

GEOCRES No. 40112-23DIST. 1 REGION \_\_\_\_\_

W.P. No. \_\_\_\_\_

CONT. No. \_\_\_\_\_

W. O. No. 2000 - 11025

STR. SITE No. \_\_\_\_\_

HWY. No. 2LOCATION SLOPE FAILUREEAST OF THAMES RIVERNo. of PAGES - 1

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT. \_\_\_\_\_

REMARKS: \_\_\_\_\_

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ENGINEERING MATERIALS OFFICE  
FOUNDATION DESIGN SECTION

WP Thames River DIST 1  
HWY 2 STR SITE

Slope Failure East of Thamesville

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FOUNDATION INVESTIGATION REPORT  
For  
Highway 2 Slope Failure East of Thamesville  
Lot 6A, River Range SLR, Zone Township  
District #1, Chatham

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INTRODUCTION

This report contains the results of a Foundation Investigation carried out to provide recommendations to rectify the existing slope failure, at the above location during the period from 87-05-20 to 87-06-03. The borings were advanced by NX casing (8.9 cm O.D.) using a diamond drill mounted on skids.

SITE DESCRIPTION

The site is located approximately 8 km east of Thamesville on Highway 2 on the north side of the Thames River. The physiographic region is the Bothwell Sand Plains cut by the Thames River which in this area is part of the St. Clair Clay Plains. The terrain is flat with the river cutting a valley approximately 15 m deep at the site. The land is used largely for agricultural purposes. To the north is a Blueberry farm and to the south of the river is the Moravian Indian Reserve No. 47.

SUBSURFACE CONDITIONS

Three sampled boreholes and three dynamic cone penetration tests were carried out at the site. Sampling was performed to a maximum depth of 18.9 m to elevation 175.6 m and the cone tests from ground level to a maximum depth of 11.9 m to elevation 178.4 m.

The material encountered at the surface under the shoulders was 1.5 m of silty sand fill on top of approximately 1.5 m of loose to compact original silty sand, traces of wood and roots. At the toe of the slope by the river bank the top 1.7 m varied from silty clay some sand to silty sand. Beneath these deposits was a stiff to hard silty clay with thin layers of silty clay

to clay, traces of sand. At the rivers edge the silty clay was found below 15 cm of topsoil. Beneath the silty clay a deposit of very dense silty sand, trace to some gravel was found at approximate elevation 176.6 m±. A brief description of the different soil types is given below.

#### Silty Sand, Trace of Gravel

This 2.7 to 2.9 m thick layer was encountered under the shoulders of the highway. It consisted of approximately 1.5 m of silty sand fill on top and approximately 1.5 m of original silty sand. Both layers contain traces of gravel.

Laboratory tests indicate that the average natural moisture content of the material was 10%, ranging from 6.5 to 13%. The results from the grain size distribution test are shown in Figure 1. The denseness of the material ranged from very dense to loose.

#### Silty Clay to Clay

Beneath the above noncohesive material was a stiff to hard silty clay with thin layers of silt at the top to clay, traces of sand. It was encountered 3.1 to 3.4 m below the ground surface at elevation 191.9 to 191.5 m under the shoulders to elevation 176.9 m (14.6 m+ thick). At the bottom of the slope it was found at the surface to elevation 176.3 m (5.6 m thick), however it contained some layers of the silty sand layer described above within the top 1.8 m. At the rivers edge the silty clay was found below 15 cm of topsoil.

The physical properties of the material as determined by field and laboratory tests are listed below:

	<u>Mean</u>
Natural Moisture Content (w)	26.2%
Liquid Limit ( $w_L$ )	43.0%
Plastic Limit ( $w_p$ )	18.9%

The results from the grain size distribution tests are shown on Figure 2. Figure 3 indicates that the material plots mainly as a CI to a CH. The consistency of the deposit ranges from stiff to hard.

Silty Sand, Trace/Some Gravel

Encountered below the silty clay deposit described above was a deposit of silty sand, trace/some gravel. This was found at elevation 176.9 under the shoulder (borehole 1) and elevation 176.3 m at the toe of the slope by the river (borehole 3).

The denseness of the deposit was very dense. The laboratory tests indicate a natural moisture content of 13%. The results from two grain size distribution tests show 4 to 21% gravel, 59 to 64% sand and 20 to 32% fines.

GROUNDWATER CONDITIONS

Groundwater in the boreholes observed during the field investigation were:

<u>Borehole</u>	<u>Elevation (m)</u>
1	189.3
2	191.6
3	181.1

The boreholes indicate the groundwater level to be in general just above the bottom of top silty sand layers. The water level will most likely vary with the seasons and along the river bank with the river water level.

## DISCUSSION AND RECOMMENDATIONS

The existing slope is eroding away and rock fill has been placed by the patrol yard along the major eroded areas of the top slope. The deposit of very fine sand encountered along the shoulders to elevation 191.9 m is susceptible to frost, erosion and seepage forces. Such material can not remain stable with gradients steeper than 3 or 4 horizontal to 1 vertical.

It is recommended that from station 14+560 to 14+830 on the south side of Highway 2 the following remedy be carried out.

