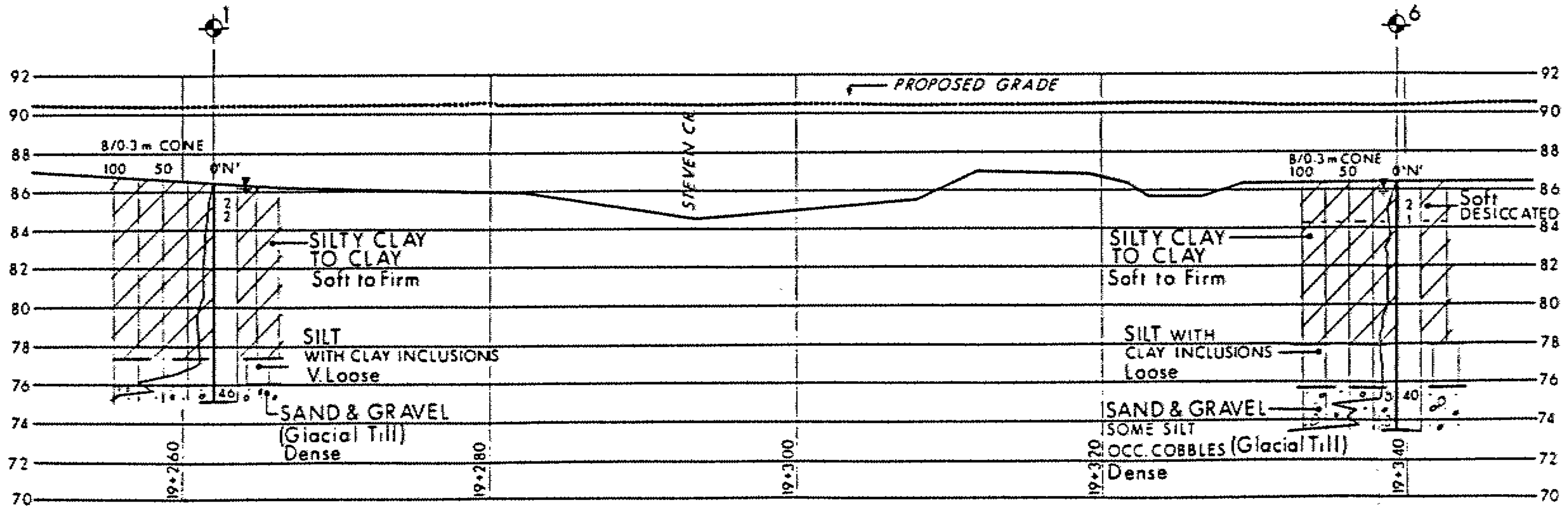
Steven Creek Bridge

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-207 88 10



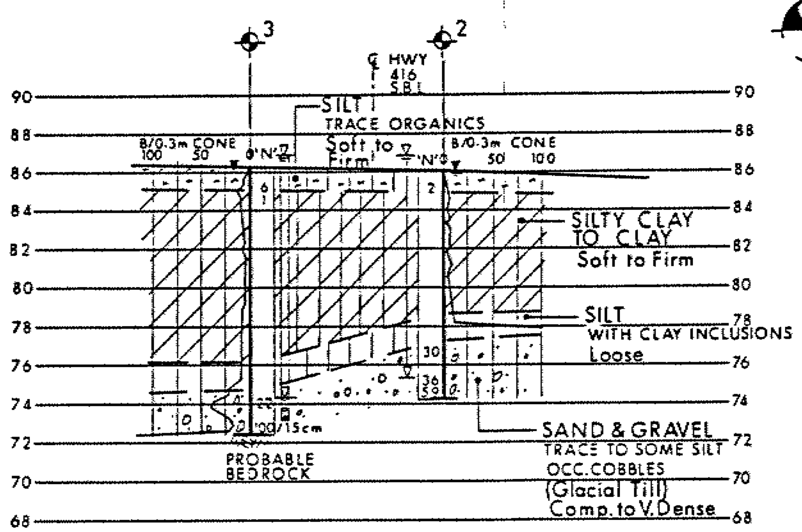
PLAN

SCALE
5m 0 5m



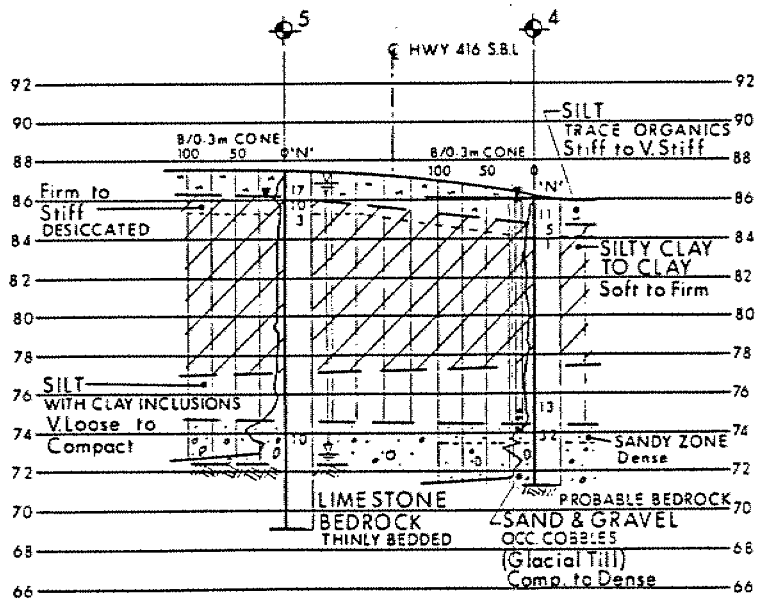
℄ PROFILE HWY 416 S.B.L

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

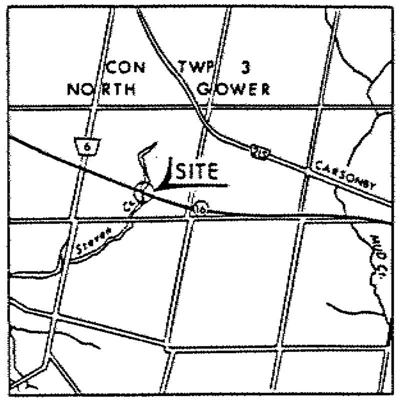
METRIC
DIMENSIONS ARE IN METRES AND/OR MILLIMETRES UNLESS OTHERWISE SHOWN. STATIONS IN KILOMETRES + METRES.

CONT No
WP No 187-89-03

SHEET

STEVEN CREEK
BORE HOLE LOCATIONS & SOIL STRATA

STRATA ENGINEERING CORP.



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
▽	Head ARTESIAN WATER Encountered
▯	Stand Pipe

No	ELEVATION	CO-ORDINATES NORTH	CO-ORDINATES EAST
1	86.5	5 001 962.8	368 833.0
2	86.1	5 001 982.5	368 832.5
3	86.3	5 001 980.4	368 820.4
4	86.2	5 002 012.5	368 828.0
5	87.6	5 002 011.0	368 812.0
6	86.3	5 002 037.8	368 811.0

=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-214

HWY No 416			DIST 9
SUBM'D A A	CHECKED	DATE May 11 1991	SITE 3-356/2
DRAWN A K	CHECKED	APPROVED	DWG 1878903-A

REF No E-55-416-3 91 01

DOCUMENT MICROFILMING IDENTIFICATION

G.I.-30 SEPT. 1976

GEOCRES No. 316-214

DIST. 9 REGION

W.P. No. 187-89-03

CONT. No. 96-07

W. O. No.

STR. SITE No. 3-356/2

HWY. No. 416

LOCATION Hwy 416 & Steven Creek

No. of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

STRATA ENGINEERING CORP.
RESEARCH . ENGINEERING . SCIENCE

Tel.: (416) 441-2560
Fax: (416) 441-4161
Suite ~~410~~ 120, 170 The Donway West,
Don Mills, Ontario, Canada M3C 2G3

FOUNDATION INVESTIGATION REPORT
for
Steven Creek Bridge

W.P. 187-89-03, District 9, Ottawa
Highway 416, Str. Site: 3-356/2

GEOCRES # 31G-21A

Strata Project: E-90-037A

Date of Submission: 1992 04 07

Report Distribution:

M.T.O.Foundations	13 copies
UMA Engineering	2 copies
McCormick Rankin	1 copy
Strata File E-90-037A	1 copy

Nature, to be commanded. must be obeyed

TABLE OF CONTENTS

FOUNDATION INVESTIGATION REPORT
for
Steven Creek Bridge

W.P. 187-89-03, District 9, Ottawa
Highway 416, Str. Site: 3-356/2

1.0 INTRODUCTION

Strata Engineering Corp. has been retained by UMA Engineering to carry out a foundation investigation for the crossing of the proposed southbound lanes of Highway 416 and Steven 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 in Rideau Township, some 35 km south of Ottawa along Highway 16. The location is shown in the key plan on Drawing 1878903-A, appended. The proposed bridge centreline is approximately 30 m west of the existing 20 m single span structure on Highway 16. At this location Steven Creek is approximately 12 m wide and 3 m deep. The flow is in an easterly direction towards the Rideau River. The south approach to this site is flat and clear of vegetation. The north approach is bush covered. A tributary stream flows from the northwest to join Steven Creek to the west of the existing bridge.

The site lies within the physiographic area known as the North Gower Drumlin Field. The drumlins have a north-south orientation. The area has been inundated by the Champlain Sea which has caused the drumlins to be covered with a mantle of marine soil, predominantly silt and Leda clay.

