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CONT. No. 94-55

W. O. No.

STR. SITE No.

HWY. No. 403

LOCATION Hwy 403 - ~~Haley~~ Access Culvert

No. of PAGES -

OVERSIZE DRAWINGS TO BE INCLUDED WITH THIS REPORT.

REMARKS:

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foundation investigation and design report

ENGINEERING MATERIALS OFFICE
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CONT 94-55

WP 114-87-00(A) DIST 4

HWY 403 STR SITE -

Hwy. 403 North-South Concrete Access Culvert

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FOUNDATION INVESTIGATION REPORT

FOR

Hwy 403 North-South Concrete Access Culvert

WP 114-87-00(A), Hwy 403

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the proposed concrete access culvert type structure. The structure is designed to enable farming equipment, materials and personnel to be transported beneath the proposed Hwy 403 which will be supported by the structure. The proposed structure is perpendicular to the proposed Hwy 403 as shown on the attached drawing 1148700(A)-A.

SITE DESCRIPTION AND GEOLOGY

The site is situated at the proposed Hwy 403, approximately mid-distance between Jerseyville Rd. and Hwy 2. The site is accessible by existing private gravel roads extending from Parsonage Rd. which starts at Jerseyville Rd. and Jury Rd. which starts at Hwy 2/53 in Brant County, Township of Brantford.

Grading and drainage work has been completed under Contract 90-66 in the area and the Hwy 403 right-of-way imprint is evident on both sides of the proposed culvert. The highway appears to be within a shallow excavation cut at the site location. East of the site, beyond the extent of Contract 90-66, the land is forested and populated with tall deciduous trees.

The land beyond the Hwy 403 is generally gently rolling terrain. Land use is primarily agricultural farmland.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 40m.

INVESTIGATION PROCEDURE

General

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and the laboratory testing program are discussed below.

Field Investigation

The fieldwork for this project was carried out between 92 05 11 and 92 05 13 and consisted of two (2) sampled boreholes advanced to depths ranging from 42.7m to 43.5m accompanied by two (2) dynamic cone penetration tests carried out to depths ranging from 15.2m to 17.1m. The boreholes were advanced through the overburden using track mounted units employing conventional continuous flight hollow stem augering techniques and also casing/washboring methods. Conventional rock coring techniques using BW casing and BX core barrels were used to retrieve up to 3m of rock core.

Subsoil samples were generally retrieved at 1.5m intervals for the surficial 18m or so and at 3m intervals thereafter. Both disturbed and undisturbed subsoil samples were retrieved within the surficial 22m. Disturbed samples only were retrieved beneath this depth. Disturbed subsoil samples were retrieved in accordance with the Standard Penetration Test (ASTM D1586) using a standard split spoon sampler driven into the soil and undisturbed subsoil samples were retrieved using a thin wall sampler pushed hydraulically into the soil in accordance with procedures outlined in ASTM D1587.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The test was carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Rock core samples were identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock core were placed in standard rock core boxes and carefully transported to the laboratory.

Groundwater levels were determined by monitoring the water levels in the open boreholes throughout the duration of the field investigation. All boreholes were backfilled upon completion of the field work.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples. These tests included:

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Test
2) Particle Size Analysis	2) Unconfined Compression
3) Natural Moisture Contents	
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Detailed rock core logging was conducted in the laboratory by an in-house resident geologist.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

General

Subsurface conditions across the site are uniform and consist of three (3) distinct layers of overburden overlying bedrock. The surficial deposit consists of a cohesive clayey silt to silty clay that extends to depths ranging from 12.2m to 13m below the ground surface. The deposit has a firm to very stiff consistency and contains random interbeds of plastic silt approximately 25mm to 75mm in thickness within the lower three (3) metres of the deposit.

The surficial cohesive clayey silt to silty clay deposit is underlain by a plastic silt that has a loose denseness and contains random interbedded layers of cohesive clayey silt.

The plastic silt stratum is in turn underlain by a second cohesive clayey silt to silty clay deposit which has a thickness of 20.6m to 22.1m. This deposit also contains random thin interbeds of plastic silt of thickness ranging from 25mm to 100mm. This deposit extends to the bedrock surface which exists at an elevation of 178.1m to 178.6m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700(A)-A in the Appendix. A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Boreholes sheets in the Appendix.

Clayey Silt to Silty Clay

The surficial stratum at the site consists of a cohesive clayey silt to silty clay that extends for a thickness of 12.2 to 13 metres. Within the lower three metres of the deposit, thin layers or seams of plastic silt generally 25mm to 100mm in thickness exist. The deposit has been oxidized for the surficial 3 to 3.8 metres and is brown in colour within this depth. Below this depth, the deposit is unoxidized and grey in colour. A grain size distribution envelope produced by mechanical sieve and hydrometer analysis is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed of grain sizes smaller than 75 micrometre. The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 45% to 84% and clay percentages ranging from 28% to 55%. In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below.

Atterberg Limit Tests were carried out on the fine grained soil and the results are plotted on Figure 2 in the Appendix and summarized on Table 1 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 1 - Atterberg Limit Test Results

	Range	# of Tests
Natural Moisture Content (w%)	25-31	7
Liquid Limit (w_L%)	31-41	7
Plastic Limit (w_P%)	18-22	7
Plasticity Index (Ip%)	13-21	7
Bulk Unit Weight (kN/m3)	18.9-19.7	6

The test results clearly reveal that the soil has a plasticity ranging from low to intermediate and hence can be categorized as clayey silt (CL) to silty clay (CI). Natural moisture contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state. An Atterberg Limit Test conducted on a sample of an interbedded silt layer confirms that the material is an inorganic silt of low plasticity (ML). The liquid limit (w_L) and the plasticity index (Ip) for a silt interbed in sample TW8, BH1 was determined to be 23% and 3% respectively. The material possesses no dry strength, no toughness and a quick dilatancy, properties which are consistent with this classification.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests and unconfined compression tests. The results of these tests are plotted on the individual Record of Borehole Sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. The undrained shear strength of the surficial clayey silt to silty clay ranges from 30 kPa to 90 kPa which is equivalent to a consistency ranging from firm to very stiff. The sensitivity of the soil as defined by the ratio of the undrained strength in the undisturbed state to the undrained strength, at the same water content, in the remoulded state was also determined by the field vane test. Sensitivity values range from 1 to 4 indicating an insensitive to moderately sensitive material.

The upper desiccated unoxidized brown crust has a greater strength and a consistency ranging from stiff to very stiff. The 'N' values as determined by the Standard Penetration Test ranged from 12 blows/0.3m to 18 blows/0.3m within this upper crust. Beneath this upper zone, 'N' values ranged from 5 blows/0.3m to 7 blows/0.3m.

The compressibility characteristics of the clayey silt to silty clay stratum were determined by conducting one dimensional consolidation tests on two (2) representative samples. The results of the tests are shown graphically on Figure 4 in the Appendix. The consolidation curves are plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load (log p). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (p_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The two consolidation curves reveal preconsolidation pressures ranging from 220 kPa to 330 kPa. The effective overburden pressures for these two preconsolidation pressures are 140 kPa and 130 kPa respectively. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 80 kPa to 200 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.13 to 0.2.

Silt with interbedded layers of Clayey Silt

A cohesionless silt of quick dilatancy interbedded with thin layers of cohesive clayey silt exists below the clayey silt to silty clay surficial deposit and extends to depths ranging from 18.1m to 19.8m below the ground surface. The thickness of this stratum ranges from 5.1m to 7.6m and the cohesive interbedded seams or layers are approximately 25mm to 75mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

A grain size distribution envelope as determined by mechanical sieve and hydrometer analysis is shown on Figure 5 in the Appendix. The envelope illustrates primarily silt percentage (88-90%) with traces to some clay. The silty soil does however exhibit plasticity and the results of Atterberg Limit Tests carried out on some representative samples of the material are summarized in Table 2 below.

Table 2 - Plastic Silt

	Range	# of Tests
Natural Moisture Content (w%)	27-28	3
Liquid Limit (w_L%)	23-24	3
Plastic Limit (w_P%)	20-22	3
Plasticity Index (Ip%)	1-4	3

The test results reveal that the soil is a plastic silt (ML categorization). Natural moisture contents exceed the liquid limit of the soil.

Due to the percentages of clay and the layers of interbedded clayey silt, vanes could be torqued and in situ tests were conducted. The results revealed undrained shear strength values ranging from approximately 30 to 62 kPa. The results, in general, were erratic and devoid of any pattern which is perhaps indicative of the high silt percentages.

The 'N' values as derived from the Standard Penetration Test reveal values ranging from 5 to 6 blows/0.3m. This is representative of a loose state of denseness.

Clayey Silt to Silty Clay with random interbedded layers of Silt

Underlying the plastic silt with interbedded layers of clayey silt, a second cohesive deposit consisting of clayey silt to silty clay extending to the bedrock surface exists. The surface of the deposit exists at an elevation ranging from 198.7m to 200.7m and the deposit has a thickness in the order of magnitude of 20.6m to 22.1m. Random interbedded layers or seams of plastic silt ranging in thickness from 25mm to 100mm are also present within the cohesive deposit.

A grain size distribution envelope illustrating the gradation of the material of this deposit is shown on Figure 6 in the Appendix. The envelope clearly illustrates that the material is fine grained with grain sizes less than 75 micrometres. Typically, clay percentages range from 25% to 32% and silt percentages range from 68% to 75%.

In accordance with the MTO Soil Classification system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 3 below. Natural Moisture Contents are also included in the Table below.

Table 3 - Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	24-28	5
Liquid Limit (w_L%)	24-37	5
Plastic Limit (w_P%)	17-20	5
Plasticity Index (Ip%)	8-17	5

The test results reveal that the soil has a low to intermediate plasticity and hence can be classified as a clayey silt to silty clay. Natural moisture contents are generally similar to the liquid limit of the soil.

An Atterberg Limit Test conducted on a sample of an interbedded silt layer confirms that the material is an inorganic silt of low plasticity (CL - ML). The liquid limit (w_L) and plasticity index (Ip) for a silt interbed in sample TW12, BH2 was determined to be 24% and 5% respectively.

The consistency and undrained shear strength of the soil was determined by conducting in situ vane tests and interpretation of SPT 'N' values. Undrained shear strength values are plotted on the individual Record of Borehole sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. The undrained shear strength values ranged from 50 kPa to 90 kPa with the strength increasing with depth. The sensitivity of the soil as determined by the field vane test ranged from 2 to 4 indicating an insensitive to moderately sensitive material. The SPT 'N' values ranged from 9 blows/0.3m to 28 blows/0.3m. Based on the undrained shear strength and SPT 'N' values, the clayey silt to silty clay can be described as having a stiff to very stiff consistency.

Bedrock

The bedrock consisting of a "vuggy" dolostone of the Amabel Formation underlies the clayey silt to silty clay with random layers or seams of interbedded silt deposit at an elevation of approximately 178.1m to 178.6m. The bedrock was cored in BX size up to 3.1m in depth.

The dolostone bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey to medium dark grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Rock Core Description".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and physical index property testing. Recoveries ranged from 90% to 100% and RQD's ranged from 61% to 78% indicating that the rock is of good quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of investigation were approximately 3 to 4 metres below the ground surface (elevation 215.8m to 214.5m).

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

DISCUSSION AND RECOMMENDATION

It is proposed to construct a concrete access overpass at station 17+585 as shown on Dwg. 1148700(A)-A in the Appendix. The culvert, which will enable the transportation of farming equipment beneath the proposed Hwy 403 has the following dimensions:

Height (m) - 4
Width (m) - 6
Length (m) - 60

The proposed grade for the Hwy 403, which initially is a four lane median divided highway with ultimate widening plans, is approximately at elevation 219 metres. The culvert invert elevation is proposed at elevation 214 metres. Hence, with a 4 metre culvert structure height, 1 metre of fill cover will be placed above the roof of the structure.

The Hwy 403 exists in a shallow excavation cut at the site. As mentioned earlier, the grading and drainage for the highway has been completed under Contract No. 90-66. An additional 4 to 5 metre excavation cut will be necessary for the installation of the concrete structure.

To facilitate the design and construction of the proposed structure foundations and related earthworks, the following foundation and geotechnical recommendations are provided in the scope of this report.

1) Structure Foundations
2) Approach Cuts

3) Backfill to Structure

4) Construction Considerations

1) Structure Foundations

It is recommended that the access structure be designed as a box type culvert founded on a conventional slab type foundation. For purposes of the OHBDC, the bearing capacities tabulated in Table 4 can be used.

Table 4 - Culvert Shallow Foundation Design

Culvert Invert Elevation (m)	Bedding		Factored Capacity at U.L.S. (kPa)	Bearing Capacity at S.L.S Type II (kPa)
	Thickness (m)	Material		
214	0.5	Granular 'A'	175	125

As indicated in Table 4, it is further recommended that the culvert foundation pad be placed on a well compacted Granular 'A' pad of 0.5m thickness below the culvert invert. The granular pad shall be placed and compacted in accordance with OPSS 501 series to achieve 100 percent of maximum dry density (see Method A - 501.08.02). The excavation for the bedding shall extend to a width of a minimum 1.0m on either side of the culvert.

Any softened material at the culvert bedding founding elevation shall be subexcavated and replaced with the granular 'A' material.

Settlements induced as a result of the applied pressures tabulated in Table 4 will be due to the recompression of the founding soil and elastic in nature. These settlements will occur during or immediately following construction and are anticipated to be within 25mm total or differential.

The capacities provided in Table 4 apply to vertical loads only. These capacities must be reduced to account for any load inclination. This reduction shall be carried out in accordance with Section 6-7.3.3.5 of the O.H.B.D.C.

2) Approach Cuts

General

Approach cuts in the order of five (5) metres will be required at either portal to the concrete access structure. The design of excavation cuts as proposed must address two major considerations:

1) Global Stability
2) Surficial Stability

These two considerations are described below.

Global Stability

The critical condition examined in the evaluation of excavation cuts such as those proposed at the site location is the long term (drained) condition and consequently an effective stress analysis was conducted. In all cases, stability computations were carried out using an in-house MTOslope application software package which is based on Sarma's method of limiting equilibrium. The formulation of Sarma's method is described in a paper entitled "Stability Analysis of Embankments and Slopes", Sarma, S.K. (1973), Geotechnique 23, No. 3, pp 423-433.

The process of stability analyses involves the selection of pertinent shear strength parameters and physical soil properties such as unit weight, inputting the subsurface and groundwater conditions and then designing a surface geometry that produces an acceptable factor of safety of 1.3 using the MTOslope program.

Figure 8 in the Appendix illustrates the subsurface conditions and relevant subsoil parameters used in the stability analyses. In all cases, circular slip surfaces were evaluated and a critical slip surface was searched.

The results of the analysis reveal that excavation cut slopes up to six (6) metres can be safely designed and constructed at a 2H:1V slope geometry.

Surficial Stability

Drained stability analysis of slopes are very sensitive to groundwater levels and pore pressures that can develop in the slope. Therefore slope protection and drainage measures will be required to ensure their long term surficial stability. By employing a 0.6m thick granular blanket consisting of pervious material such as Granular 'A', softening of material due to freeze-thaw cycles and development of excess pore water pressures can be prevented in the overburden. The granular blanket shall be extended to the phreatic water table surface (approximately elevation 216m). The granular blankets should be designed in conjunction with a permanent drainage system that will discharge drained water from the slope. It is recommended that toe drains be constructed consisting of a perforated pipe encased with a suitable geotextile filter fabric and in turn surrounded by a suitable granular soil filter material.

Normal slope vegetation cover shall be established as per conventional MTO standards as soon as possible to provide surface erosion protection.

3) Backfill to Structure

Material

It is recommended that Granular 'A' or Granular 'B' be used behind the concrete access structure walls placed as shown on OPSD 800 series. The application of granular material combined with weep holes in the culvert walls to drain any accumulation of water in the backfill will prevent hydrostatic pressure build-up. Design parameters of the soil are given in Table 5 below.

Table 5 - Backfill Properties

	Granular 'A'	Granular 'B'
Angle of Internal Friction (ϕ) (unfactored)	35°	30°
Unit Weight (kN/m^3) , γ	22.8	21.2
*Coefficient of Active Earth Pressure (Ka)		
- S.L.S	0.27	0.33
- U.L.S	0.33	0.40
*Coefficient of Earth Pressure at Rest (Ko)		
- S.L.S	0.43	0.50
- U.L.S	0.50	0.58

*These earth pressure coefficients apply to horizontal backfill surfaces only. The appropriate consideration shall be given to account for sloping backfill.

Longitudinal Earth Slopes

Longitudinal fill slopes up to approximately 5 metres in height will be constructed from the highway roadway surface limit to the culvert invert. In order to determine the safe geometry of these slopes, a total stress slope stability analysis was conducted. The stability computations were carried out using the in-house MTOslope application software package mentioned previously. Circular slip surfaces were analyzed using the subsurface conditions and soil parameters as shown in Figure 9. A factor of safety of 1.3 was considered acceptable.

The results of the analyses indicate that longitudinal fill slopes up to 5 metres can be constructed at 2H:1V.

4) Construction Considerations

Excavation

Temporary excavation slopes within the surficial clayey silt to silty clay stratum to facilitate the construction of the structure shall not be steeper than 1.5H:1V.

Dewatering

No dewatering problems are anticipated during the construction of the structure due to the impervious nature of the surficial clayey silt to silty clay. Any localized seepage or surface runoff can be easily controlled and readily discharged using conventional sump pumping techniques.

Backfilling and Compaction

In the placement of the backfill material, all softened material should be excavated for their full depth within the plan limits prior to fill placement. Backfill shall be placed simultaneously behind both sides of the structure walls and at no time shall the difference in elevation be greater that 500mm. The backfill shall be constructed in 300mm lifts in accordance with OPSS 902 series and applicable OPSD series. The backfill shall be compacted to achieve the target maximum dry density as outlined in OPSS 501.07.08.

Heavy vibratory equipment should be avoided in the backfill construction because of the close proximity to the structure. It is therefore recommended that hand compaction equipment be employed in backfilling the sides of the culvert.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto Student Engineer, utilizing equipment owned and operated by Atcost Drilling Ltd. and London Soil Testing. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out By T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by MR. M. S. Devata, Chief Foundation Engineer.