1. Subexcavate from the pavement edge to the silty clay at approximate elevation 191.9 m extending with a downward grade of 5% outward to the exposed slope. The subexcavated area should be backfilled with well compacted Granular 'A', and the final slope should not be steeper than 2 to 1. See Figure 4 in the Appendix for clarification.

## Embankment

Embankment reconstruction below the subexcavated silty sand (elev. 191.9 m) should be carried out with a side slope not steeper than 2 horizontal to 1 vertical. For this portion benching should be carried out as per OPSD 208.01 dated 83-12-01 consisting of any acceptable well compacted earth fill.

This remedial work need not be completed over the full length in one season. It would be better to carry out the remedial work over the worst portion, approximately 60 m in length. This should be carefully monitored to determine if significant improvement has occurred. If improvement is noted the treatment should be carried out at your convenience over the remainder of the section.

## MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of Mrs. P. Marks, Foundation Engineer. The equipment used for the foundation

investigation was owned and operated by Master Soil. This report was prepared by Pamela Marks and reviewed by Mr. Ken Selby.



*Pamela Marks*

P. Marks, P.Eng.  
Foundation Engineer

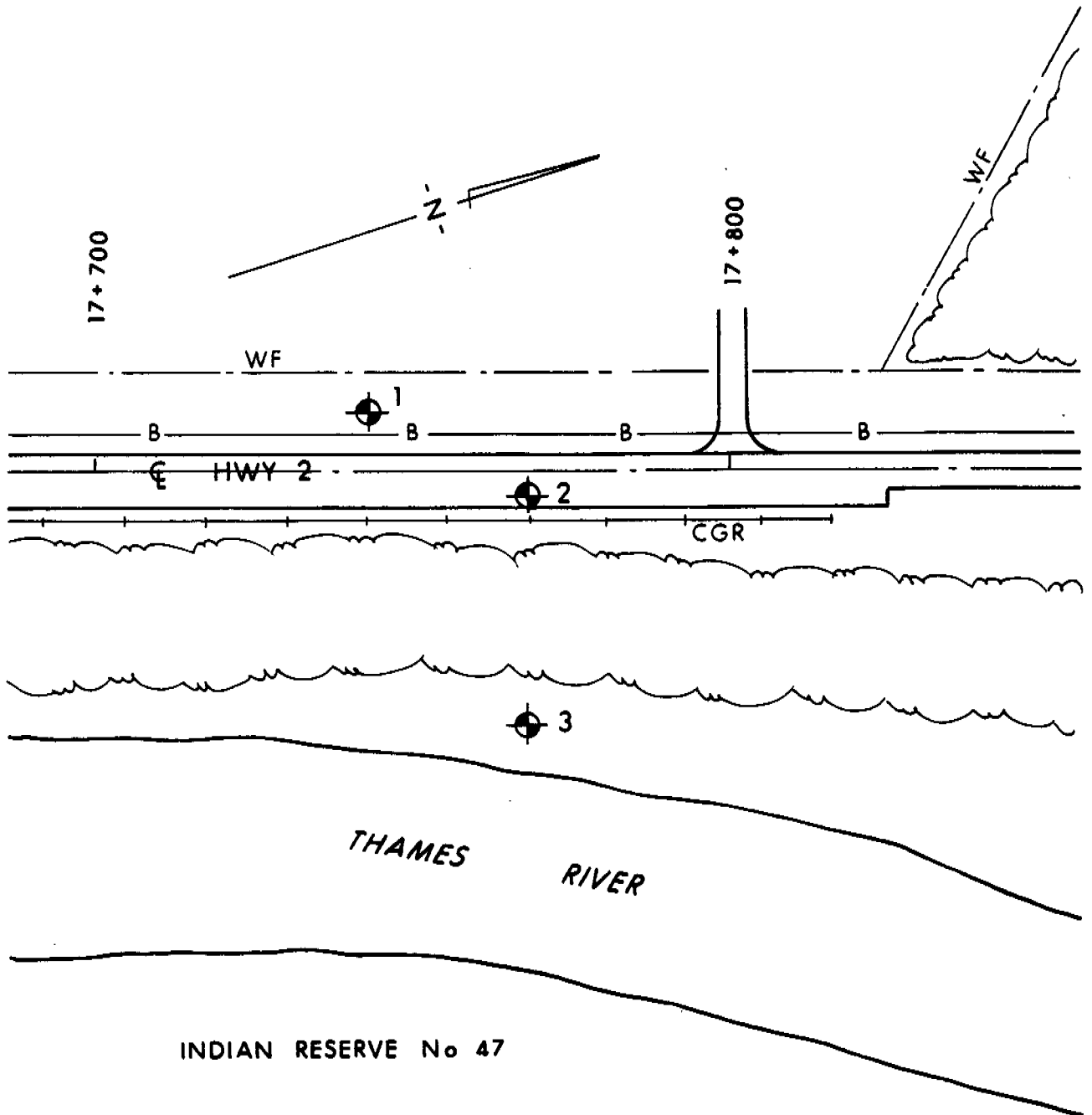
*K. G. Selby*

K.G. Selby, P.Eng.  
Chief Foundations Engineer  
(West)