Bedrock in this area has been mapped as magnesium limestone to dolostone of the Oxford Formation, Lower Ordovician age.

Due to the undulating nature of the topography there are springs within the area. Water enters the soil in high ground, usually a glacial landform where the mantle of marine soil is relatively thin. Springs are frequently found where erosion has removed much of the cohesive overburden material. Artesian pressures exist at depth.

3.0 FIELD AND LABORATORY WORK

The field work, carried out between 1990 10 22 and 25, 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 other two holes were drilled for the north and south approach fills. The borehole elevations, referenced to Geodetic datum, were supplied by UMA Engineering. The locations of the boreholes are shown on Drawing 1878903-A.

Drilling was performed with bombardier mounted CME 55 drill rigs. Hollow stem augers were used to advance the boreholes. Boreholes 1 and 6 for the approaches were terminated within the highest competent stratum. Boreholes 3 and 4 for the structure were terminated at auger refusal. Bedrock was proven in Borehole 5 by diamond coring. It was intended to prove bedrock in Borehole 2, however artesian conditions required its premature termination.

Standard Penetration Tests were used to sample very dense or non-cohesive strata. 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 carried out to measure the undrained shear strength. Remoulded strengths were also determined to assess the sensitivity of the soil.

Upon completion of each borehole, water levels were measured in the uncased hole. Boreholes 1, 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 boreholes was monitored over a period of a week.

Borehole 2, in which high artesian pressures were present, was sealed with a polymer additive to stop the flow. Considerable difficulties were encountered in stemming the flow of water. Initial attempts resulted in the water finding a new path to the nearby cone test location, and upwards of two days were required to effect proper closure of all artesian conditions near this borehole.

Recovered soil samples were transported to our Don Mills Laboratory where they were visually examined and classified. Tests for index properties such as moisture contents, Atterberg Limits, and grain size analyses were performed on selected samples. Unconfined compression tests were conducted on seven of the thin walled samples. One consolidation test was also performed. The test results are given on the Record of Boreholes and on Figures 1 to 4 in the Appendix.

4.0 SUBSURFACE CONDITIONS

4.1 General

The soil stratigraphy consists of silt with trace organics overlying a sensitive silty clay to clay deposit above a silt stratum. The silt is underlain by a very dense sand and gravel glacial till. Limestone bedrock is fractured.

Details are provided below.

4.2 Silt, Trace Organics

Where present, there is some 400 mm of topsoil. Closer to the banks of the creek there is up to 1.4 m of brown silt with trace of organics. The moisture content ranged from 22 to 36 per cent. N values ranged from 2 to 17 blows/0.3 m indicating the consistency to range between soft and stiff.

4.3 Silty Clay to Clay

A silty clay to clay deposit was found below the topsoil or surficial silt with trace of organics. Its thickness varied from 6.2 m to 9.1 m, with its base between 76 m and 78 m. The silt content increases with depth.

The moisture content of this material generally increases with depth down to elev. 81±m below which the moisture content decreases. A desiccated crust is present in Boreholes 4, 5 and 6. Atterberg limit tests (Figure 1) indicate a medium to high plasticity for this soil. Below the desiccated crust, the moisture content is generally higher than the liquid limit, resulting in a liquidity index of 1 or greater.

N values ranged from 0 to 10 blows/0.3 m. The higher values being in the upper desiccated crust which has a lower moisture content.

Field vane tests indicate undrained shear strengths of 15 kPa to 48 kPa, generally increasing with depth at a c_u/p_o ratio of about 0.28. The sensitivity of the silty clay was found to be between 5 and 9 with a couple extreme values of 3 and 22. Unconfined compression test values ranged from 12 kPa to 30 kPa. Based on the measured undrained shear strengths, the deposit has an overall consistency ranging from soft to firm.

The result of one consolidation test carried out on a 75 mm sized thin walled tube sample is shown on Figure 2. The preconsolidation pressure, p_c, is 160 kPa±. The recompression index, C_r is 0.04 and the compression index, C_c, is 1.7.

4.4 Silt

Silt, ranging in thickness from 1.4 m to 3.0 m, is present below the silty clay to clay stratum. This deposit is non homogenous and contains inclusions of silty clay which diminish with depth. The sand content increases with depth.

The moisture content of the silt ranged from 20 to 38 per cent, the higher values being associated with the presence of the clay inclusions. Atterberg limit tests show the soil to be non-plastic. One grain size curve is shown on Figure 3.

Vane tests were attempted in this deposit in the belief that it was a plastic soil. However the thin walled tube samples taken in this stratum reveal the soil to be silt. Therefore, the reported vane shear strength values are not an appropriate indicator of strength for this deposit. N values of 0 to 13 blows/0.3 m indicate the soil to be very loose to compact.

4.5 Sand and Gravel (Glacial Till)

Below elev. ±75 m the silt deposit is underlain by a glacial till consisting of a mixture of sand and gravel with traces of silt and clay. The moisture content ranged from 5 to 20 per cent, with an average of 10 per cent. Grain size distribution curves are shown on Figure 4 and indicate a composition ranging from uniform fine to medium sand to well graded sand and gravel. N values in this glacial till deposit ranged from 10 to 59 blows/0.3 m indicating it to be compact to very dense.

4.6 Limestone Bedrock

Limestone bedrock was encountered at elevations of 71 m to 72 m and was proven by coring in Borehole 5. It is thinly bedded with recoveries ranging from 77 % to 100 %, the RQD values were all below 18 % indicating very poor quality.

5.0 GROUNDWATER CONDITIONS

In boreholes close to the stream, the water levels were the same as those of the stream, which was at elev. 86.1 m on 1991 10 24.

The sand and gravel deposit above the bedrock is under artesian pressure, with the water level rising to elev. 87.0 m, some 1+m above ground surface.

Water level observations are summarized below:

Borehole	**W.L. Elev.** (m)	**Art. W.L.** (m)	**Date**
1	86.2	-	1990 10 22
2	86.0	87.0	1990 10 23
3	86.1	87.0	1990 10 24
4	86.2	-	1990 10 26
5	86.0	87.0	1990 10 26
6	86.0	-	1990 10 26

6.0 DISCUSSION AND RECOMMENDATIONS

6.1 General

It is proposed to construct southbound lanes 30 m to the west of the existing Highway 16 which will be upgraded to 4 lane freeway standards between Highway 401 and Ottawa. This will entail the construction of a bridge across Steven Creek.

The proposed structure is expected to be similar to the existing single span structure below the present highway. Approach fill heights are proposed to be in the order of 4 to 5 m.

This investigation indicates the presence of a surficial organic layer overlying a soft silty clay to clay above a loose silt. The silt overlies a compact to very dense sand and gravel glacial till stratum in contact with a fractured limestone bedrock. Groundwater in the sand and gravel deposit is under artesian pressure.

6.2 Structure Foundations

The presence of weak and relatively compressible soils near the surface precludes the use of conventional spread footings for the structure. A deep foundation is therefore required.

Due to artesian conditions at depth, caissons seated within the bedrock may not be feasible, owing to potential dewatering and artesian flow control problems. Therefore, steel H piles driven to bedrock or within the glacial till stratum are recommended.

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.

Normally, steel H piles such as HP 310 x 110 are 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 of 50 kJ or more to achieve the required capacities.

For pile length estimation, assume the pile toes to reach bedrock at about elevation 72 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 72 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 Provisions No. 109F03 (latest revision). The following parameters are recommended for the 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 Fills

Organic materials at the shoreline should be excavated from below the limits of the approach fills down to the silty clay to clayey silt stratum. Subexcavated areas should be backfilled with Granular B or other non-cohesive granular materials.

Fills no higher than 6 m may be built with 2:1 side slopes. For such fills, the undrained shear strength (Figure 5) profile shows no danger of deep-seated instability. The estimated total settlement of the final embankment is estimated to be in the order of 30 mm after construction.

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 stratum is expected to be minimal and capable of being handled by pumping from sumps located within the excavation.

7.0 CLOSURE

The field work was supervised by A. C. Abel. The drilling equipment was rented from F. E. Johnston and Marathon Drilling companies, Ottawa.

Respectfully Submitted:
STRATA ENGINEERING CORP.

