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HWY. No. 416

LOCATION HWY 416 & CAMBRIAN RD.

U<sup>1</sup>PASS (STR #23)

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OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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## **FOUNDATION DESIGN SECTION**

**foundation  
investigation and  
design report**

ENGINEERING MATERIALS OFFICE  
FOUNDATION DESIGN SECTION

WP 128-87-09

DIST 9

HWY 416

STR SITE 3-551

Hwy. 416 and Cambrian Road Underpass

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FOUNDATION INVESTIGATION REPORT  
For  
Hwy. 416 and Cambrian Road Underpass  
W.P. 128-87-09, Site No. 3-551  
Hwy. 416, District 9, Ottawa

INTRODUCTION

This report summarizes the results of a foundation investigation conducted at the aforementioned site. It is proposed to construct a two span structure which will carry Cambrian Road over the proposed Hwy. 416. This report contains factual information obtained from this investigation pertaining to structural foundations and related earth works within 100 m of the structure.

SITE DESCRIPTION

The site is located approximately 1 km south of Jock River and 85 m west of Cedarview Road along Cambrian Road in the City of Nepean, Regional Municipality of Ottawa-Carleton.

The topography of the area consists of a flat plain occupied by farmers fields. East of Cedarview Road there is a swampy woodlot consisting mainly of cedars. Approximately 500 m west of the site there is a sand and gravel ridge which rises 22 m above the plain. To the north of Cambrian Road this ridge is being mined for aggregates and to the south lies the Trail Road Landfill site owned and operated by the Regional Municipality of Ottawa-Carleton.

At the time of the investigation the surrounding farmers fields and ditches were filled with water. The surface water drains north to Jock River through ditches along Cedarview Road and a ditch located 60 m west of the centreline of Hwy. 416.

Physiographically, the site lies in the area known as the Ottawa Valley clay plains founded in the lowlands of the St. Lawrence, which are characterized by clay plains interrupted by ridges of rock or sand and gravel. The bedrock in the area is of the Gull River formation of the

middle ordovician period. It consists of limestone with interbedded shale layers. The overburden is relatively thin and was deposited during and immediately following the wisconsinan glaciation at which time the area was depressed from the effect of the glaciation.

### INVESTIGATION PROCEDURES

Soil data and inherent properties were obtained by in situ and laboratory testing. The procedures employed are discussed below.

#### Field Investigation

The field work for the investigation was carried out between 89 05 18 to 89 05 30 and consisted of eight sampled boreholes which were advanced to a maximum depth of 27.8 m (elevation 64.3 m) below the ground surface. Boreholes were located along the relocated Cambrian Road south of the existing road with two boreholes placed at east abutment, two placed at the piers, two placed at the west abutment and two boreholes located within the east/west approach ramps. Dynamic cone penetration tests were advanced at all borehole locations with 2 additional tests at centre pier locations and one test approximately 50 m west of the proposed Hwy. 416 centreline. Dynamic cone tests were advanced to a maximum depth of 24.7 m (elevation 67.0 m). Bedrock cores were obtained at one location (BH 23-2). Artesian conditions overlying the bedrock made it difficult to core bedrock at the other borehole locations.

The elevations of the boreholes advanced at the site varied from 91.7 m to 92.3 m.

In general, the subsoil samples in the surficial cohesive overburden were retrieved at 0.8 to 1.5 m intervals using a shelly tube sampler in accordance with Standard Procedures (ASTM D 1587). The shelly tube samples were supplemented by retrieving disturbed subsoil samples using a split spoon sampler in accordance with Standard Practice (ASTM D 1587). The shelly tubes were used to provide relatively undisturbed material for laboratory evaluation and testing. In view of the extreme sensitivity of

the soil at this site, special care was required for sample and handling the samples. The sensitive clay is difficult to recover because it liquifies along the inside wall of the shelby tube when the tube is pushed into the clay.

In situ vane tests were also conducted between the aforementioned sampling intervals to determine the undisturbed and remolded undrained shear strengths of the cohesive deposits. The vane shear test was conducted employing the standard MTO 'N' value in accordance with ASTM D 2573 change in consistency due to remolding (sensitivity) was also found by measuring the ratio of the undrained, unconfined compression strengths before and after remolding. The clay is soft and sensitive so the vane had to be carefully lowered to the required depth. In areas of questionable shear strengths additional vane testing was conducted.

All subsoil samples were identified in the field and returned to the laboratory for further examination and applicable testing.

Water levels were monitored throughout the duration of the investigation in open boreholes, by installing two piezometers and in the case of artesian aquifer conditions water levels were monitored by stabilizing the head in the casing or augers by extending them to greater heights. All boreholes were backfilled upon completion of the field work.

Survey information related to the location and elevation of boreholes was provided by the Eastern Region, Surveys and Plans Section.

#### Laboratory Analysis

The following laboratory tests were carried out on select soil samples.

- 1) Atterberg Limit Test
- 2) Grain Size Distribution
- 3) Unit Weights
- 4) Natural Moisture Contents

Laboratory Test results are given in the following section of this report and are illustrated on Figures and Borehole Log sheets included in the Appendix.

#### SUBSURFACE CONDITIONS

The subsoil stratigraphy consisted of a surficial deposit of slightly desicated brown clayey silt ranging in thickness from 2.1 m to 2.7 m. This deposit is underlain by an extensive deposit of 14.6 m to 15 m of sensitive grey clayey silt to silty clay. Below the above deposits rests a 3.7 m to 6.4 m thick deposit of silty clay to clay. This deposit confines an aquifer contained in approximately 2 m of sand and gravel. The sand and gravel deposit overlies dolomite bedrock.

West of the site there is a sand and gravel ridge being mined for aggregates. The sand and gravel ridge is pervious and is believed to be the source for the confined augifer underlying the clay at the Cambrian Road site.

The plan and location of borings and the stratigraphical profile are shown on Dwg. No. 1288709-A in the attached appendix. The field and laboratory test results are plotted on the Record of Borehole sheets also included in the Appendix of this report. A brief description of the different soil types is given below.

#### Clayey Silt, some Sand, trace Organics

The surficial material consists of 2.1 m to 2.7 m of a desicated brown clayey silt, which contains a trace of organics and topsoil at or near the surface. Cambrian Road fill crosses this deposit and consists of 1 m and sand and gravel. This deposit extends down to an elevation of 90.0 m being relatively flat throughout the site with a distinct transition from the relatively strong brown clayey-silt to the underlying weaker grey clayey silt to silty clay.



Results of Grain Size Distribution tests carried out on select samples are shown on Figure 1 in the Appendix, in an envelope form. The results summarize Grain Size Distribution Tests carried out on this material throughout the site. The results indicate the material contains a large percentage of clay and silt with some sand. The deposit is comprised primarily of 0% gravel, 11-19% sand, 51-70% silt and 15-39% clay.

The results from the Atterberg Limit Tests performed on the fine fraction of this deposit is summarized as follows:

	<u>Range</u>	<u>No. of Tests</u>
Natural Moisture Content (w)	11-43	7
Liquid Limit ( $w_L$ )	25-32	7
Plastic Limit ( $w_p$ )	12-22	7
Plastic Index ( $I_p$ )	9-17	7
Sensitivity	5-10	5
Undrained Shear Strength $C_u$ (kPa) (Field)	27-54	5

From the Plasticity Chart (Figure 2), the layer can be classified as a clayey silt of low plasticity. Unit weight measurements carried out on samples from this stratum yielded dry unit weights of 17.9 kg/m<sup>3</sup> to 19 kg/m<sup>3</sup>.

In this stratum the shear strength (in situ) varied from 27-54 kpa indicating a firm to stiff consistency. The measured shear strengths are widely scattered due to the variable desiccation of this surficial deposit, however a clear decrease with depth can be seen (see Figure 2). In situ sensitivity ranged from 6 to 10 corresponding to a sensitive to very sensitive classification.

The Standard Penetration resistance 'N' values ranged from 2 to 9 blows/0.3 m.

Clayey Silt to Silty Clay with pockets of Organics, and occasional silty Fine Sand Seams

The brown clayey silt is underlain by a much softer and more sensitive grey clayey silt to silty clay deposit starting at an elevation of 90.0 m. This deposit is 14.6 m to 15 m thick with the bottom of the deposit relatively flat at elevation 75.0 m to 75.4 m. This marine clay increases in plasticity with depth such that at its lower boundary it is a silty clay. It contains charcoal black organics particles throughout distinguishing this deposit from the underlying silty clay to clay. Occasional seams of silty sand were encountered at the upper boundary of this deposit.

Results of Grain Size Distribution Tests carried out on select samples are shown on Figure 3 in the Appendix, in an envelope form. The results indicate the material contains a very large percentage of clay and silt with a trace of sand. The deposit is comprised primarily of 0-2% gravel, 2-17% sand, 34-56% silt and 32-64% clay.

The results from the Atterberg Limit Tests performed on the fine fraction of this deposit is summarized as follows:

	<u>Range</u>	<u>No. of Tests</u>
Natural Moisture Content (w)	34-62	25
Liquid Limit ( $w_L$ )	30-50	25
Plastic Limit ( $w_p$ )	13-24	25
Plastic Index ( $I_p$ )	11-28	25
Sensitivity	3-100	240
Undrained Shear Strength $C_u$ (kPa) (Field)	12-56	240
Unconfined Compression (U-kPa)	13-35	16
Unconsolidated Undrained (UU-kPa)	17-38	10

From the Plasticity Chart (Figure 4), the layer can be classified as a clayey silt to silty clay of low to intermediate plasticity. The average natural moisture content of this deposit exceeds the liquid limit by an average of 15%. When disturbed, this deposit will liquify because of the high moisture content.

The undrained shear strength ranges from 12 kPa to 56 kPa as indicated in Figure 5, which plots shear strength vs. elevation profile.

Observations reveal that the soil decreases in strength from an average of 32 kPa at the upper limit of this deposit to an average of 20 kPa between elevation 88 m to elevation 84 m. Below elevation 84 m the undrained shear strength gradually increases with depth to an average strength of 45 kPa at the lower boundary of this deposit. The shear strength has an average range of 8 to 10 kPa at any particular depth. The range could be caused by the random occurrence of silty fine sand seams. The sensitivity ranges from extra sensitive to quick throughout the deposit with higher sensitivities usually in the upper half. Unit weight measurements carried out on samples from this stratum yielded dry unit weights of 16-18.2 kN/m<sup>3</sup>.

Consolidation testing in the laboratory was also performed to determine the settlement characteristics of this deposit. Key inherent parameters measured from e vs. log curves are given below:

Table 1

	<u>Elevation (m)</u>	<u>Pc (kPa)</u>	<u>Cc</u>	<u>e<sub>o</sub></u>	<u>Cv (m<sup>2</sup>/year)</u>
BH 23-1 (TW6)	84.4	110	0.474	1.022	
BH 23-1 (TW8)	81.0	108	0.700	1.644	
BH 23-5 (TW3)	88.8	59	0.413	1.139	10.62
BH 23-5 (TW7)	82.6	145	0.856	1.394	
BH 23-6A (TW3)	85.8	102	0.716	1.249	4.14
BH 23-8 (TW7)	82.7	100	1.10	1.611	6.96
BH 23-11 (TW4)	87.3	82	0.584	1.181	

Cv - Coefficient of Consolidation

Pc - Preconsolidation Pressure - using casagrande

Cc - Coefficient Construction of Compressibility

e<sub>o</sub> - initial void ratio

\*Laboratory curves corrected using schmertmann method to account for the sampling and preparation disturbances.

The Figures indicate that the preconsolidation pressure ranged from 59 to 145 kPa and is on average 37 kPa greater than the existing effective overburden pressure.

Silty Clay to Clay, trace of Sand

Underlying the above material encountered at an elevation of 75.4 m to 75.0 m (3.7 m to 7 m thick) is a deposit of silty clay to clay, trace sand. The lower boundary of this material is not clearly defined because the deposit contains occasional sand and gravel pockets below elevation 74.0 m which increase in frequency with depth and as a result no clear demarcation can be defined between this layer and the underlying sand and gravel.

Categorization of the sand and gravel deposit has been based on the detection of artesian conditions. This deposit was distinguished from the overlying clayey silt to silty clay by a lighter grey colour and by the absence of black organic particles and silty fine sand seams.

Results of Grain Size Distribution Tests carried out on select samples are shown on Figure 6 in the Appendix, in an envelope form. The results indicate the material contains a very large percentage of clay and silt. The deposit is comprised of 0% gravel, 0-1% sand, 39-56% silt, and 44-60% clay.

The results from the Atterberg Limit Tests performed on the fine fraction of this deposit is summarized as follows:

	<u>Range</u>	<u>No. of Tests</u>
Natural Moisture Content (w)	52-62	5
Liquid Limit ( $w_L$ )	42-49	5
Plastic Limit ( $w_p$ )	20-22	5
Plastic Index ( $I_p$ )	22-28	5
Sensitivity	5-13	5
Undrained Shear Strength $C_u$ (kPa) (Field)	42-60	5
Unconfined Compression (U-kPa)	35-41	3
Unconfined Undrained (UU-kPa)	32-52	2

From the Plasticity Chart (Figure 7), the layer can be classified as having intermediate plasticity. The Natural Moisture Content is high in this deposit and exceeds the liquid limit. Bulk density ranged from 16-17 kN/m<sup>3</sup>.

The undrained shear strength ranged from 42 kPa to 60 kPa as indicated in Figure 5, which plots shear strength vs. elevation profile. The deposit thus has a firm to stiff consistence. The sensitivity ranges from sensitive to extra-sensitive, thus this deposit was not as sensitive as the overlying deposit.

Consolidation Tests were performed to determine the compressibility characteristics of this deposit. The key parameters taken from void ratio-pressure curves are given below.

	<u>Elevation (m)</u>	<u>Pc (kPa)</u>	<u>Cc</u>	<u>Co</u>
BH 23-1 (TW13)	73.7	205	1.18	1.517

\*See Previous deposit for parameter definitions.

#### Sand and Gravel, occasional Cobbles and Boulders

This permeable non-cohesive deposit underlies the silty clay to clay deposit. It is composed of sand and gravel with occasional boulders and cobbles and it overlies bedrock.

The upper boundary of this deposit ranges from elevation 71.7 m to 68.6 m and it is approximately 2.3 m thick. The exact boundaries of this deposit were only established in BH 23-2, because of the artesian conditions. The remaining boreholes were terminated above within this stratum. However, sampling and test wells done for the Region of Ottawa-Carleton Trail Road landfill site by Gartner Lee and Associates indicates that the sand and gravel deposit tends to thicken towards the west with the upper boundary rising and the thickness of the overlying confining clay decreasing. Due to the artesian conditions split spoon sampling was not done in this

deposit. Cone tests could not penetrate this deposit probably due to the presence of coarser particles within this deposit.

### Dolomite Bedrock

Bedrock was proven by obtaining BXL cores in one borehole (BH 23-2). In addition, Gartner Lee and Associates established bedrock elevations in a test well situated 65 m west of the proposed Hwy. 416 centreline. The bedrock is fairly flat at elevation 66.3 m west of Hwy. 416. Extrapolation of bedrock elevations in the area allows us to assume it also extends east of Hwy. 416 at an elevation of 66.3 m, however none of the boreholes penetrated to bedrock in this area.

Detailed descriptions of the rock are attached in the Appendix.

Core Recoveries and Rock Quality Designation (RQD) were determined in situ and also in the laboratory to evaluate the competence and integrity of the rock.

Based on these results, the bedrock can be described as fine grained containing interbeds of silt, strong to very strong, and unweathered. Rock Core Recovery and Rock Core Quality Designation values ranged from 91-100% and 0-77% respectively.

### GROUNDWATER

Groundwater was observed to be perched on the surface of the clayey silt layer in the surrounding farm fields. Within the surficial deposit groundwater is 0.3 m to 0.9 m below the ground surface. It rises from the west at elevation 91.2 m to the east at 91.9 m. There may be a seasonal fluctuation in the groundwater levels. There is also an aquifer confined below elevation 71.7 m to 68.6 m which causes an artesian flow to the surface when penetrated (BH 23-5, 23-11). The measured artesian heads ranged from elevation 94.5 m to 95.5 m or 2.4 m to 3.3 m above ground level. It should be noted that it was difficult to confine the flow from the aquifer and accurately measure the stabilized water level. The actual artesian head may be higher than recorded.

## DISCUSSION AND RECOMMENDATIONS

It is proposed to construct a 9 m wide two span underpass to carry Cambrian Road over the new Hwy. 416. The proposed construction would involve approach embankments of 7.4 m height above the existing grade.

A plan and profiles illustrating the proposed construction and shown on Dwg. 1288709-A included in the Appendix.

Recommendations from a geotechnical standpoint are given in the following sections regarding the design and construction of foundations and associated earthworks.