## **APPENDIX**



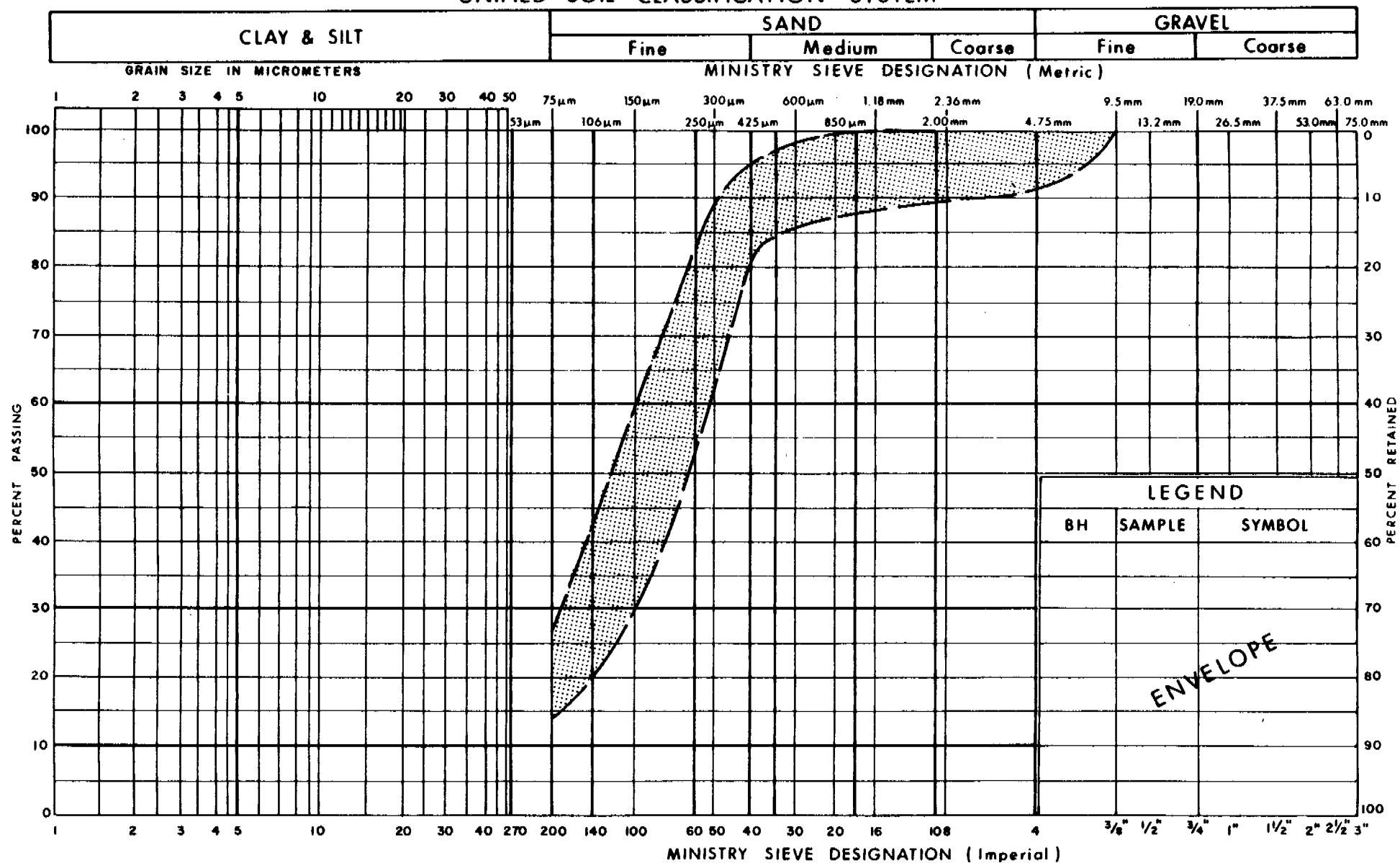
BH 1	STA 14+743.0	OFFSET 6.1 m LT
" 2	" 14+768.0	" 4.6 m RT
" 3	" 14+768.0	" 40.2 m RT