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

ACA/lr

REGISTERED PROFESSIONAL ENGINEER
C. MIRZA
PROVINCE OF ONTARIO

C. Mirza, P. Eng.
Senior Principal

Report Distribution:

M.T.O.Foundations	13 copies
UMA Engineering	2 copies
McCormick Rankin	1 copy
Strata File E-90-037A	1 copy

APPENDIX

Explanation of Terms used in this Report

Record of Boreholes 1 to 6

Figures 1 to 4

Drawing 1878903-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 (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

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_a	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	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				k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	I_C	1	CONSISTENCY INDEX $= \frac{w_L - w}{I_P}$	j	kN/m^3	SEEPAGE FORCE
γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL	e_{max}	1,%	VOID RATIO IN LOOSEST STATE			

OFFICE REPORT ON SOIL EXPLORATION

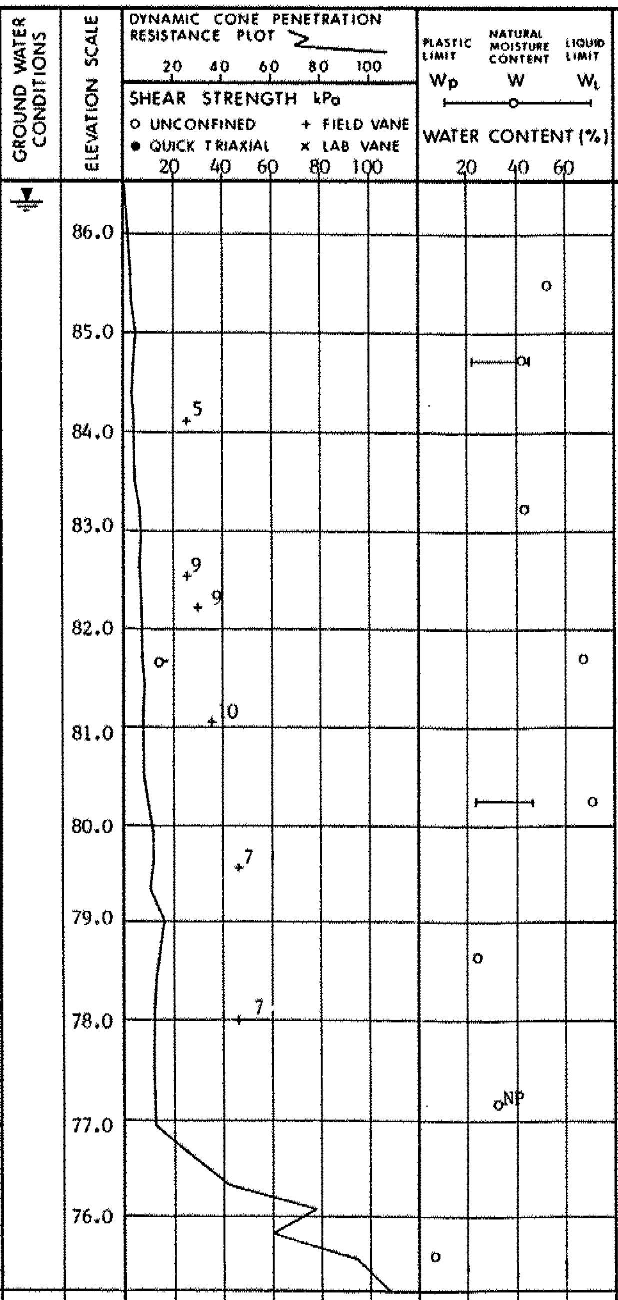
Ministry of Transportation Ontario

RECORD OF BOREHOLE No1

METRIC

W P 187-89-03
LOCATION N: 5 001 962.8 ; E: 368 833.0
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 22
CHECKED BY C.M.

SOIL PROFILE ELEV DEPTH	DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.5	Ground Surface					
0.0	350mm Topsoil					W. L. on 1990 10 22
	Silty Clay to Clay	1	SS	2		
		2	SS	2		
	Soft to Firm	3	TW	PM		
		4	TW	PM	15.2	
	Grey	5	TW	PH		
		6	TW	PH		
77.4 9.1	Silt with Clay Inclusions V. Loose Grey	7	SS	*		
76.0 10.5	Sand and Gravel (Glacial Till) Dense Grey	8	SS	46		37 53 (10)
75.2 11.3	End of Borehole * Penertrated by weight of Hammer and Rods					



+3, x5 : Numbers refer to Sensitivity

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

Ministry of Transportation Ontario

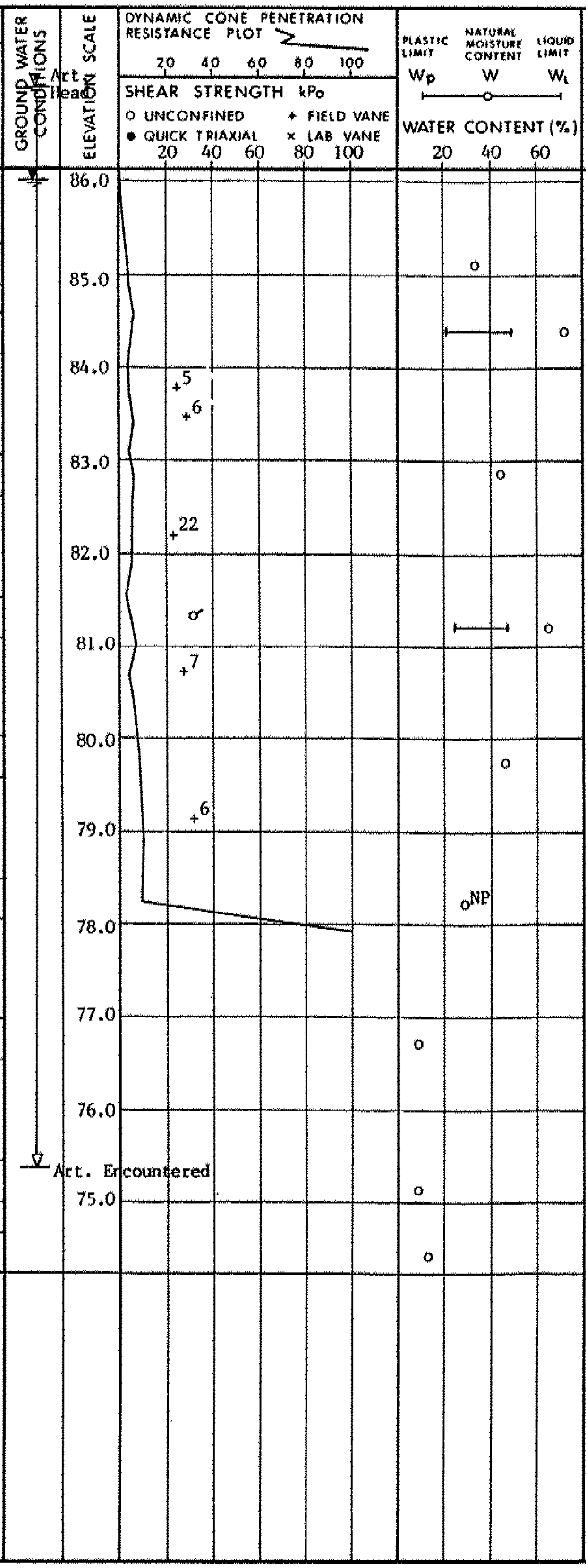
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 2

METRIC

W P 187-89-03
LOCATION N: 5 001 982.5 E: 368 832.5
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 23
CHECKED BY C.M.

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.1	Ground Surface					
0.0	Silt trace Organics Soft Brown	1	SS	2		W. L. on 1990 10 23
84.8 1.3	Silty Clay to Clay Firm Grey	2	SS	*		
		3	TW	PM		
		4	TW	PM	15.4	
		5	TW	PH		
78.6 7.5	Silt with Clay Inclusions Loose Grey	6	TW	PH		
77.2 8.9	Sand and Gravel trace Silt (Glacial Till) Occ. Cobbles Compact to V. Dense Grey	7	SS	30		
		8	SS	36		30 62 (8)
74.2		9	SS	59		
11.9	End of Borehole * Penetrated by weight of Hammer and Rods					



+3, x5 : Numbers refer to Sensitivity

20 15 -5 10 (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

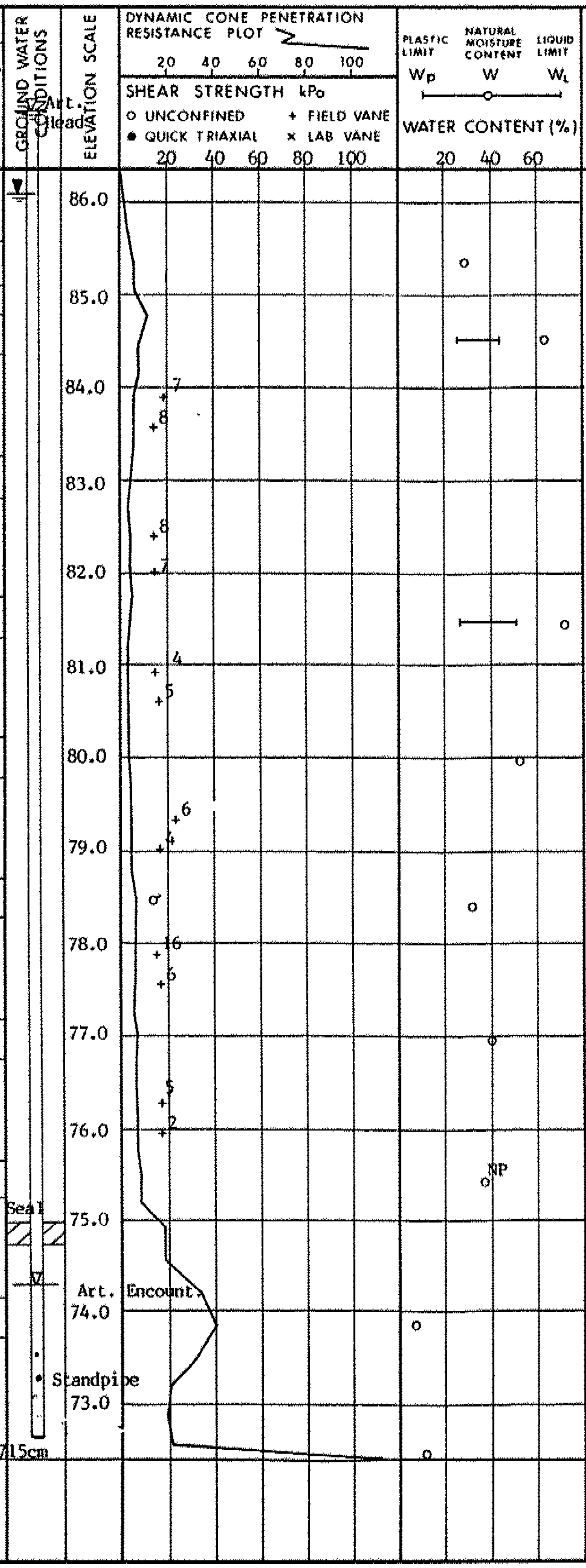
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No3

METRIC

W P 187-89-03
LOCATION N: 5 001 980.4 ; E: 368 820.4
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 23
CHECKED BY C.M.