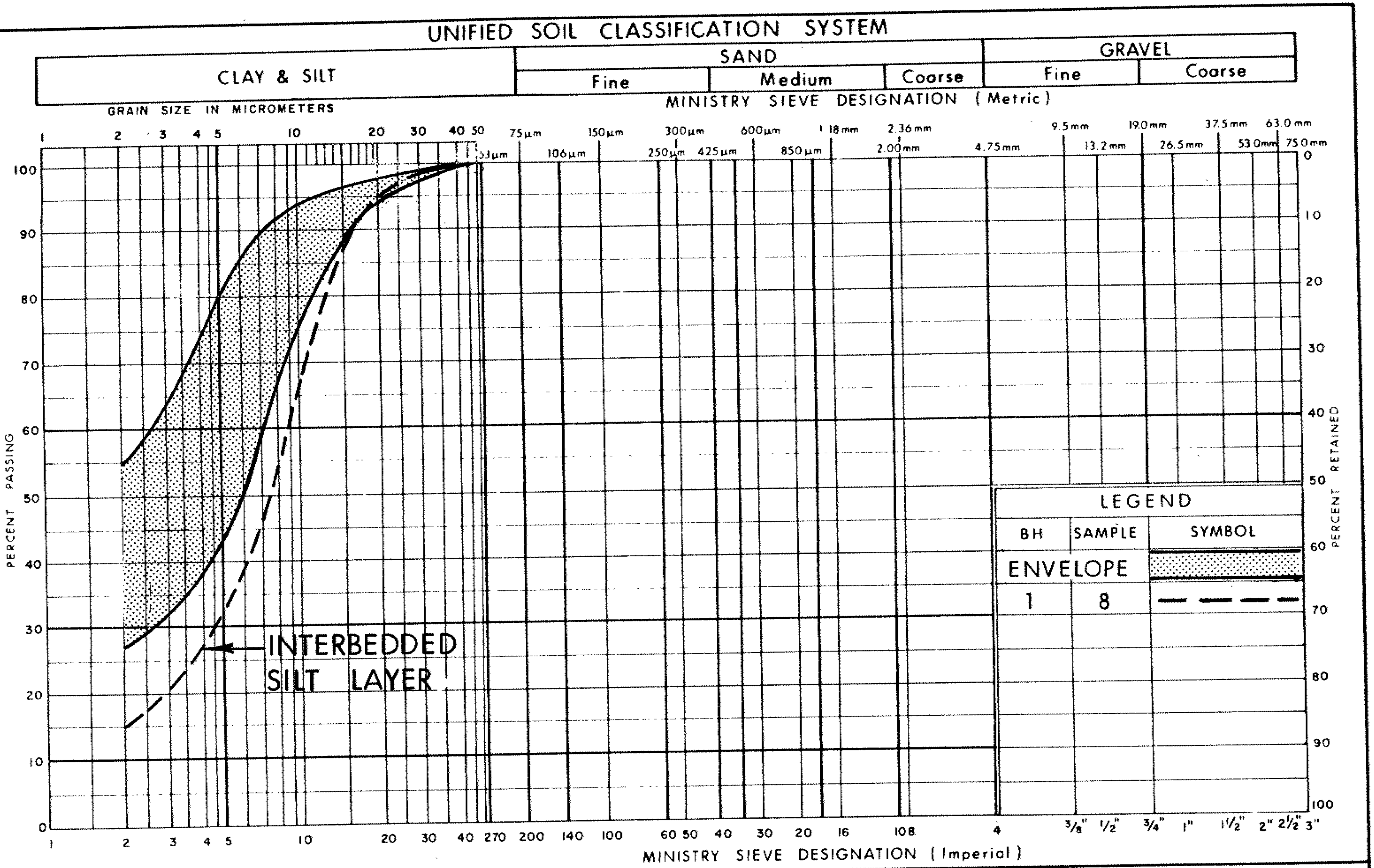
LICENSED PROFESSIONAL ENGINEER
A. J. Sangiuliano
PROVINCE OF ONTARIO

T. Sangiuliano, P.Eng.
Foundation Engineer

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

APPENDIX

78 12 M



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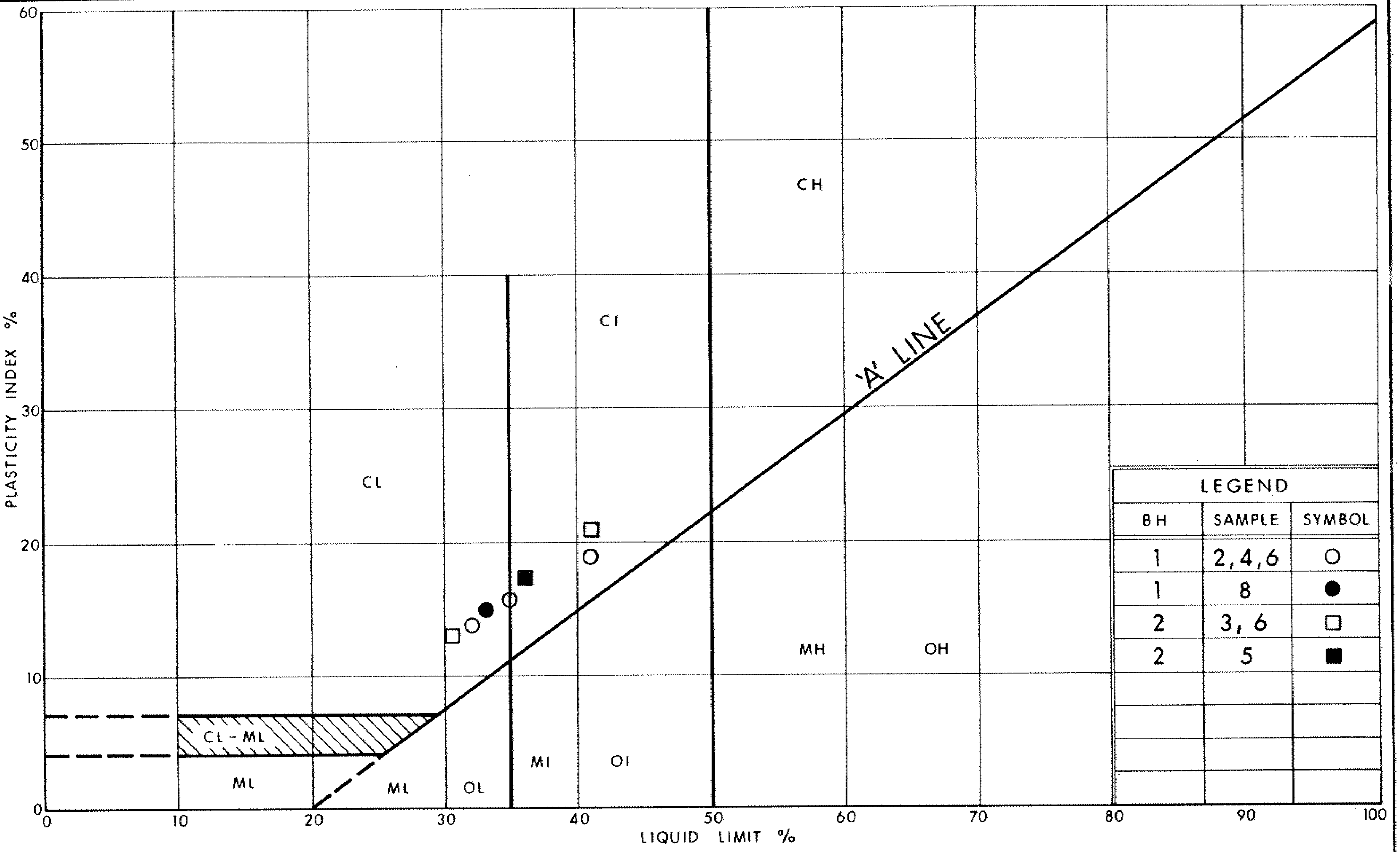
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY

FIG No 1

W P 114-87-00(A)

Oct 75, FF-S-21



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PLASTICITY CHART

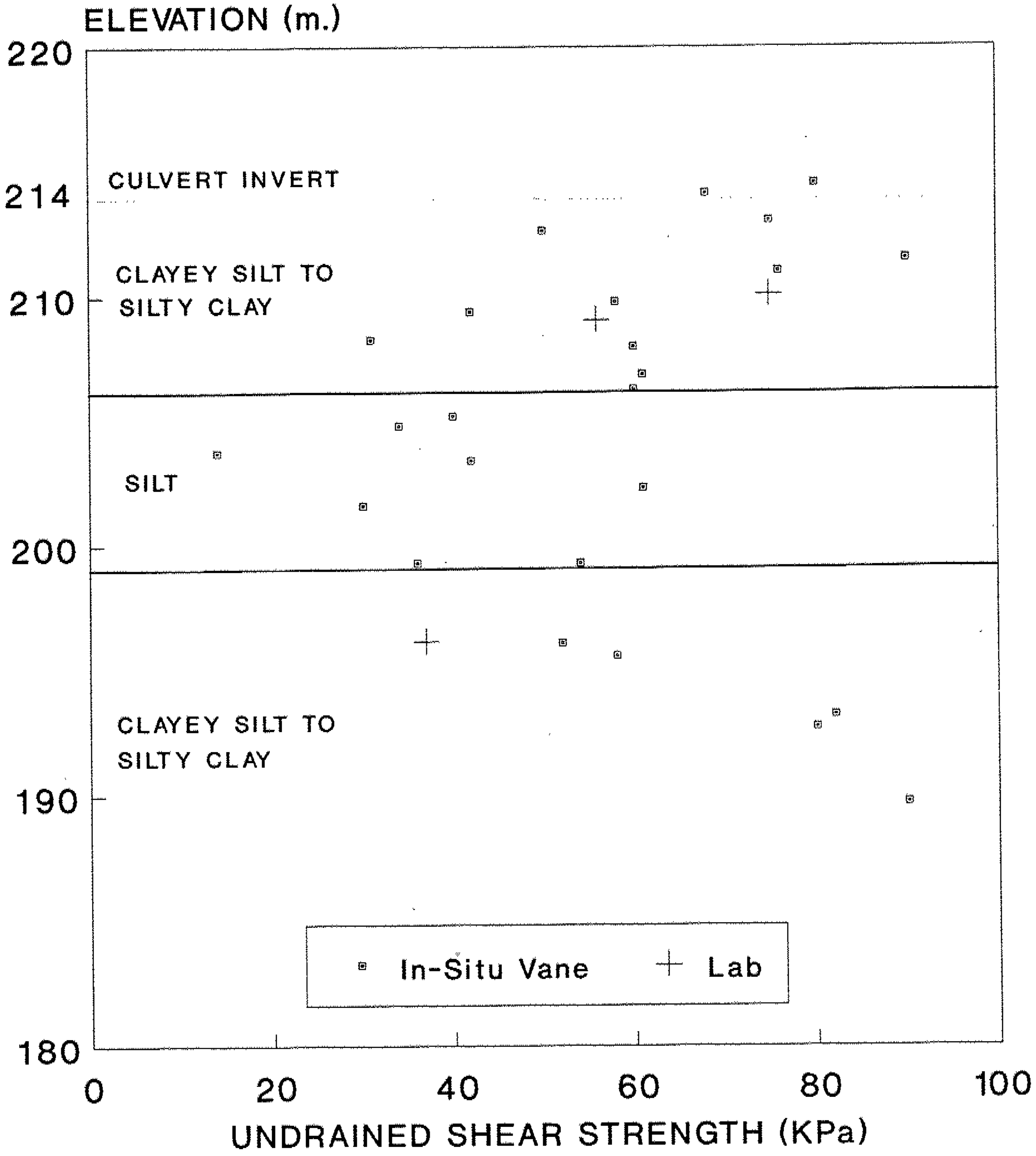
CLAYEY SILT TO SILTY CLAY

FIG No 2

W P 114 - 87 - 00 (A)

FIGURE 3

UNDRAINED SHEAR STRENGTH VS. ELEVATION



WP 114-87-00(A)

VOID RATIO-PRESSURE CURVES

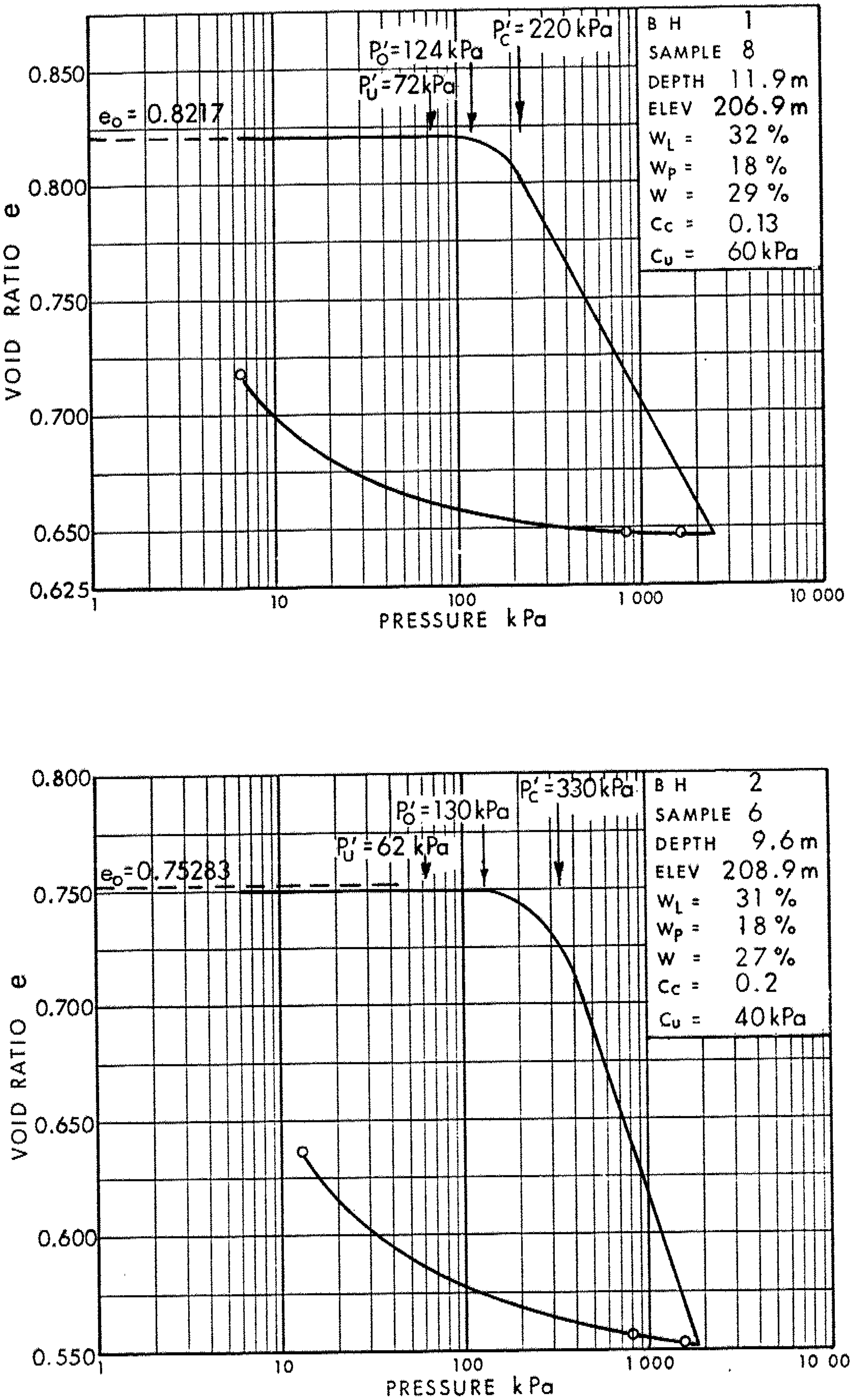
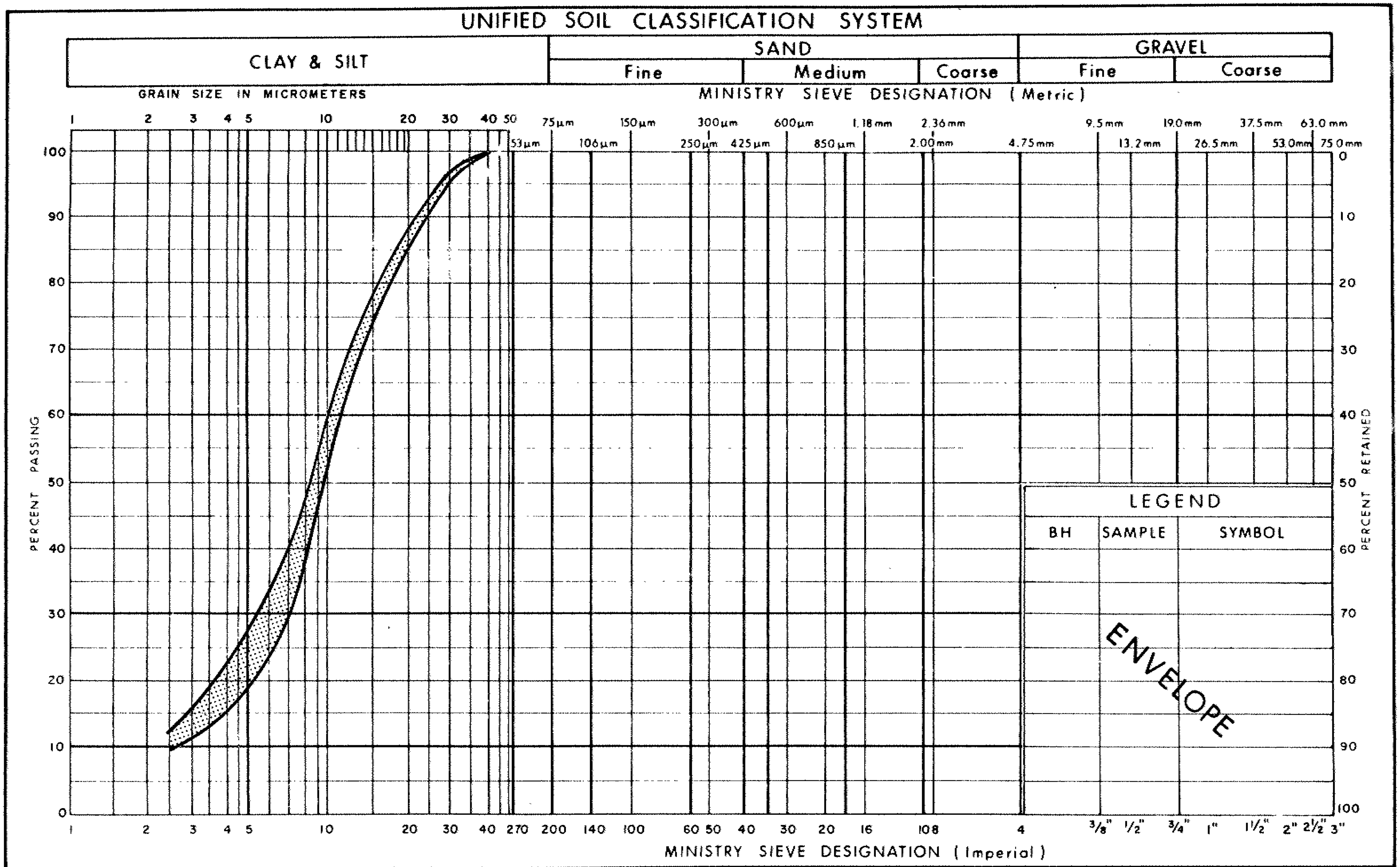


Fig 4

78 12 M



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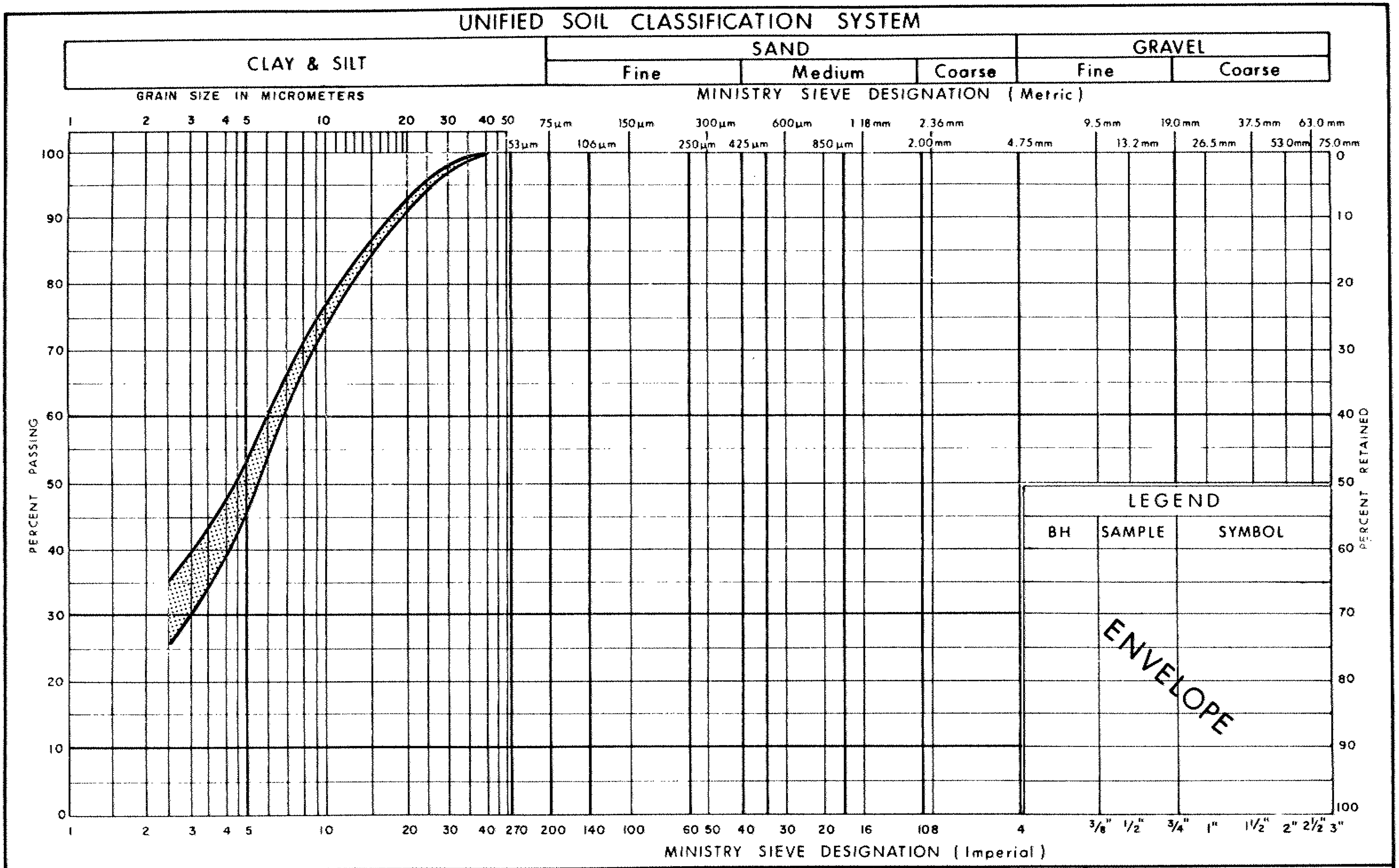
GRAIN SIZE DISTRIBUTION
SILT
WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 5