SCALE 1:1000

SKETCH SHOWING BORE HOLE LOCATION

## UNIFIED SOIL CLASSIFICATION SYSTEM

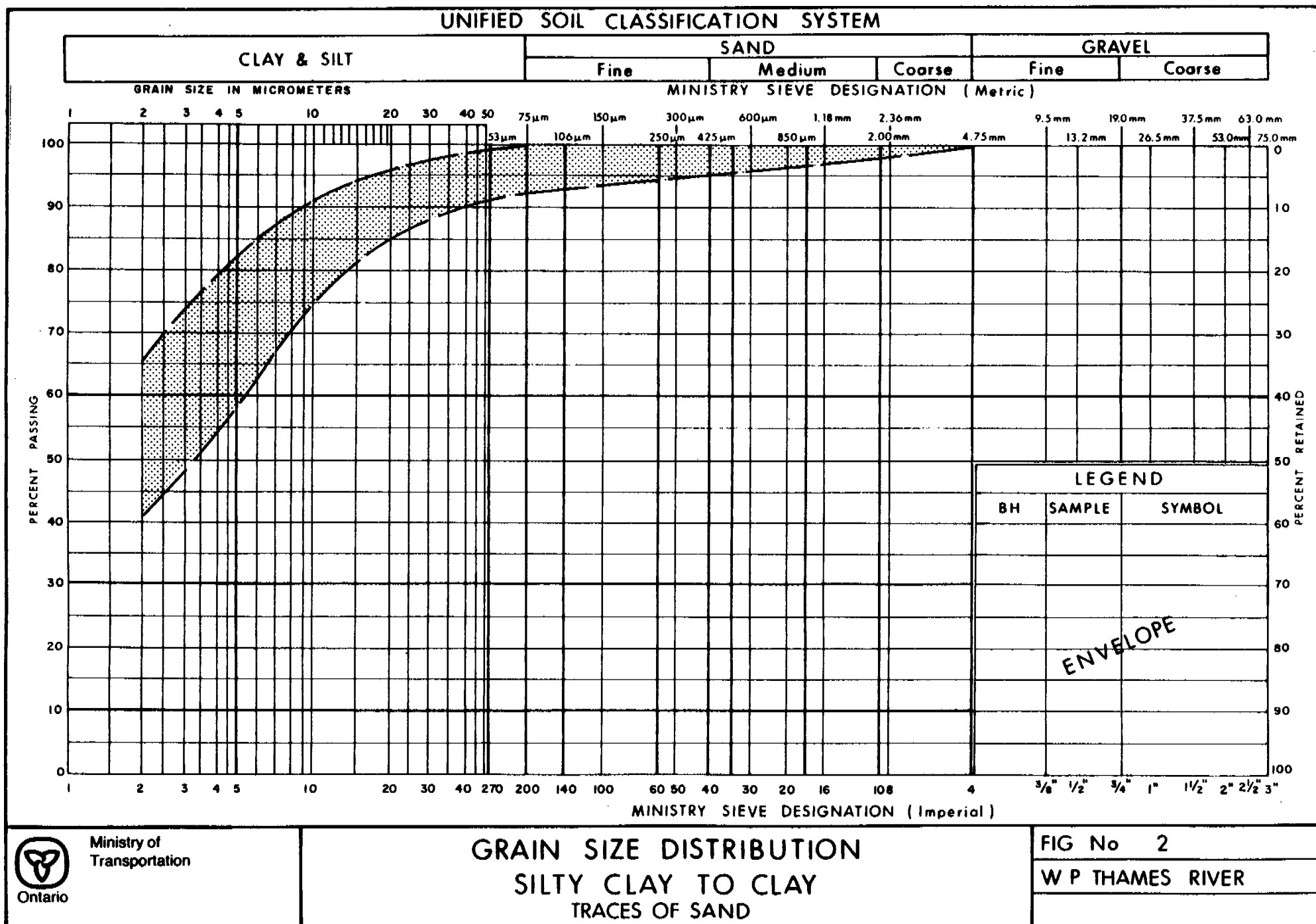
Ministry of  
Transportation

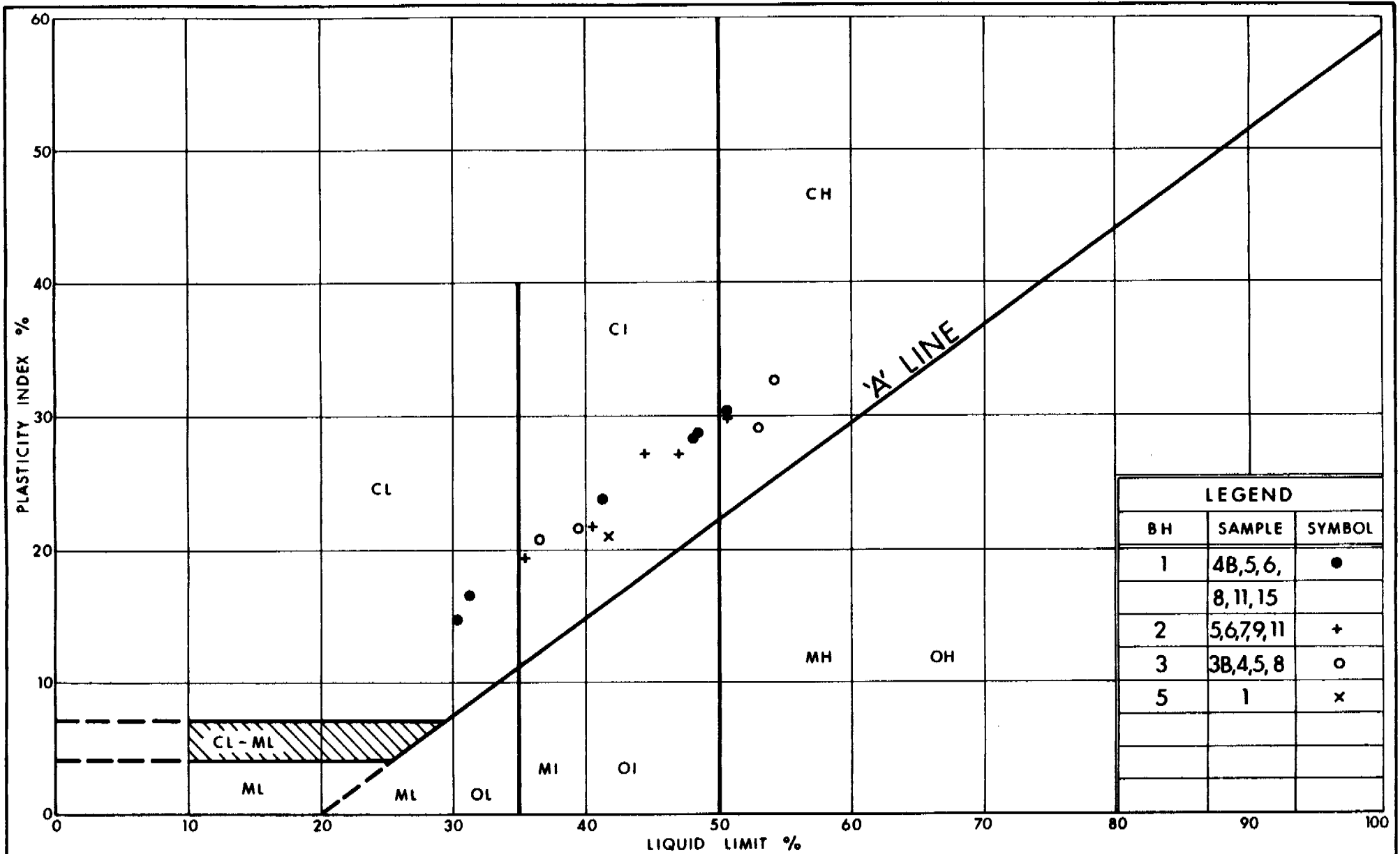
## Ontario

GRAIN SIZE DISTRIBUTION  
SILTY SAND  
TRACES OF GRAVEL