SOIL PROFILE		SAMPLES			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	γ kg/m³	GR SA SI CL
86.3	Ground Surface					
0.0 85.0	Silt trace Organics Firm Brown	1	SS	6		W.L. on 1990 10 24
1.3	Silty Clay to Clay	2	SS	1		
	Soft	3	TW	PM		
		4	TW	PM	15.5	Consol. Test Figure 2
	Grey	5	TW	PM		
		6	TW	PM	19.1	
76.1		7	TW	PM		
10.2 74.7	Silt with Clay Inclusions Loose Grey	8	TW	PH		
11.6	Sand and Gravel some Silt (Glacial Till) Occ Cobbles	9	SS	22		
72.4	Compact to Very Dense Grey	10	SS	100/15cm		14 66 (20)
13.9	End of Borehole Probable Bedrock					



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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

Ministry of Transportation
Ontario

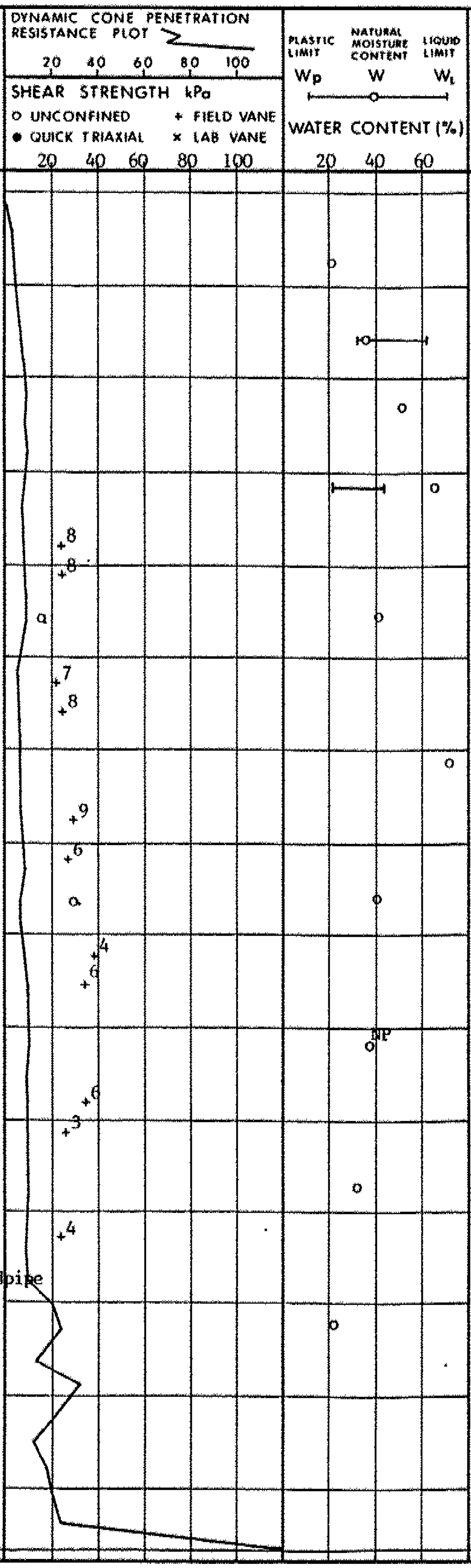
RECORD OF BOREHOLE No 4

METRIC

W P 187-89-03
LOCATION N: 5 002 012.5; E: 368 828.0
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 24
CHECKED BY C.M.

OFFICE REPORT ON SOIL EXPLORATION

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.2	Ground Surface							
0.0	Silt trace Organics Stiff					86.0		W.L. on 1990 10 26
84.8	Brown	1	SS	11		85.0		
1.4	Silty Clay to Clay Desiccated	2	SS	5		84.0		
		3	SS	1		83.0		
	Soft to Firm	4	TW	PM		82.0		
		5	TW	PM		81.0	17.3	
		6	TW	PM		80.0		
	Grey					79.0		
77.4		7	TW	PM		78.0	17.6	
8.8	Silt with Clay Inclusions V. Loose to Compact	8	TW	PM		77.0		
						76.0		
74.4	Grey	9	SS	13	Seal	75.0		
11.8	Sandy Zone	10	SS	32	Standpipe	74.0		0 99 (1)
	Sand and Gravel (Glacial Till) Occ. Cobbles Dense					73.0		
71.3	Grey					72.0		
14.9	End of Borehole Probable Bedrock							



+3, x5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Ministry of Transportation
Ontario

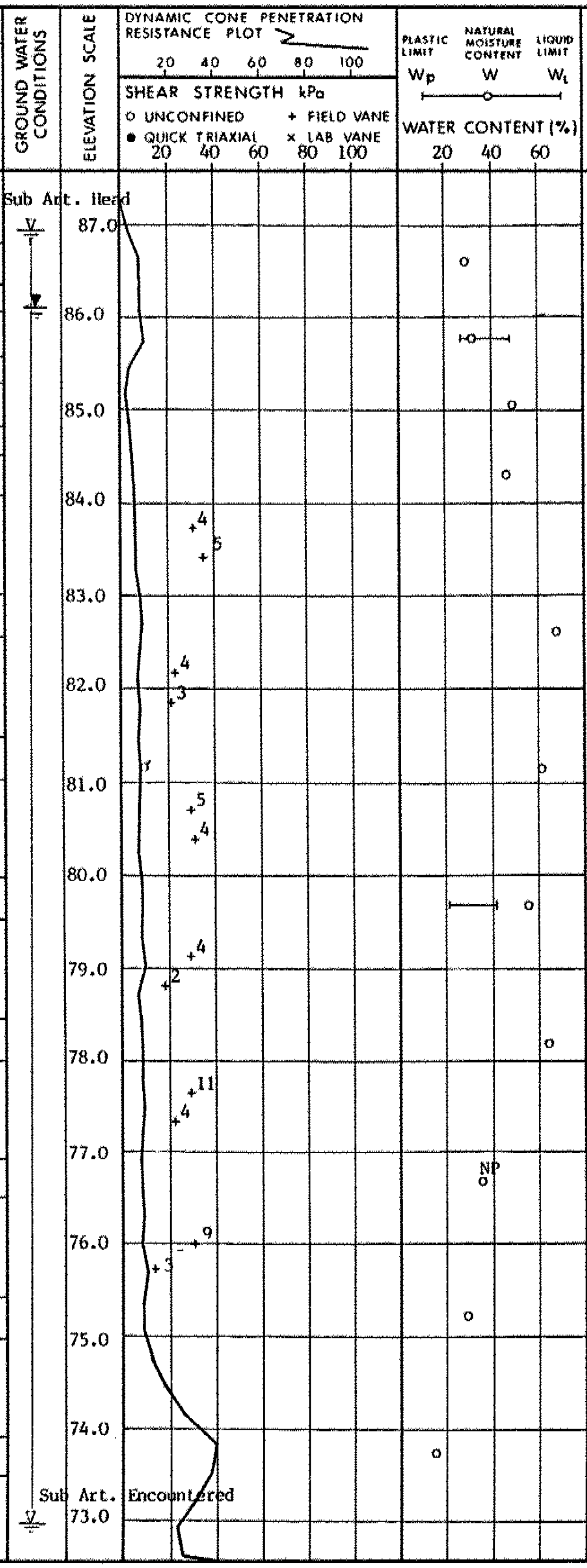
OFFICE REPORT ON SOIL EXPLORATION

RECORD OF BOREHOLE No 5

METRIC

W P 187-89-03
DIST 9 HWY 416
DATUM Geodetic
LOCATION N: 5 002 011.0; E: 368 812.0
BOREHOLE TYPE Hollow Stem Auger, Dynamic Cone Penetration Test
DATE 1990 10 25
ORIGINATED BY A.A.
COMPILED BY A.K.
CHECKED BY C.M.

SOIL PROFILE		SAMPLES			UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES		
87.6	Ground Surface					
0.0	Silt trace Organics Very Stiff Brown	1	SS	17		W. L. on 1990 10 26
86.2 1.4	Silty Clay to Clay Stiff Desiccated	2	SS	10		
	Soft to Firm	3	SS	3		
		4	TW	PM		
		5	TW	PM		
	Grey	6	TW	PM	15.2	
		7	TW	PM		
		8	TW	PM		
77.1 10.5	Silt with Clay Incusions V. Loose	9	TW	PM		
	Grey	10	SS	*		0 9 (91)
74.6 13.0	Sand and Gravel (Glacial Till) Occ. Cobbles Compact Grey	11	SS	10		
72.6 15.0	Cont. on Page 2					



+3, ×5 : Numbers refer to Sensitivity

20
15 ⌖ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 5 cont'd

METRIC

W P 187-89-03
LOCATION N: 5 002 011.0 ; E: 368 812.0
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 25
CHECKED BY C.M.