W P 114-87-00 (A)

78 12 M



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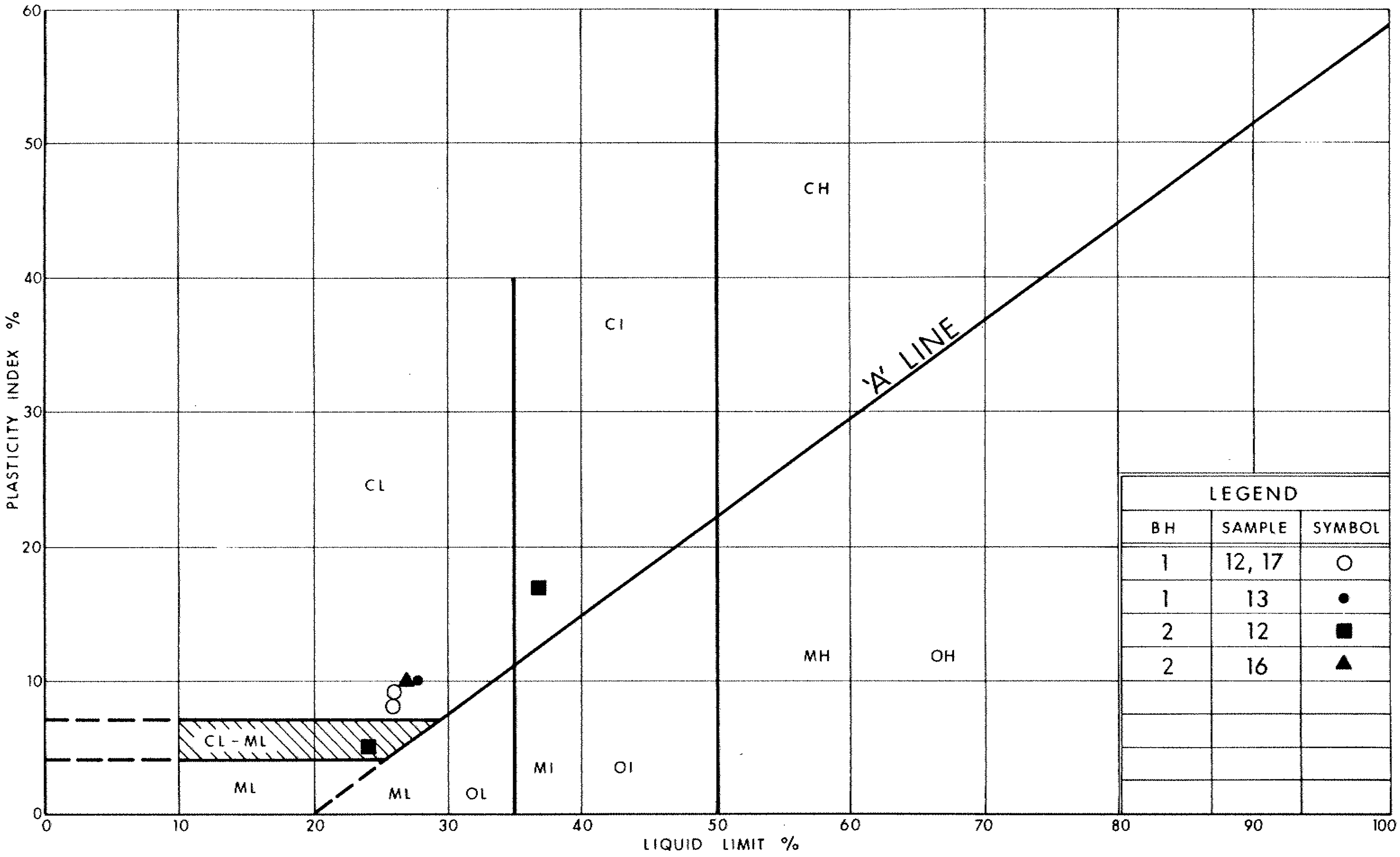
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM INTERBEDDED LAYERS OF SILT

FIG No 6

W P 114 - 87 - 00 (A)

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
1	12, 17	○
1	13	●
2	12	■
2	16	▲

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PLASTICITY CHART
CLAYEY SILT TO SILTY CLAY
WITH RANDOM INTERBEDDED LAYERS OF SILT

FIG No 7

W P 114-87-00 (A)

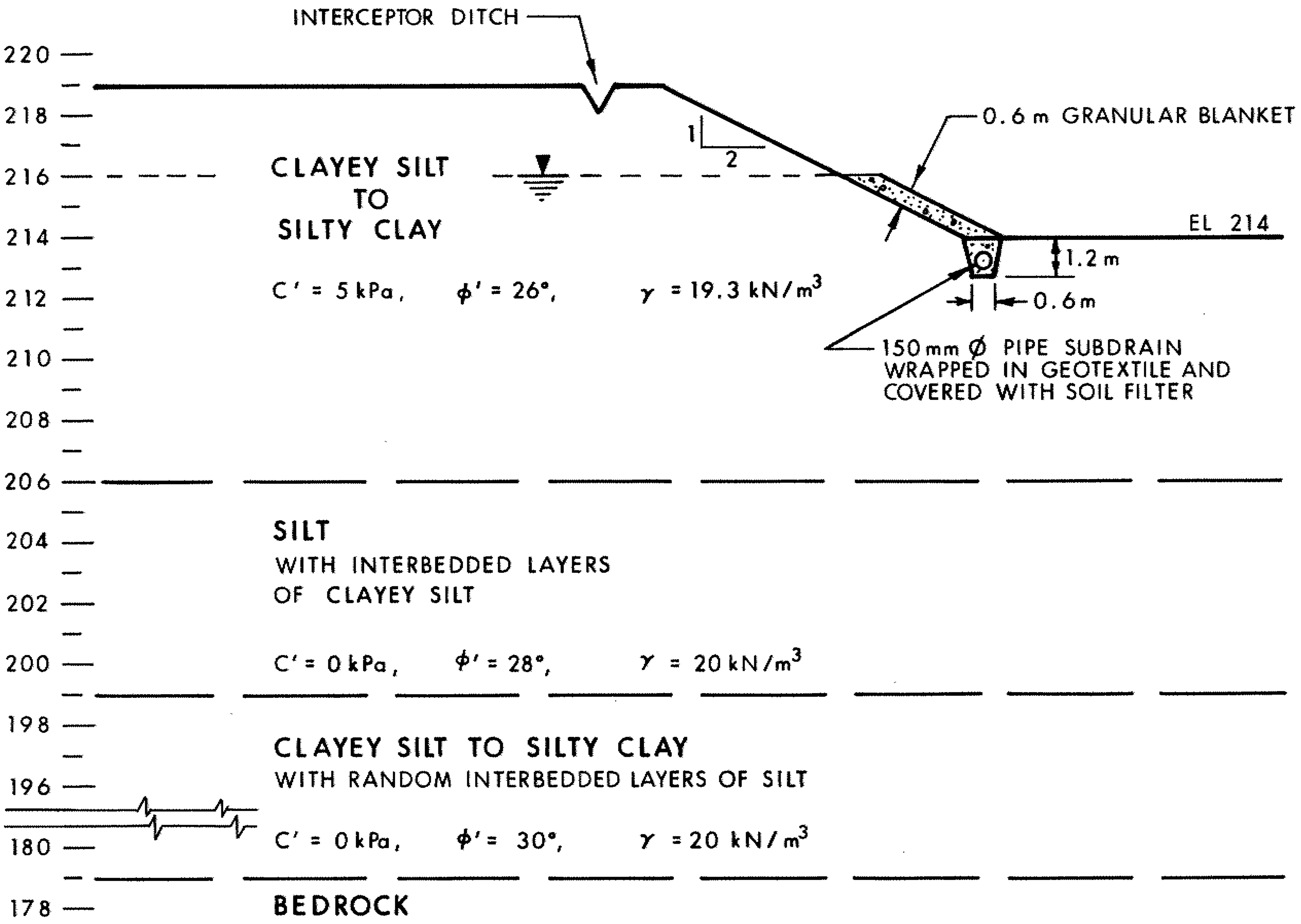


Figure 8. EFFECTIVE STRESS ANALYSIS APPROACH CUT SLOPES - STABILITY ANALYSES AND SLOPE TREATMENT SCHEME

NOT TO SCALE

HWY 403 DIST 4
WP 114-87-00(A)

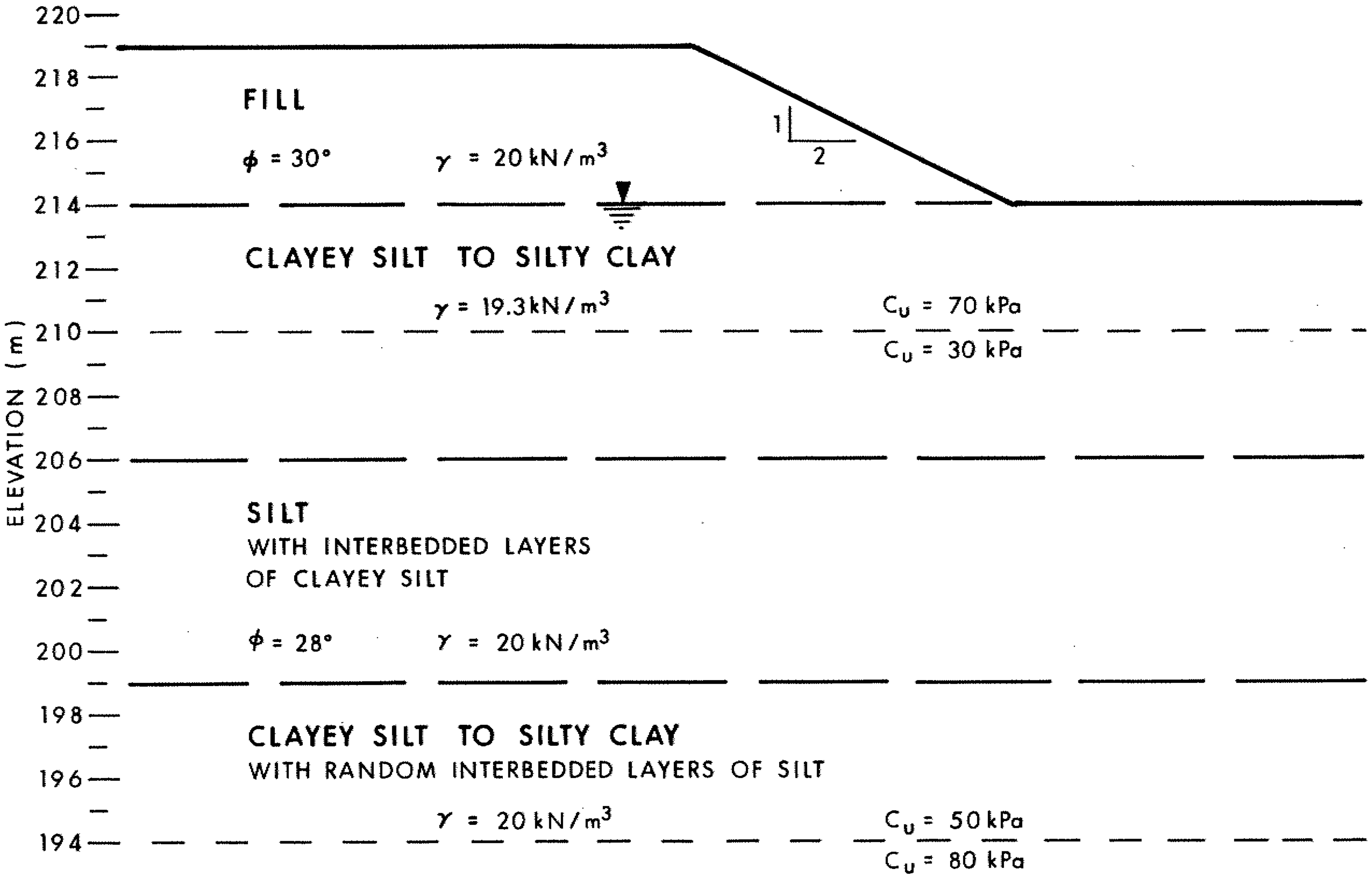


Figure 9. TOTAL STRESS ANALYSIS
LONGITUDINAL FILL SLOPES

HWY 403 DIST 4
WP 114-87-00(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

RECORD OF BOREHOLE No 1

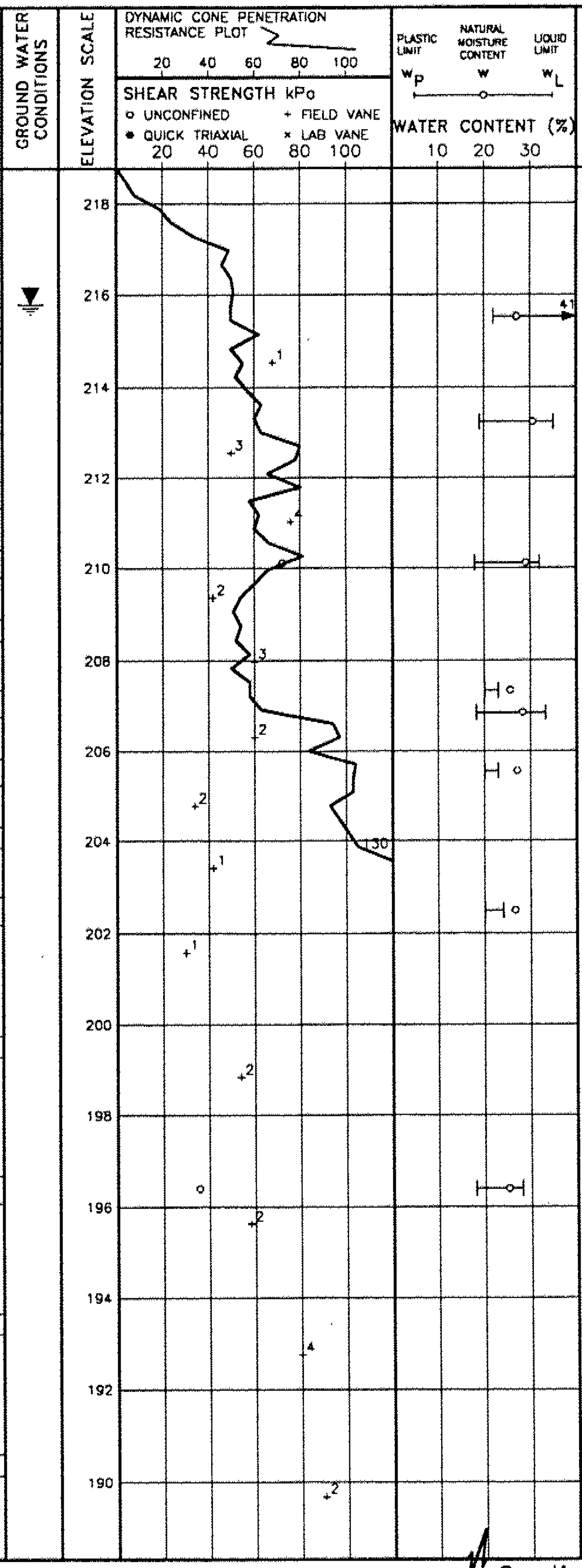
1 OF 2 METRIC

W.P. 114-87-00(A) LOCATION Co-ords: N 4 782 414.3; E 253 508.6 ORIGINATED BY TS

DIST 4 HWY 403 BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test COMPILED BY LD

DATUM Geodetic DATE 92 05 11-13 CHECKED BY PP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
218.8	Ground Surface								
0.0	Clayey Silt to Silty Clay Firm to Stiff	1	SS	12					
		2	SS	14	19.7	0	0	60	40
	Brown Grey	3	SS	7					
		4	SS	5	18.9	0	0	45	55
		5	TW	PH					
		6	TW	PH	19.5	0	0	60	40
	random interbeds of Silt	7	SS	7					
		8	TW	PH		0 0	0 0	84 70	16 30
205.8 13.0	Silt with interbedded layers of Clayey Silt Grey, Loose	9	TW	PH		0	0	90	10
		10	SS	5					
		11	TW	PH		0	0	88	12
200.7 18.1	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff	12	SS	9					
		13	TW	PH	19.2	0	0	75	25
		14	SS	13					
		15	SS	14					
188.3 30.5									



Continued

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

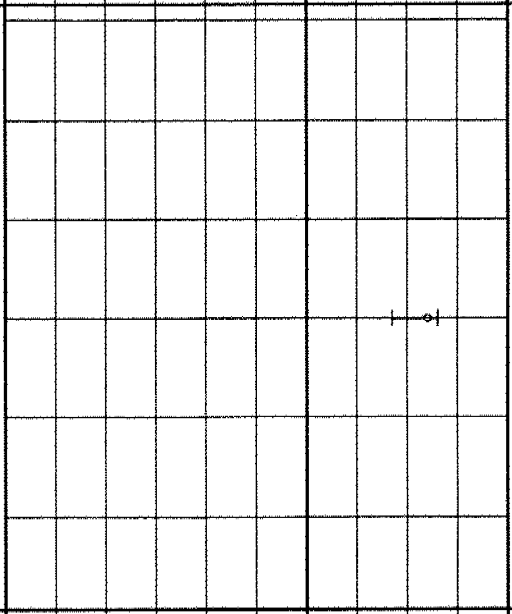
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

Continued

RECORD OF BOREHOLE No 1 2 OF 2 METRIC

W.P. 114-87-00(A) LOCATION Co-ords: N 4 782 414.3; E 253 508.6 ORIGINATED BY TS
DIST 4 HWY 403 BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test COMPILED BY LD
DATUM Geodetic DATE 92 05 11-13 CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
188.3	Continued										
30.5							188				
			16	SS	16						
							186				
	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff						184				
			17	SS	21		182				0 0 70 30
							180				
178.6			18	SS	18						
40.2	Bedrock - Dolostone Light Grey, Unweathered Medium Strong		19	RC	REC 94%		178				RQD = 74%
176.1			20	RC	REC 100%						RQD = 61%
42.7	End of Borehole										