### Structure Foundations

The predominant soil strata at the site consists of a soft to firm clayey silt to silty clay and silty clay to clay. These strata are underlain by sand and gravel followed probably by bedrock. The weak consistency of the cohesive layers, extending to more than 18 m depth below existing grade, precludes then use of shallow spread footings located on or within the cohesive layers or a perched foundation on compacted granular fill placed above the cohesive layers. It is recommended that all foundations are supported on deep foundations.

### Steel H-Piles

From considerations of the high sensitivity of the cohesive deposits to disturbance and the presence of artesian groundwater conditions in the underlying sand and gravel stratum, it is recommended that a non-displacement type pile, such as steel H-piles would be the most suited foundation type for this site. For purposes of O.H.B.D.C., the following design axial bearing capacities are given for a 310x110 steel H-pile.

	<u>Pier</u>	<u>Abutment</u>
Factored Capacity at U.L.S. kN	1600	875*
Bearing Capacity at S.L.S. Type II kN	1100	620*

\*Lower capacities from consideration of downdrag forces acting on the piles.

Consideration should be given to advance fill placement to reduce post-construction settlement and associated downdrag forces. It is considered that if the fill could be placed, say, six to twelve months in advance of the pile installation, most of, if not all of the downdrag forces could be eliminated. However, if this option is favoured the embankment settlements should be monitored to ensure that the consolidation settlements have been fully realized before piling is commenced. The Foundation Design Section should be consulted regarding preloading, settlement monitoring and timing of pile installation. To prevent damage to the piles during installation, the steel H-piles should be provided with standard MTO tip reinforcement.

To prevent loss of fines along the wall of the piles resulting from the artesian groundwater pressures existing in the sand and gravel layer, it is recommended that an 'inverted' filter layer should be placed at the ground surface where the piles would be located. Typical details of such a scheme are shown on Figure 8.

It is recommended that all lateral loads are carried out by batter piles. However, from consideration of relatively large settlements that would result due to the construction of the approach embankments, the batter should be maintained at 6V:1H or steeper.

All pile caps should be provided with 1.8 m of equivalent earth cover for frost protection purposes.

### Caissons

Alternatively, a concrete filled caisson socketed into bedrock may also be used at the site. However, installation of the caisson should take into account, possible disturbance of the cohesive layers and the presence of excess hydro strata head in the underlying sand and gravel deposit. If this option is favoured, detailed comments would be provided by this section regarding the design and installation of caissons.



### Lateral Earth Pressure on Structures

Free draining materials such as Granular 'A' or Granular 'B' shall be used within a wedge behind the abutments and retaining walls bounded by a planerising at 60° to the horizontal as per O.H.B.D.C. With the provision of weepholes or drains in the abutment walls, hydrostatic pressures behind the walls could be eliminated. Design parameters for a horizontal backfill are given below.

Table 2

	Granular 'A'	Granular 'B'
Angle of Internal Friction, $\phi$ (unfactored)	35	30
Unit Weight, kN/m <sup>3</sup>	22.8	21.2
Coefficient of Active Earth Pressure, $K_a$		
- S.L.S.	0.27	0.33
- U.L.S.	0.33	0.40
Coefficient of Earth Pressure at Rest, $K_o$		
- S.L.S.	0.43	0.50
- U.L.S.	0.50	0.58

### Slope Stability

The stability of the slopes was analyzed using Bishop's total shear method assuming a fill density of 21.1 kN/m<sup>3</sup> (Granular 'B') and static loading conditions. The parameters used in the design are shown on Figure 9 and the results of the analysis on Figures 10 and 11. The results of the stability analysis indicate that the maximum height of fill without a berm is only 3.5 m.

Alternatively, consideration may be given to the use of lightweight fills. The maximum height of the embankment without a berm would be about 5 to 5.5 m using a lightweight fill with a compacted unit weight of 13.5 kN/m<sup>3</sup>.

### Settlement

Construction of an embankment as proposed would results in some immediate settlement due to elastic compression of the fill itself as well as some long term settlement due to the consolidation of the foundation silty clay layers. The calculated consolidation settlements are tabulated below.

Table 3

#### Computed long Term Settlements

Fill Height (m)	Settlement in mm	
	Granular Fill	Lightweight Fill
3	310	35
5	740	360
7	1100	630

Since the calculated long term consolidation settlements are large, several options may be considered to maintain the post construction differential settlement between the pile supported bridge structure and approach fill to, say, less than 0.3 m.

1. Increase the length of structure such that the height of fill would be less than 4.5 m, assuming that the embankment is constructed using a lightweight fill with a unit weight of  $13.5 \text{ kN/m}^3$ .
2. Preload the area (using granular fill). Use sand grains or circle drains in the foundation clay, to facilitate a faster rate of consolidation. Once sufficient consolidation settlement has been realized, the preload fill may be removed and replaced by lightweight fill.

Either of these two options would result in a satisfactory performance of the structure and approach fills. The choice between the above two options

or the selection of any other option would be based on technical and economical considerations.

### Construction

Existing ground is not considered trafficable for heavy construction equipment, such as pile driving rigs, concrete trucks. Access and haul roads would be required to facilitate construction at this site.

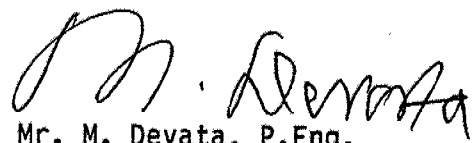
In the abutment area, the pile caps may be perched within the embankment fill. This would reduce the need to do excavation through the sensitive silty clay deposits at the abutment locations. However, at the pier locations, excavations for pile caps would be required below existing grade. Temporary excavations to depths of 2 m or less below grade may be carried out using 1V:1H. Slope, provided the excavated materials are not stockpiled near the crest of the slope. Under no circumstances should construction traffic be allowed on the excavated base, especially if the base is below or in close proximity to the groundwater level.

### MISCELLANEOUS

The field work for this project was supervised by Mr. S. Holmes, Foundation Engineer, and Mr. B. Sedgewick, Engineering Student. The equipment used was owned and operated by Marathon Drilling Co. Ltd. This report was prepared by Dr. B. Iyer, Senior Foundation Engineer, and reviewed by Mr. M. Devata, Chief Foundation Engineer.



Dr. B. Iyer, P.Eng.  
Senior Foundation Engineer



Mr. M. Devata, P.Eng.  
Chief Foundation Engineer

## APPENDIX

## 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
$\sigma$	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

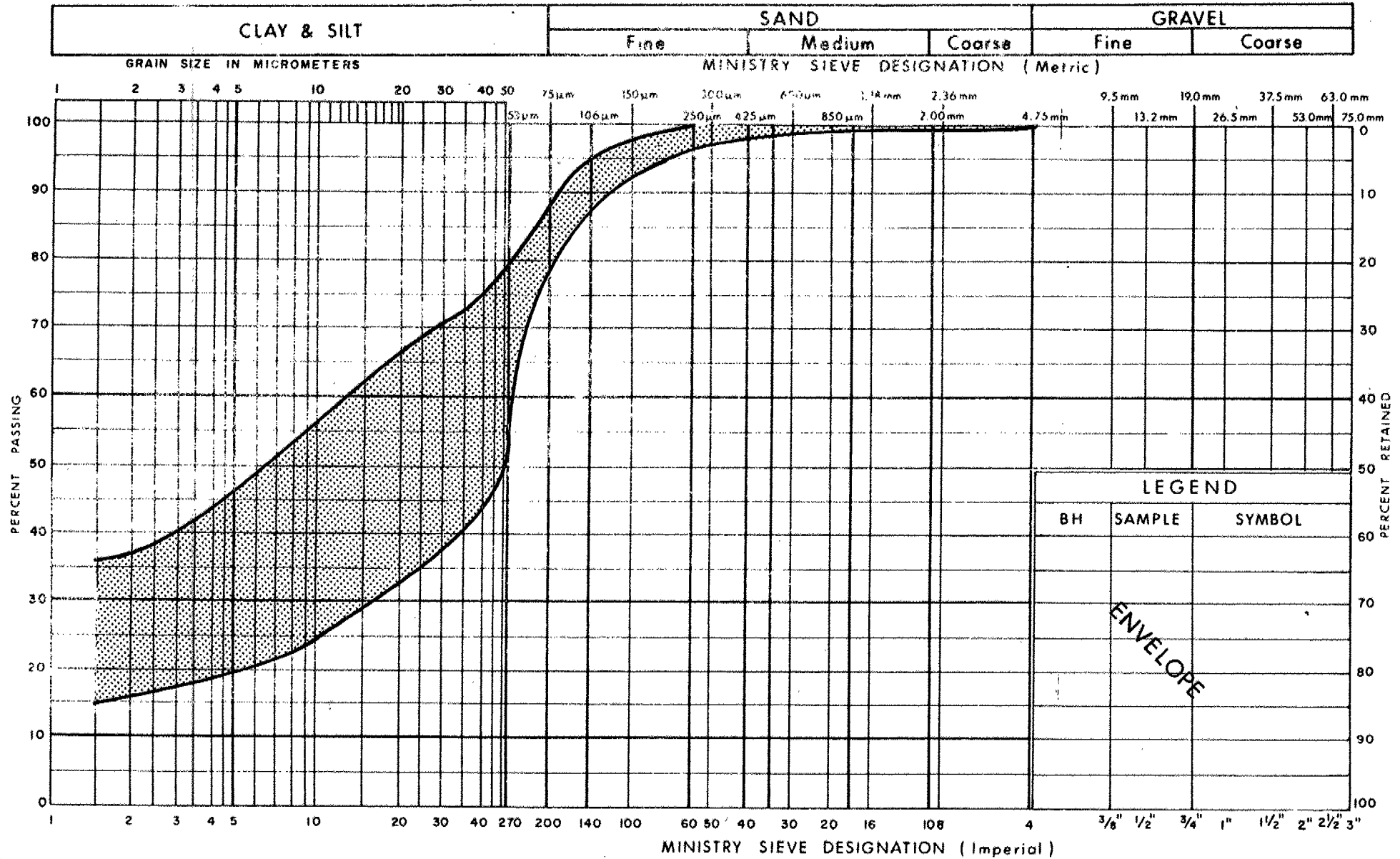
### MECHANICAL PROPERTIES OF SOIL

$m_v$	kPa <sup>-1</sup>	COEFFICIENT OF VOLUME CHANGE
$C_c$	1	COMPRESSION INDEX
$C_s$	1	SWELLING INDEX
$C_\alpha$	1	RATE OF SECONDARY CONSOLIDATION
$C_v$	m <sup>2</sup> /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 = $\frac{c_u}{\tau_r}$