SOIL PROFILE			SAMPLES					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
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
72.6	Cont from Page 1										
72.4 15.2	Limestone Bedrock Thinly Bedded		12	BX RC	Rec 77		72.0				RQD = 0 %
			13	BX RC	Rec 71%						RQD = 0%
			14	BX RC	Rec 83%		71.0				RQD = 0 %
			15	BX RC	Rec 98%		70.0				RQD = 0 %
69.0			16	BX RC	Rec 100%						RQD = 18%
18.6	End of Borehole * Penetrated by weight of Hammer and Rods										

OFFICE REPORT ON SOIL EXPLORATION

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

$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

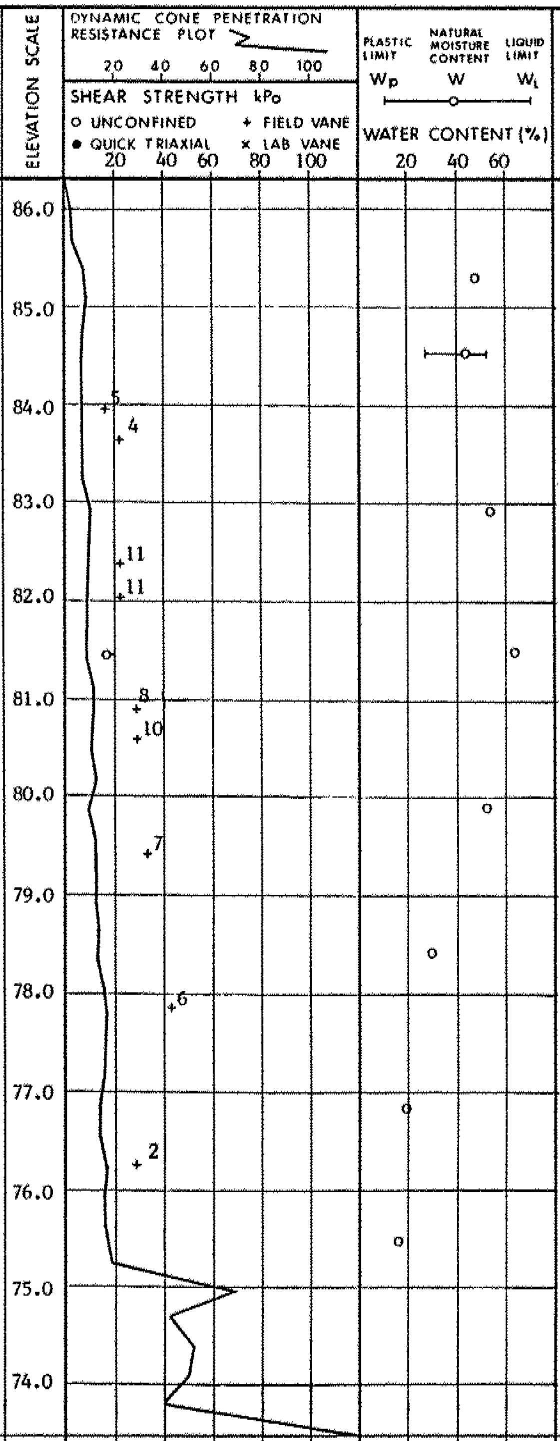
Ministry of Transportation Ontario

RECORD OF BOREHOLE No6

METRIC

W P 187-89-03 LOCATION N: 5 002 037.8 E: 368 811.0 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 25 CHECKED BY C.M.

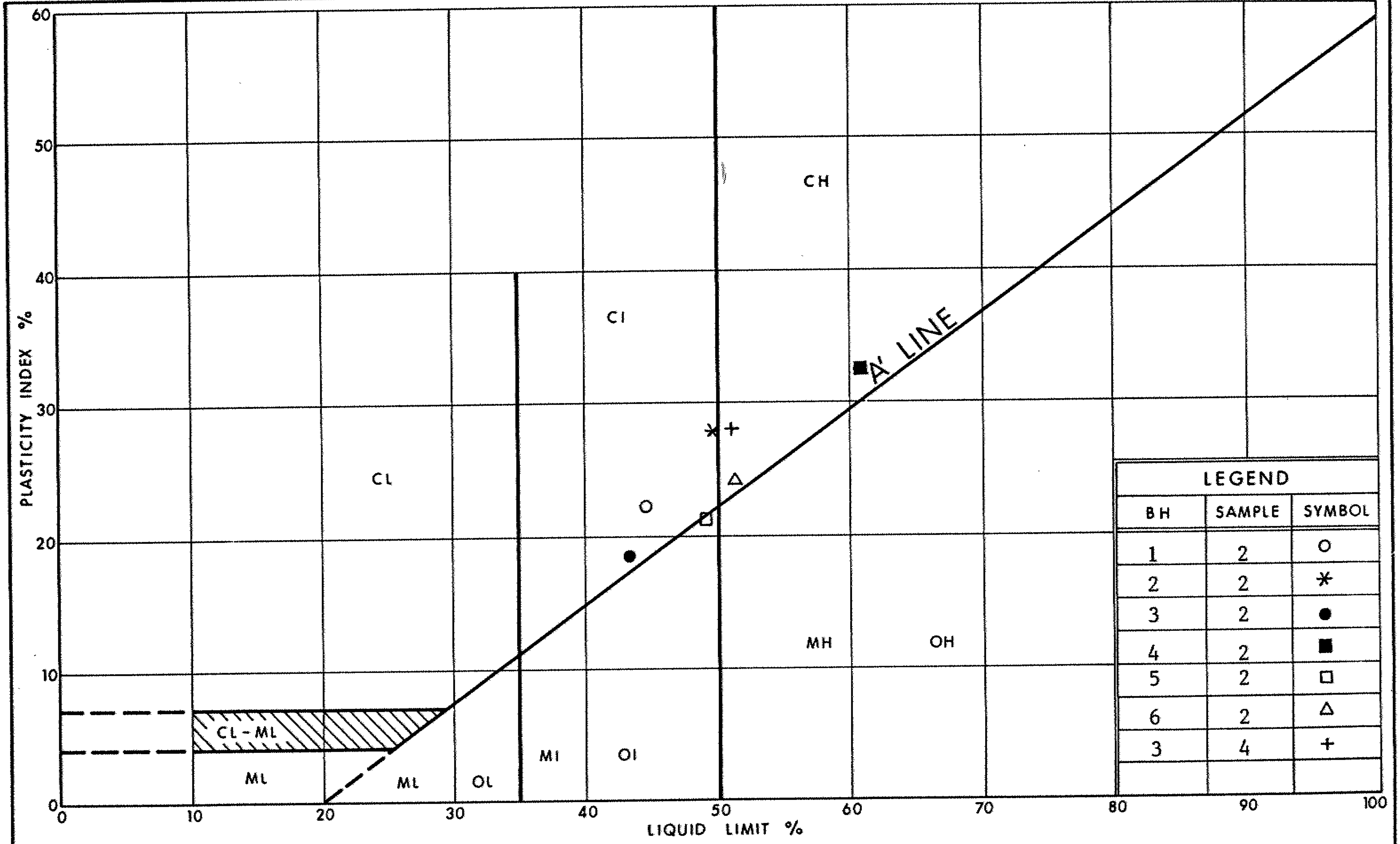
SOIL PROFILE			SAMPLES					
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kg/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
86.3	Ground Surface							
0.0	400 mm Topsoil					▽		W.L. on 1990 10 26
	Silty Clay to Clay		1	SS	2			
	Desiccated		2	SS	1			
	Soft to Firm		3	TW	PM			
			4	TW	PM		15.1	
	Grey		5	TW	PM			
			6	TW	PM			
78.0 8.3	Silt with Clay Inclusions Loose Grey		7	TW	PH			
75.7 10.6	Sand and Gravel some Silt (Glacial Till) Occ. Cobbles Dense Grey		8	SS	40			10 76 (14)
73.5 12.8	End of Borehole							



+3, ×5 : Numbers refer to Sensitivity

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

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
1	2	○
2	2	✳
3	2	●
4	2	■
5	2	□
6	2	△
3	4	+