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

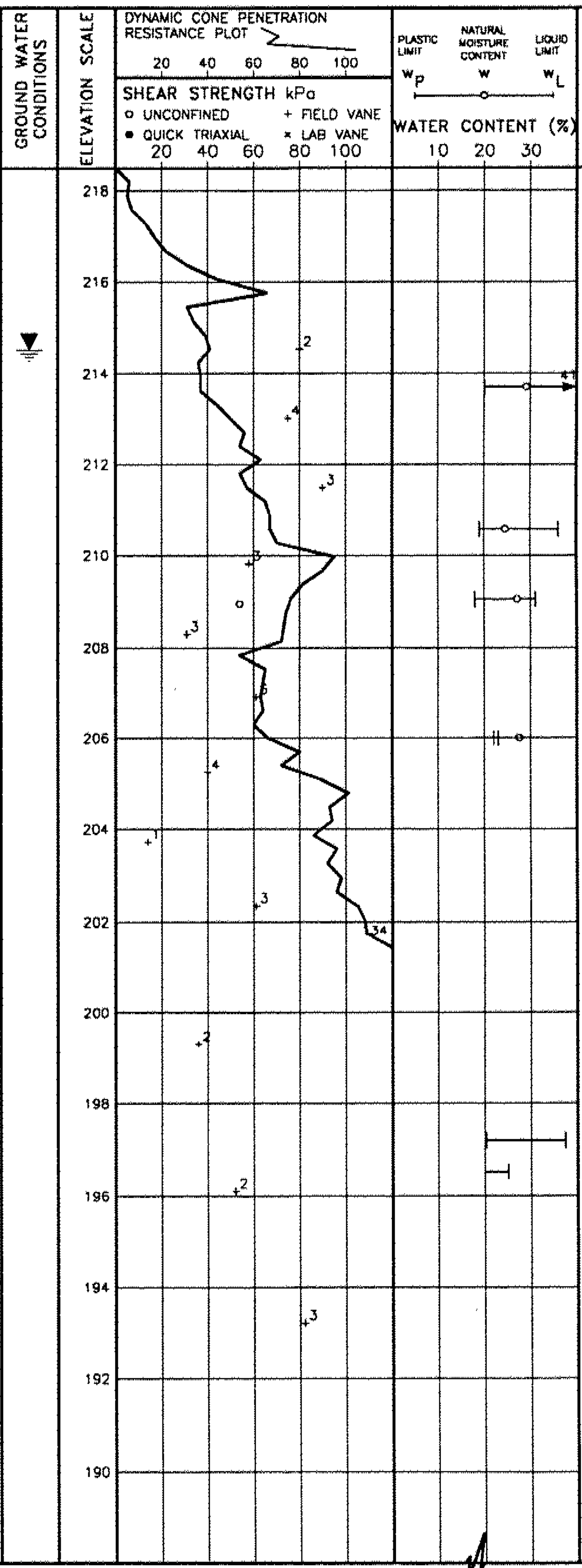
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

1 OF 2 METRIC

W.P. 114-87-00(A)
LOCATION Co-ords: N 4 782 361.0; E 253 525.1
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test
COMPILED BY LD
DATUM Geodetic
DATE 92 05 11-13
CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
218.5 0.0	Clayey Silt to Silty Clay								
		1	SS	18					
	Brown, Very Stiff								
	Grey, Firm to Stiff	2	SS	8					
		3	SS	7	19.6	0	0	48	52
		4	SS	7					
		5	TW	PH	19.1	0	0	72	28
	random interbeds of Silt	6	TW	PH	19.6	0	0	63	37
		7	SS	7					
206.3 12.2	Silt with interbedded layers of Clayey Silt Grey, Loose	8	TW	PH		0	0	89	11
		9	TW	PH					
		10	SS	6					
		11	SS	5					
198.7 19.8	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff	12	TW	PH					
		13	SS	11					
		14	SS	12					
188.0 30.5									



Continued

+3, ×5 : Numbers refer to Sensitivity

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

Continued

Ministry of Transportation
Ontario

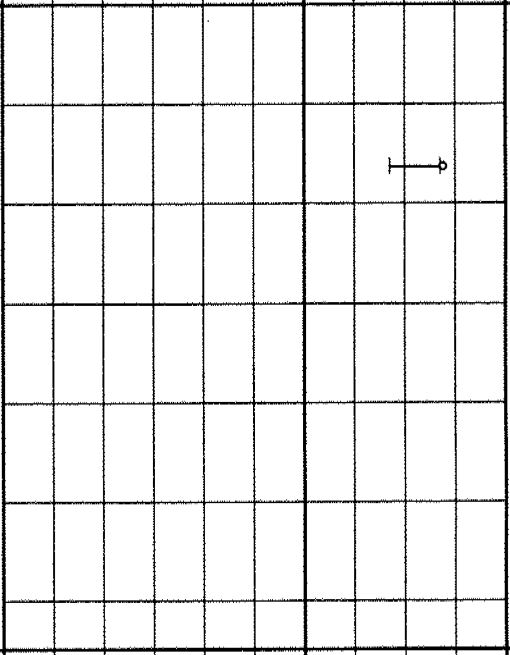
Foundation Design

RECORD OF BOREHOLE No 2

2 OF 2 METRIC

W.P. 114-87-00(A)
LOCATION Co-ords: N 4 782 361.0; E 253 525.1
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test
COMPILED BY LD
DATUM Geodetic
DATE 92 05 11-13
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
188.0	Continued										
30.5	Clayey Silt of Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff	▨	15	SS	15						
							186				
			16	SS	9						0 0 68 32
							184				
			17	SS	12		182				
							180				
178.1			18	SS	28						
40.4	Bedrock – Dolostone Light Grey, Unweathered Medium Strong	▨	19	RC	REC 95%		178				RQD = 67%
175.0			20	RC	REC 90%		176				RQD = 78%
43.5	End of Borehole										



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

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

ROCK CORE DESCRIPTION
WP 114-87-00A

	CORE RECOVERY				CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	19 20	40.23-41.15 41.15-42.67	94 100	74 61	40.23-42.67	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
2	19 20	40.44-41.96 41.96-43.49	95 90	67 78	40.44-43.49	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to dipping, undulating to planar, smooth to rough.

*CR = CORE RECOVERY

*RQD = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

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

METRIC

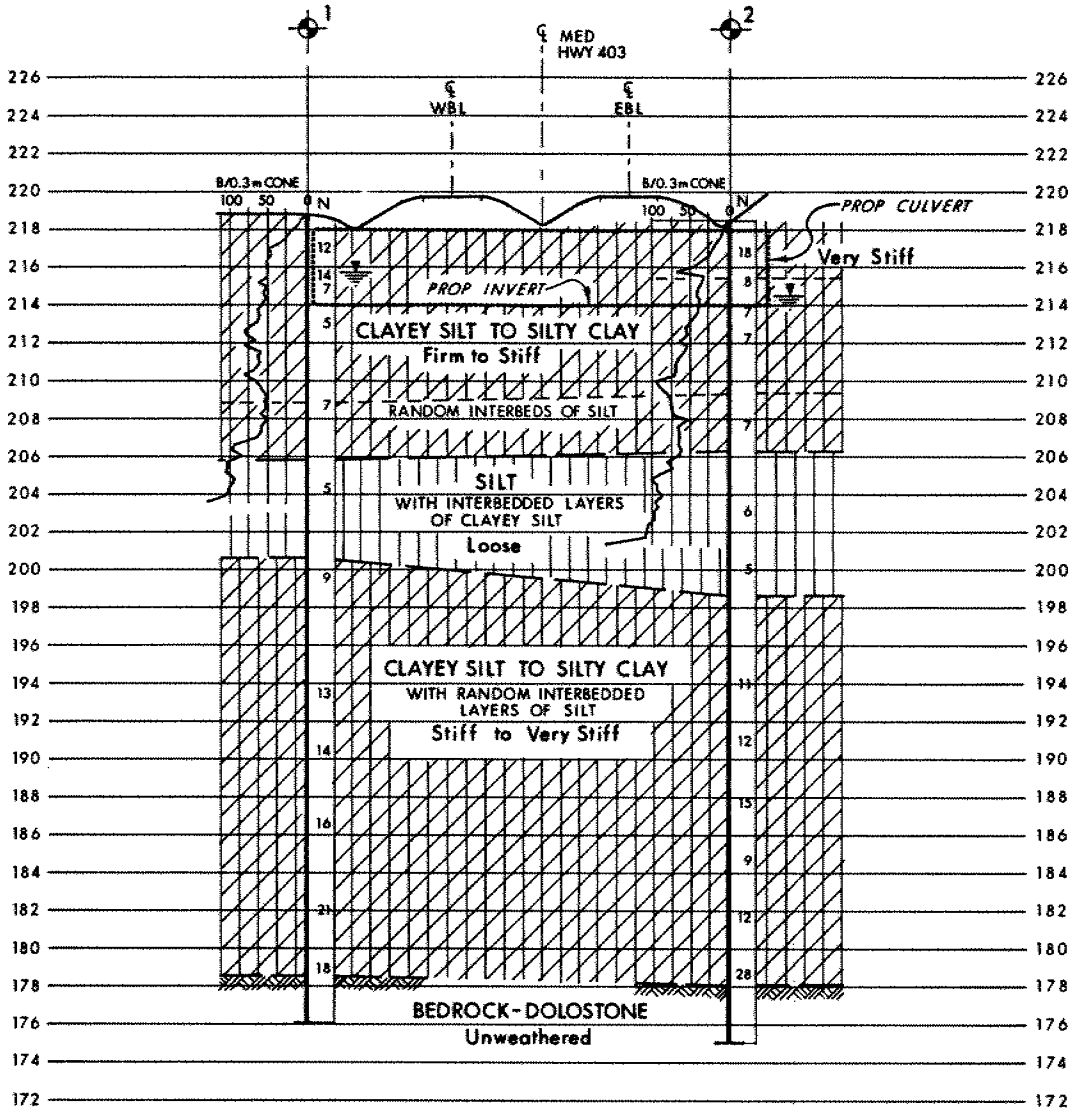
DIMENSIONS ARE IN METRES
AND/OR MILLIMETRES UNLESS
OTHERWISE SHOWN. STATIONS
IN KILOMETRES + METRES.

CONT No
WP No 114-87-00(A)

SHEET

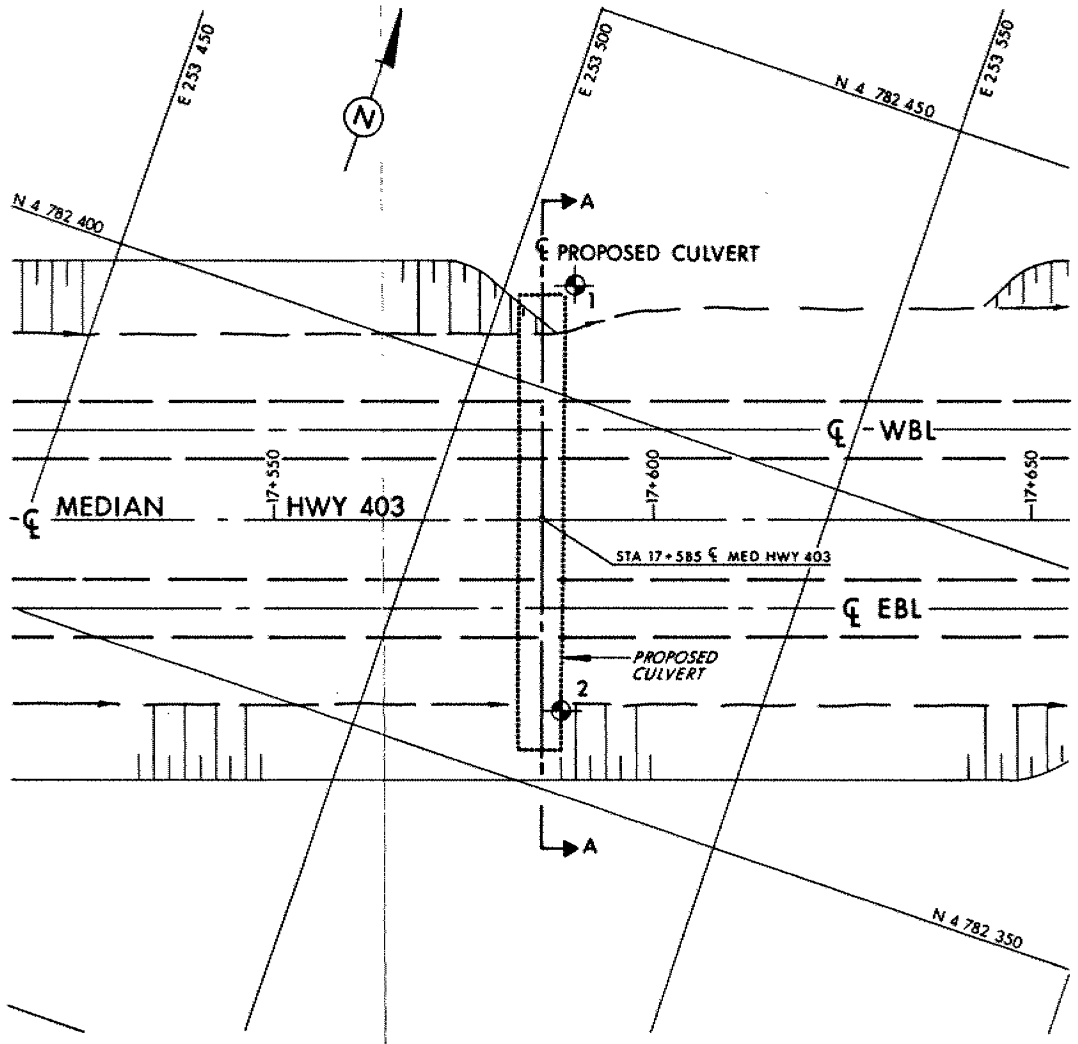
PROPOSED NORTH-SOUTH CONCRETE ACCESS CULVERT

BORE HOLE LOCATIONS & SOIL STRATA



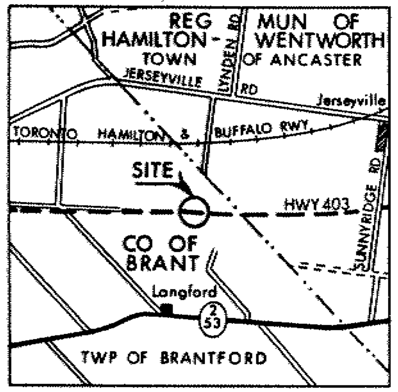
SECTION A-A

SCALES
10m 5 0 10m HOR
4m 2 0 4m VERT



PLAN

SCALE
10m 5 0 10m



KEY PLAN

SCALE
1km 0 1km

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 1992 05.

No	ELEVATION	CO-ORDINATES NORTH	EAST
1	218.8	4 782 414.3	253 508.6
2	218.5	4 782 361.0	253 525.1

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: 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 40P1-87

HWY No 403			DIST 4
SUBM'D TS	CHECKED TS	DATE 1992 08 28	SITE
DRAWN RS	CHECKED	APPROVED	DWG 1148700(A)-A

REF No CONT No 90-66, Sheets 18 & 24, McCormick Rankin, Cons. Eng.

FOUNDATION INVESTIGATION REPORT

CONTRACT NO. 94-55

Ministry of
Transportation

Ontario

INDEX

Note: For purposes of the contract, this report supersedes all other Foundation Reports prepared by, or for the Ministry in connection with the above mentioned projects.

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γ'	kN/m^3	UNIT WEIGHT OF SUBMERGED SOIL

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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
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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

FOUNDATION INVESTIGATION REPORT

FOR

Hwy 403 North-South Concrete Access Culvert

WP 114-87-00(A), Hwy 403

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the proposed concrete access culvert type structure. The structure is designed to enable farming equipment, materials and personnel to be transported beneath the proposed Hwy 403 which will be supported by the structure. The proposed structure is perpendicular to the proposed Hwy 403 as shown on the drawing 1148700(A)-A.*

SITE DESCRIPTION AND GEOLOGY

The site is situated at the proposed Hwy 403, approximately mid-distance between Jerseyville Rd. and Hwy 2. The site is accessible by existing private gravel roads extending from Parsonage Rd. which starts at Jerseyville Rd. and Jury Rd. which starts at Hwy 2/53 in Brant County, Township of Brantford.

Grading and drainage work has been completed under Contract 90-66 in the area and the Hwy 403 right-of-way imprint is evident on both sides of the proposed culvert. The highway appears to be within a shallow excavation cut at the site location. East of the site, beyond the extent of Contract 90-66, the land is forested and populated with tall deciduous trees.

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* DWG NO 2 OF THE CONTRACT DWG'S

The land beyond the Hwy 403 is generally gently rolling terrain. Land use is primarily agricultural farmland.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 40m.

INVESTIGATION PROCEDURE

General

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and the laboratory testing program are discussed below.

Field Investigation

The fieldwork for this project was carried out between 92 05 11 and 92 05 13 and consisted of two (2) sampled boreholes advanced to depths ranging from 42.7m to 43.5m accompanied by two (2) dynamic cone penetration tests carried out to depths ranging from 15.2m to 17.1m. The boreholes were advanced through the overburden using track mounted units employing conventional continuous flight hollow stem augering techniques and also casing/washboring methods. Conventional rock coring techniques using BW casing and BX core barrels were used to retrieve up to 3m of rock core.

Subsoil samples were generally retrieved at 1.5m intervals for the surficial 18m or so and at 3m intervals thereafter. Both disturbed and undisturbed subsoil samples were retrieved within the surficial 22m. Disturbed samples only were retrieved beneath this depth. Disturbed subsoil samples were retrieved in accordance with the Standard Penetration Test (ASTM D1586) using a standard split spoon sampler driven into the soil and undisturbed subsoil samples were retrieved using a thin wall sampler pushed hydraulically into the soil in accordance with procedures outlined in ASTM D1587.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The test was carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Rock core samples were identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock core were placed in standard rock core boxes and carefully transported to the laboratory.

Groundwater levels were determined by monitoring the water levels in the open boreholes throughout the duration of the field investigation. All boreholes were backfilled upon completion of the field work.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples. These tests included:

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Test
2) Particle Size Analysis	2) Unconfined Compression
3) Natural Moisture Contents	
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Detailed rock core logging was conducted in the laboratory by an in-house resident geologist.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

General

Subsurface conditions across the site are uniform and consist of three (3) distinct layers of overburden overlying bedrock. The surficial deposit consists of a cohesive clayey silt to silty clay that extends to depths ranging from 12.2m to 13m below the ground surface. The deposit has a firm to very stiff consistency and contains random interbeds of plastic silt approximately 25mm to 75mm in thickness within the lower three (3) metres of the deposit.

The surficial cohesive clayey silt to silty clay deposit is underlain by a plastic silt that has a loose denseness and contains random interbedded layers of cohesive clayey silt.

The plastic silt stratum is in turn underlain by a second cohesive clayey silt to silty clay deposit which has a thickness of 20.6m to 22.1m. This deposit also contains random thin interbeds of plastic silt of thickness ranging from 25mm to 100mm. This deposit extends to the bedrock surface which exists at an elevation of 178.1m to 178.6m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700(A)-A*. A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Boreholes sheets in the Appendix.

Clayey Silt to Silty Clay

The surficial stratum at the site consists of a cohesive clayey silt to silty clay that extends for a thickness of 12.2 to 13 metres. Within the lower three metres of the deposit, thin layers or seams of plastic silt generally 25mm to 100mm in thickness exist. The deposit has been oxidized for the surficial 3 to 3.8 metres and is brown in colour within this depth. Below this depth, the deposit is unoxidized and grey in colour. A grain size distribution envelope produced by mechanical sieve and hydrometer analysis is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed of grain sizes smaller than 75 micrometre. The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 45% to 84% and clay percentages ranging from 28% to 55%. In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below.