### PHYSICAL PROPERTIES OF SOIL

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

## UNIFIED SOIL CLASSIFICATION SYSTEM

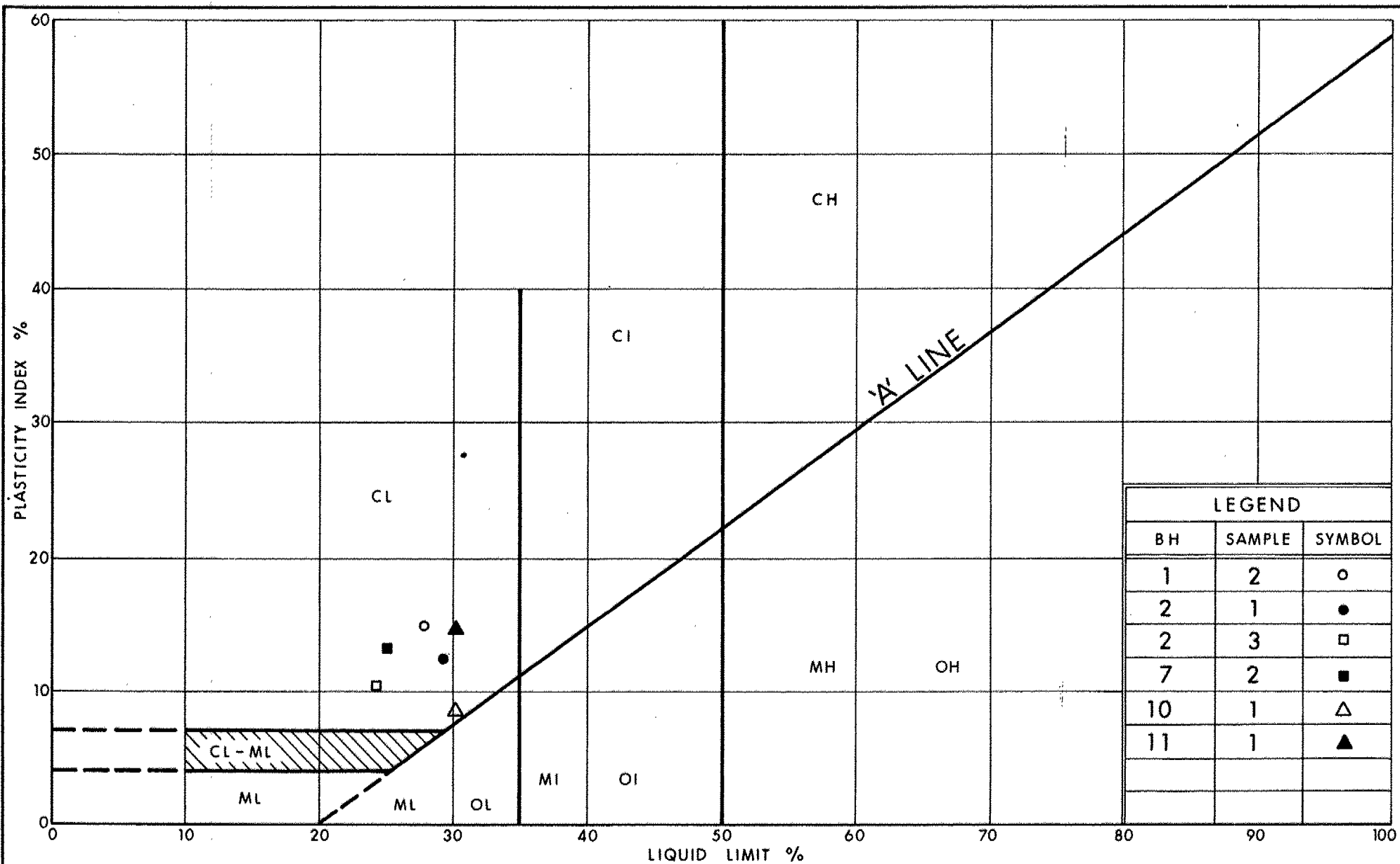


Ministry of  
Transportation

**GRAIN SIZE DISTRIBUTION**  
**CLAYEY SILT**  
 SOME SAND, TRACE ORGANICS

FIG No 1

W P 128-87-09



Ministry of  
Transportation

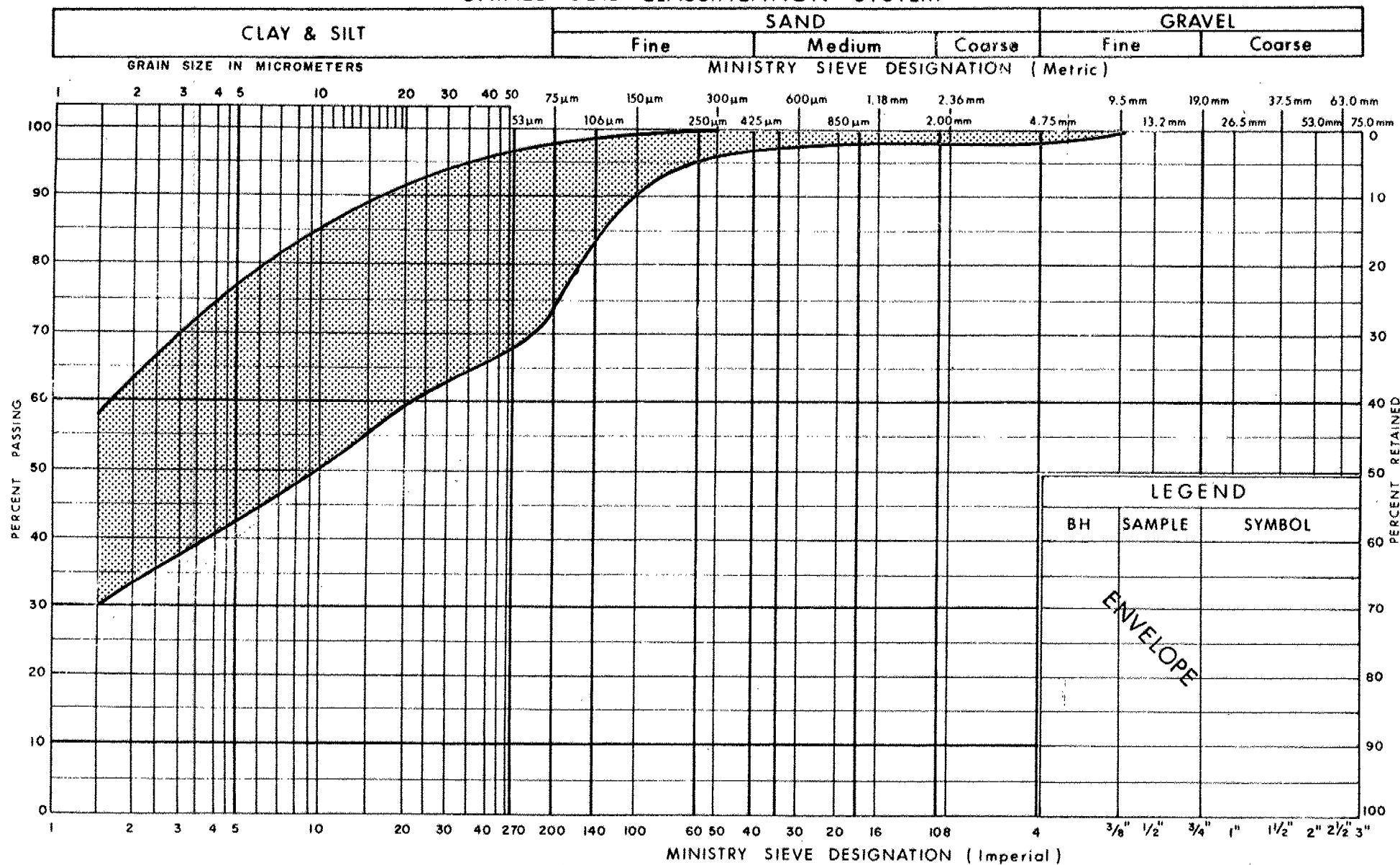
Ontario

# PLASTICITY CHART CLAYEY SILT SOME SAND, TRACE ORGANICS

FIG No 2

W P 128-87-09

## UNIFIED SOIL CLASSIFICATION SYSTEM



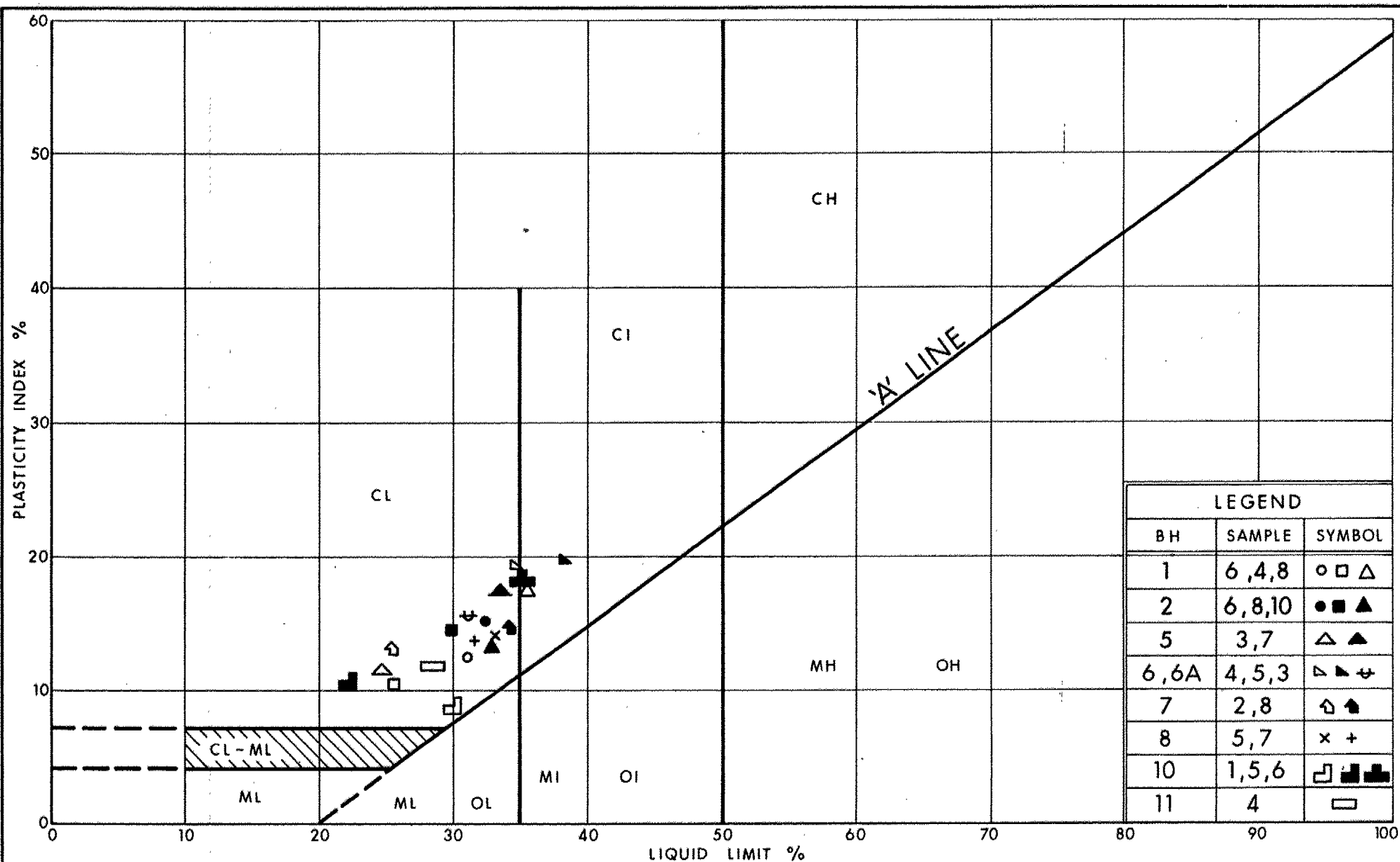
Ministry of  
Transportation

**GRAIN SIZE DISTRIBUTION**  
**CLAYEY SILT TO SILTY CLAY**  
 OCCASIONAL SILTY FINE SAND SEAMS, EXTRA SENSITIVE TO QUICK

FIG No 3

W P 128-87-09



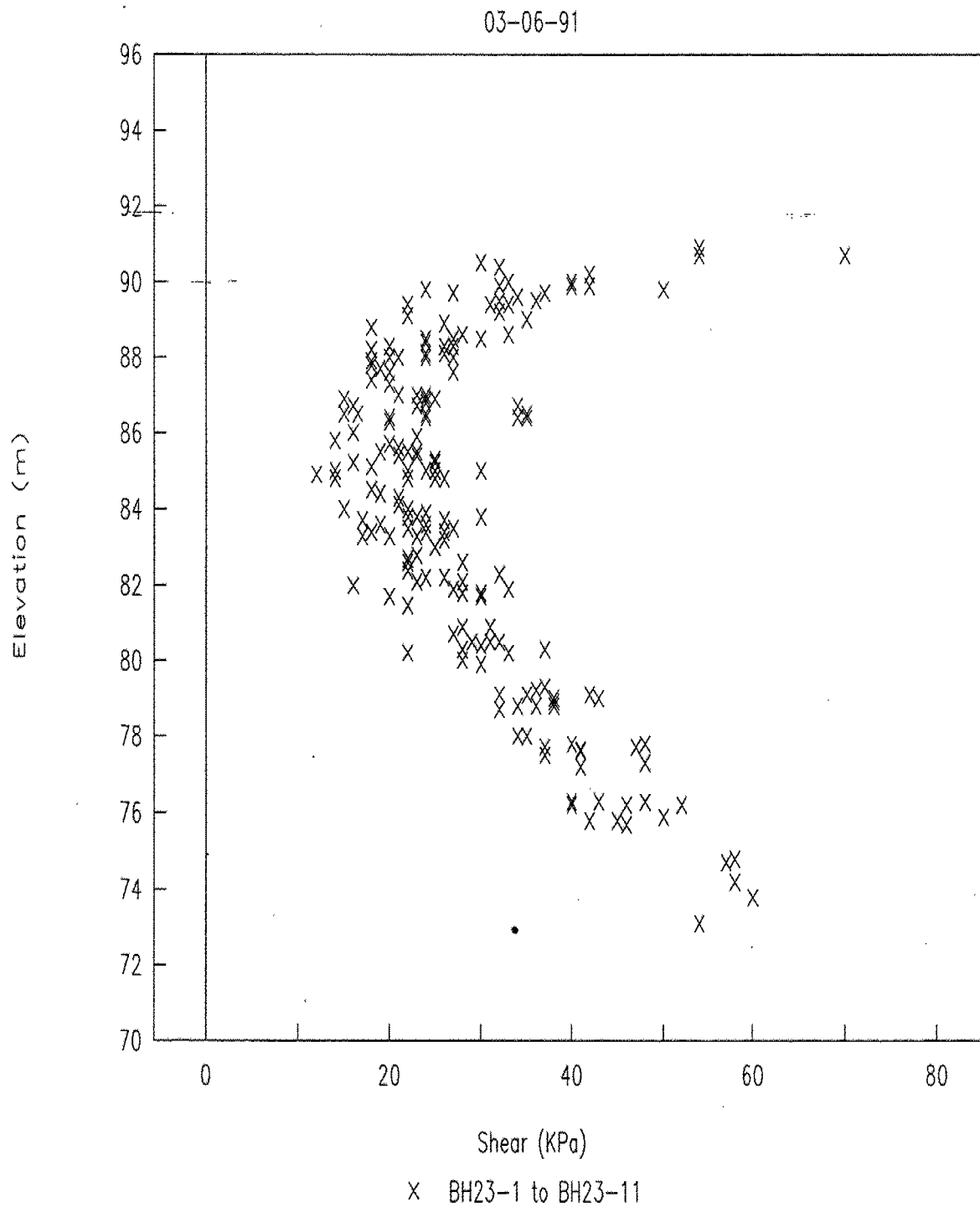


Ministry of  
Transportation

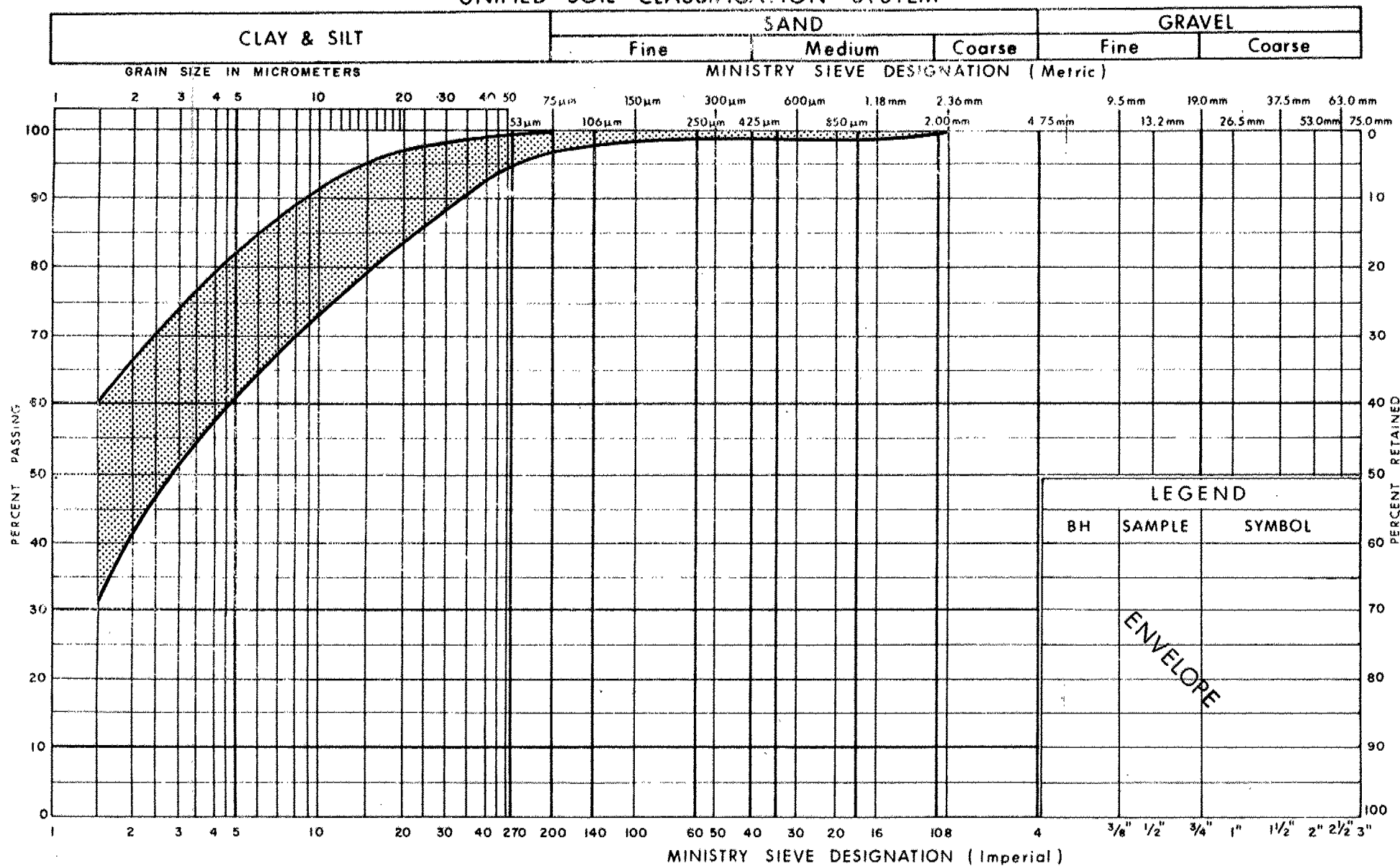
PLASTICITY CHART  
CLAYEY SILT TO SILTY CLAY  
OCCASIONAL SILTY FINE SAND SEAMS, EXTRA SENSITIVE TO QUICK