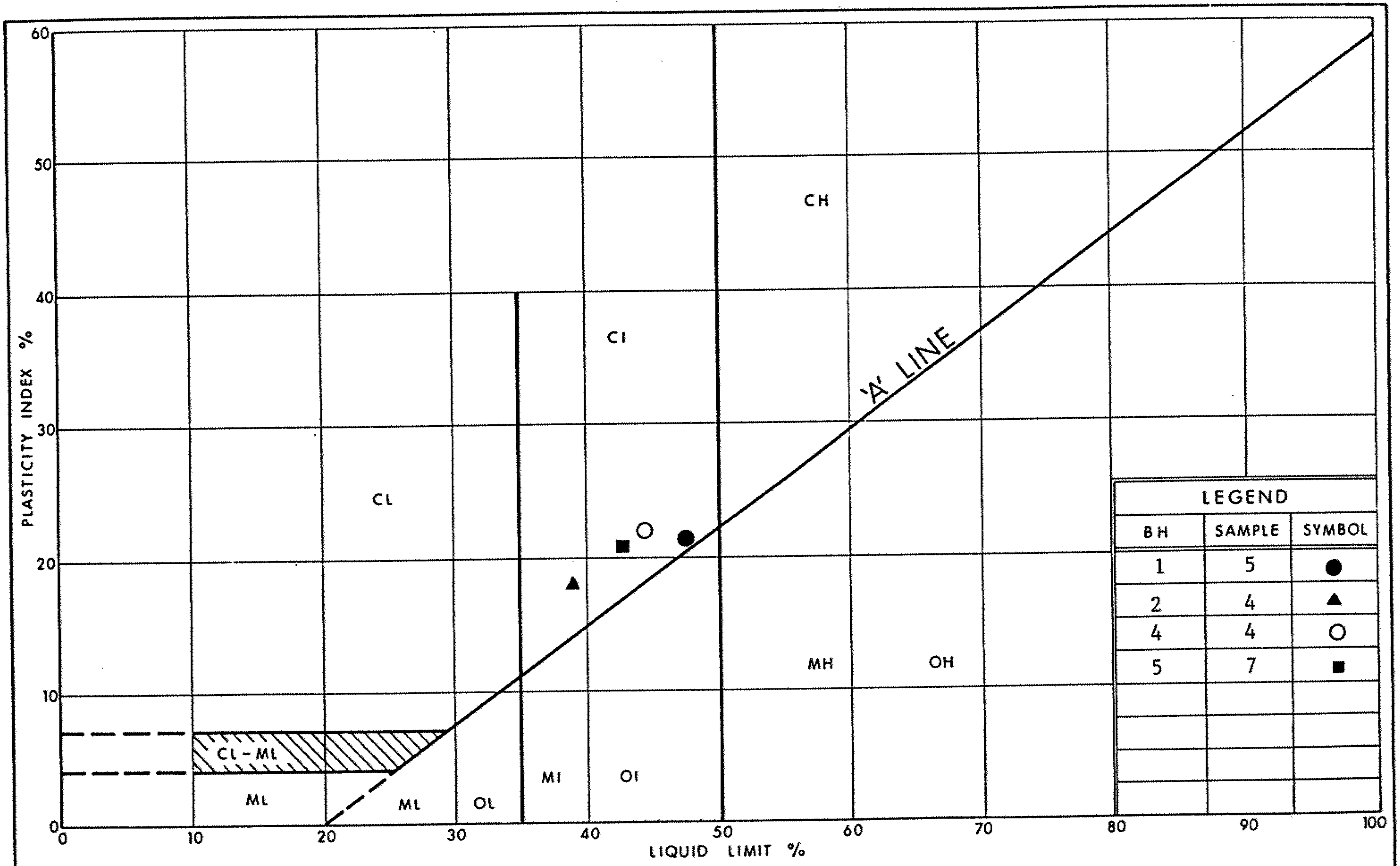
Ministry of Transportation
Ontario

PLASTICITY CHART

Silty Clay to Clay

FIG No 1A
W P 187-89-03
Steven Creek Bridge

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
1	5	●
2	4	▲
4	4	○
5	7	■

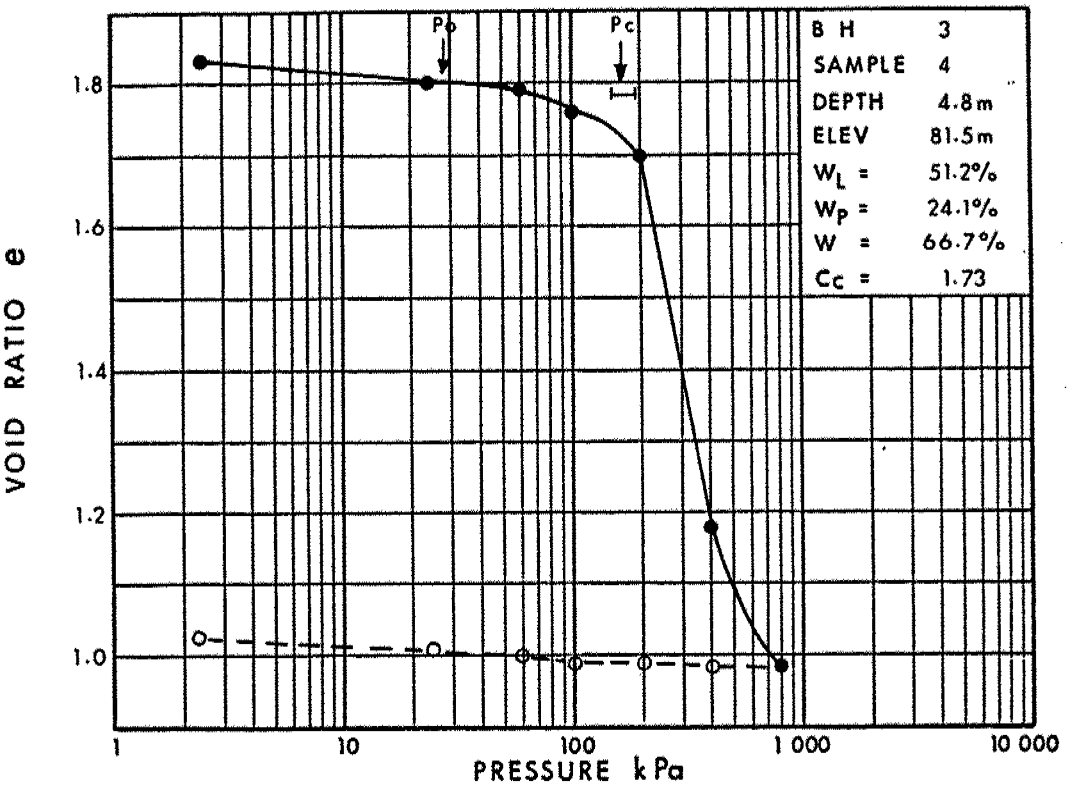
Ministry of Transportation
Ontario

PLASTICITY CHART

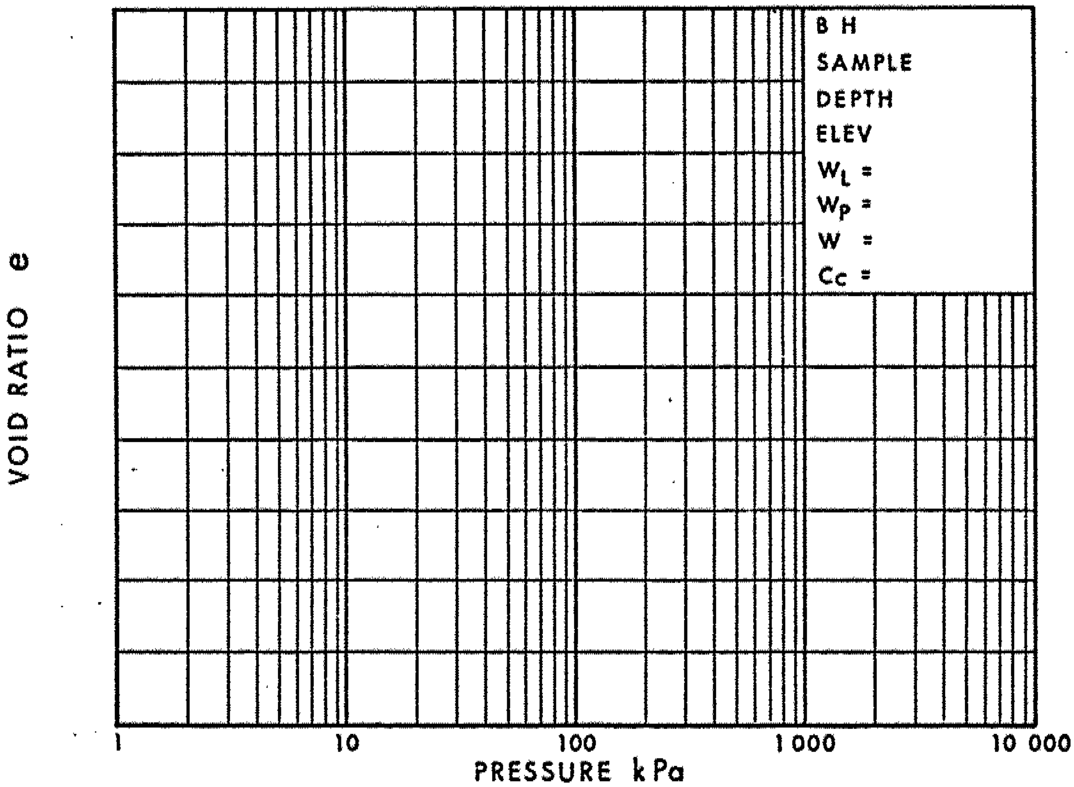
Silty Clay

FIG No 1B
W P 187-89-03
Steven Creek Bridge

VOID RATIO-PRESSURE CURVES