Atterberg Limit Tests were carried out on the fine grained soil and the results are plotted on Figure 2 in the Appendix and summarized on Table 1 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

* DWG NO 2 OF THE CONTRACT DWG'S

Table 1 - Atterberg Limit Test Results

	Range	# of Tests
Natural Moisture Content (w%)	25-31	7
Liquid Limit (w_L%)	31-41	7
Plastic Limit (w_P%)	18-22	7
Plasticity Index (Ip%)	13-21	7
Bulk Unit Weight (kN/m3)	18.9-19.7	6

The test results clearly reveal that the soil has a plasticity ranging from low to intermediate and hence can be categorized as clayey silt (CL) to silty clay (CI). Natural moisture contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state. An Atterberg Limit Test conducted on a sample of an interbedded silt layer confirms that the material is an inorganic silt of low plasticity (ML). The liquid limit (w_L) and the plasticity index (Ip) for a silt interbed in sample TW8, BH1 was determined to be 23% and 3% respectively. The material possesses no dry strength, no toughness and a quick dilatancy, properties which are consistent with this classification.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests and unconfined compression tests. The results of these tests are plotted on the individual Record of Borehole Sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. The undrained shear strength of the surficial clayey silt to silty clay ranges from 30 kPa to 90 kPa which is equivalent to a consistency ranging from firm to very stiff. The sensitivity of the soil as defined by the ratio of the undrained strength in the undisturbed state to the undrained strength, at the same water content, in the remoulded state was also determined by the field vane test. Sensitivity values range from 1 to 4 indicating an insensitive to moderately sensitive material.

The upper desiccated unoxidized brown crust has a greater strength and a consistency ranging from stiff to very stiff. The 'N' values as determined by the Standard Penetration Test ranged from 12 blows/0.3m to 18 blows/0.3m within this upper crust. Beneath this upper zone, 'N' values ranged from 5 blows/0.3m to 7 blows/0.3m.

The compressibility characteristics of the clayey silt to silty clay stratum were determined by conducting one dimensional consolidation tests on two (2) representative samples. The results of the tests are shown graphically on Figure 4 in the Appendix. The consolidation curves are plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load (log p). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (p_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The two consolidation curves reveal preconsolidation pressures ranging from 220 kPa to 330 kPa. The effective overburden pressures for these two preconsolidation pressures are 140 kPa and 130 kPa respectively. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 80 kPa to 200 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.13 to 0.2.

Silt with interbedded layers of Clayey Silt

A cohesionless silt of quick dilatancy interbedded with thin layers of cohesive clayey silt exists below the clayey silt to silty clay surficial deposit and extends to depths ranging from 18.1m to 19.8m below the ground surface. The thickness of this stratum ranges from 5.1m to 7.6m and the cohesive interbedded seams or layers are approximately 25mm to 75mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

A grain size distribution envelope as determined by mechanical sieve and hydrometer analysis is shown on Figure 5 in the Appendix. The envelope illustrates primarily silt percentage (88-90%) with traces to some clay. The silty soil does however exhibit plasticity and the results of Atterberg Limit Tests carried out on some representative samples of the material are summarized in Table 2 below.

Table 2 - Plastic Silt

	Range	# of Tests
Natural Moisture Content (w%)	27-28	3
Liquid Limit (w_L%)	23-24	3
Plastic Limit (w_P%)	20-22	3
Plasticity Index (Ip%)	1-4	3

The test results reveal that the soil is a plastic silt (ML categorization). Natural moisture contents exceed the liquid limit of the soil.

Due to the percentages of clay and the layers of interbedded clayey silt, vanes could be torqued and in situ tests were conducted. The results revealed undrained shear strength values ranging from approximately 30 to 62 kPa. The results, in general, were erratic and devoid of any pattern which is perhaps indicative of the high silt percentages.

The 'N' values as derived from the Standard Penetration Test reveal values ranging from 5 to 6 blows/0.3m. This is representative of a loose state of denseness.

Clayey Silt to Silty Clay with random interbedded layers of Silt

Underlying the plastic silt with interbedded layers of clayey silt, a second cohesive deposit consisting of clayey silt to silty clay extending to the bedrock surface exists. The surface of the deposit exists at an elevation ranging from 198.7m to 200.7m and the deposit has a thickness in the order of magnitude of 20.6m to 22.1m. Random interbedded layers or seams of plastic silt ranging in thickness from 25mm to 100mm are also present within the cohesive deposit.

A grain size distribution envelope illustrating the gradation of the material of this deposit is shown on Figure 6 in the Appendix. The envelope clearly illustrates that the material is fine grained with grain sizes less than 75 micrometres. Typically, clay percentages range from 25% to 32% and silt percentages range from 68% to 75%.

In accordance with the MTO Soil Classification system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 3 below. Natural Moisture Contents are also included in the Table below.

Table 3 - Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	24-28	5
Liquid Limit (w_L%)	24-37	5
Plastic Limit (w_P%)	17-20	5
Plasticity Index (Ip%)	8-17	5

The test results reveal that the soil has a low to intermediate plasticity and hence can be classified as a clayey silt to silty clay. Natural moisture contents are generally similar to the liquid limit of the soil.

An Atterberg Limit Test conducted on a sample of an interbedded silt layer confirms that the material is an inorganic silt of low plasticity (CL - ML). The liquid limit (w_L) and plasticity index (Ip) for a silt interbed in sample TW12, BH2 was determined to be 24% and 5% respectively.

The consistency and undrained shear strength of the soil was determined by conducting in situ vane tests and interpretation of SPT 'N' values. Undrained shear strength values are plotted on the individual Record of Borehole sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. The undrained shear strength values ranged from 50 kPa to 90 kPa with the strength increasing with depth. The sensitivity of the soil as determined by the field vane test ranged from 2 to 4 indicating an insensitive to moderately sensitive material. The SPT 'N' values ranged from 9 blows/0.3m to 28 blows/0.3m. Based on the undrained shear strength and SPT 'N' values, the clayey silt to silty clay can be described as having a stiff to very stiff consistency.

Bedrock

The bedrock consisting of a "vuggy" dolostone of the Amabel Formation underlies the clayey silt to silty clay with random layers or seams of interbedded silt deposit at an elevation of approximately 178.1m to 178.6m. The bedrock was cored in BX size up to 3.1m in depth.

The dolostone bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey to medium dark grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Rock Core Description".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and physical index property testing. Recoveries ranged from 90% to 100% and RQD's ranged from 61% to 78% indicating that the rock is of good quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of investigation were approximately 3 to 4 metres below the ground surface (elevation 215.8m to 214.5m).

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto Student Engineer, utilizing equipment owned and operated by Atcost Drilling Ltd. and London Soil Testing. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

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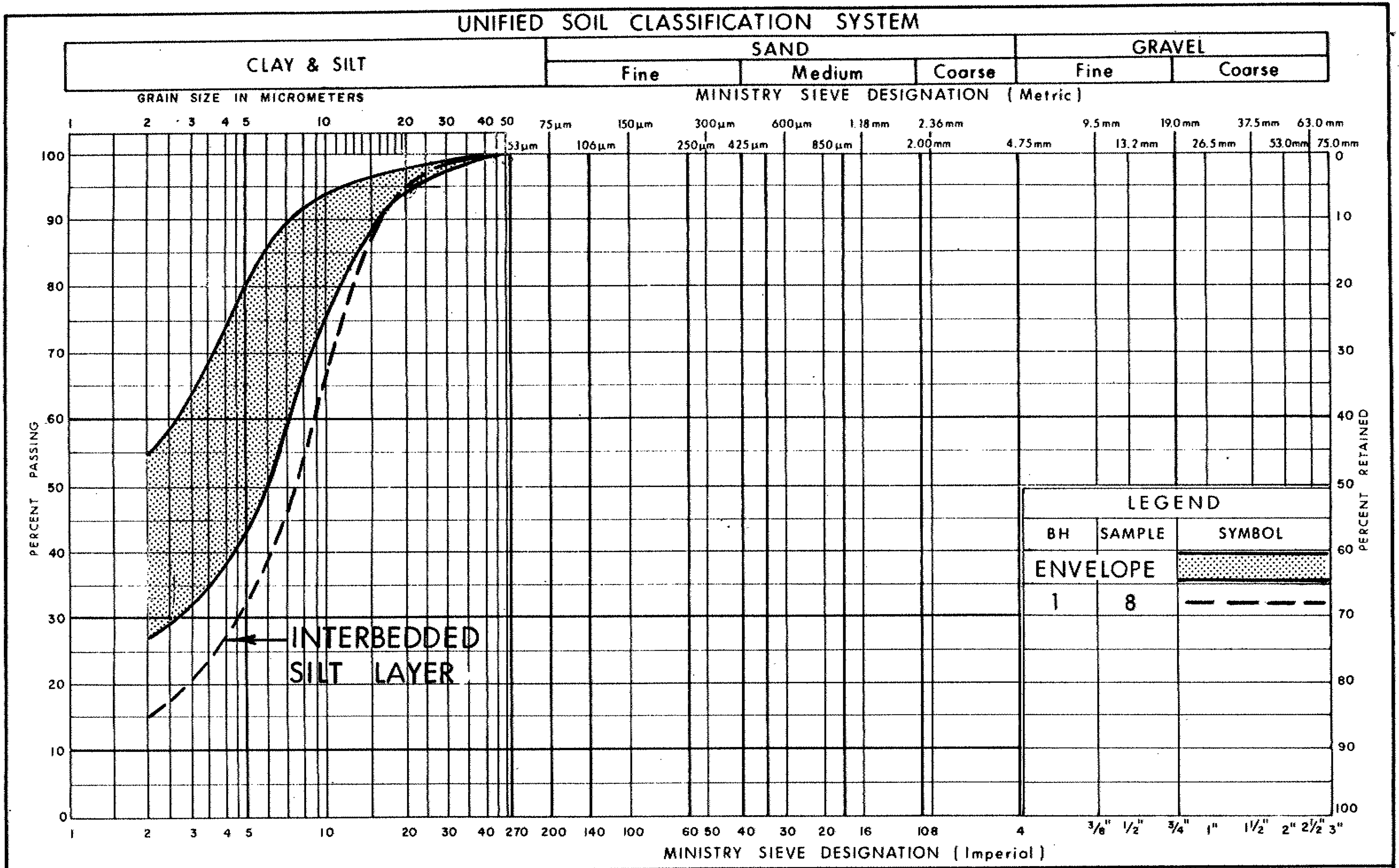
APPENDIX

78 12 M



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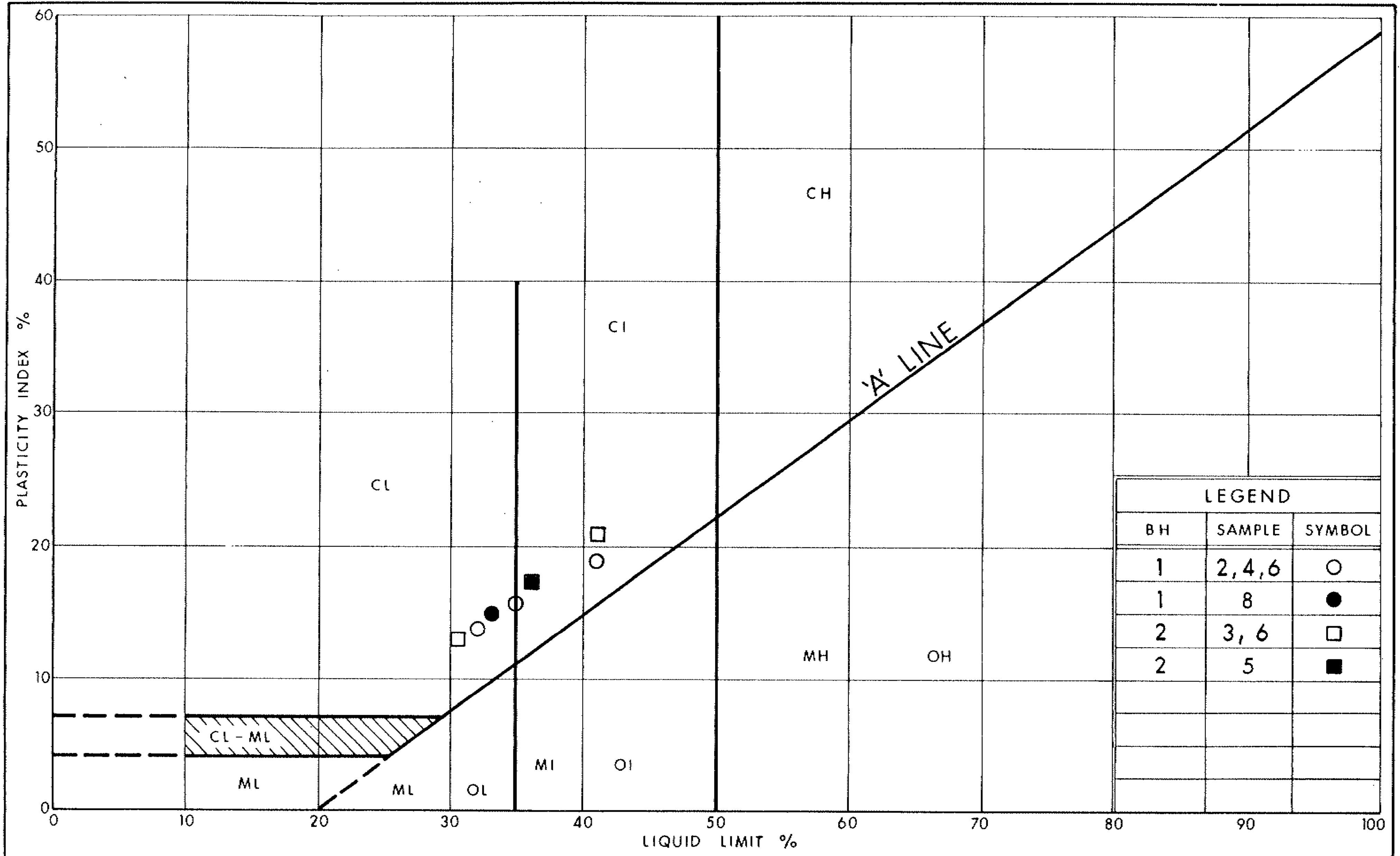
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY

FIG No 1

W P 114-87-00(A)

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
1	2, 4, 6	○
1	8	●
2	3, 6	□
2	5	■

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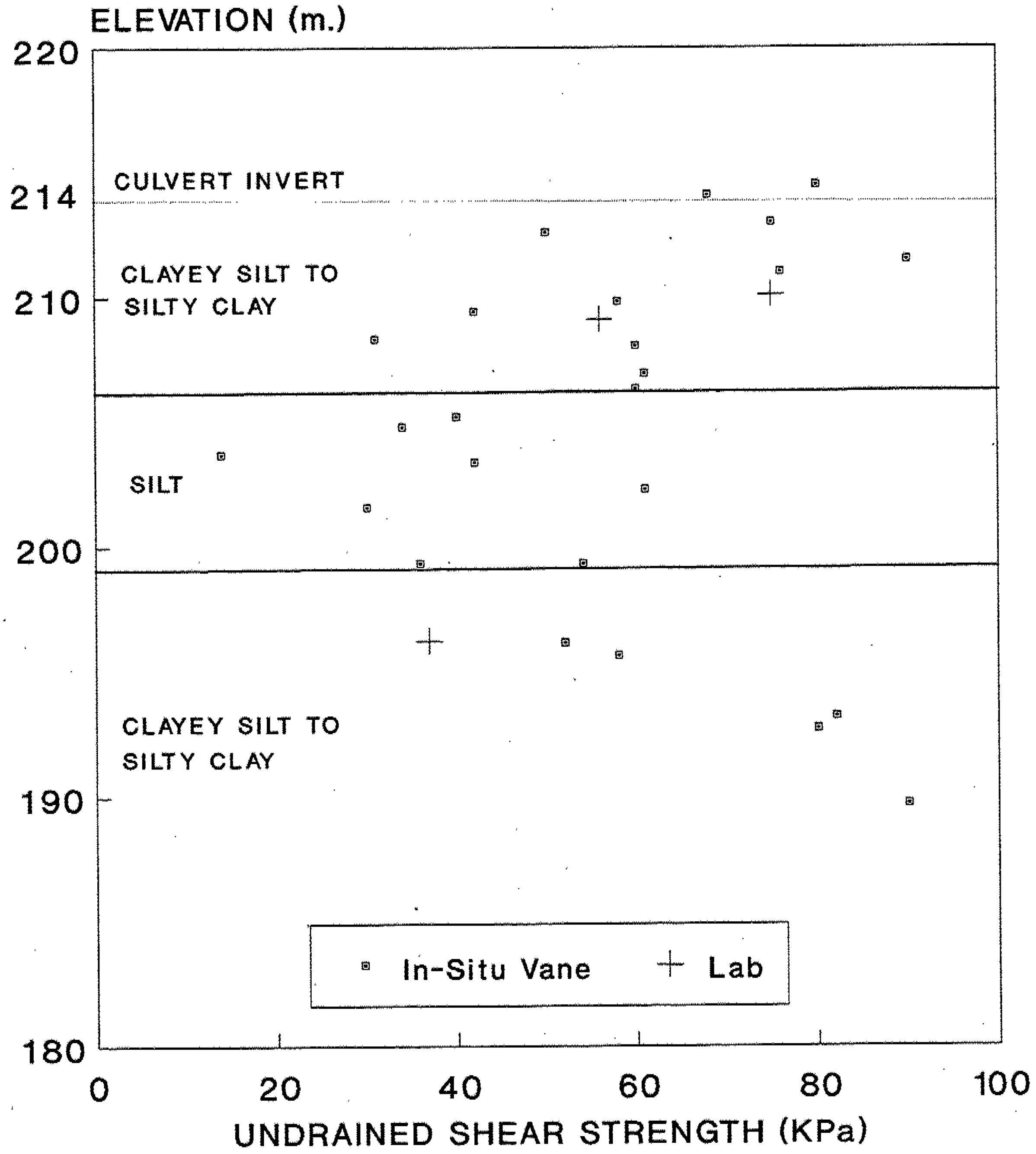
PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY

FIG No 2

W P 114 - 87 - 00 (A)

FIGURE 3
UNDRAINED SHEAR STRENGTH VS. ELEVATION



WP 114-87-00(A)