FIG No 4

W P 128-87-09



## UNIFIED SOIL CLASSIFICATION SYSTEM

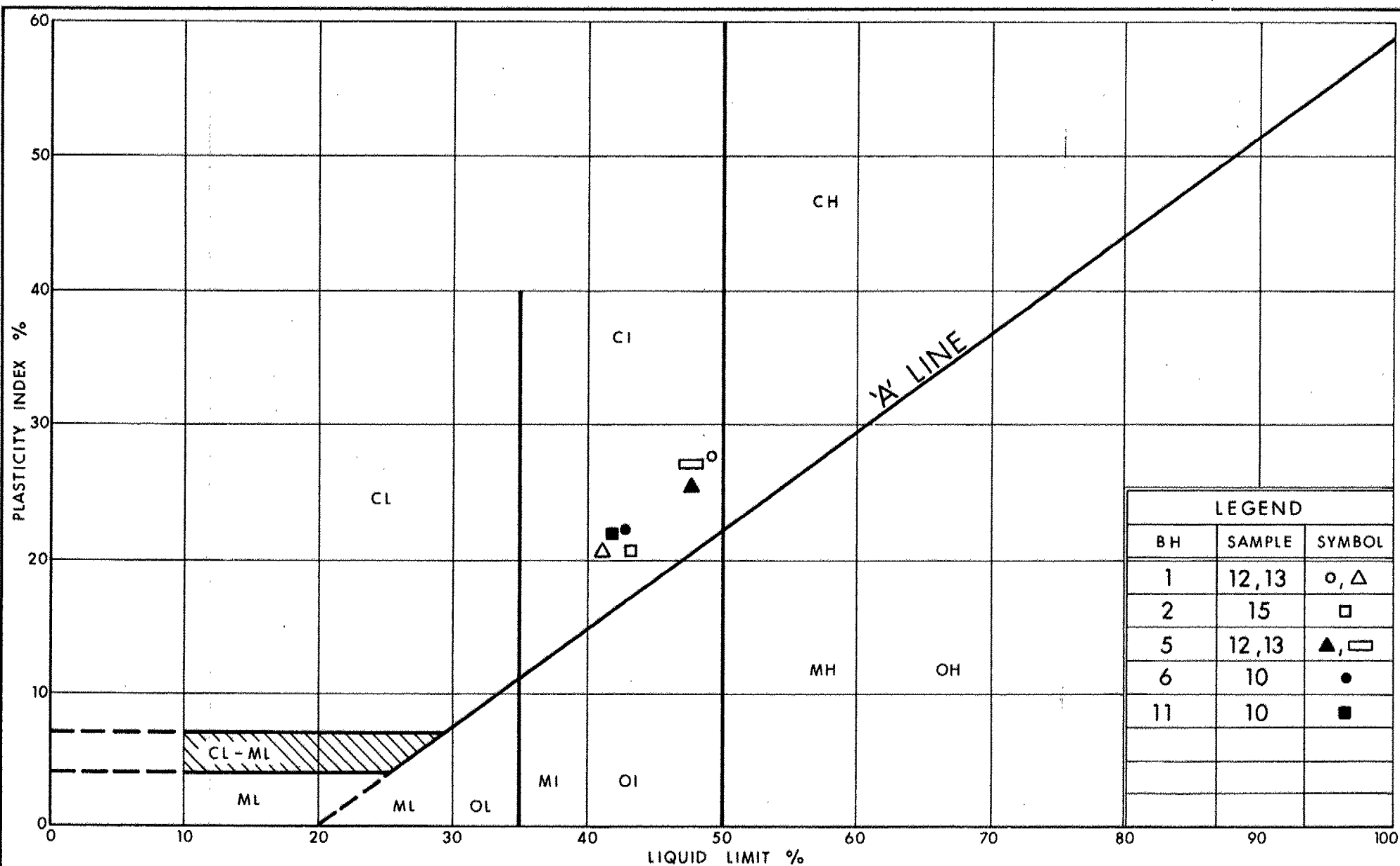


Ministry of  
Transportation

**GRAIN SIZE DISTRIBUTION**  
**SILTY CLAY TO CLAY**  
**TRACE SAND**

FIG No 6

W P 128-87-09



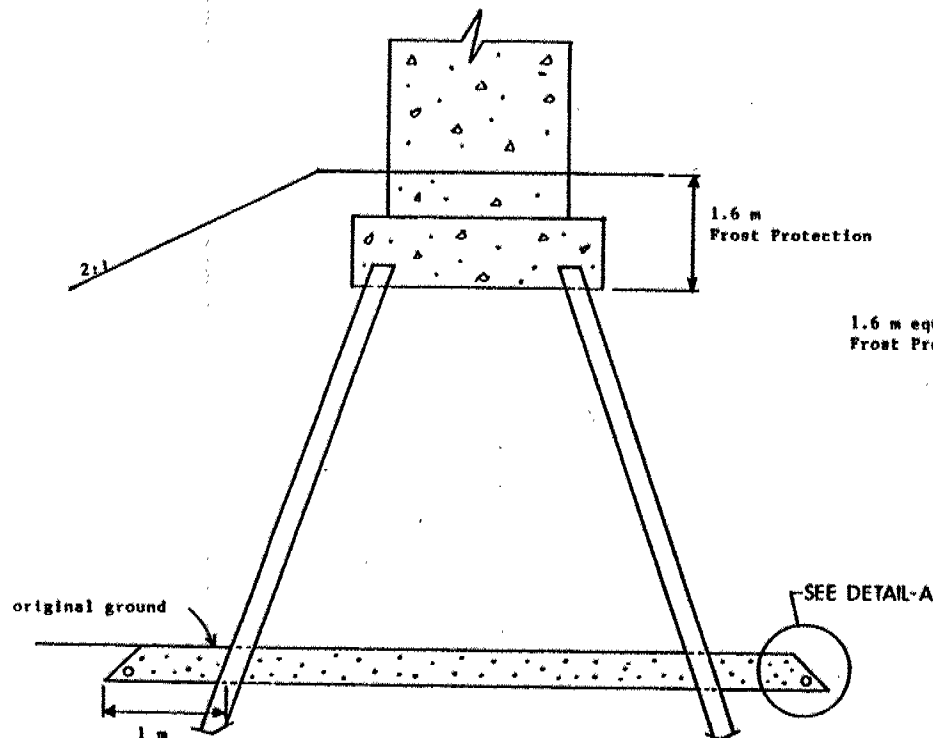
Ministry of  
Transportation

Ontario

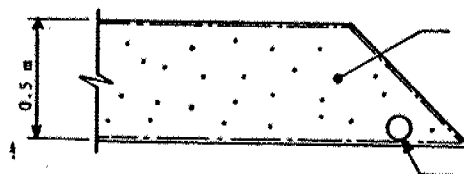
# PLASTICITY CHART SILTY CLAY TO CLAY TRACE SAND

FIG No 7

W P 128-87-09



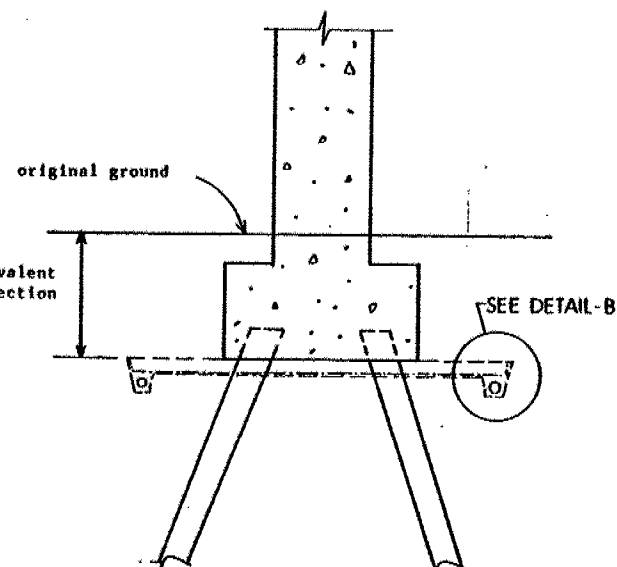
ABUTMENT SECTION (TYP)



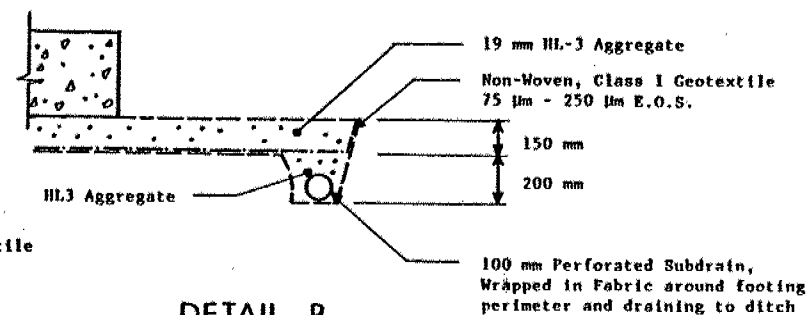
DETAIL A

19 mm HL-3 Aggregate  
Completely wrapped in  
non-woven, Class 1 Geotextile  
75 µm - 250 µm E.O.S.

100 mm Perforated  
Subdrain, wrapped in  
Fabric around perimeter  
of blanket and draining  
to ditch



PIER SECTION (TYP)



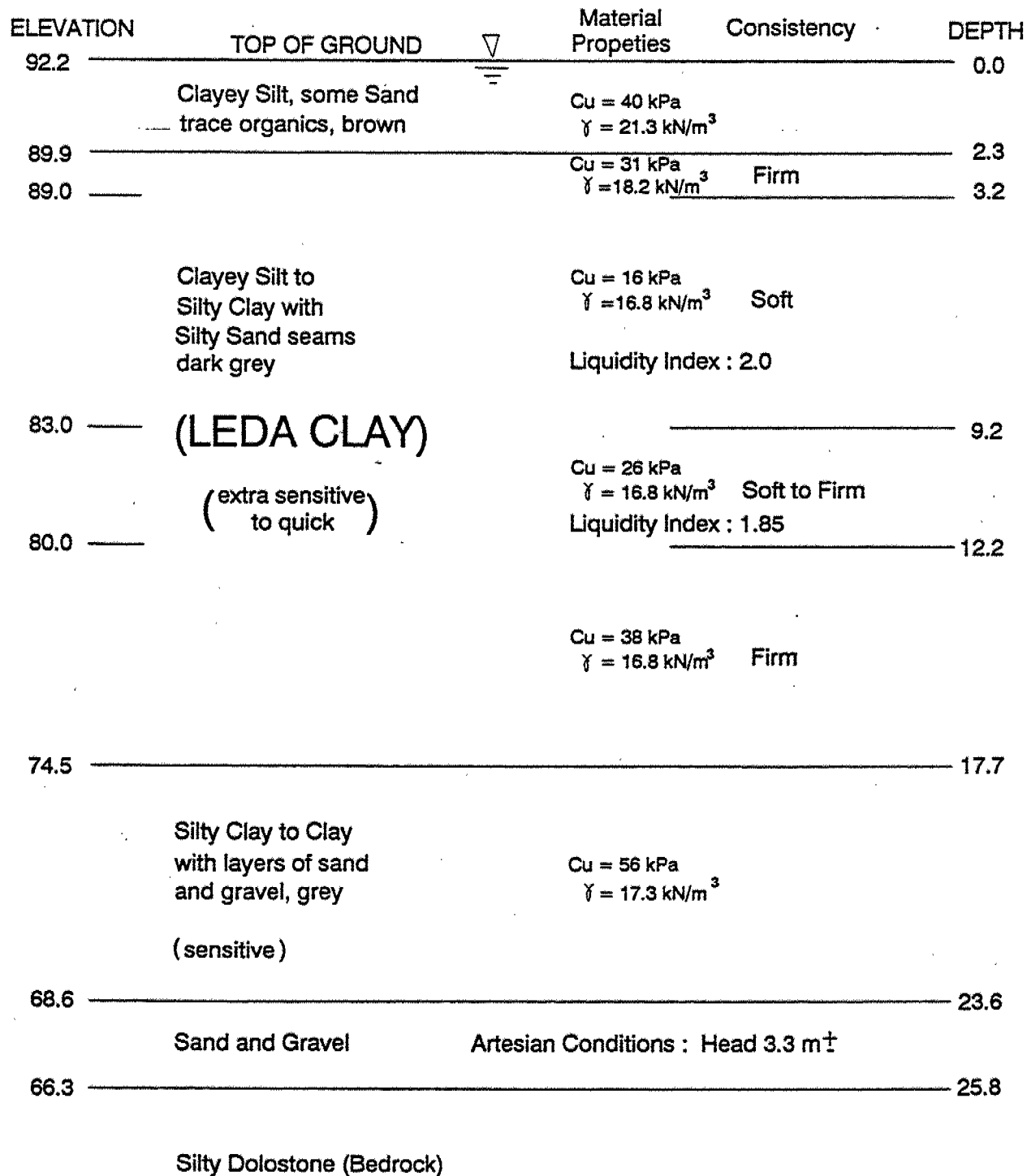
DETAIL B

NOTES:

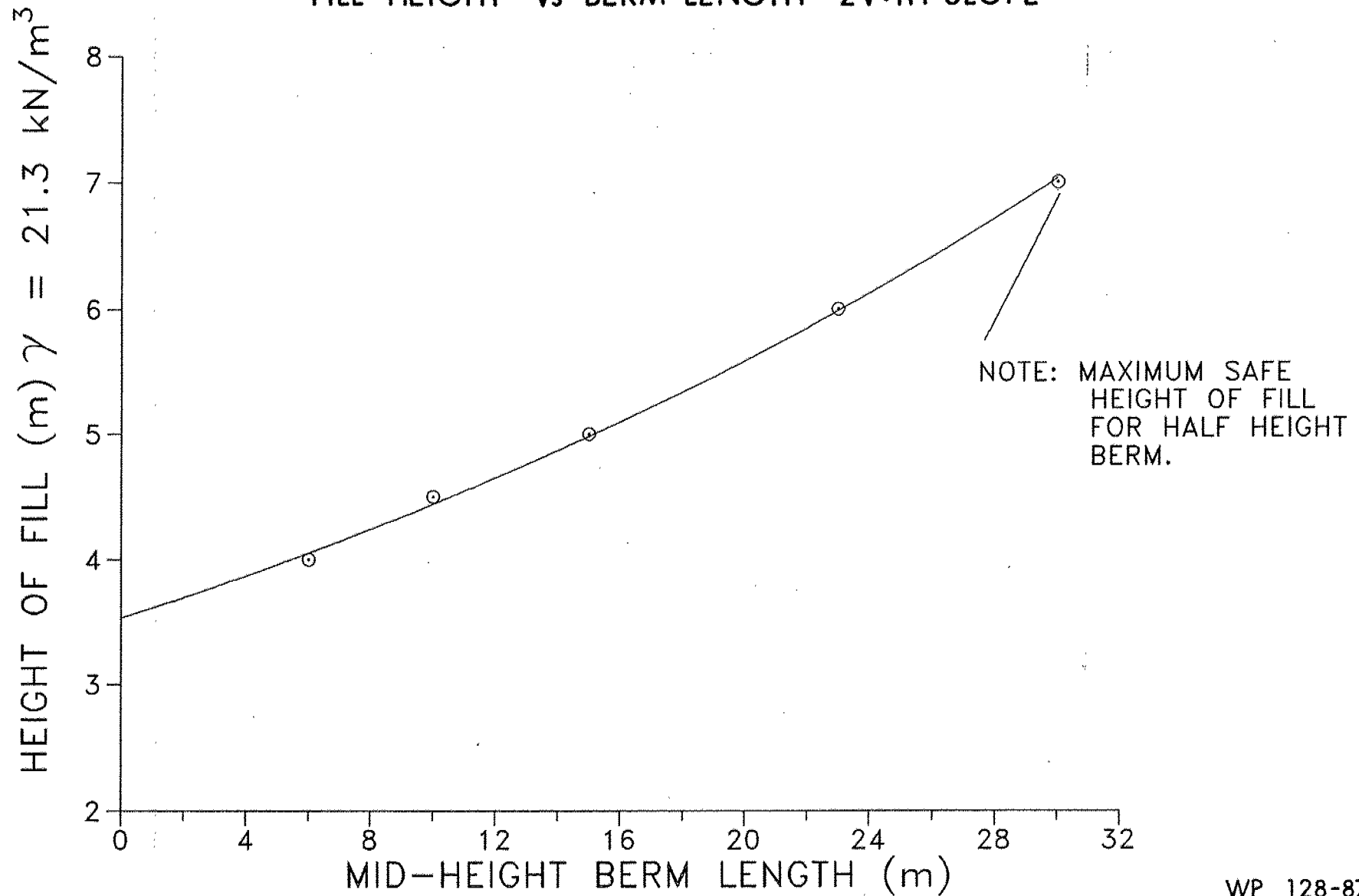
1. The drainage blankets should be in place prior to pile driving
2. The geotextile should be cut with a 300 mm x 300 mm "x" at locations where piles will penetrate. This is applicable only to the pier locations
3. If blanket at pier locations is disturbed during pile driving, the blanket should be restored to the details shown on this drawing after the completion of the pile driving

FIGURE 8 - DRAINAGE BLANKET DETAILS  
FOR ABUTMENTS & PIERS

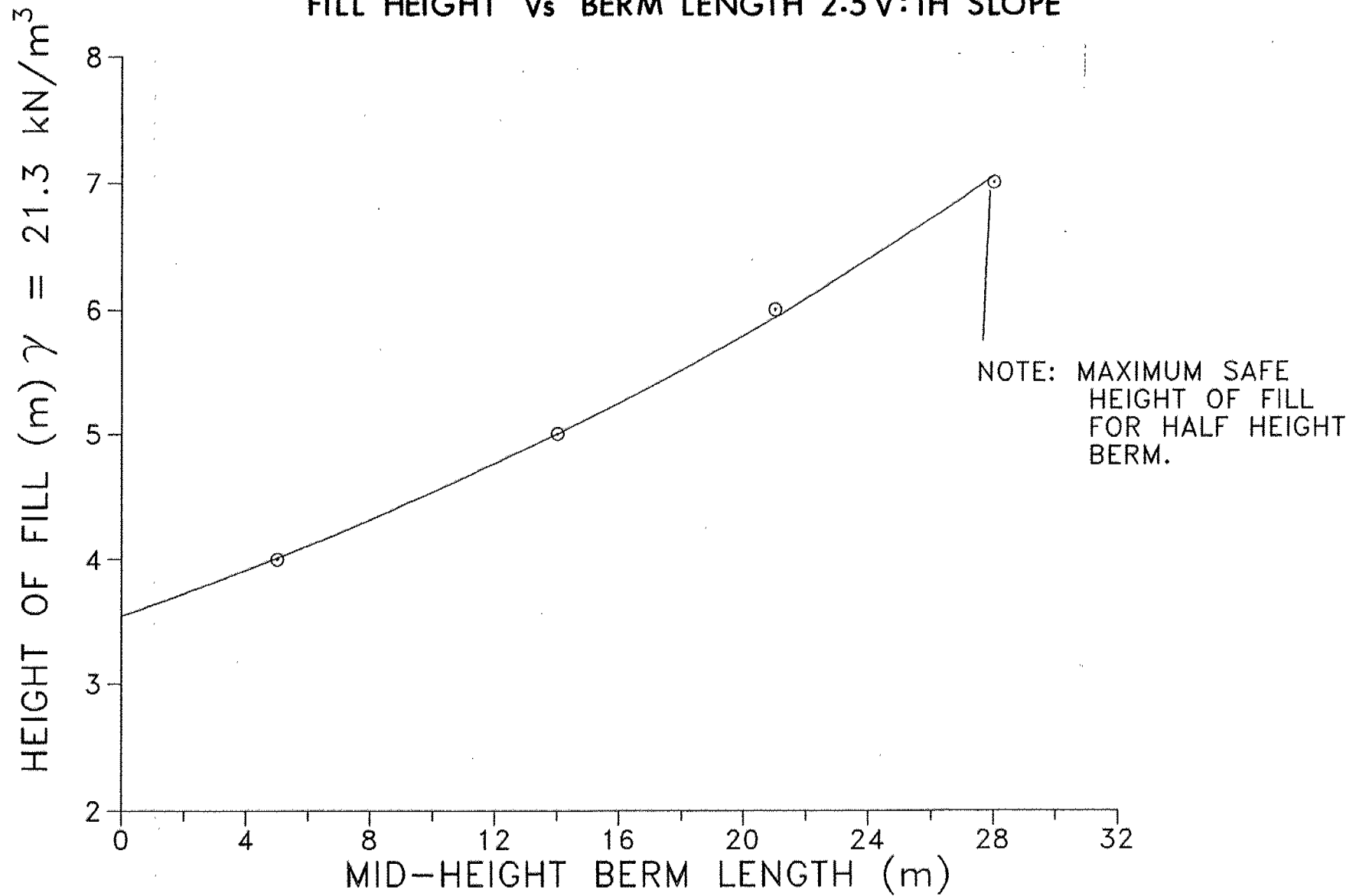
# STRATIGRAPHICAL PLOT - CAMBRIAN Rd.