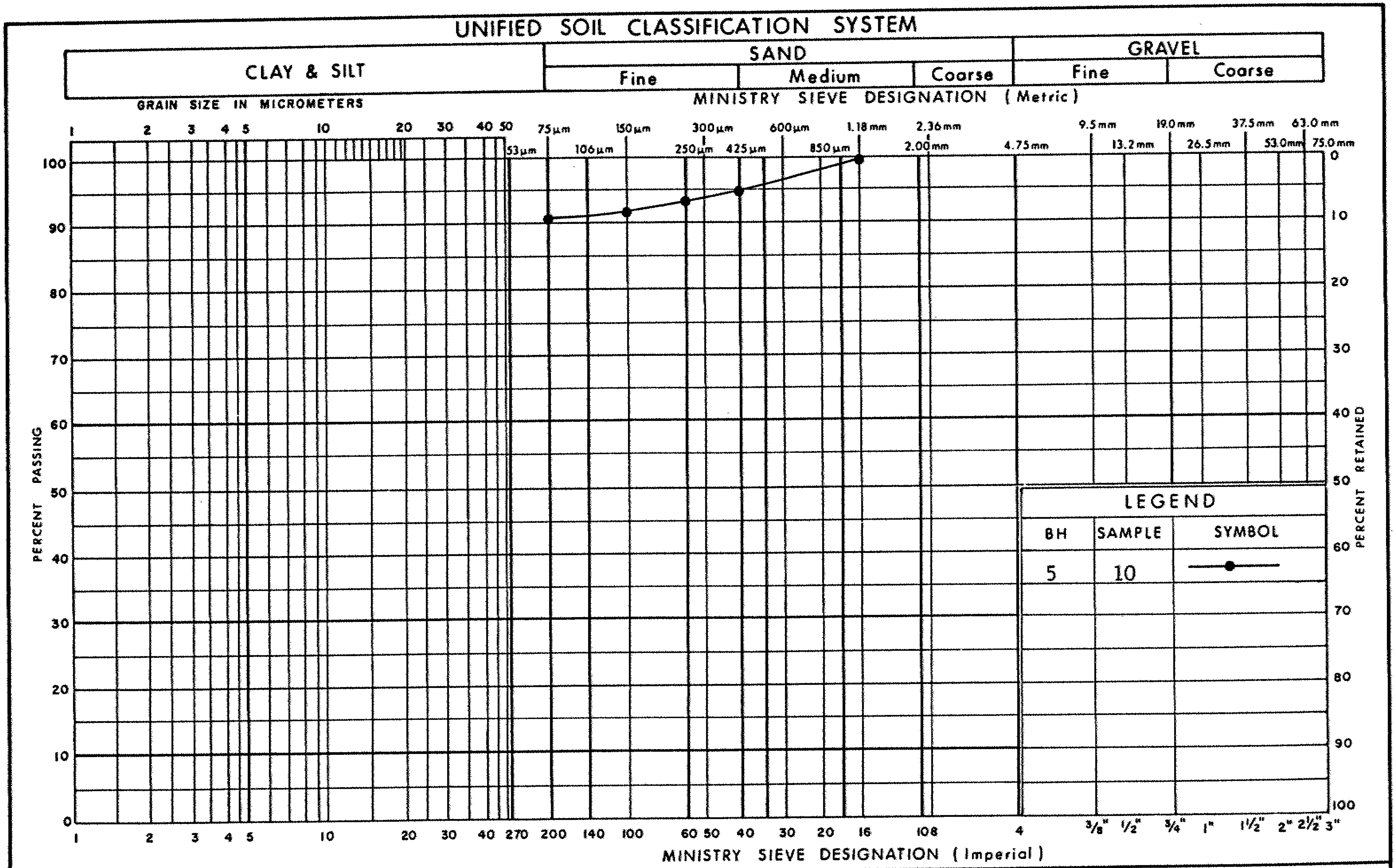
B H 3
SAMPLE 4
DEPTH 4.8 m
ELEV 81.5 m
W_L = 51.2%
W_P = 24.1%
W = 66.7%
Cc = 1.73



B H
SAMPLE
DEPTH
ELEV
W_L =
W_P =
W =
Cc =

Fig 2

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

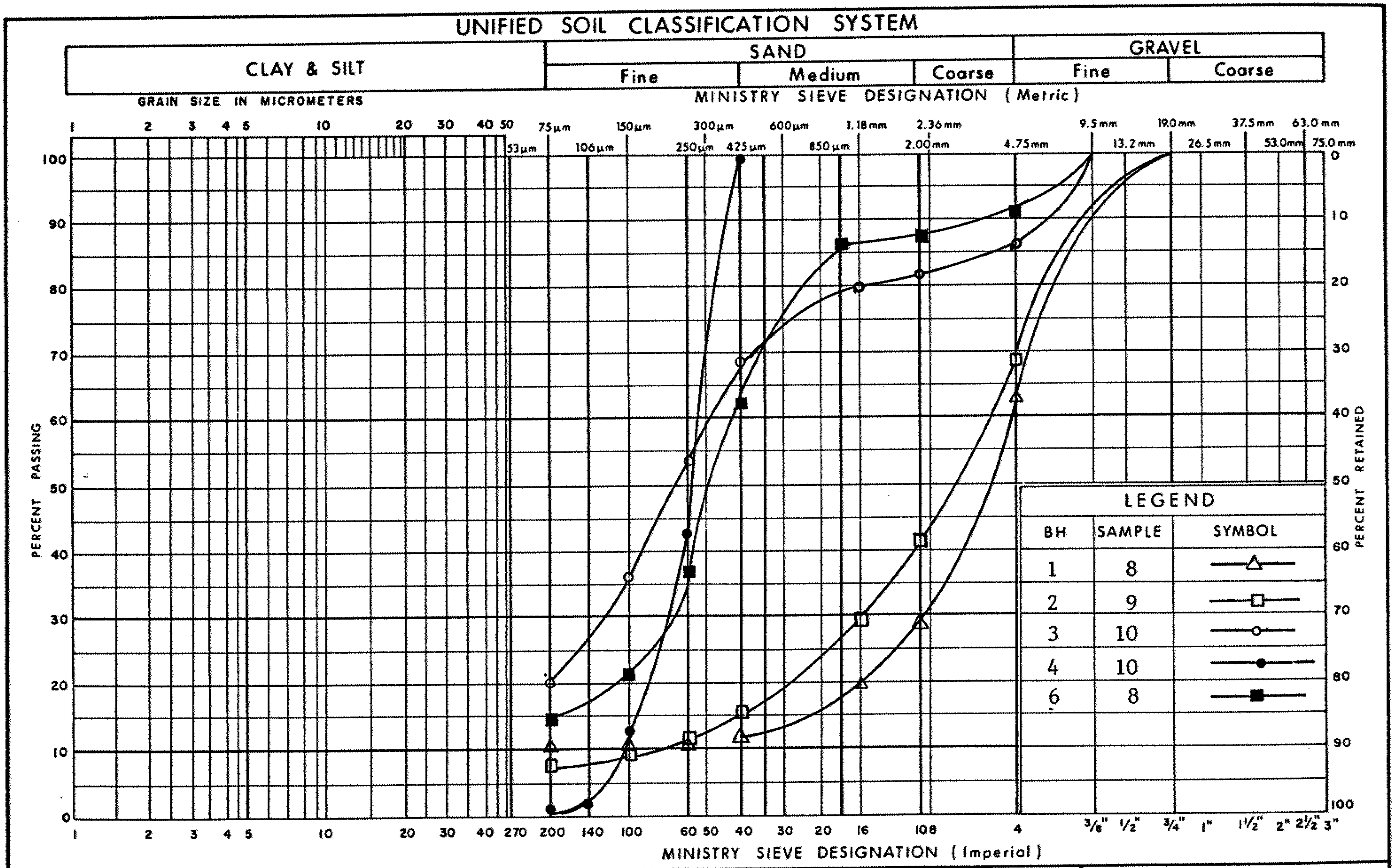
Silt

FIG No 3

W P 187-89-03

Steven Creek Bridge

78 12 M



Ministry of Transportation
Ontario

GRAIN SIZE DISTRIBUTION

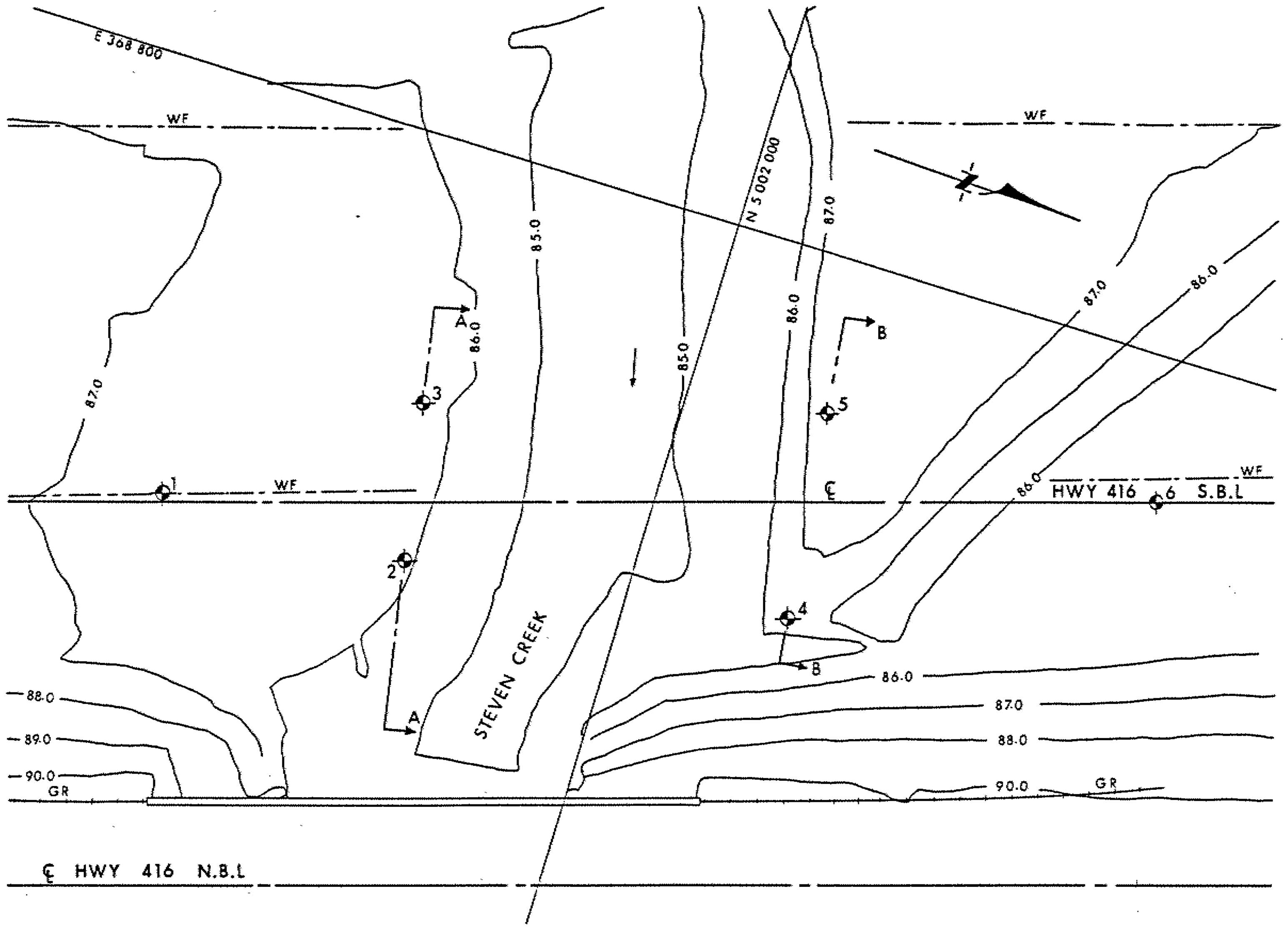
Sand and Gravel (Glacial Till)