VOID RATIO - PRESSURE CURVES

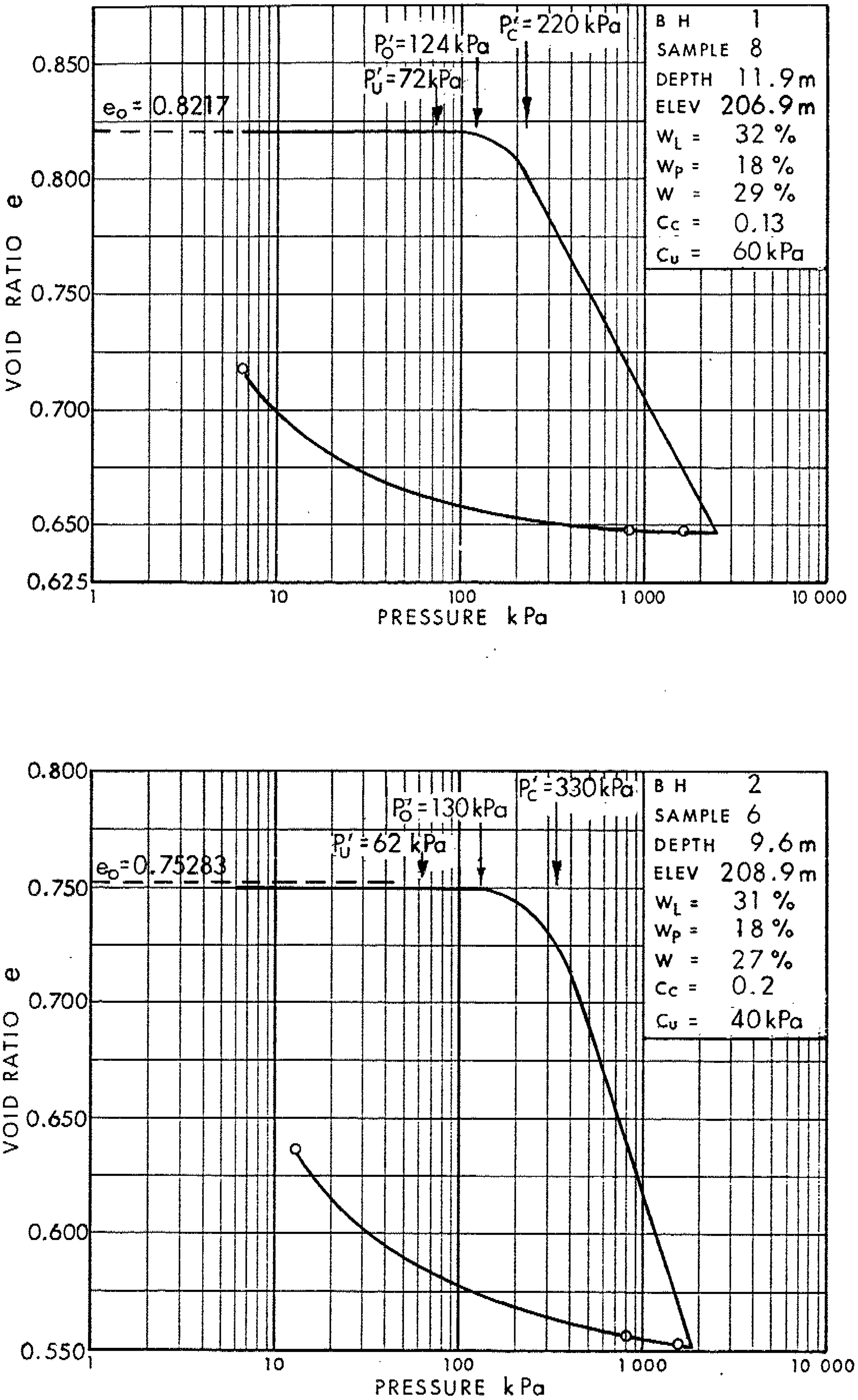
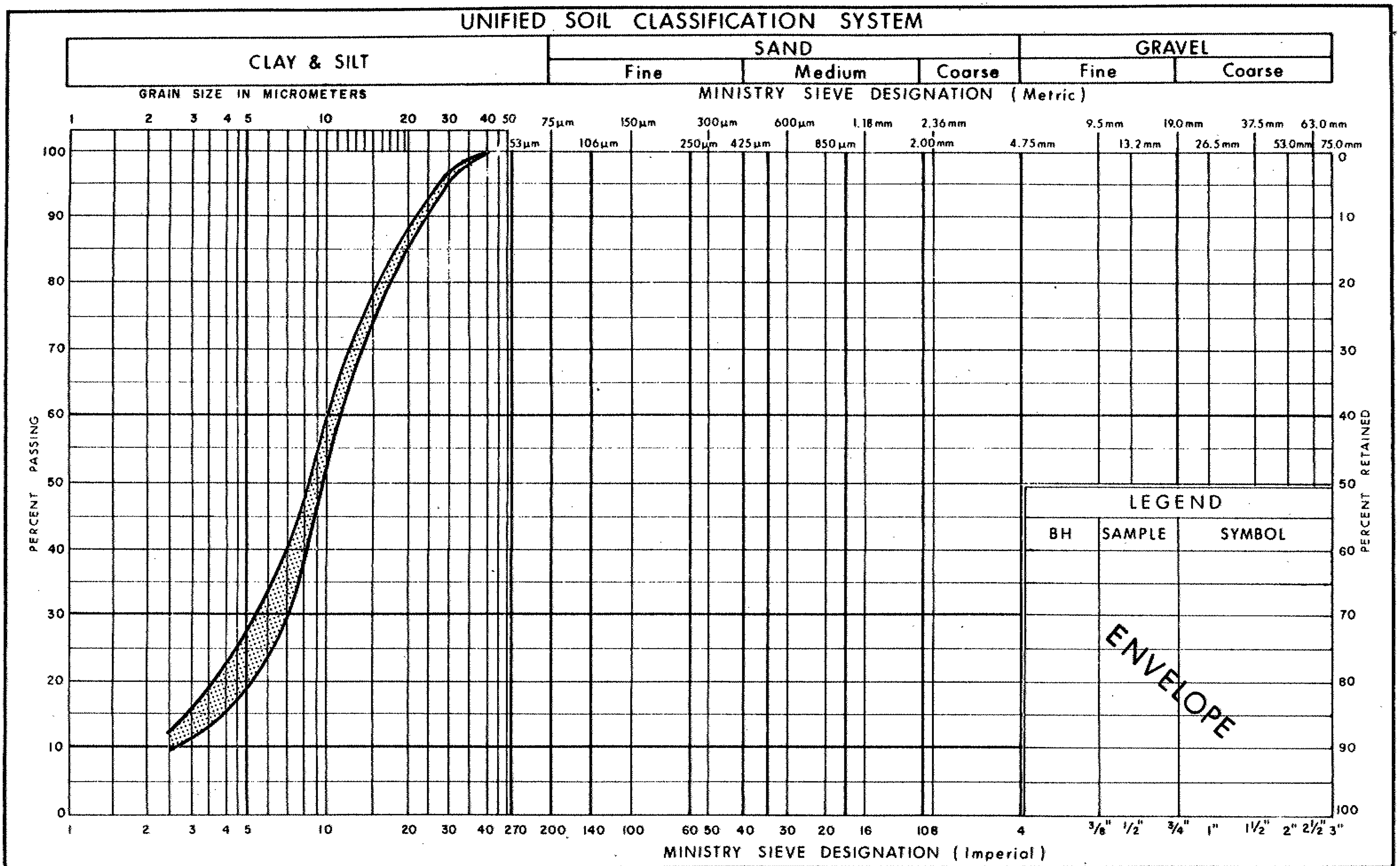


Fig 4

78 12 M



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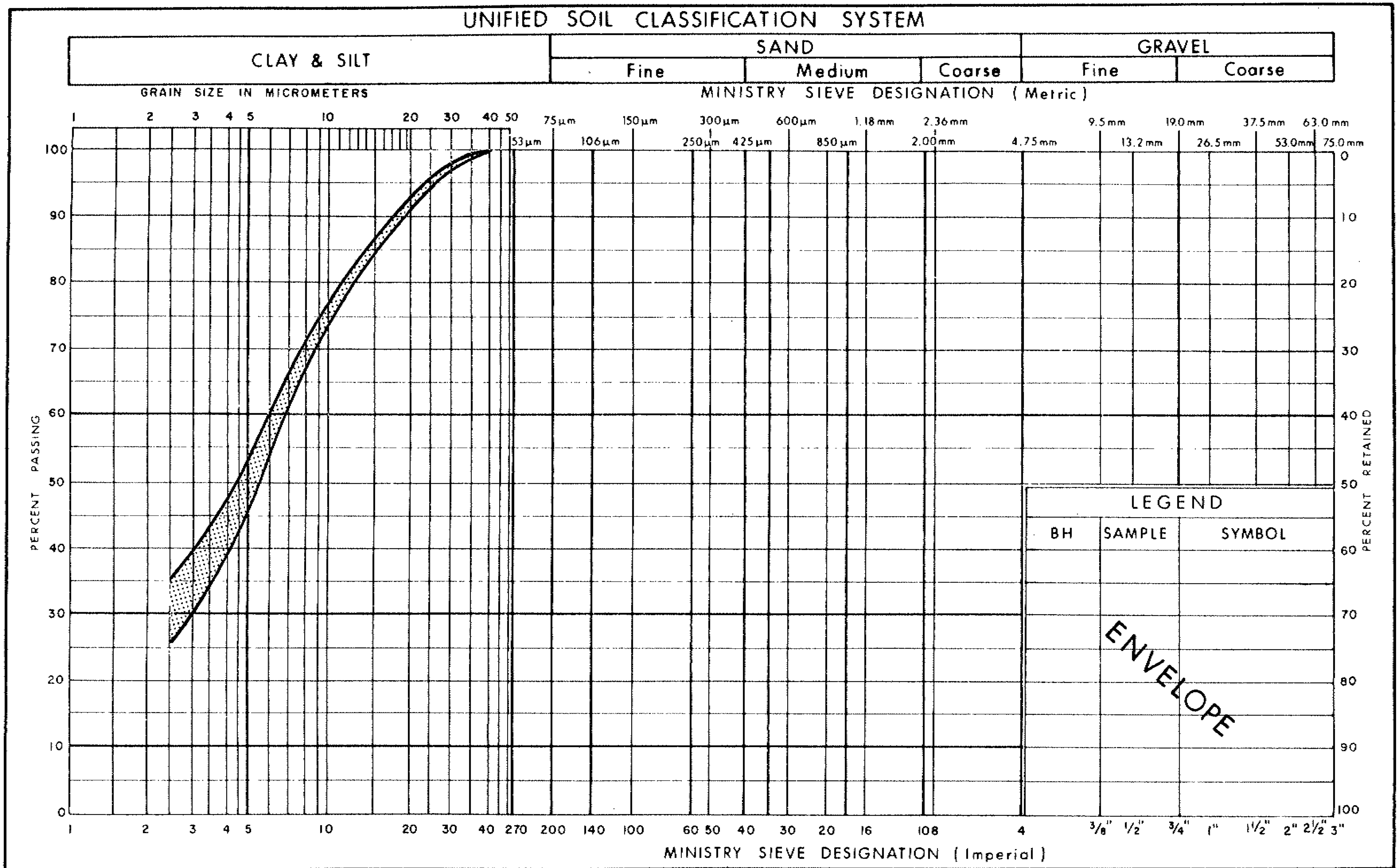
GRAIN SIZE DISTRIBUTION
SILT
WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 5

W P 114-87-00 (A)

78 12 M



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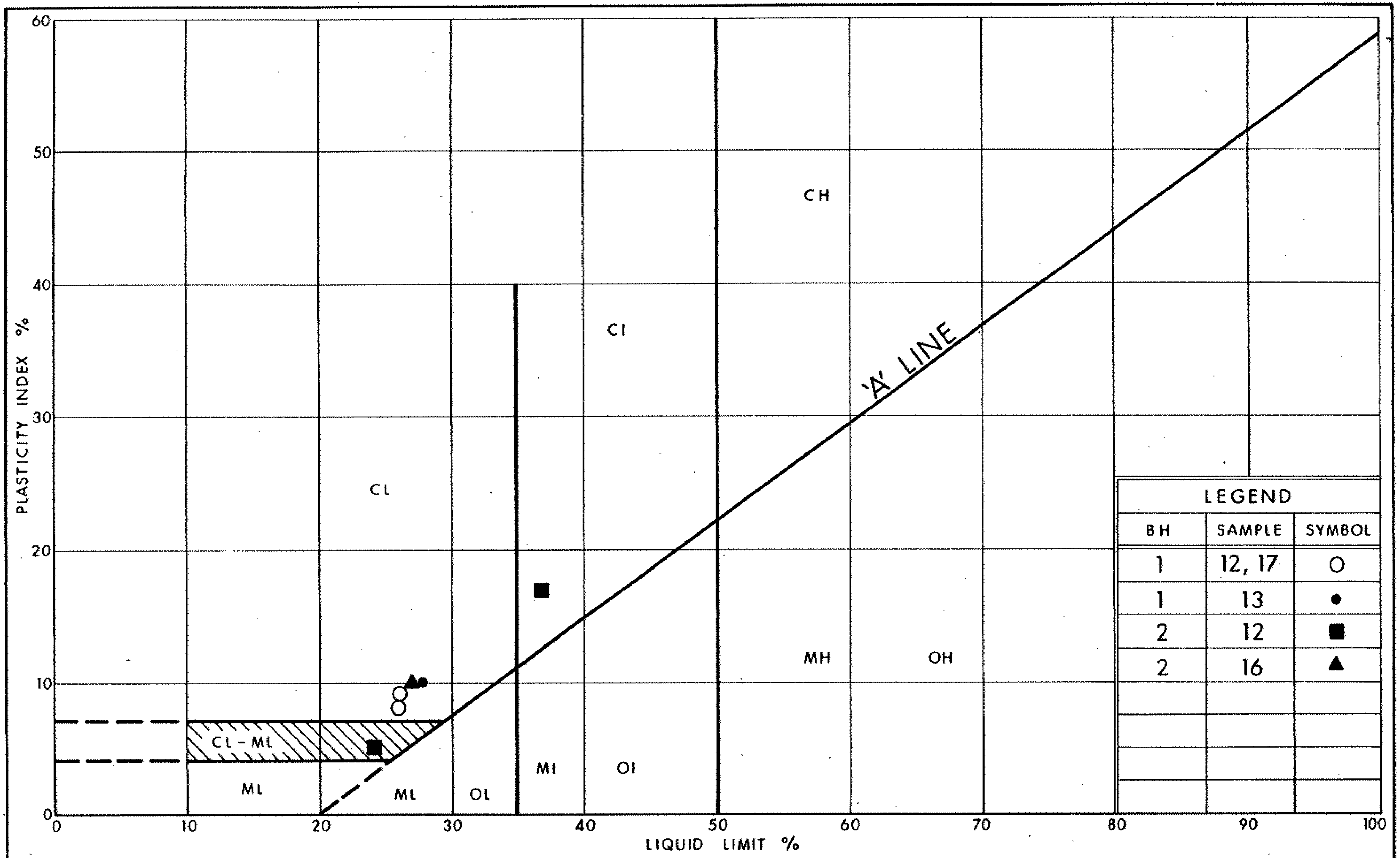
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM INTERBEDDED LAYERS OF SILT

FIG No 6

W P 114 - 87 - 00 (A)

Oct 75, FF-S-21



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PLASTICITY CHART
CLAYEY SILT TO SILTY CLAY
WITH RANDOM INTERBEDDED LAYERS OF SILT

FIG No 7

W P 114-87-00 (A)

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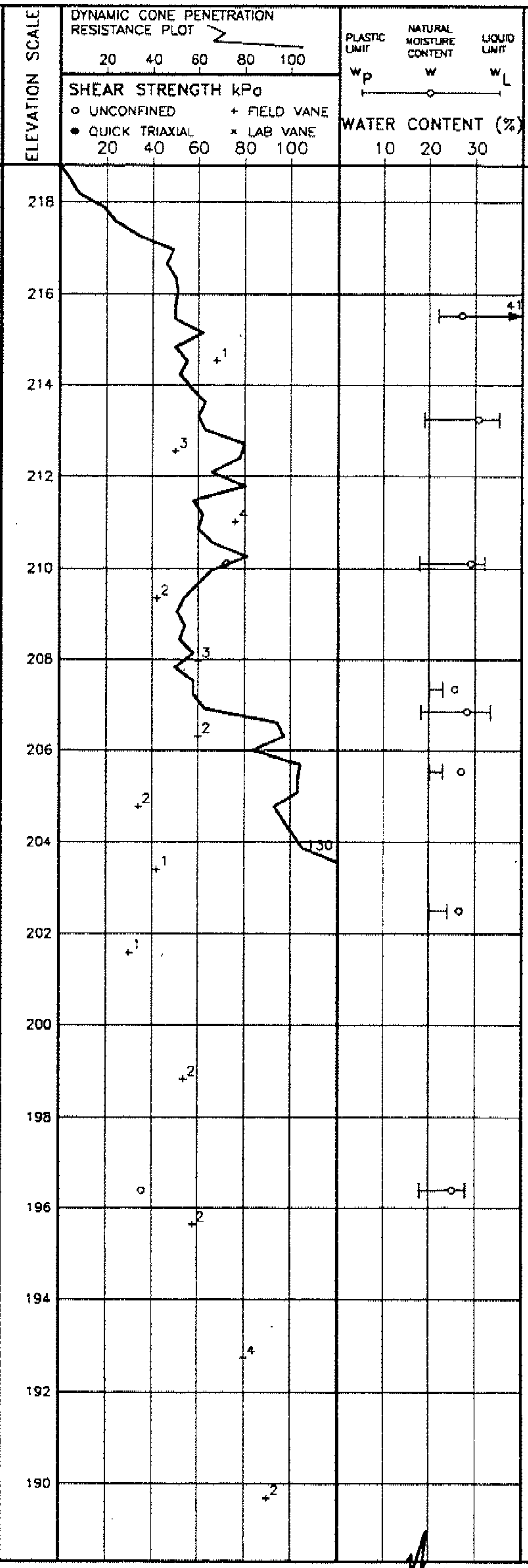
Foundation Design

RECORD OF BOREHOLE No 1

1 OF 2 METRIC 24

W.P. 114-87-00(A)	LOCATION Co-ords: N 4 782 414.3; E 253 508.6		ORIGINATED BY TS
DIST 4	HWY 403	BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test	COMPILED BY LD
DATUM Geodetic		DATE 92 05 11-13	CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
218.8	Ground Surface										
0.0	Clayey Silt to Silty Clay Firm to Stiff		1	SS	12						
	Brown		2	SS	14	▼	19.7	0	0	60	40
	Grey		3	SS	7						
			4	SS	5		18.9	0	0	45	55
			5	TW	PH						
			6	TW	PH		19.5	0	0	60	40
	random interbeds of Silt		7	SS	7						
			8	TW	PH			0 0	0 0	84 70	16 30
205.8 13.0	Silt with interbedded layers of Clayey Silt Grey, Loose		9	TW	PH			0	0	90	10
			10	SS	5						
			11	TW	PH			0	0	88	12
200.7 18.1	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff		12	SS	9						
			13	TW	PH		19.2	0	0	75	25
			14	SS	13						
			15	SS	14						
188.3 30.5	Continued										



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

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

Continued

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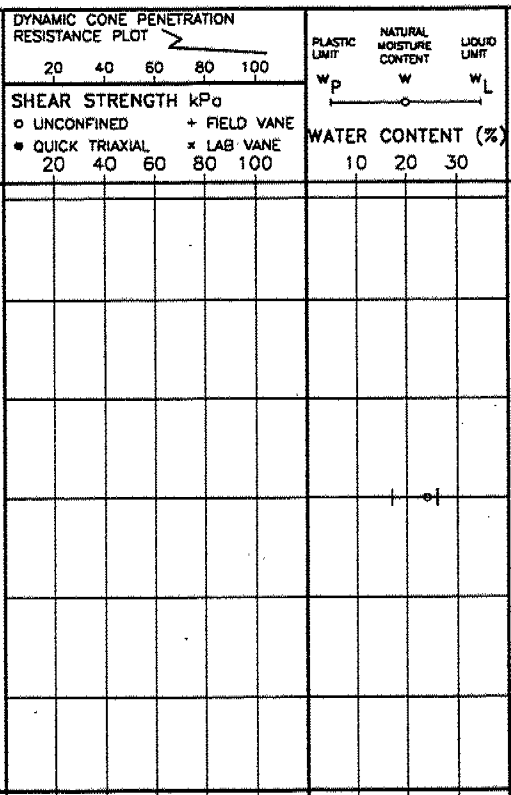
Foundation Design

RECORD OF BOREHOLE No 1

2 OF 2 METRIC 25

W.P. 114-87-00(A)
DIST 4 HWY 403
DATUM Geodetic
LOCATION Co-ords: N 4 782 414.3; E 253 508.6
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test
DATE 92 05 11-13
ORIGINATED BY TS
COMPILED BY LD
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES				
188.3	Continued								
30.5							188		
			16	SS	16				
							186		
	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff						184		
			17	SS	21		182		0 0 70 30
							180		
178.6			18	SS	18				
40.2	Bedrock – Dolostone Light Grey, Unweathered Medium Strong		19	RC	REC 94%		178		RQD = 74%
			20	RC	REC 100%				RQD = 61%
176.1 42.7	End of Borehole								