# FILL HEIGHT Vs BERM LENGTH 2V:1H SLOPE



# FILL HEIGHT Vs BERM LENGTH 2.5 V:1H SLOPE





# VOID RATIO - PRESSURE CURVES

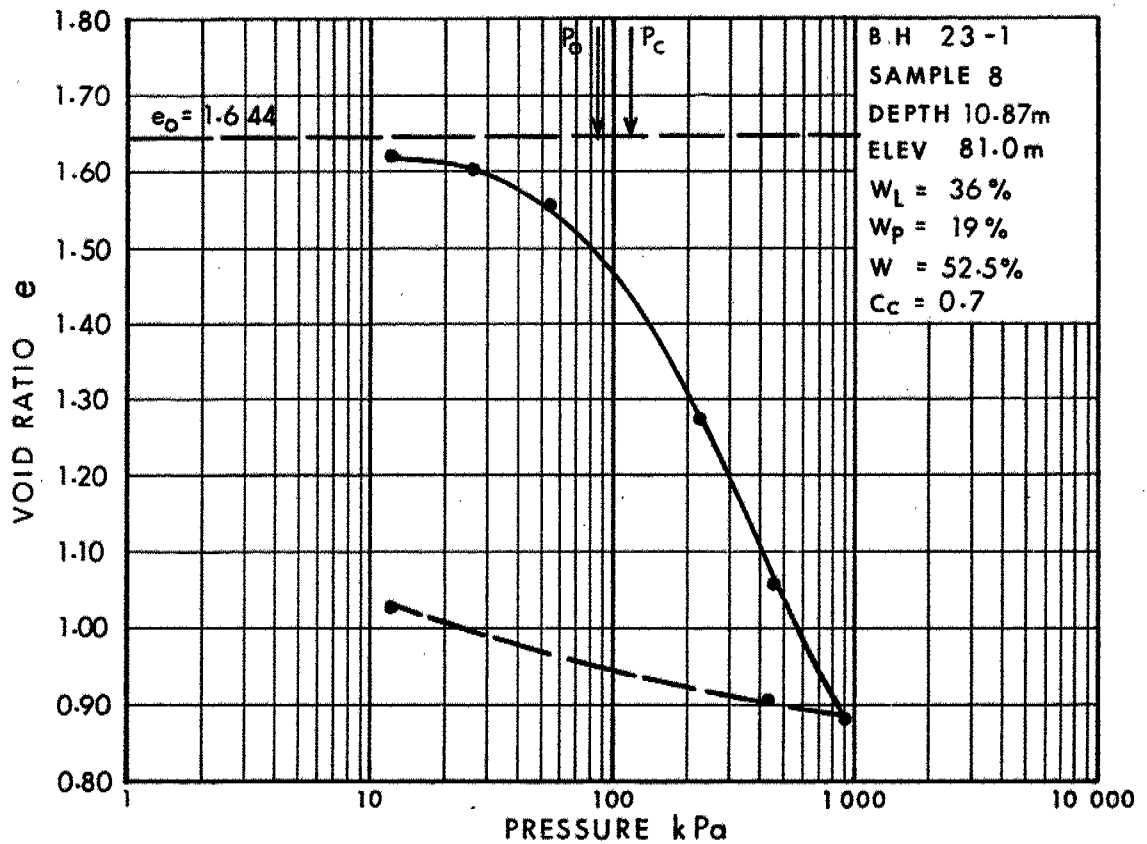
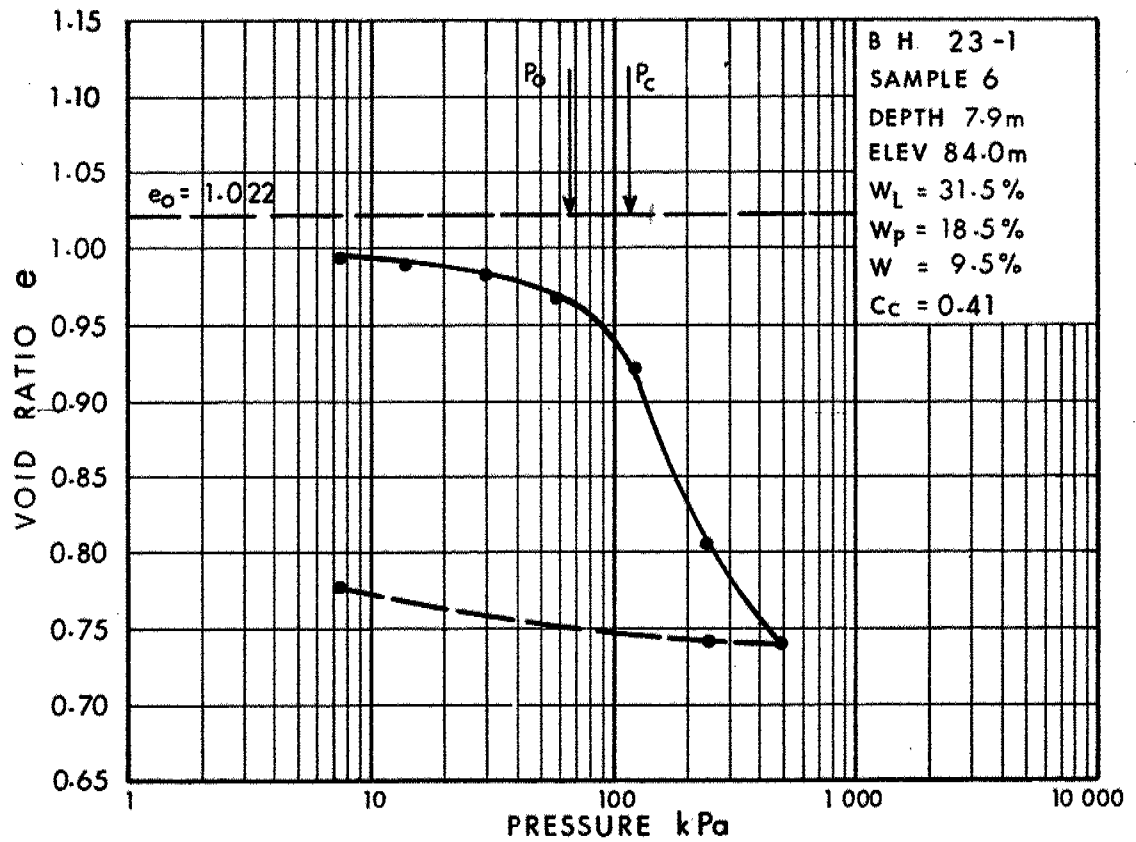
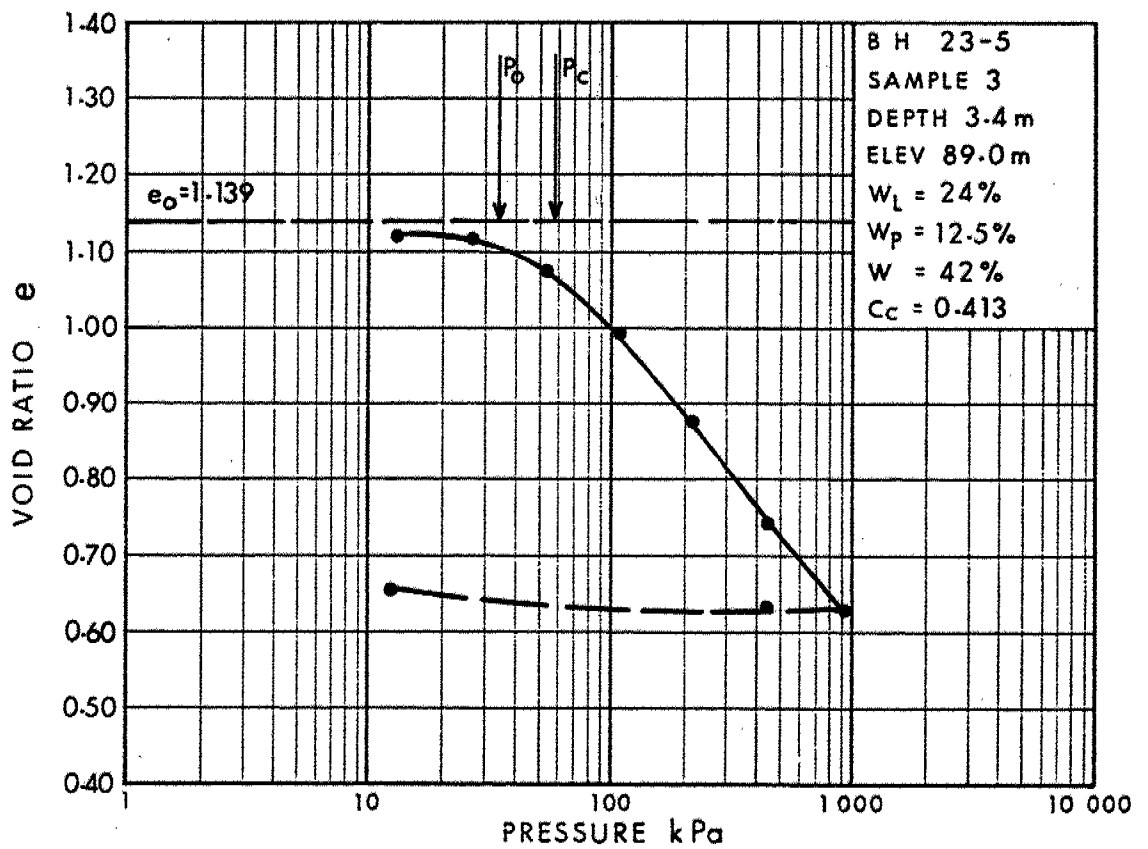
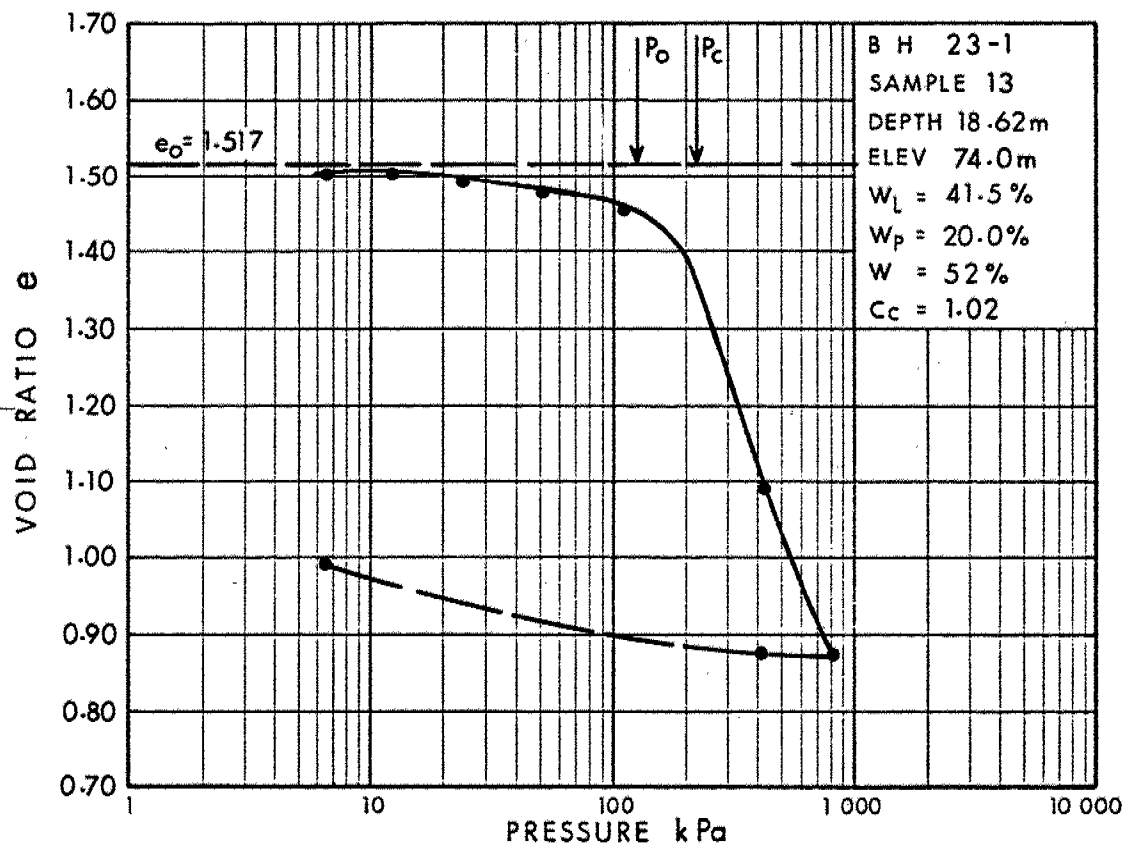