FIG No 1

W P THAMES RIVER





Ministry of  
Transportation

Ontario

# PLASTICITY CHART SILTY CLAY TO CLAY

FIG No 3

W P THAMES RIVER

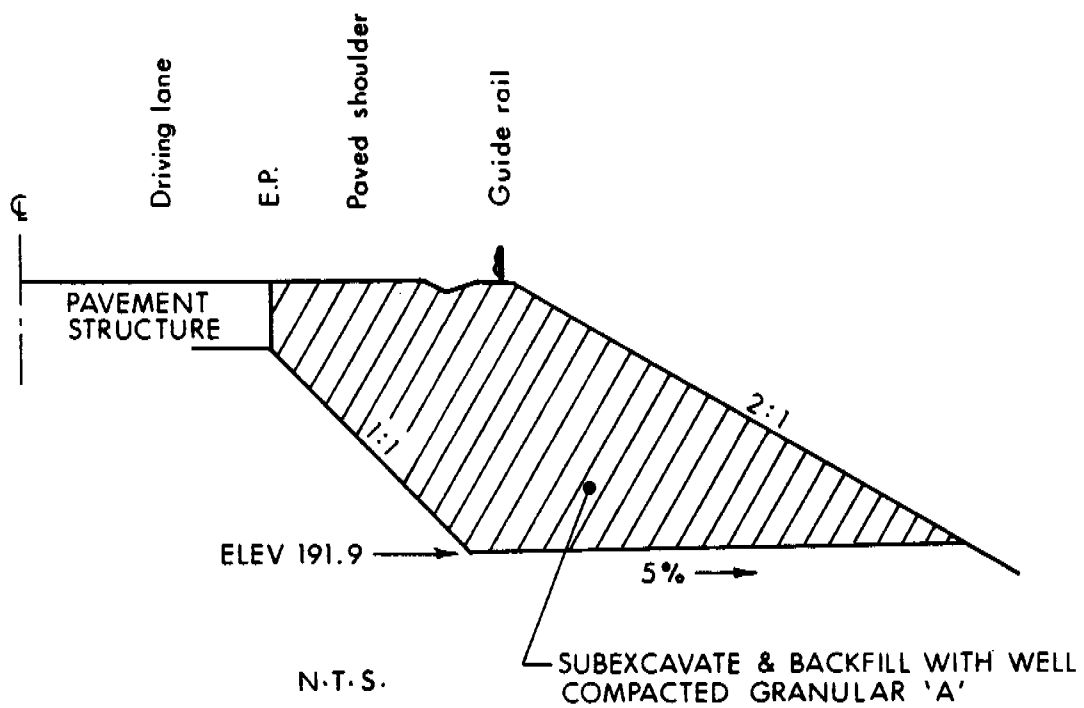
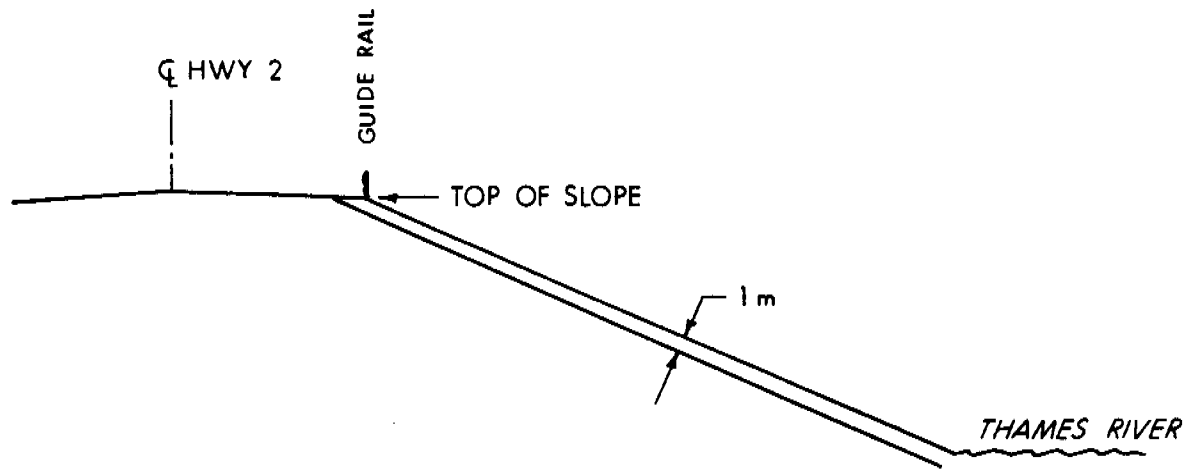
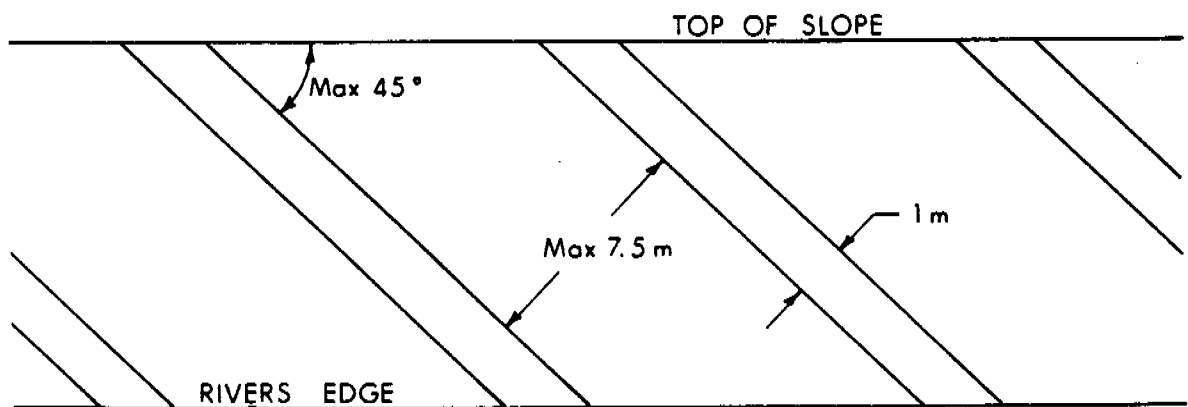