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

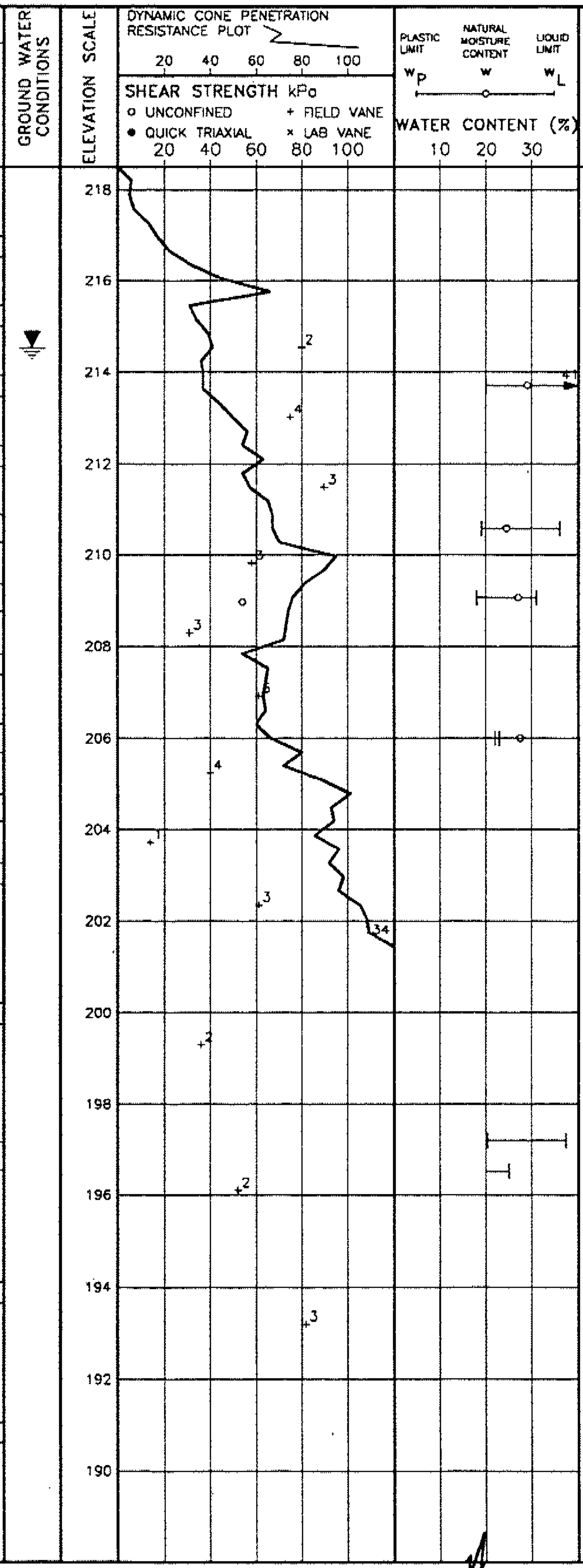
$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

1 OF 2 METRIC 26

W.P. 114-87-00(A)	LOCATION Co-ords: N 4 782 361.0; E 253 525.1		ORIGINATED BY LD
DIST 4	HWY 403	BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test	COMPILED BY LD
DATUM Geodetic		DATE 92 05 11-13	CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
218.5									
0.0	Clayey Silt to Silty Clay								
		1	SS	18					
	Brown, Very Stiff								
	Grey, Firm to Stiff	2	SS	8					
		3	SS	7	19.6	0	0	48	52
		4	SS	7					
		5	TW	PH	19.1	0	0	72	28
	random interbeds of Silt	6	TW	PH	19.6	0	0	63	37
		7	SS	7					
206.3 / 12.2	Silt with interbedded layers of Clayey Silt Grey, Loose	8	TW	PH		0	0	89	11
		9	TW	PH					
		10	SS	6					
		11	SS	5					
198.7 / 19.8	Clayey Silt to Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff	12	TW	PH					
		13	SS	11					
		14	SS	12					
188.0 / 30.5	Continued								



Continued

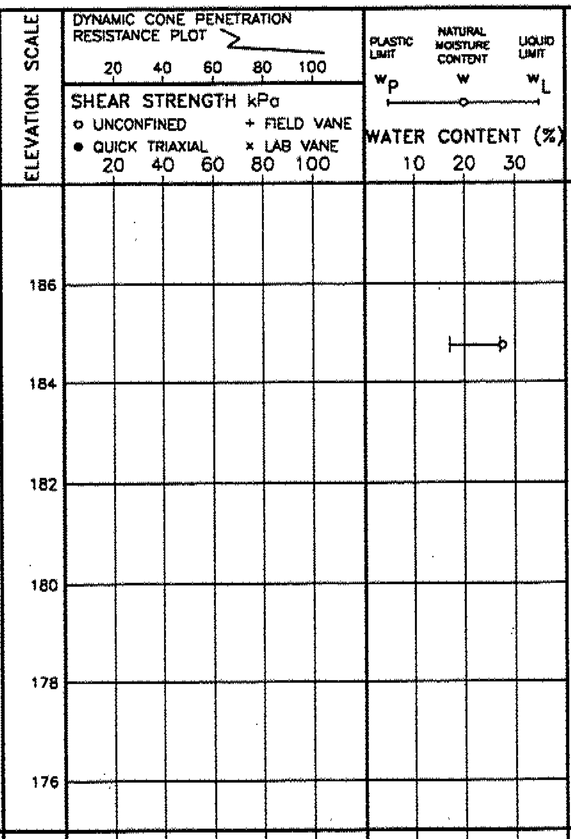
+3, ×5 : Numbers refer to Sensitivity

20 15◇5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

2 OF 2 METRIC 27

W.P. 114-87-00(A)
LOCATION Co-ords: N 4 782 361.0; E 253 525.1
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring and Cone Test
COMPILED BY LD
DATUM Geodetic
DATE 92 05 11-13
CHECKED BY PP



SOIL PROFILE ELEV DEPTH	DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
188.0	Continued							
30.5	Clayey Silt of Silty Clay with random interbedded layers of Silt Grey, Stiff to Very Stiff		15	SS	15			
			16	SS	9			0 0 68 32
			17	SS	12			
			18	SS	28			
178.1 40.4	Bedrock – Dolostone Light Grey, Unweathered Medium Strong		19	RC	REC 95%			RQD = 67%
			20	RC	REC 90%			RQD = 78%
175.0 43.5	End of Borehole							

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

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

ROCK CORE DESCRIPTION
WP 114-87-00A

Page 1 of 1

	CORE RECOVERY				CORE DESCRIPTION	
BH#	**RC#**	**DEPTH (m)**	**% CR***	**% RQD***	**DEPTH (m)**	**DESCRIPTION**
1	19	40.23-41.15	94	74	40.23-42.67	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	20	41.15-42.67	100	61		
2	19	40.44-41.96	95	67	40.44-43.49	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to dipping, undulating to planar, smooth to rough.
	20	41.96-43.49	90	78		

***CR** = CORE RECOVERY

***RQD** = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

FOUNDATION INVESTIGATION REPORT

FOR

Proposed Embankment at the

Hwy 403 - Dunmark Lake West Crossing

WP 114-87-00B

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the embankment fills proposed at the Dunmark Lake West - Hwy 403 crossing. Embankment fills up to approximately seven (7) metres have been proposed at the specific site location. At the time of the investigation, the valley at the site location contained approximately up to 1.5 metres of standing water.

SITE DESCRIPTION AND GEOLOGY

The site is located within the limits of the valley containing the Dunmark Lake (referred to Dunmark Lake West in this report). The site is situated approximately 0.5km. east of Sunnyridge Rd, approximately 1 to 2 km. south of Jerseyville Rd. within the Regional Municipality of Hamilton-Wentworth. The valley is confined by earth ridges up to fourteen (14) metres in height to the west and up to approximately seven (7) metres in height to the east. The existing valley slopes are relatively flat and are estimated to range from 4H:1V to 5H:1V. These slopes reveal no signs of instability. The slopes are generally covered by both tall and short coniferous trees.

The existing valley at the proposed Hwy. 403 crossing is contained within the private ownership of the Heron Links Golf Course. The golf course is located immediately south of the proposed highway.

A natural drainage valley is located north of the Dunmark Lake West. It appears that drainage from Sunnyridge Rd. and the general catchment area occurs within this existing drainage valley.

The area north-east of the site consists of agricultural farmland. Residential homes are located north-west of the site location.

The waters of the Dunmark Lake are murky and unclear. The depth of the water was approximately 1 metre at the time of the investigation, although this water level has been known to fluctuate throughout the year. In fact, the water level has been completely drawn down during past summers as a result of irrigation conducted at the Heron Links golf course. Wild grass and weed are present within the northern limits of the lake.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. The Dunmark Lake is located within a low lying basin created by glaciation.

Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness ranging from approximately thirty (30) metres within the valley to thirty-eight (38) metres at the crest of the valley.

INVESTIGATION PROCEDURE

GENERAL

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and laboratory testing program are discussed below.

Field Investigation

The fieldwork was carried out in two separate stages and hence within two different site mobilizations. In the initial stage, one borehole accompanied by two (2) dynamic cone penetration tests were advanced as part of a preliminary type investigation that occurred between 91 02 18-22. The borehole (BH1) was advanced to a depth of 38.3m, whilst the dynamic cone penetration tests were advanced to depths of 6.1m and 15.5m. The borehole and dynamic cone penetration test were advanced on land west of the existing Dunmark Lake West employing a track mounted CME 75 equivalent drilling unit.

A more detailed investigation was conducted between 92 07 09 and 92 07 22 that included a total of five (5) additional boreholes. The boreholes were advanced to depths ranging from 4.8m to

31.9m. Two (2) of the boreholes were advanced on land using conventional track mounted drilling units equivalent to Central Mining Equipment (CME) 55's. Both boreholes were advanced to auger refusal encountered at the probable bedrock surface.

Three (3) boreholes were advanced within the waters of the Dunmark Lake using a raft and a more portable, lighter diamond drill unit. The diamond drill used was a skid mounted Boyles Bros. No. 1 unit that had a weight of approximately 900kg.

Conventional hollow stem augering techniques were used to advance the boreholes on land. Offshore, conventional diamond drilling techniques were used.

Both disturbed and undisturbed samples were retrieved in the overburden both on land and offshore. Subsoil samples were retrieved at both 0.7 metre and 1.5 metre intervals on land. Offshore, surface samples were taken and then sampling proceeded at both 0.7 metre and 1.5 metre intervals. Disturbed subsoil samples were retrieved using a 50mm diameter split spoon sampler driven in accordance with the Standard Penetration Test (SPT - ASTM D1586). Relatively undisturbed samples were also retrieved within the weaker cohesive materials using a 57mm diameter thin wall sampler. The thin wall sampler was pushed manually into the soil offshore and hydraulically on land in accordance with procedures outlined in ASTM D1587. Wash samples were also retrieved at the boreholes advanced offshore.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The test was carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Groundwater levels were determined by monitoring the water levels in the open boreholes and the lake level throughout the duration of the field investigation. All boreholes were backfilled upon completion of the fieldwork.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans. A boat was required to enable the borehole layout offshore. Long steel rods were used to stake the boreholes in the waters of Dunmark Lake.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples. These tests are tabulated in Table 1 below:

Table 1 - Physical/Mechanical Property Testing

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Test
2) Particle Size Analysis	
3) Natural Moisture Contents	
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

GENERAL

Subsurface conditions across the site are uniform and generally consists of extensive stratifications of silt and clayey silt to silty clay. The surficial deposit which underlies the standing waters of Dunmark Lake (up to 1.5 metres) consists of a cohesive clayey silt to silty clay with random layers of silt. The thickness of this deposit ranges from 2.2 metres to 9.1 metres. The stratum generally has a very stiff consistency.

The surficial cohesive clayey silt deposit is underlain by a plastic silt that has a loose to compact denseness and contains random interbedded seams/layers of stiff to very stiff clayey silt to silty clay. The thickness of this stratum ranges from 10.5m to 15.7m.

The plastic silt stratum is in turn underlain by a cohesive clayey silt deposit which has a thickness ranging from 6.1m to 8.7m. This deposit also contains random layers of plastic silt. The cohesive material has a stiff to very stiff consistency.

A lower silt deposit with interbedded layers of clayey silt to silty clay underlies the lower cohesive clayey silt. This deposit has a thickness of 4.8 to 6.1 metres and overlies the probable bedrock surface as determined by auger refusal.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700B-A*. A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as wall as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Boreholes sheets in the Appendix.

Water

Approximately up to 1.5m of standing water was present in the Dunmark Lake West at the time of the investigation. The water was murky and calm at the time of the investigation.

* DWG NO 2 OF THE CONTRACT DWG'S

Clayey Silt to Silty Clay with random layers of Silt

The surficial stratum at the site consists of a cohesive clayey silt to silty clay that extends for a thickness ranging from 2.2 metres to 9.1 metres below the ground surface. Within the valley, the thickness of the deposit is within 4.6 metres, but at the crest of the slope, the deposit thickens to 9.1 metres. The deposit also contains traces of organics within the surficial three (3) metres and also contains random interbedded layers of silt of thickness ranging up to 100mm.

The colour of the deposit is primarily brown to mottled grey-brown but changes to grey at a depth as shallow as 3.0 metres at some locations. This varying colour is indicative of different depths of oxidation at the site.

A grain size distribution envelope produced by mechanical sieve and hydrometer analysis for this material is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed of grain sizes smaller than 75 micrometres. The grain size distribution envelope illustrates silt percentages ranging from 35% to 62% and clay percentages ranging from 34% to 65%. In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below. Atterberg Limit Tests were carried out on the fine grained soil and the results are plotted on Figure 2 in the Appendix and summarized on Table 2 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 2 - Atterberg Limit Test Results - Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	29 - 37	7
Liquid Limit (w_L%)	34 - 49	7
Plastic Limit (w_P%)	18 - 26	7
Plasticity Index (Ip%)	13 - 27	7
Bulk Unit Weight (kN/m^3)	18.4 - 18.7	1

The test results clearly reveal that the soil has a plasticity that ranges from low to intermediate and hence can be categorized as a clayey silt (CL) to silty clay (CI). Natural moisture contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests. In general, the material exhibited sufficient undrained shear strengths that inhibited the torquing of the vane. Hence, undrained shear strengths are generally in excess of 120 kPa.

The 'N' values as determined by the Standard Penetration Test ranged from 2 blows/0.3m to 30 blows/0.3m. Within the lake, the 'N' values were lower and generally less than 10 blows/0.3m, for the surficial metre and a half or so. The larger 'N' values, (values exceeding 10 blows/0.3m) were retrieved offshore.

Silt with interbedded seams/layers of Clayey Silt to Silty Clay

A cohesionless silt of quick dilatancy interbedded with random layers of cohesive clayey silt to silty clay exists below the clayey silt to silty clay surficial deposit and extends to depths ranging from 15.0m to 24.8m below the ground or water surface. The thickness of this stratum ranges from 10.5m to 15.7m and the cohesive interbedded seams or layers are approximately 25mm to 150mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Grain size distribution envelopes as determined by mechanical sieve and hydrometer analysis for both the cohesionless host silt and cohesive layers of clayey silt to silty clay are shown on Figure 3 in the Appendix. The envelopes illustrate silt percentages ranging up to 92% with traces of clay for the silt material and for the cohesive layers, silt percentages range from 67% to 86% and the clay fraction ranges from 14% to 42%. In accordance with the MTO Soil Classification system, materials with gradations of this nature are categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 4 and summarized in Table 3 below. Natural Moisture Contents are also included in the Table below.

Table 3 - Atterberg Limit Test Results
Silt with interbedded seams/layers of
Clayey Silt to Silty Clay

a) Silt

	Range	# of Tests
Natural Moisture Content (w%)	24 - 33	6
Liquid Limit (w_L%)	18 - 23	6
Plastic Limit (w_P%)	16 - 19	6
Plasticity Index (Ip%)	1 - 4	6

b) Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	28 - 35	3
Liquid Limit (w_L%)	25 - 37	3
Plastic Limit (w_P%)	17 - 18	3
Plasticity Index (Ip%)	7 - 19	3

The test results reveal that the main component of the deposit behaves as a plastic silt (ML). The interbedded cohesive layers have a low to intermediate plasticity (CL to CI).

In situ vane tests conducted within this deposit revealed undrained shear strength values ranging from 70 kPa to in excess of 120 kPa. It can therefore be concluded that the cohesive layers have a stiff to very stiff consistency, although the larger undrained shear strength values may be attributable to the presence of the silt material.

The sensitivity of the cohesive soil also determined by the vane test ranged from 2 to 5 indicating a low to moderately sensitive material.

The 'N' values as derived from the Standard Penetration Test range from 3 blows/0.3m to 16 blows/0.3m. Based on these 'N' values it can be stated that the deposit has a loose to compact denseness.

Clayey Silt with Random Layers of Silt

Underlying the plastic silt with interbedded seams/layers of clayey silt to silty clay, a second cohesive deposit consisting of clayey silt exists. This deposit also contains random layers of plastic silt ranging in thickness from 50mm to 150mm. The thickness of the entire stratum ranges from 6.1m to 8.7m.

A grain size distribution envelope illustrating the gradation of the cohesive material of this deposit and the interbedded silt layers is shown on Figure 5 in the Appendix. The envelope clearly illustrates that the material is fine grained with grain sizes less than 75 micrometres. Typically, clay percentages range from 22% to 45% and silt percentages range from 55% to 78%, within the cohesive material.

In accordance with the MTO Soil Classification system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 6 and summarized in Table 4 below. Natural Moisture Contents are also included in the Table below.

Table 4 - Clayey Silt with random layers of Silt

	Range	# of Tests
Natural Moisture Content (w%)	25 - 34	8
Liquid Limit (w_L%)	25 - 34	8
Plastic Limit (w_P%)	16 - 19	8
Plasticity Index (Ip%)	6 - 17	8

The test results reveal that the cohesive soil has a low plasticity and hence can be classified as a clayey silt (CL). Natural moisture contents are generally similar to the liquid limit of the soil.

The consistency and undrained shear strength of the soil was determined by conducting in situ vane tests and interpretation of SPT 'N' values. Undrained shear strengths ranged from 50 kPa to 100 kPa indicating a stiff to very stiff consistency. The 'N' values as determined by the SPT ranged from 6 blows/0.3m to 20 blows/0.3m confirming the stiff to very stiff consistency.

The compressibility characteristics of the clayey silt stratum was determined by conducting a one dimensional consolidation test on a representative sample of the material. The results of the test is shown graphically on Figure 7 in the Appendix. The consolidation curve is plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load (log p). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (p_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The consolidation curve reveals a preconsolidation pressure of 460 kPa. The effective overburden pressure of the sample tested is approximately 180 kPa. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 280 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.4.

Silt with interbedded layers of Clayey Silt to Silty Clay

A second cohesionless deposit of plastic silt exists beneath the lower cohesive deposit of clayey silt. This deposit has a thickness ranging from 4.8m to 6.1m. Once again, stratification is present within the deposit and random layers of cohesive clayey silt to silty clay ranging in thickness from 25mm to 100mm are present within the deposit. The host material is a plastic inorganic silt that exhibits a quick dilatancy, no dry strength and no toughness, which is characteristic of this material. An Atterberg Limit test carried out on a representative sample of this silt material (BH2, SS14) confirms that the material behaves as a plastic silt (w_L = 23%, I_P = 3%). The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Standard Penetration Tests conducted within this deposit reveal 'N' values ranging from 6 blows/0.3m to 18 blows/0.3m indicating a loose to compact state of denseness.

Probable Bedrock

The bedrock was inferred at three borehole location (BH's 1,2 and 3) from auger and tricone refusal. The refusal was encountered at a uniform elevation of 181.7m to 182.4m across the site. Based on data retrieved at neighbouring sites, the bedrock surface elevation appears to be uniform from the proposed Sunnyridge Rd./Hwy. 403 structure to the Big Creek/Hwy. 403 structure and it is suspected that the bedrock is "vuggy" dolostone of the Amabel formation.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes and monitoring the lake level throughout the duration of the field investigation. The lake level at the time of the investigation was approximately elevation 211.5m. On land the water level varied from elevation 217.7 (measured on 91 02 23) or approximately 3 metres below the ground surface at the crest of the slope to Elevation 210.7m to 211.2m on shore immediately adjacent to the Dunmark Lake West.