Fig 12

W P 128-87-09

# VOID RATIO - PRESSURE CURVES



# VOID RATIO - PRESSURE CURVES

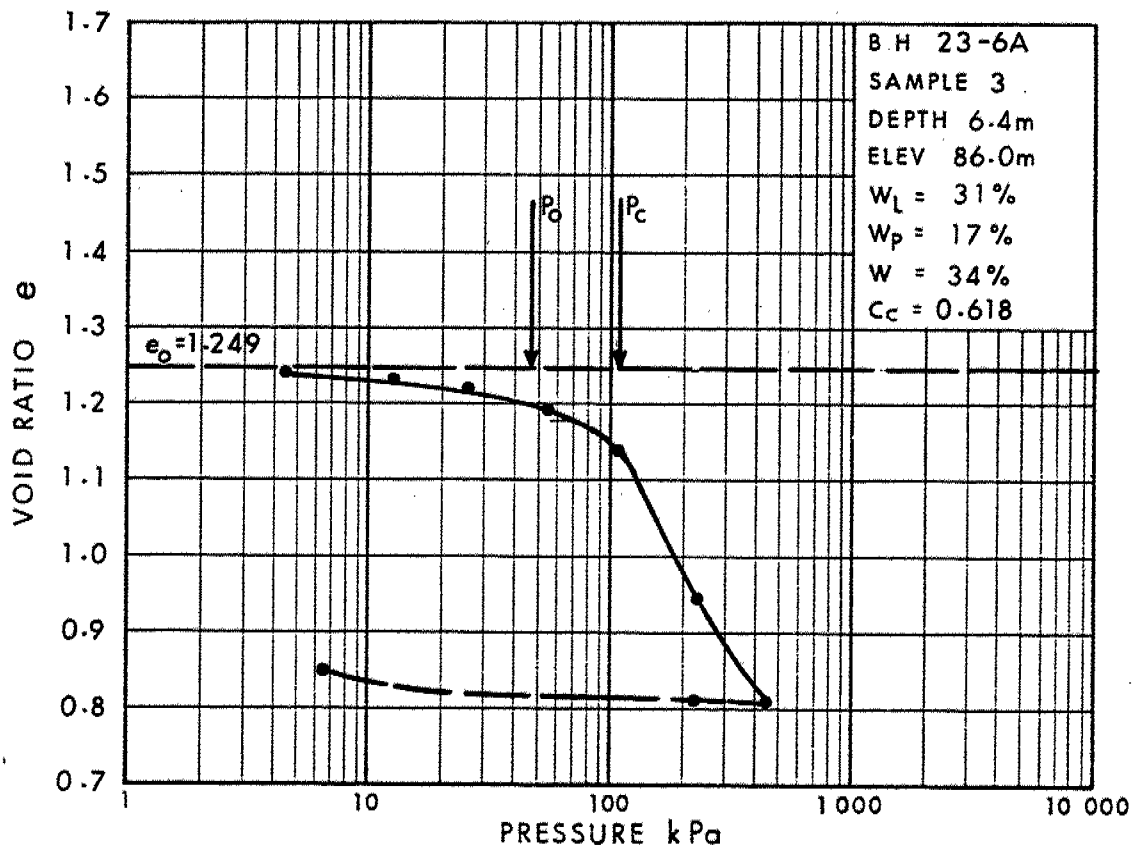
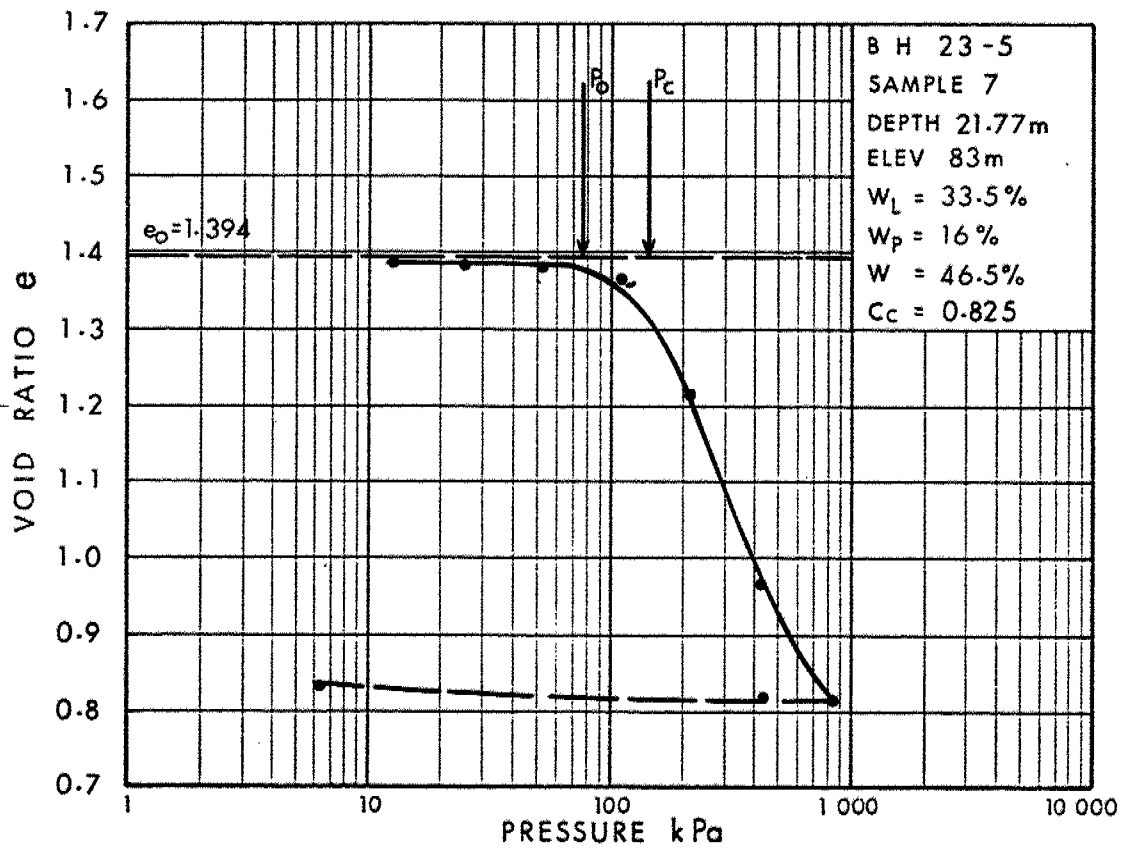
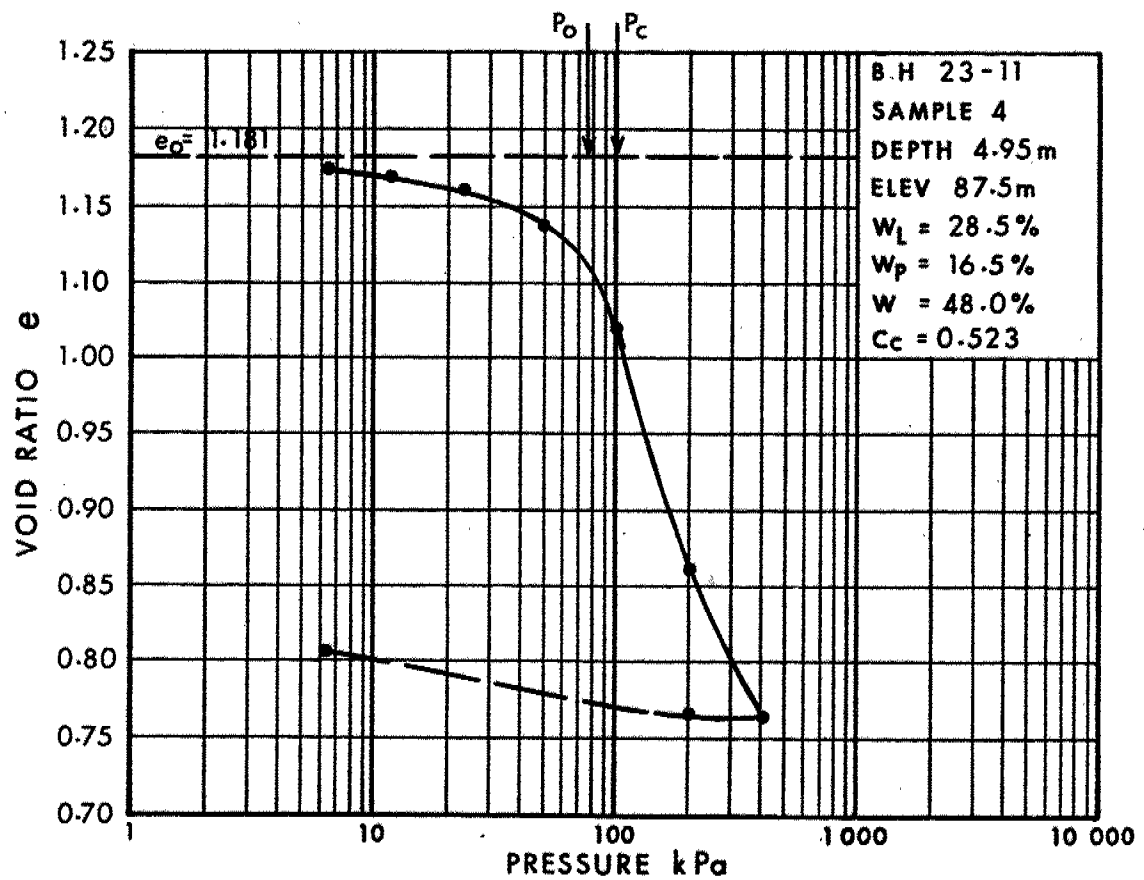
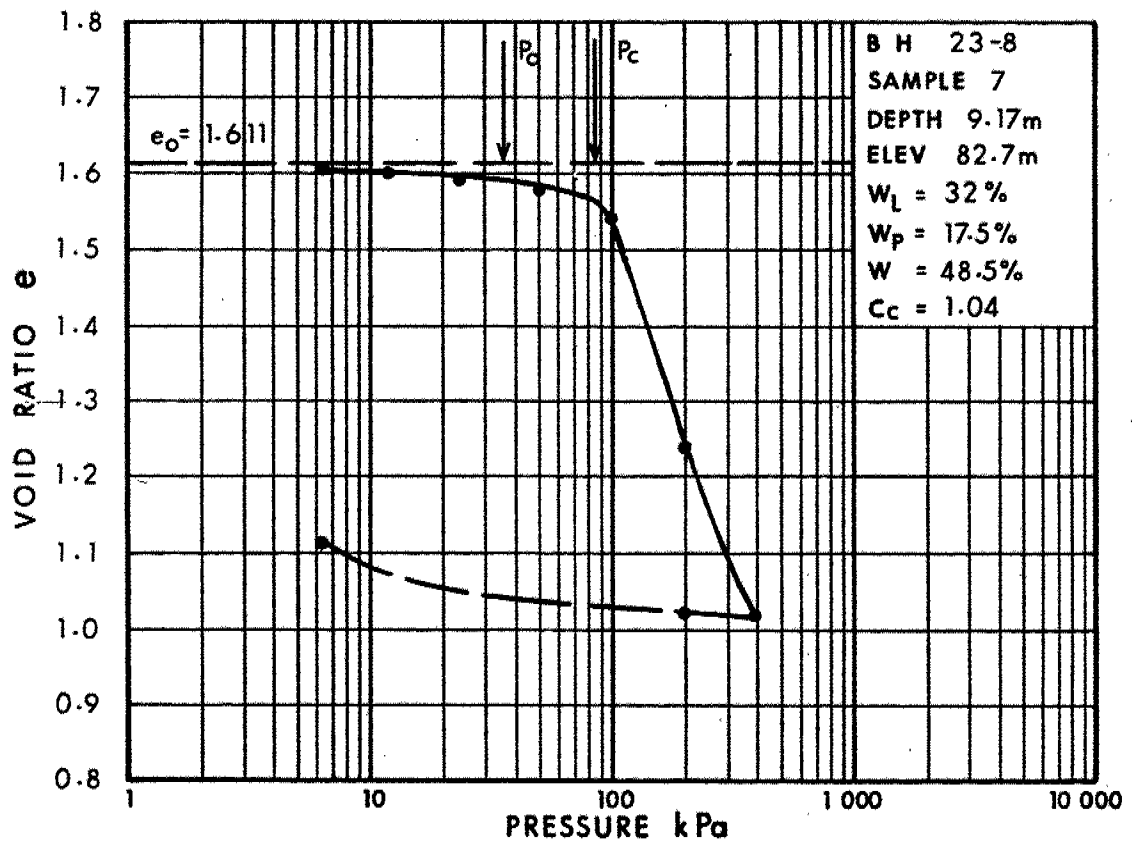


Fig 14

# VOID RATIO - PRESSURE CURVES



# RECORD OF BOREHOLE No 23-1

1 OF 1

METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 496.5, E 362 755.6 ORIGINATED BY S.M.H.  
DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger, Cone Test COMPILED BY M.M.  
DATUM Geodetic DATE 89-05-25 CHECKED BY B.I.

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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60					
92.3	Ground Surface													
0.0	Clayey Silt, some Sand, trace Organics		1	SS	4		92							
89.9	Firm		2	SS	1		90							0 15 56 29
2.4			3	TW	PM		88							
			4	TW	OW		86							0 17 50 33
			5	TW	OW		84							
			6	TW	OW		82							9 47 44
			7	TW	OW		80							
	Clayey Silt to Silty Clay with pockets of Organics, Occasional Silty fine Sand seams		8	TW	OW		78							
	Extra Sensitive to Quick		9	SS	OW		76							
	Soft to Firm		10	SS	OW		74							
75.0			11	TW	OW									
17.3	Silty Clay to Clay, trace Sand		12	SS	OW								16.4	0 3 33 64
73.1	Stiff		13	TW	OW								16.6	0 0 55 45
19.2	End of Borehole													
69.7														
22.6	Probable Sand and Gravel													
68.8														
23.5	End of Cone Test													

# RECORD OF BOREHOLE No 23-1A 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 499.4, E 362 760.9 ORIGINATED BY BS  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger COMPILED BY AL/MM  
 DATUM Geodetic DATE 89-05-30 CHECKED BY BI

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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPa					
92.3	Ground Surface								○ UNCONFINED + FIELD VANE • QUICK TRIAXIAL x LAB VANE					
0.0	Probable Clayey Silt, some Sand, trace Organics Firm						92							
89.9							90							
2.4	Probable Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams Extra Sensitive to Quick Soft to Firm						88							
							86							
							84							
82.4														
9.9	End of Borehole													

# RECORD OF BOREHOLE No 23-2 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 499.7, E 362 772.0 ORIGINATED BY S.M.H.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger, BW Casing, BXL Rock Core, Cone Test COMPILED BY M.M.  
 DATUM Geodetic DATE 89-05-23 CHECKED BY B.J.

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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60					
92.1	Ground Surface													
0.0	Clayey Silt, some Sand, trace Organics, Firm  Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams  Extra sensitive to quick Soft to Firm		1	SS	2									0 12 64 24
			2	SS	1									
90.0			3	SS	1									0 15 59 25
2.1			4	SS	OW									
			5	TW	OW									
			6	TW	OW									0 11 50 39
			7	TW	PH									
			8	TW	OW								17.3	0 9 46 45
			9	TW	OW									
			10	TW	OW								17.1	0 6 51 43
			11	TW	PH									
			12	TW	DW								16.9	0 3 43 54
			13	TW	OW									
75.0			14	TW	PH								16.4	2 3 35 60
17.1	Silty Clay to Clay, trace Sand Firm  Occasional pockets of Sand and Gravel		15	SS	3									0 0 56 44
			16	SS	2									
68.6			17	SS	8									
23.5														
	Sand and Gravel, occasional Cobbles and Boulders		18	RC	REC	27%								RQD 0%
66.3			19	RC	REC	80%								RQD 80%
25.8	Limestone Bedrock with Shale seams		20	RC	REC	100%								RQD 38%
64.3			21	RC	REC	93%								RQD 67%
27.8	End of Borehole													

# RECORD OF BOREHOLE No 23-2B 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 500.7, E 362 771.0 ORIGINATED BY SH  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger COMPILED BY AL/MM  
 DATUM Geodetic DATE 89-05-30 CHECKED BY BI

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPa						
92.1	Ground Surface							○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE				
0.0	Probable Clayey Silt, some Sand, trace Organics Firm							10 20 30 40 50	20 40 60						
90.0															
2.1	Probable Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams  Extra Sensitive to Quick  Soft to Firm														
82.2															
9.9	End of Borehole														



# RECORD OF BOREHOLE No 23-3 1 OF 1 METRIC

W.P. 128-97-09 LOCATION Coords: N 5 011 519.2, E 362 743.6 ORIGINATED BY SH  
 DIST 9 HWY 416 BOREHOLE TYPE Cone Test COMPILED BY JW/MM  
 DATUM Geodetic DATE 89-05-24 CHECKED BY BI

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	W <sub>p</sub> W W <sub>L</sub>	WATER CONTENT (%)	7	GR SA SI CL		
91.7	Ground Surface													
0.0	Probable Clayey Silt, some Sand, trace Organics						91							
90.0							89							
1.7	Probable Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams						87							
							85							
							83							
							81							
							79							
							77							
75.0							75							
16.7	Probable Silty Clay to Clay trace Sand						73							
							71							
							69							
68.0														
23.7	Probable Sand and Gravel, occasional Cobbles and Boulders													
67.0														
24.7	End of Cone Test													

# RECORD OF BOREHOLE No 23-4 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 515.8; E362 801.0 ORIGINATED BY SH  
 DIST 9 HWY 416 BOREHOLE TYPE Cone Test COMPILED BY JW/DT  
 DATUM Ceodetic DATE 89-05-24 CHECKED BY BI

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	WATER CONTENT (%)
								SHEAR STRENGTH kPa										
							○ UNCONFINED	+ FIELD VANE	● QUICK TRIAXIAL	× LAB VANE								
92.3	Ground Surface						10	20	30	40	50	20	40	60	GR SA SI CL			
0.0	Probable Clayey Silt, some Sand, trace Organics						92											
90.1							90											
2.2							88											
	Probable Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams						86											
							84											
							82											
							80											
							78											
							76											
75.0							74											
17.3	Probable Silty Clay to Clay						72											
							70											
69.0							68											
23.3	Probable Sand and Gravel occasional Cobbles and Boulders																	
67.6																		
24.7	End of Cone Test																	

# RECORD OF BOREHOLE No 23-5 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Co-ords: N 5 011 542.2; E 362 834.4 ORIGINATED BY B.S.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger and Cone Test COMPILED BY P.T.  
 DATUM Geodetic DATE 89-05-24 to 25 CHECKED BY B.I.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W <sub>P</sub>	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60	20 40 60					
92.2	Ground Surface														
0.0	Clayey Silt, some Sand, trace Organics Firm		1	SS	2										
90.1			2	TW	PM										
2.1			3	TW	PM										
	Clayey Silt to Silty Clay with pockets of Organics and occasional silty fine Sand seams  Extra Sensitive to Quick Soft to Firm		4	TW	OW										
			5	TW	OW										
			6	TW	OW										
			7	TW	OW										
			8	TW	OW										
			9	TW	OW										
			10	TW	OW										
			11	TW	OW										
75.4			12	TW	OW										
16.8	Silty Clay to Clay, trace Sand Firm to Stiff		13	TW	PM										
73.0															
19.2	End of Borehole														
	Probable Silty Clay to Clay, trace Sand														
71.0															
21.2	Probable Sand, Gravel occasional Cobbles and Boulders														
69.9															
22.3	End of Cone Test														
	** Estimated elevation of artesian flow encountered from cone hole  • To 95.2 ±														

# RECORD OF BOREHOLE No 23-6

1 OF 1

METRIC

W.P. 128-87-09 LOCATION Coords: N 5 011 530.5; E 362 828.0 ORIGINATED BY B.S.  
DIST 9 HWY 416 BOREHOLE TYPE H.S Auger, BW Casing and Cone Test COMPILED BY P.T.  
DATUM Geodetic DATE 89-05-18 to 23 CHECKED BY B.I.