FIG 4 - SUBEXCAVATION OF VERY FINE SAND



SIDE VIEW OF FRENCH DRAIN EXTENDING  
FROM THE SHOULDER INTO THE RIVER

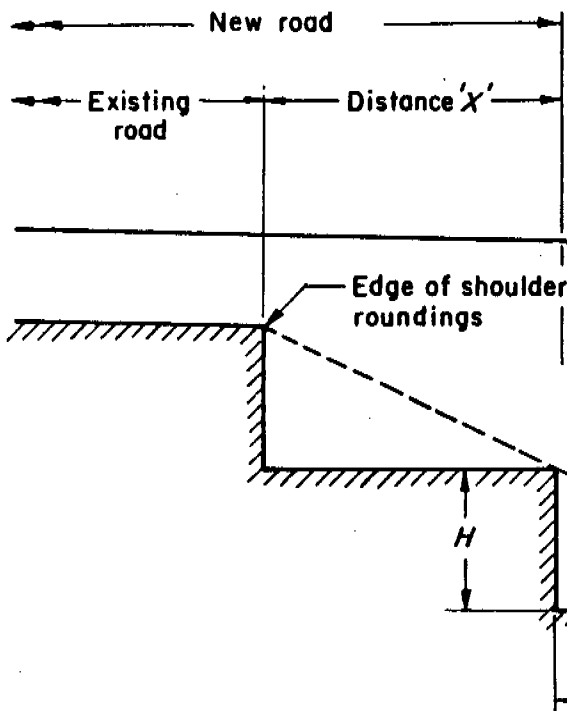
N.T.S.