FIG No 4

W P 187-89-03

Steven Creek Bridge

MINISTRY OF TRANSPORTATION, ONTARIO PH-D-207 88 10



PLAN

SCALE
5m 0 5m

METRIC

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

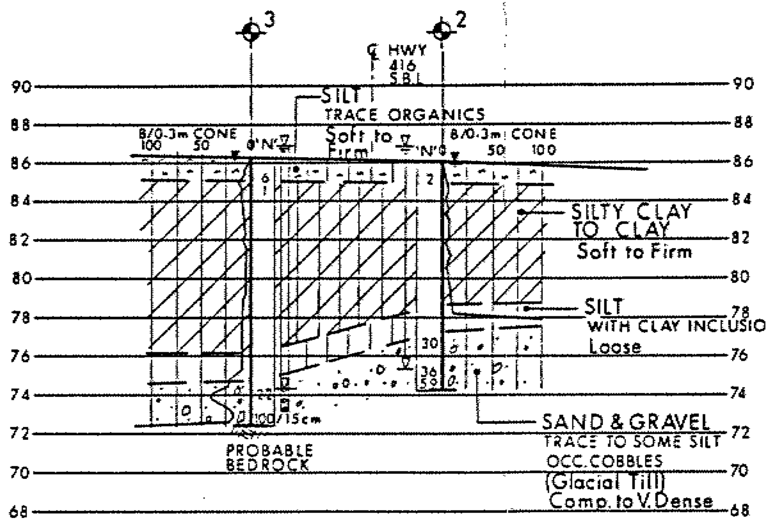
CONT No
WP No187-89-03

SHEET

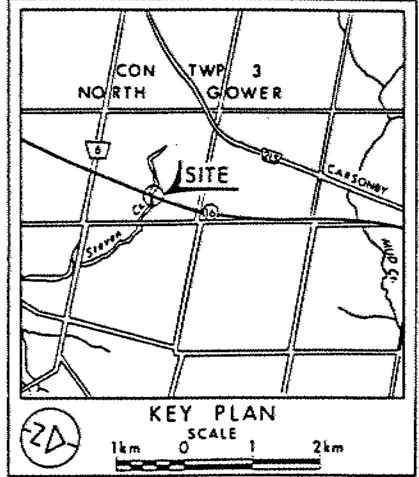
STEVEN CREEK

BORE HOLE LOCATIONS & SOIL STRATA

STRATA ENGINEERING CORP.



SECTION A-A



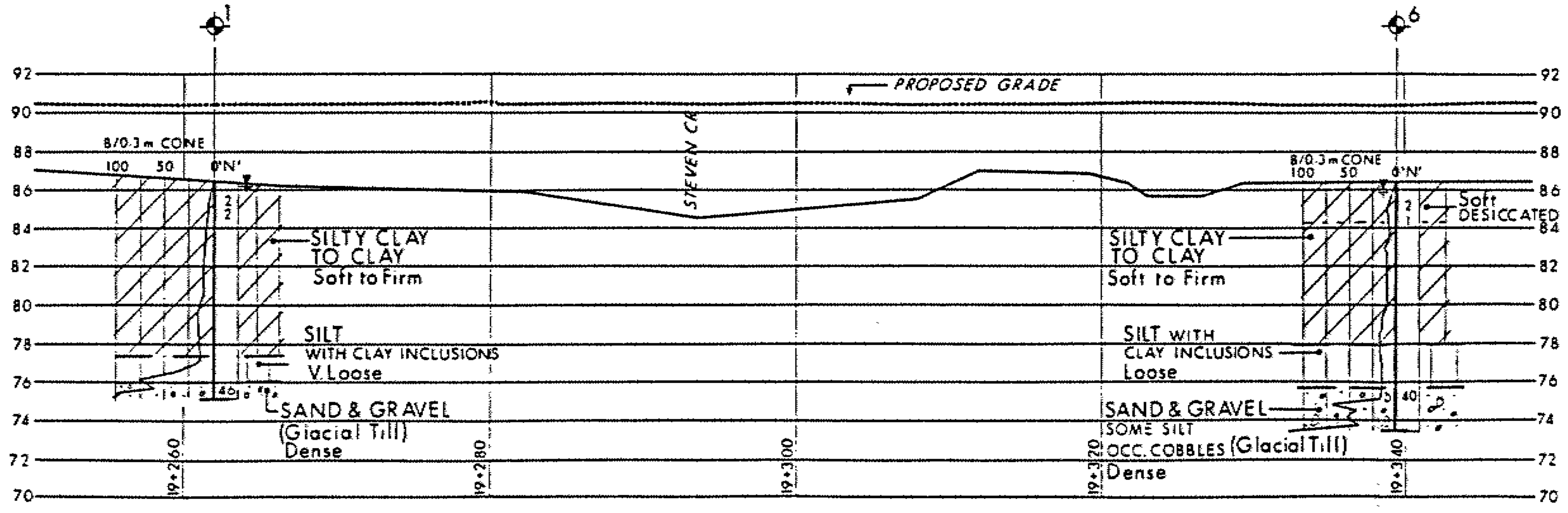
KEY PLAN
SCALE
1km 0 1 2km

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

LEGEND

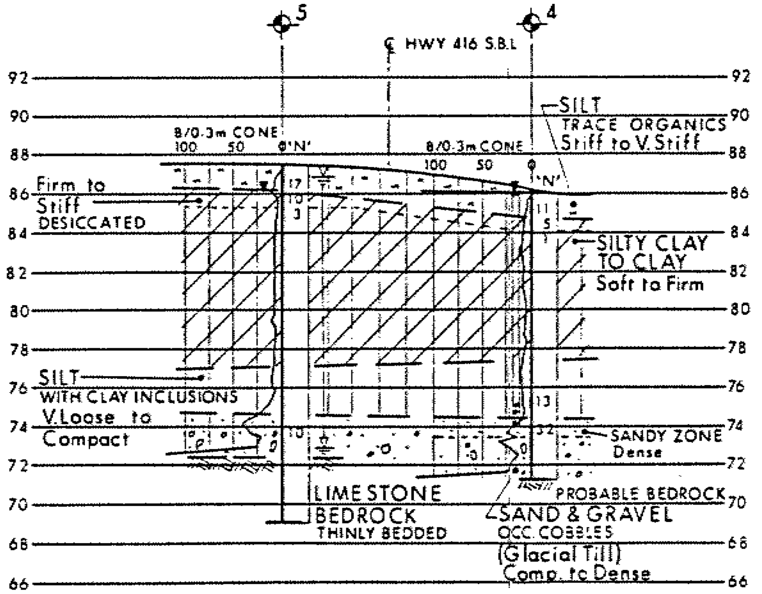
- ● Bore Hole
- ⊕ Dynamic Cone Penetration Test (Cone)
- ◈ Bore Hole & Cone
- N Blows/0.3m (Std Pen Test, 475 J/blow)
- CONE Blows/0.3m (60° Cone, 475 J/blow)
- W L at time of investigation Oct 1990
- Head ARTESIAN WATER Encountered
- Stand Pipe

No	ELEVATION	CO-ORDINATES NORTH	CO-ORDINATES EAST
1	86.5	5 001 962.8	368 833.0
2	86.1	5 001 982.5	368 832.5
3	86.3	5 001 980.4	368 820.4
4	86.2	5 002 012.5	368 828.0
5	87.6	5 002 011.0	368 812.0
6	86.3	5 002 037.8	368 811.0



℄ PROFILE HWY 416 S.B.L

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



SECTION B-B

-≡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-214

HWY No 416			DIST 9
SUBM'D A A	CHECKED	DATE May 11 1991	SITE 3-356/2
DRAWN A K	CHECKED	APPROVED	DWG 1878903-A

REF No E-55-416-3 91 01