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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60					
92.2	Ground Surface													
0.0	Clayey Silt, some Sand, trace Organics Firm		1	SS	2	To 94.7	92							
90.1			2	TW	PH									
2.1			3	SS	OW		90							
			4A	SS	OW		88							
	Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams  extra sensitive to quick soft to firm		5A	SS	OW		86							
			4	TW	OW		84						17.4	0 0 55 45 48
			5	TW	OW		82						16.7	0 3 44 53
			6	TW	OW		80							
			7	TW	OW		78							
			8	TW	OW		76						16.2	
			9	TW	OW		74						17.0	0 0 50 50
75.4			10	TW	OW		72							
16.8	Silty Clay to Clay Firm		11	SS	2									
	Occasional pockets of Sand and Gravel		12	SS	2									
71.7														
20.5	Probable Sand and Gravel occasional Cobbles and Boulders					Art. Encount								
70.9														
21.3	End of Borehole													
	• Phreatic Water Surface not observed													

# RECORD OF BOREHOLE No 23-6A 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Co-ords: N 5 011 527.2; E 362 829.6 ORIGINATED BY B.S.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger COMPILED BY P.T.  
 DATUM Ceodetic DATE 89-05-23 CHECKED BY B.I.

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					
92.2	Ground Surface																
0.0	Clayey Silt, some Sand, trace Organics						92										
90.0	Firm						90										
2.2	Clayey Silt to Silty Clay with packets of Organics and occasional Silty fine Sand seams		1	TW	OW		88										
	Extra Sensitive to Quick Soft		2	TW	OW		86										
84.9			3	TW	OW											17.6	0 8 50 42
7.3	End of Borehole																
	• Water Level Not established																

# RECORD OF BOREHOLE No 23-7 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Co-ords: N 5 011 453.2, E 362 688.9 ORIGINATED BY B.S.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S. Auger and Cone test COMPILED BY P.T.  
 DATUM Geodetic DATE 89-05-27 to 29 CHECKED BY B.L.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT      NATURAL MOISTURE CONTENT      LIQUID LIMIT			UNIT WEIGHT 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa		WATER CONTENT (%)					
92.1								20 40 60 80 100		W <sub>p</sub> W      W <sub>L</sub>					
0.0	Clayey Silt, some Sand, trace Organics Firm		1	SS	2										
89.7			2	TW	PM										
2.4	Clayey Silt to Silty Clay with pockets of Organics and occasional Silty Fine Sand seams Extra Sensitive to Quick Soft to Firm		3	SS	PM										
			4	TW	OW										
			5	SS	OW										
			6	TW	PM										
			7	SS	OW										
			8	TW	OW										
			9	SS	OW										
78.7															
13.4	End of Borehole														

# RECORD OF BOREHOLE No 23-8

1 of 1

METRIC

W.P. 128-87-09 LOCATION Co-ords: N 5 011 472.4; E 362 722.4 ORIGINATED BY S.M.H.  
DIST 9 HWY 416 BOREHOLE TYPE H.S Auger and Cone Test COMPILED BY P.T.  
DATUM Geodetic DATE 89-05-26 CHECKED BY B.I.

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 7 kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60					
92.1	Ground Surface													
0.0	Clayey Silt, some Sand, trace Organics Firm		1	SS	1									
89.8			2	TW	PH									
2.3														
	Clayey Silt to Silty Clay with pockets of organics and occasional Silty fine Sand seams Extra Sensitive to Quick Soft to Firm		3	SS	OW								0 29 39 32	
			4	TW	PM									
			5	SS	OW								0 9 56 35	
			6	TW	OW									
			7	TW	OW								16.6 0 6 50 44	
			8	SS	OW									
			9	TW	OW									
			10	SS	2									
			11	TW	OW								16.0 0 2 36 62	
75.8														
16.3	End of Borehole													
	Probable Silty Clay to Clay, trace Sand													
70.8														
21.3	End of Cone Test													

## METRIC

DATUM Geodetic DATE 89-05-29 CHECKED BY B.I.

+3, x5: Numbers refer to Sensitivity





# RECORD OF BOREHOLE No 23-10 1 OF 1 METRIC

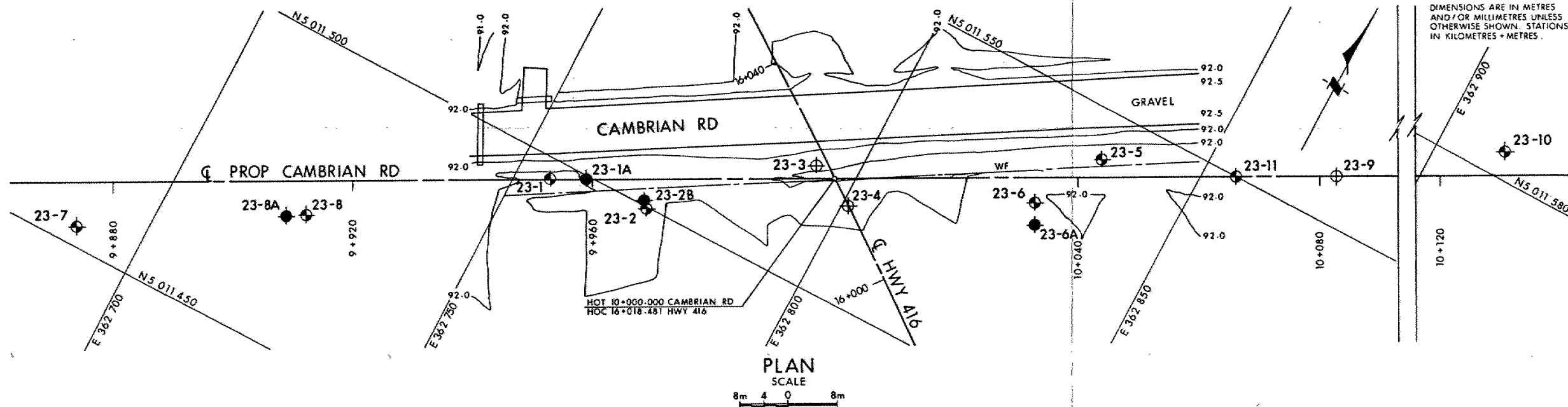
W.P. 128-87-09 LOCATION Co-ords: N 5 011 584.4; E 362 910.6 ORIGINATED BY B.S.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S Auger and Cone Test COMPILED BY P.T.  
 DATUM Geodetic DATE 89-05-29 CHECKED BY B.L.

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT w <sub>p</sub>	NATURAL MOISTURE CONTENT w	LIQUID LIMIT w <sub>L</sub>	UNIT WEIGHT γ kN/m <sup>3</sup>	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	SHEAR STRENGTH kPa					
93.2	Ground Surface							○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE					
0.0	Sand and Gravel		1	SS	9	*	92	Augered					0 15 70 15	
	Clayey Silt, some Sand, trace Organics, occasional pockets of Sand		2	SS	1									
90.0	Stiff													
3.2			3	TW	PH		90							
	Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams		4	SS	OW									
	Extra Sensitive to Quick		5	TW	OW							17.3	0 14 49 37	
	Soft to Firm		6	SS	OW								0 10 45 45	
			7	TW	OW									
			8	SS	OW									
			9	TW	OW									
			10	SS	OW								0 3 45 52	
78.3														
14.9	End of Borehole													
	* Water level not observed													

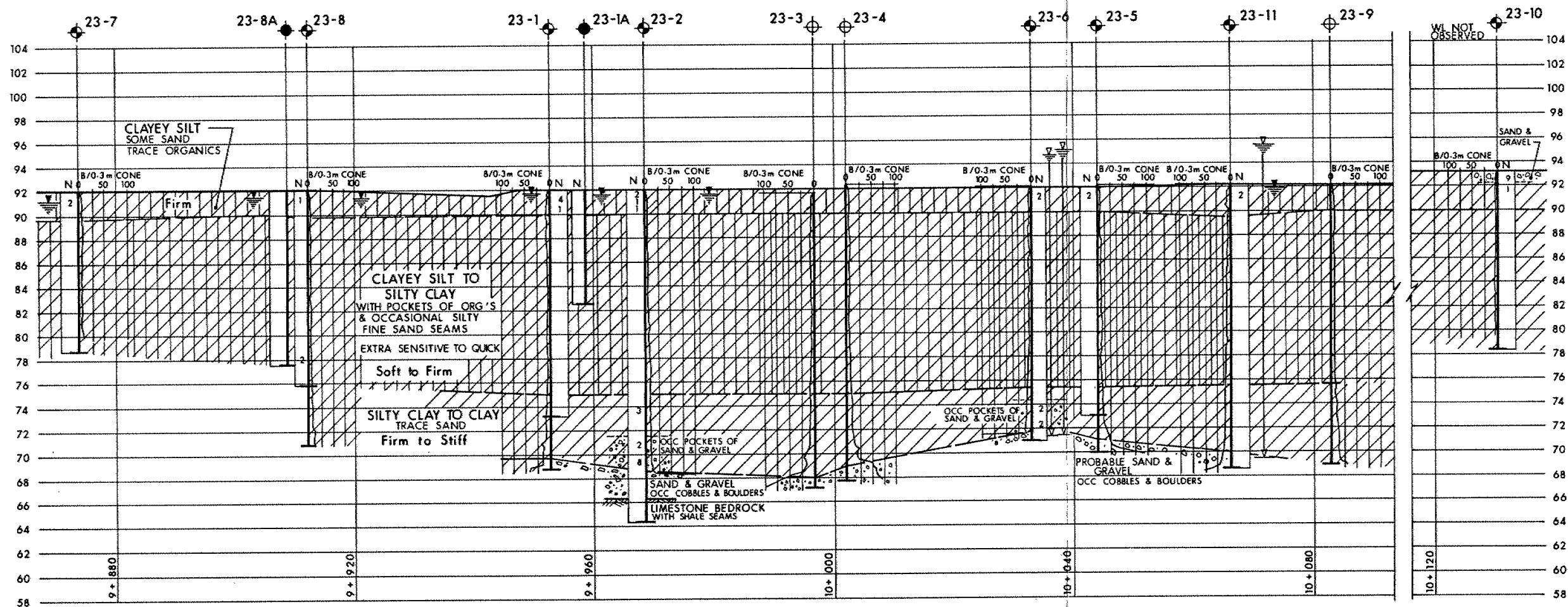
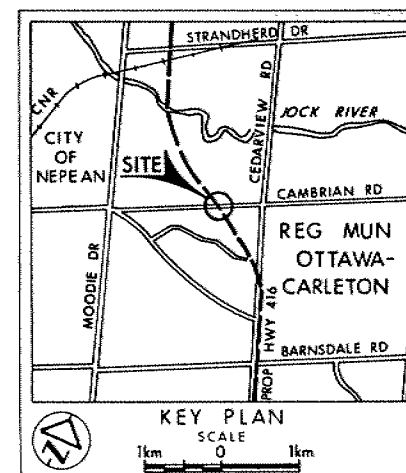
# RECORD OF BOREHOLE No 23-11 1 OF 1 METRIC

W.P. 128-87-09 LOCATION Co-ords: N 5 011 550.0; E 362 855.1 ORIGINATED BY B.S.  
 DIST 9 HWY 416 BOREHOLE TYPE H.S Auger and Cone Test COMPILED BY P.T.  
 DATUM Geodetic DATE 89-05-26-27 CHECKED BY B.I.

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					
92.2																	
0.0	Clayey Silt, some Sand, trace Organics Firm		1	SS	2		92										0 11 50 39
89.5			2	TW	-		90										
2.7	Clayey Silt to Silty Clay with pockets of Organics and occasional Silty fine Sand seams Extra Sensitive to Quick Soft to Firm		3	SS	OW		88									17.3	0 12 45 43
			4	TW	OW		86										
			5	SS	OW		84										
			6	TW	-		82										
			7	SS	-		80										
			8	TW	OW		78										
			9	SS	OW		76										
			10	TW	PM												0 2 43 55
			11	SS	PM												
75.6																	
16.6	End of Borehole																
	Probable Silty Clay to Clay, trace Sand																
70.0																	
12.2	Probable Sand and Gravel, occasional Cobbles and Boulders																
68.5																	
23.7	End of Cone Test ** Estimated elevation of Artesian flow encountered from Cone hole • To 95.5 ±																

**METRIC**DIMENSIONS ARE IN METRES  
AND/OR MILLIMETRES UNLESS  
OTHERWISE SHOWN. STATIONS  
IN KILOMETRES + METRES.CONT No  
WP No 128-87-09CAMBRIAN RD  
(STRUCTURE - 23)  
BORE HOLE LOCATIONS & SOIL STRATA

SHEET



PROFILE CAMBRIAN RD

SCALE  
8m 4 0 8m Hor  
4m 2 0 4m Vert**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 89 05
- Head
- ARTESIAN WATER Encountered

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
23-1	92.3	5 011 496.5	362 755.6
23-1A	92.3	5 011 499.4	362 760.9
23-2	92.1	5 011 499.7	362 772.0
23-2B	92.1	5 011 500.7	362 771.0
23-3	91.7	5 011 519.2	362 743.6
23-4	92.3	5 011 515.8	362 801.0
23-5	92.2	5 011 542.2	362 834.4
23-6	92.2	5 011 530.5	362 828.0
23-6A	92.2	5 011 527.2	362 829.6
23-7	92.1	5 011 453.2	362 688.9
23-8	92.1	5 011 472.4	362 722.4
23-8A	92.1	5 011 470.7	362 719.4
23-9	92.1	5 011 557.8	362 869.9
23-10	93.2	5 011 584.4	362 910.6
23-11	92.2	5 011 550.0	362 855.1

**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**

Subsoil information for BH 23-2B & 23-6A refer to Record of Borehole sheets

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-198

HWY No 416	DIST 9
SUBMD MM	CHECKED DATE 91 06 07 SITE 3-551
DRAWN DT	CHECKED APPROVED DWG 1288709-A

## MEMORANDUM

To: Mr. J. E. Gruspier,  
Regional Materials Engineer,  
Eastern Region,  
KINGSTON, Ontario.

FROM: Foundation Section,  
Materials & Testing Div.,  
Room 107, Lab. Bldg.

ATTENTION

DATE: September 23, 1968

OUR FILE REF:

IN REPLY TO

707-3 1968

SUBJECT:

## FOUNDATION INVESTIGATION REPORT

For the Stability of the  
South Approach Embankment between  
Sta. 249+00 & Sta. 243+00 at the  
Crossing of the C.P.R. Tracks and  
Prop. Hwy. 31 Bypass (Winchester)  
Townships of Winchester - Mountain  
Co. of Dundas, District 9 (Ottawa)  
W.J. 68-F-13-2 -- W.P. 335-65

Attached, we are forwarding to you, our detailed foundation investigation report on the subsoil conditions existing at the above structure site, with respect to the stability of the South Approach Embankment.

We believe that the factual data and recommendations contained therein, will prove adequate for your present requirements. Should additional information be required, please do not hesitate to contact our Office.

AGS/MdeF  
Attach.

*A. G. Stermac*  
A. G. Stermac  
PRINCIPAL FOUNDATION ENGINEER

cc: Messrs. B. R. Davis (2)  
H. A. Tregaskes  
D. W. Farren  
S. J. Markiewicz  
C. R. Robertson  
G. Scott  
B. A. Singh  
Foundations Files  
Gen. Files

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  2. SUBSOIL CONDITIONS:
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    - 2.3) Glacial Till - Clayey Silt with Sand and some Gravel.
  3. GROUNDWATER CONDITIONS.
  4. DISCUSSION AND RECOMMENDATIONS.
  5. MISCELLANEOUS.
-

FOUNDATION INVESTIGATION REPORT  
For the Stability of the  
South Approach Embankment between  
Sta. 249+00 & Sta. 243+00 at the  
Crossing of the C.P.R. Tracks and  
Prop. Hwy. 31 Bypass (Winchester)  
Townships of Winchester - Mountain  
Co. of Dundas, District 9 (Ottawa)  
W.J. 68-F-13-2 -- W.P. 335-65

1. INTRODUCTION:

The Foundation Report W.J. 68-F-13, submitted on April 8, 1968, presented all the factual data obtained from a subsoil investigation carried out in the vicinity of the proposed overhead structure, to carry Highway 31 across the existing C.P.R. tracks, just west of the Town of Winchester. The subsoil in the immediate vicinity of the structure crossing consists of a competent glacial till deposit. Based on this information, recommendations were made in our original foundation report pertaining to foundation design of the structure and stability of the associated approach embankments.

On August 20, 1968, the Foundation Section was requested, verbally by the Eastern Regional Materials Section, to carry out an additional investigation in order to assess the stability of the South approach embankment between Stations 249+00 and 243+00, beyond the limits of the proposed overhead. The height of fill in this area will range between 11 and 32 ft.; shallow borings put down by the Regional Materials Section, revealed the presence of a silty clay deposit immediately below the ground surface.