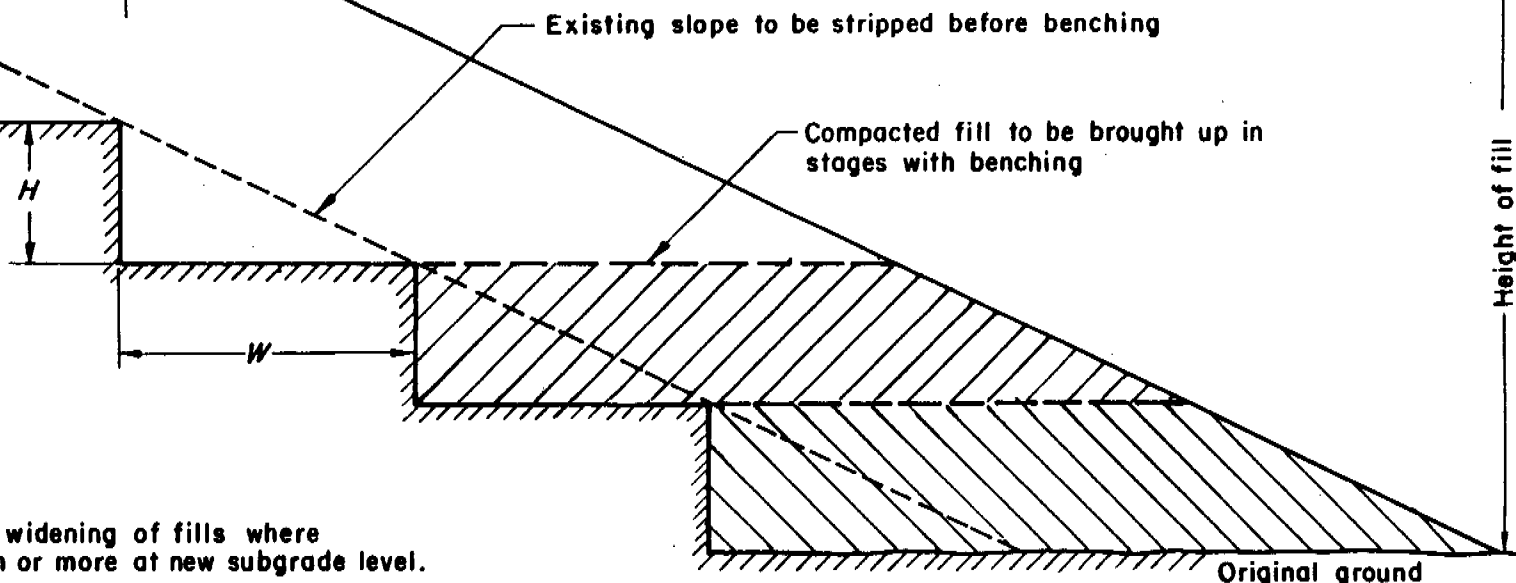
FRONT VIEW OF FRENCH DRAINS EXTENDING FROM THE TOP OF  
THE SLOPE (SHOULDER) INTO THE THAMES RIVER

N.T.S.

FIG 5 - FRENCH DRAINS



MAX HEIGHT AND WIDTH OF BENCHES <i>H</i> = Height, <i>W</i> = Width				
Existing slopes	Fills 3.5m or more		Fills under 3.5m	
	<i>W</i>	<i>H</i>	<i>W</i>	<i>H</i>
3:1 to 2:1	2.50	Var	1.25	Var
2:1	1.25	Var	600	Var



#### NOTES:

- This Standard applies to widening of fills where the distance 'X' is 1.0 m or more at new subgrade level.
- Benching is not required on existing slopes flatter than 3:1 or where specified.
- Benchs are to be excavated one level at a time and the compacted fill brought up before the next benching level is excavated.
- All dimensions are in millimetres or metres unless otherwise shown.

ONTARIO PROVINCIAL STANDARD DRAWING

BENCHING  
OF  
EARTH SLOPES

Date 1983 12 01 Rev

Date

OPSD-208.01

## 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 T W ADVANCED HYDRAULICALLY
CS CHUNK SAMPLE	PM T W ADVANCED MANUALLY
TW THINWALL OPEN	FS FOIL SAMPLE

### MECHANICAL PROPERTIES OF SOIL

$m_v$	$\text{kPa}^{-1}$	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$c_v$	$\text{m}^2/\text{s}$	COEFFICIENT OF CONSOLIDATION
H	m	DRAINAGE PATH
$T_v$	1	TIME FACTOR
U	%	DEGREE OF CONSOLIDATION
$\sigma'_{vo}$	kPa	EFFECTIVE OVERBURDEN PRESSURE
$\sigma'_p$	kPa	PRECONSOLIDATION PRESSURE
$\tau_f$	kPa	SHEAR STRENGTH
$c'$	kPa	EFFECTIVE COHESION INTERCEPT
$\phi'$	-°	EFFECTIVE ANGLE OF INTERNAL FRICTION
$c_u$	kPa	APPARENT COHESION INTERCEPT
$\phi_u$	-°	APPARENT ANGLE OF INTERNAL FRICTION
$\tau_R$	kPa	RESIDUAL SHEAR STRENGTH
$\tau_r$	kPa	REMOULDED SHEAR STRENGTH
$S_t$	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

### STRESS AND STRAIN

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

### PHYSICAL PROPERTIES OF SOIL

$\rho_s$	$\text{kg}/\text{m}^3$	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	$e_{\min}$	1, %	VOID RATIO IN DENSEST STATE
$\gamma_s$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	$I_D$	1	DENSITY INDEX = $\frac{e_{\max} - e}{e_{\max} - e_{\min}}$
$\rho_w$	$\text{kg}/\text{m}^3$	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
$\gamma_w$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF WATER	$S_r$	%	DEGREE OF SATURATION	$D_n$	mm	n PERCENT - DIAMETER
$\rho$	$\text{kg}/\text{m}^3$	DENSITY OF SOIL	$w_L$	%	LIQUID LIMIT	$C_u$	1	UNIFORMITY COEFFICIENT
$\gamma$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SOIL	$w_p$	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
$\rho_d$	$\text{kg}/\text{m}^3$	DENSITY OF DRY SOIL	$w_s$	%	SHRINKAGE LIMIT	q	$\text{m}^3/\text{s}$	RATE OF DISCHARGE
$\gamma_d$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF DRY SOIL	$I_p$	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
$\rho_{\text{sat}}$	$\text{kg}/\text{m}^3$	DENSITY OF SATURATED SOIL	$I_L$	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
$\gamma_{\text{sat}}$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SATURATED SOIL	$I_C$	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
$\rho'$	$\text{kg}/\text{m}^3$	DENSITY OF SUBMERGED SOIL	$e_{\max}$	1, %	VOID RATIO IN LOOSEST STATE	j	$\text{kN}/\text{m}^2$	SEEPAGE FORCE
$\gamma'$	$\text{kN}/\text{m}^3$	UNIT WEIGHT OF SUBMERGED SOIL						





# RECORD OF BOREHOLE No 1

METRIC

W P Thames River LOCATION Sta. 14 + 743; O/S 6.1 m Lt. of E Hwy. 2 ORIGINATED BY PM  
DIST 1 HWY 2 BOREHOLE TYPE NX Casing COMPILED BY PM  
DATUM Geodetic DATE 87 05 20 to 87 05 22 CHECKED BY \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT		UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)		
194.9	Ground Level												
194.0	Topsoil												
0.5	Silty Sand (Fill)		1	SS	16		194						1 85 (14)
			2	SS	9								8 71 (21)
	Occ. Pieces of Wood and Roots		3	SS	4								3 73 (24)
191.5	Compact to Loose		4	SS	10		192						4 69 (27)
3.4			5	SS	18								13 60 (27)
			6	SS	11								0 3 (97)
	Silty Clay with Thin Layers of Silt to Clay		7	TW	PM		190						0 2 53 45
			8	SS	14								0 2 41 57
			9	SS	18		188						1 4 34 61
	Trace of Sand		10	SS	12								
			11	SS	22		186						
			12	SS	27								0 7 39 54
	Stiff to Hard		13	SS	34		184						
			15	SS	21		182						
176.9			16	SS	88	20 cm	180						
18.0	Silty Sand Trace of Gravel Very Dense						178						0 0 35 65
176.0													4 64 (32)
18.9	End of Borehole						176						

+<sup>3</sup>, x<sup>5</sup>: Numbers refer to  
Sensitivity

20  
15 5 (%) STRAIN AT FAILURE  
10



# RECORD OF BOREHOLE No 2

METRIC

W P Thames River LOCATION Sta. 14 + 768; O/S 4.6 m Rt. of Hwy. 2 ORIGINATED BY PM  
DIST 1 HWY 2 BOREHOLE TYPE NX Casing COMPILED BY PM  
DATUM Geodetic DATE 87 05 25 to 87 05 28 CHECKED BY \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60					
195.0	Ground Level													GR SA SI CL
194.8	Shoulder Pavement & Gran.													
0.4	Silty Sand (Fill) Very Dense to Compact		1	SS	73		194							0 81 (19)
			2	SS	21									1 73 (26)
			3	SS	23									1 74 (25)
191.9			4	SS	17		192							0 86 (14)
3.1			5	SS	23									3 82 (15)
	Silty Clay		6	SS	13		190							0 1 60 39
	With Thin Layers of Silt to Clay		7	SS	13									0 1 54 45
			8	SS	16									0 0 36 64
	Trace of Sand		9	SS	11		188							0 2 28 70
			10	SS	16		186							
	Stiff/ Very Stiff		11	SS	20		184							2 6 42 50
			12	SS	17		182							
			13	SS	17		180							
			14	SS	21		178							
177.0	End of Borehole													
18.0														

+<sup>3</sup>, x<sup>5</sup>: Numbers refer to  
Sensitivity

20  
15 5 (%) STRAIN AT FAILURE  
10



# RECORD OF BOREHOLE No 3

METRIC

W P Thames River LOCATION Sta. 14 + 768; O/S 40.2 m Rt. of Hwy. 2 ORIGINATED BY PM  
DIST 1 HWY 2 BOREHOLE TYPE NX Casing COMPILED BY PM  
DATUM Geodetic DATE 87 06 01 to 87 06 03 CHECKED BY \_\_\_\_\_

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W <sub>p</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
183.6	Ground Level																
0.0	Layers of Compact Silty Sand Firm		1	SS	5												0 24 60 16
			2	SS	8												0 25 (75)
			3	SS	13												0 13 43 44
			4	SS	23												0 71 (29)
	Silty Clay with Thin Layers of Silt to Clay		5	SS	26												0 3 55 42
			6	SS	10												0 1 49 50
	Trace of Sand		7	SS	11												0 1 35 64
	Very Stiff/Stiff		8	SS	7												
			9	TW	PM												
176.3																	
7.3	Silty Sand, Some Gravel		10	SS	120	23 cm	176										21 59 (20)
175.6	Very Dense																
8.0	End of Borehole																

+3, x5: Numbers refer to  
Sensitivity

20  
15  
10  
5 (%) STRAIN AT FAILURE