An investigation was subsequently carried out by this Section to determine the subsoil conditions at this site. This report contains the results of this investigation, together with our recommendations pertaining to the stability of the South approach embankment.

1. INTRODUCTION: (cont'd.) ...

At the proposed structure site the terrain is elevated above the surrounding ground. This elevated ground slopes gradually towards a level plain located about 500 ft. south of the tracks. The land is being used for farming purposes. The area is situated in the "Winchester Clay Plain" physiographic region, which is known to be covered with such glacial features as drumlins, etc.

2. SUBSOIL CONDITIONS:

2.1) General:

The initial investigation consisted of 4 boreholes, which were put down in the immediate vicinity of the proposed overhead and approaches. During the recent investigation three borings - (B.H.'s 5, 6, and 7) were put down through the relatively flat plain, south of the proposed structure. These three borings revealed that the subsoil in this area is composed of a silty clay to clayey silt stratum followed by a glacial till deposit. The surface of the glacial till deposit was encountered between elev. 219 and 225, or some 18 to 21 feet below ground level; the three borings were terminated within this deposit.

The boundaries between the different deposits are shown on the borelog sheets (B.H.'s 5, 6 and 7) contained in the Appendix. The estimated stratigraphical profile, shown on Dwg. 68-F-13-2A, is based upon this information, together with the information contained in the previous Foundation Report W.J. 68-F-13.

A description of the various soil types encountered follows:

2.2) Silty Clay to Clayey Silt with a trace of Sand and Gravel:

This deposit was observed in all three borings; it underlies a thin layer (6") of topsoil. The thickness of this stratum ranges from 18 to 21 feet. Occasional seams of silt up to 1" thick were observed throughout the deposit. In B.H. #7 the deposit is

cont'd. /3 ...



2. SUBSOIL CONDITIONS: (cont'd.) ...

2.2) Silty Clay to Clayey Silt with a trace of Sand and Gravel:  
(cont'd.) ...

more cohesive in nature and has been classified as a silty clay to clay with a trace of sand. The upper portion of the deposit (above elev. 236) appears to be desiccated and contains a trace or organic matter in the form of thin root fibres.

Atterberg limit tests, carried out on representative samples of the overall deposit, gave liquid limits ranging from 25% to 58%, plastic limits ranging from 17% to 31%, and moisture contents ranging from 18% to 39%. The consistency of the deposit, as determined from in situ vane tests and laboratory triaxial testing, ranges from very stiff, in the upper portion of the deposit, to firm with depth.

2.3) Glacial Till - Clayey Silt with Sand and some Gravel:

Underlying the silty clay to clayey silt stratum is a deposit of glacial till. The glacial till has a matrix of clayey silt binding sand and gravel. The consistency of this basically cohesive deposit ranges from firm to hard with depth. Practical refusal to wash boring techniques occurred within this deposit, between elevations 211 and 216 - i.e., the glacial till was penetrated for depths of up to 10 ft.

3. GROUNDWATER CONDITIONS:

At the time of the investigation the groundwater level across the site ranged from 4 ft. to 10 ft. below ground surface. The results of the groundwater observations are shown on the borelog sheets, as well as on Drawing 68-F-13-2A.

4. DISCUSSION AND RECOMMENDATIONS:

Competent glacial till was generally encountered at the proposed site of the overhead and its environ, with the exception of along the South approach. A very stiff to firm silty clay stratum, about 20 feet, overlies the glacial till south of Station 249+00. The height of the South embankment overlying this silty clay

cont'd. /4 ...

4. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

stratum will range from 31 ft. at Sta. 248+00 (B.H. #5) to 20 ft. at Sta. 245+00 (B.H. #7). This report will discuss the stability and settlement of this portion of the South approach embankment.

Total stress stability analyses ( $\phi = 0$ ) have been carried out both manually and by the use of the electronic computer to determine the stability of the fill sections founded on the cohesive stratum. The following assumptions were made:

Fill Material

Width of Roadway .....	48 feet
Side Slopes .....	2:1
Bulk Density .....	$\gamma = 130$ p.c.f.
Angle of Shearing Resistance .....	$\phi = 30^\circ$

Foundation Subsoil (Silty Clay to Clayey Silt)

<u>Elev.</u>	<u>Parameters</u>
240 - 230 .....	$C_u = 1800$ p.s.f.; $\gamma = 120$ p.c.f.
230 - 225 .....	$C_u = 1200$ p.s.f.; $\gamma' = 58$ p.c.f.
225 - 215 .....	$C_u = 800$ p.s.f.; $\gamma' = 58$ p.c.f.

The stability computations indicate that the embankment, whose maximum height is 30 feet, will be stable with respect to a deep-seated failure occurring within the cohesive stratum; the minimum computed factor of safety, with respect to stability, was 1.5.

Settlement calculations carried out, indicate that consolidation settlement, induced in the silty clay stratum by the surcharge loading of the fill, will be between 4 and 6 inches

cont'd. /5 ...

4. DISCUSSION AND RECOMMENDATIONS: (cont'd.) ...

under the centre-line of the highest portion of the South embankment. The total amount of the consolidation settlement predicted should occur within a period of about 1-1/2 years with 50% occurring within about 2-1/2 months.

5. MISCELLANEOUS:

The field work performed during the period August 23 - 27, 1968, together with the preparation of this report, was undertaken by Mr. W. Hutton, Project Foundation Engineer.

Equipment used was owned and operated by Johnston Drilling Co. Ltd.

The investigation was carried out under the general supervision of Mr. M. Devata, Supervising Foundation Engineer.

September, 1968.

1941年12月1日

1941年12月1日

DEPARTMENT OF HIGHWAYS - ONTARIO

## MATERIALS &amp; TESTING DIVISION

JOB 68-7-13-2

LOCATION

Sta. 245 + 00 @ Line 'A' o/s 40' Rt.

FOUNDATION SECTION

ORIGINATED BY

W. P. 335-65

BORING DATE

August 23 - 26, 1968

COMPILED BY

DATUM Geodetic

BOREHOLE TYPE

Diamond Drill - Washboring

CHECKED BY

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE BLOWS / FOOT	LIQUID LIMIT ——— WL PLASTIC LIMIT ——— wp WATER CONTENT ——— w			BULK DENSITY Y PCF	REMARKS	
ELEV DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		20 40 60 80 100	SHEAR STRENGTH P.S.F.					wp ——— w ——— WL WATER CONTENT % 15 30 45
								o - Unconfined      • - Triaxial + - Field Vane      x - Lab Vane 400 800 1200 1600 2000					
210.0	Ground Level												
20.0	Silty clay to clay with trace of sand & occ. silt seams up to 5" thick. Desiccated above elev. 236. Very stiff to firm. Brown to Grey		1	SS	10	230							
			2	TW	PM								
			3	TW	PM								
219.2						220							
20.8	Glacial Till Clayey silt with sand & some gravel. Firm to Hard.		4	SS	4								
			5	SS	20								
211.2	Grey		6	SS	15L								
20.9	End of Borehole Hammer Bouncing					210							

DEPARTMENT OF HIGHWAYS - ONTARIO

## MATERIALS &amp; TESTING DIVISION

RECORD OF BOREHOLE NO. 6

FOUNDATION SECTION

JOB 68-F-13-2 LOCATION Sta. 246 + 00 @ Line 'A' 9/s 50' Rt. ORIGINATED BY WH  
W.P. 335-65 BORING DATE August 23 - 26, 1968 COMPILED BY WH  
DATUM Geodetic BOREHOLE TYPE Diamond Drill - Washboring CHECKED BY [Signature]

SOIL PROFILE			SAMPLES			ELEV. SCALE	DYNAMIC PENETRATION RESISTANCE					LIQUID LIMIT ——— WL PLASTIC LIMIT ——— WP WATER CONTENT ——— W			BULK DENSITY Y P.C.F.	REMARKS	
ELEV DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	BLOWS / FOOT		BLOWS / FOOT 20 40 60 80 100					WATER CONTENT % 15 30 45					
							SHEAR STRENGTH P.S.F.					w p ——— w ——— w L					
							+ - Field Vane    o - Unconfined x - Lab Vane      • - Triaxial										
						400 800 1200 1600 2000											
241.0	Ground Level																
240.0	Silty clay to clayey silt with trace of sand & gravel & occ. silt seams up to 1" thick. Desiccated above elev. 236.  Very stiff to firm.  Brown to grey.		1	SS	8	240									119	▼ 236.	
			2	TW	PM											114	0 1 59 40 1 2 58 39
			3	TW	PM	230										118	
			4	TW	PM												
220.0			5	TW	PM												7 1 83 9 18 36 38 8
21.0	Glacial Till	6A	SS	23													
216.2	Clayey silt with sand & some gravel.	7	SS	95													
216.2	Very stiff to hard Grey	8	SS	123	110"												
214.8	End of Borehole																
						210											

DEPARTMENT OF HIGHWAYS - ONTARIO

## MATERIALS &amp; TESTING DIVISION

JOB 68-F-13-2

LOCATION

Sta. 248 + 00 @ Line 'A' o/s 40' Rt.

ORIGINATED BY

FOUNDATION SECTION

W. P. 335-65

BORING DATE

August 23 - 26, 1968

COMPILED BY

DATUM Geodetic

BOREHOLE TYPE

## Diamond Drill - Washboring

CHECKED BY

[illegible]

## ABBREVIATIONS USED IN THIS REPORT

### PENETRATION RESISTANCE

STANDARD PENETRATION RESISTANCE ('N') - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A STANDARD SPLIT SPOON SAMPLER 12 INCHES INTO THE SUBSOIL, DRIVEN BY MEANS OF A 140 POUND HAMMER FALLING FREELY A DISTANCE OF 30 INCHES.

DYNAMIC PENETRATION RESISTANCE - THE NUMBER OF BLOWS REQUIRED TO ADVANCE A 2 INCH, 60 DEGREE CONE, FITTED TO THE END OF DRILL RODS, 12 INCHES INTO THE SUBSOIL, THE DRIVING ENERGY BEING 350 FOOT POUNDS PER BLOW.

### DESCRIPTION OF SOIL

THE CONSISTENCY OF COHESIVE SOILS AND THE RELATIVE DENSITY OR DENSENESS OF COHESIONLESS SOILS ARE DESCRIBED IN THE FOLLOWING TERMS :-

<u>CONSISTENCY</u>	<u>'N' BLOWS / FT</u>	<u>c LB. / SQ. FT.</u>	<u>DENSENESS</u>	<u>'N' BLOWS / FT.</u>
VERY SOFT	0 - 2	0 - 250	VERY LOOSE	0 - 4
SOFT	2 - 4	250 - 500	LOOSE	4 - 10
FIRM	4 - 8	500 - 1000	COMPACT	10 - 30
STIFF	8 - 15	1000 - 2000	DENSE	30 - 50
VERY STIFF	15 - 30	2000 - 4000	VERY DENSE	> 50
HARD	> 30	> 4000		

### TYPE OF SAMPLE

S.S	SPLIT SPOON	T W	THINWALL OPEN
W S	WASHED SAMPLE	T P	THINWALL PISTON
S B	SCRAPER BUCKET SAMPLE	O S	OESTERBERG SAMPLE
A S	AUGER SAMPLE	F S	FOIL SAMPLE
C S	CHUNK SAMPLE	R C	ROCK CORE
S T	SLOTTED TUBE SAMPLE		
	P H		SAMPLE ADVANCED HYDRAULICALLY
	P M		SAMPLE ADVANCED MANUALLY

### SOIL TESTS

Q <sub>u</sub>	UNCONFINED COMPRESSION	L V	LABORATORY VANE
Q	UNDRAINED TRIAXIAL	F V	FIELD VANE
Q <sub>c<u>u</u></sub>	CONSOLIDATED UNDRAINED TRIAXIAL	C	CONSOLIDATION
Q <sub>d</sub>	DRAINED TRIAXIAL	S	SENSITIVITY



## ABBREVIATIONS USED IN THIS REPORT

### SOIL PROPERTIES

$\gamma$	UNIT WEIGHT OF SOIL (BULK DENSITY)
$\gamma_s$	UNIT WEIGHT OF SOLID PARTICLES
$\gamma_w$	UNIT WEIGHT OF WATER
$\gamma_d$	UNIT DRY WEIGHT OF SOIL (DRY DENSITY)
$\gamma'$	UNIT WEIGHT OF SUBMERGED SOIL
G	SPECIFIC GRAVITY OF SOLID PARTICLES $G = \frac{\gamma_s}{\gamma_w}$
e	VOID RATIO
n	POROSITY
w	WATER CONTENT
$S_r$	DEGREE OF SATURATION
$w_L$	LIQUID LIMIT
$w_p$	PLASTIC LIMIT
$I_p$	PLASTICITY INDEX
s	SHRINKAGE LIMIT
$I_L$	LIQUIDITY INDEX $= \frac{w - w_p}{I_p}$
$I_c$	CONSISTENCY INDEX $= \frac{w_L - w}{I_p}$
$e_{max}$	VOID RATIO IN LOOSEST STATE
$e_{min}$	VOID RATIO IN DENSEST STATE
$I_D$	DENSITY INDEX $= \frac{e_{max} - e}{e_{max} - e_{min}}$
	RELATIVE DENSITY $D_r$ IS ALSO USED
h	HYDRAULIC HEAD OR POTENTIAL
q	RATE OF DISCHARGE
v	VELOCITY OF FLOW
i	HYDRAULIC GRADIENT
k	COEFFICIENT OF PERMEABILITY
j	SEEPAGE FORCE PER UNIT VOLUME
$m_v$	COEFFICIENT OF VOLUME CHANGE $= \frac{-\Delta e}{(1+e)\Delta\sigma}$
$c_v$	COEFFICIENT OF CONSOLIDATION
$C_c$	COMPRESSION INDEX $= \frac{\Delta e}{\Delta \log_{10} \sigma}$
$T_v$	TIME FACTOR $= \frac{c_v t}{d^2}$ (d, DRAINAGE PATH)
U	DEGREE OF CONSOLIDATION
$\tau$	SHEAR STRENGTH
$c'$	EFFECTIVE COHESION
$\phi'$	EFFECTIVE ANGLE OF SHEARING RESISTANCE, OR FRICTION
$c_u$	APPARENT COHESION
$\phi_u$	APPARENT ANGLE OF SHEARING RESISTANCE, OR FRICTION
$\mu$	COEFFICIENT OF FRICTION
$S_t$	SENSITIVITY

### GENERAL

$\pi$	= 3.1416
e	BASE OF NATURAL LOGARITHMS 2.7183
$\log_e a$ OR $\ln a$	NATURAL LOGARITHM OF a
$\log_{10} a$ OR $\log a$	LOGARITHM OF a TO BASE 10
t	TIME
g	ACCELERATION DUE TO GRAVITY
V	VOLUME
W	WEIGHT
M	MOMENT
F	FACTOR OF SAFETY

### STRESS AND STRAIN

u	PORE PRESSURE
$\sigma$	NORMAL STRESS
$\sigma'$	NORMAL EFFECTIVE STRESS ( $\bar{\sigma}$ IS ALSO USED)
$\tau$	SHEAR STRESS
$\epsilon$	LINEAR STRAIN
$\gamma$	SHEAR STRAIN
$\nu$	POISSON'S RATIO ( $\mu$ IS ALSO USED)
E	MODULUS OF LINEAR DEFORMATION (YOUNG'S MODULUS)
G	MODULUS OF SHEAR DEFORMATION
K	MODULUS OF COMPRESSIBILITY
$\eta$	COEFFICIENT OF VISCOSITY

### EARTH PRESSURE

d	DISTANCE FROM TOP OF WALL TO POINT OF APPLICATION OF PRESSURE
$\delta$	ANGLE OF WALL FRICTION
K	DIMENSIONLESS COEFFICIENT TO BE USED WITH VARIOUS SUFFIXES IN EXPRESSIONS REFERRING TO NORMAL STRESS ON WALLS
$K_0$	COEFFICIENT OF EARTH PRESSURE AT REST

### FOUNDATIONS

B	BREADTH OF FOUNDATION
L	LENGTH OF FOUNDATION
D	DEPTH OF FOUNDATION BENEATH GROUND
N	DIMENSIONLESS COEFFICIENT USED WITH A SUFFIX APPLYING TO SPECIFIC GRAVITY, DEPTH AND COHESION ETC. IN THE FORMULA FOR BEARING CAPACITY
$k_s$	MODULUS OF SUBGRADE REACTION

### SLOPES

H	VERTICAL HEIGHT OF SLOPE
D	DEPTH BELOW TOE OF SLOPE TO HARD STRATUM
$\beta$	ANGLE OF SLOPE TO HORIZONTAL

#  
68-F-13-2  
W.P. # 335-65  
Hwy # 31843  
LINE A' C.P.R.  
(SOUTH APPROACH  
EMBANKMENT)