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, P. Martin and L. Dametto, Student Engineers utilizing equipment owned and operated by Atcost Soil Drilling.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by Mr. M. Devata, Chief Foundation Engineer.

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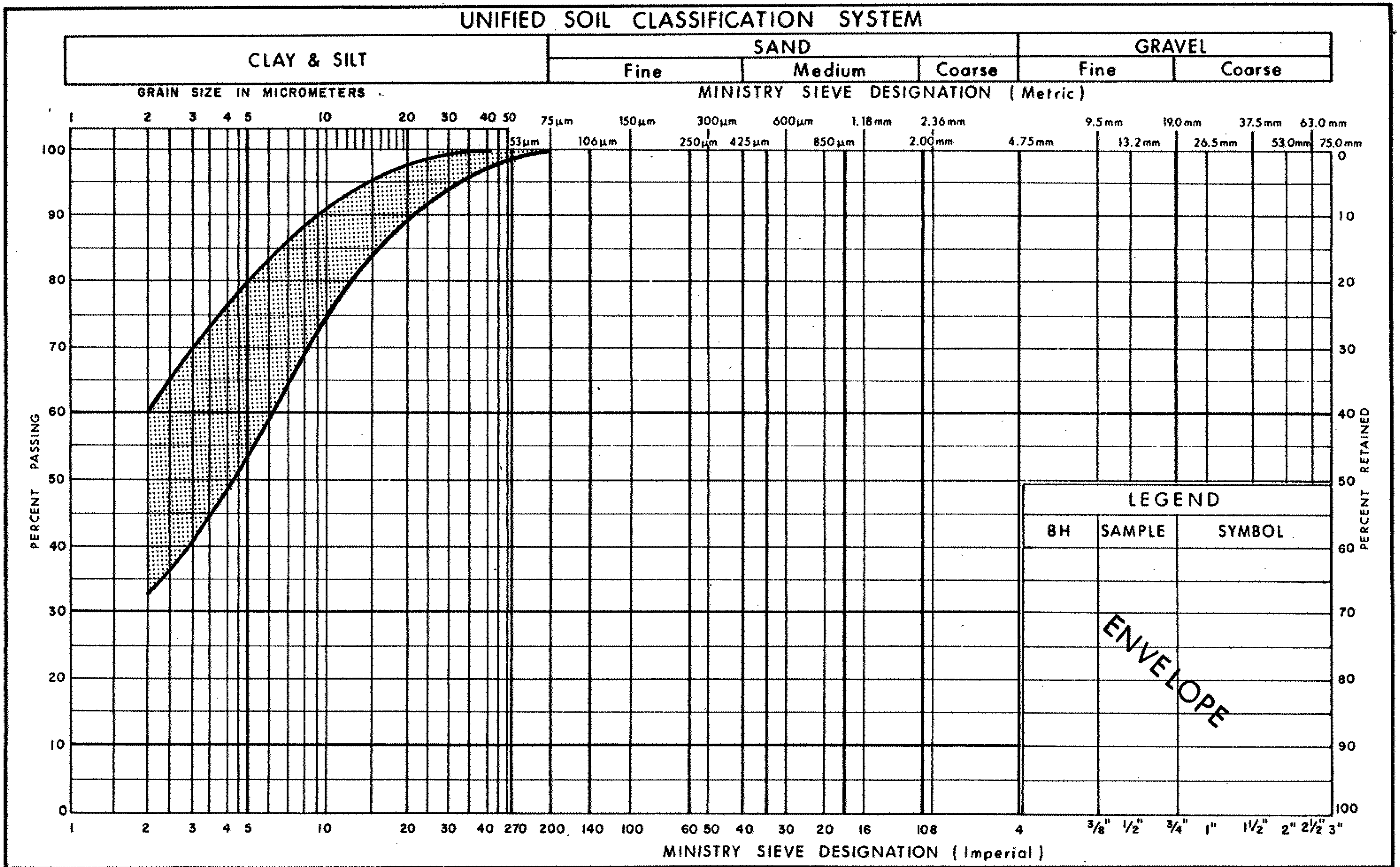
APPENDIX

78 12 M



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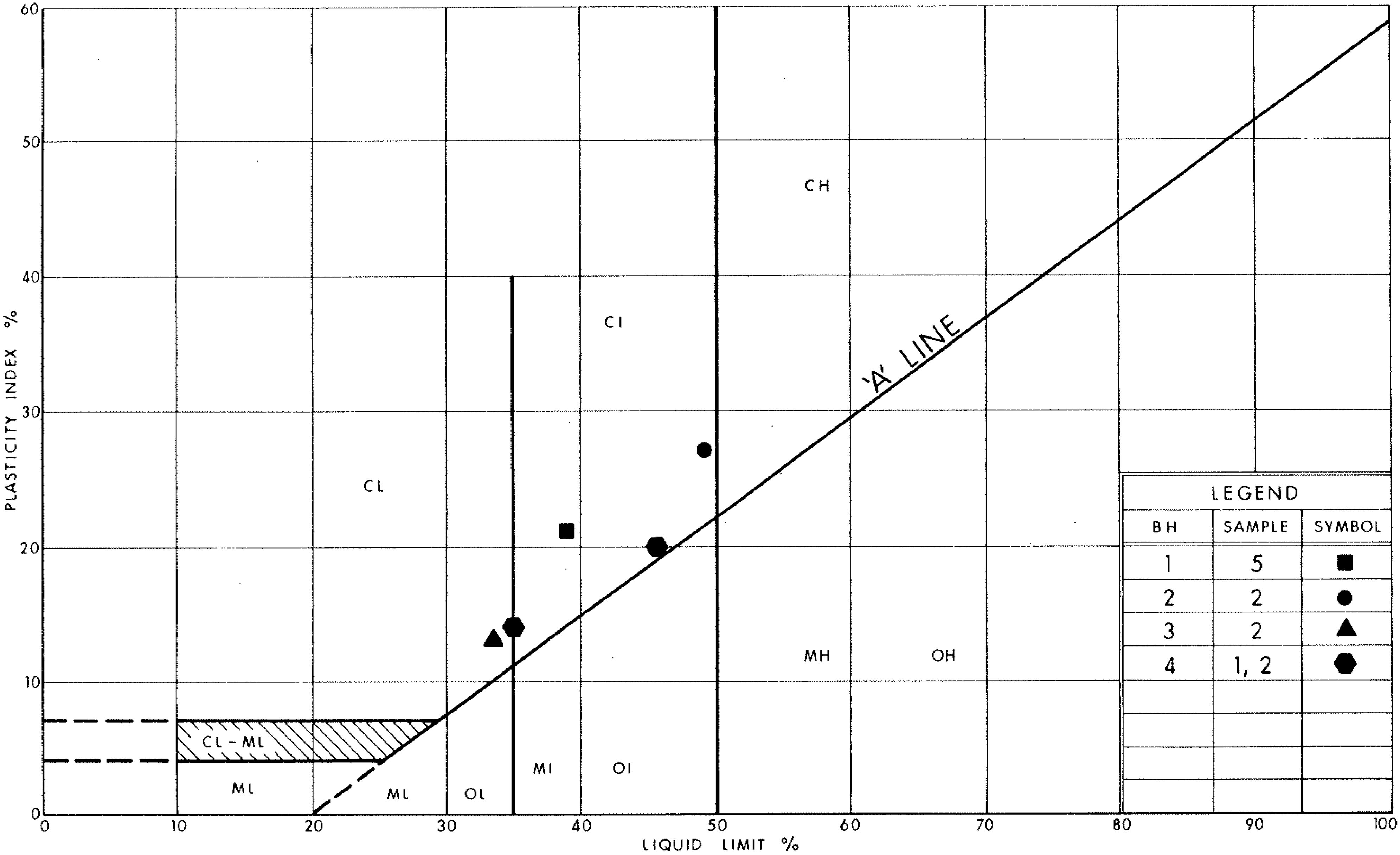
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM LAYERS OF SILT

FIG No 1

W P 114 -87-00 B

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
1	5	■
2	2	●
3	2	▲
4	1, 2	⬢

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PLASTICITY CHART

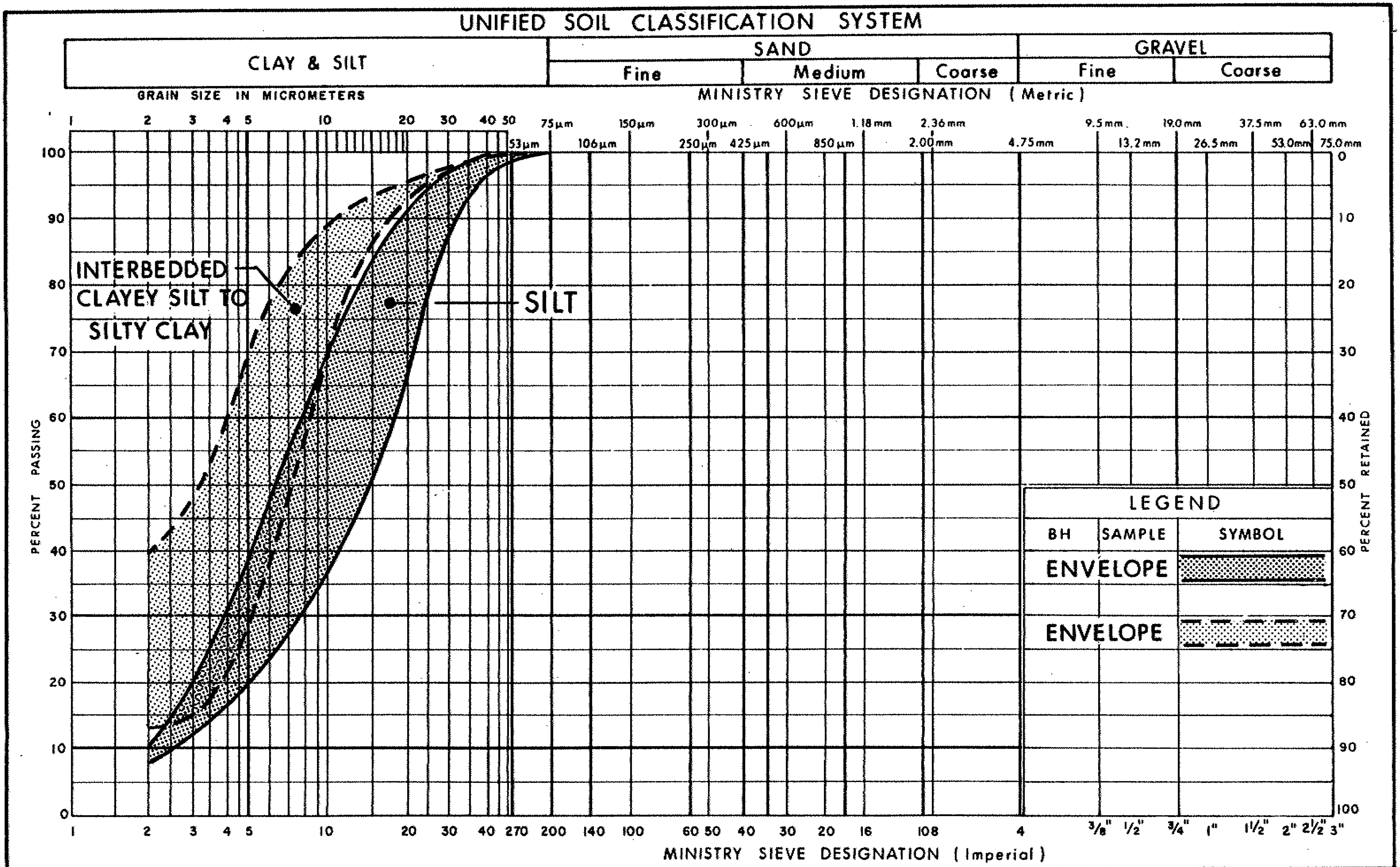
CLAYEY SILT TO SILTY CLAY

WITH RANDOM LAYERS OF SILT

FIG No 2

W P 114-87-00B

78 12 M



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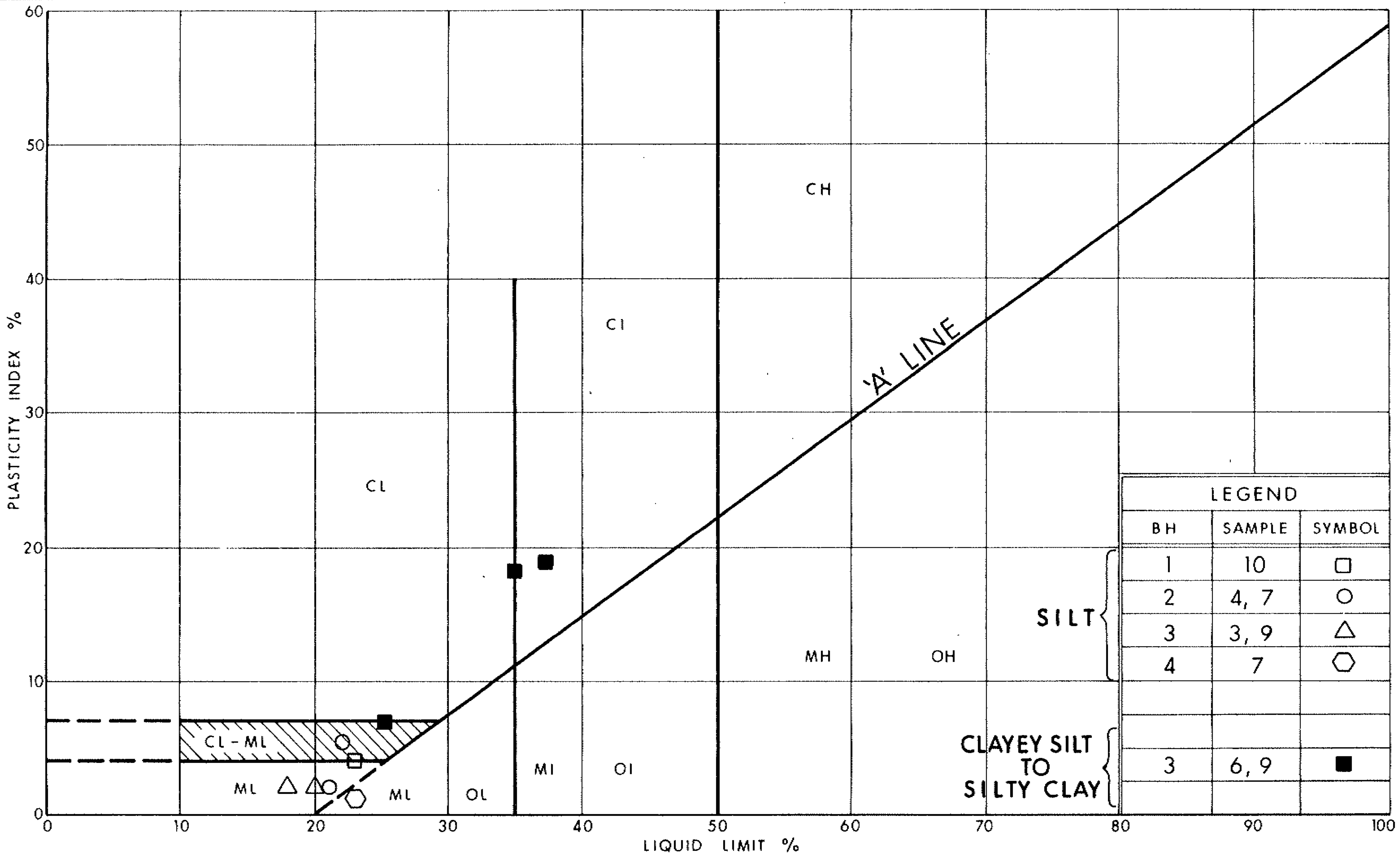
GRAIN SIZE DISTRIBUTION

SILT, WITH INTERBEDDED SEAMS/LAYERS OF CLAYEY SILT TO SILTY CLAY

FIG No 3

W P 114 - 87 - 00B

Oct 75, FF-S-21



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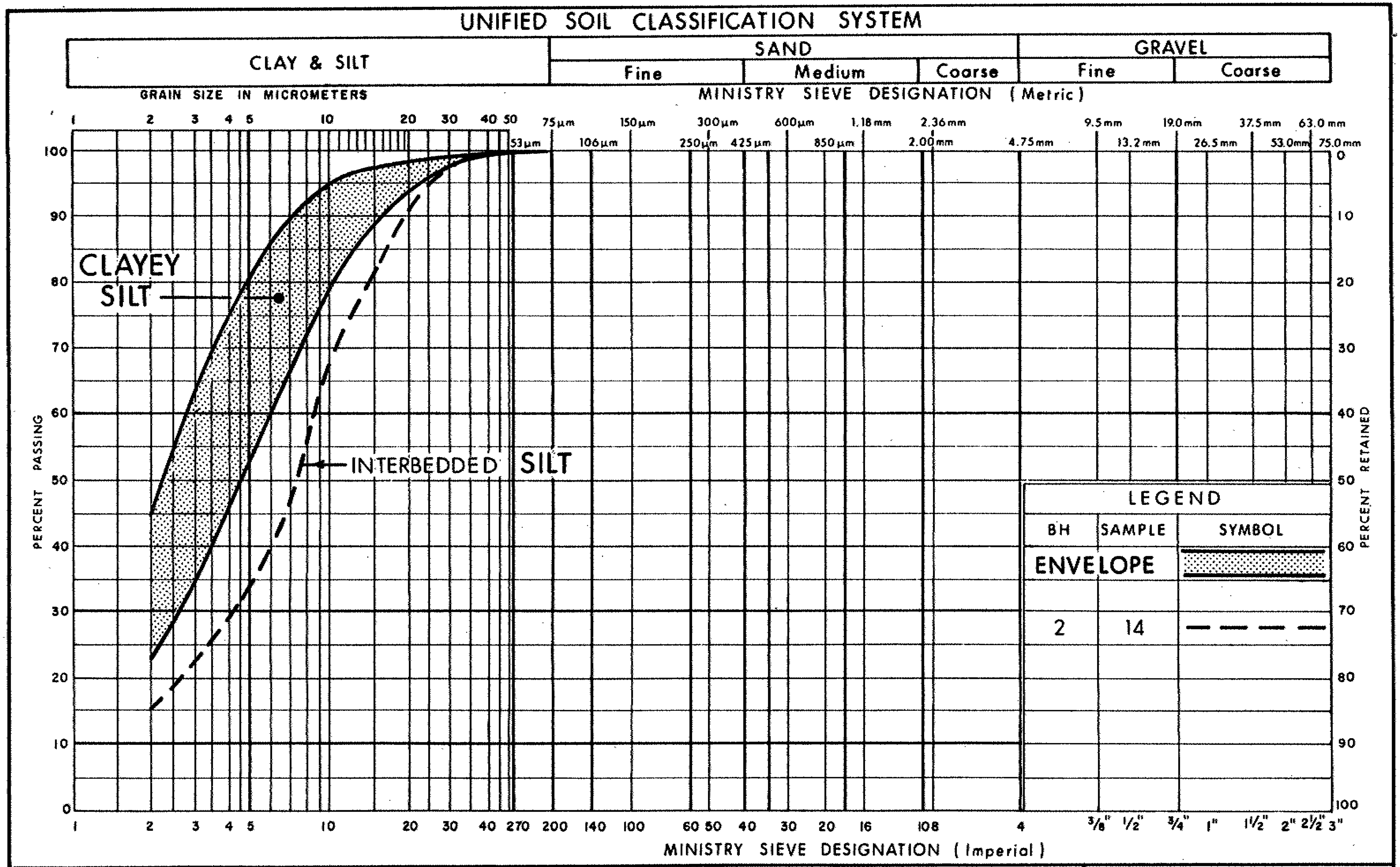
PLASTICITY CHART

SILT, WITH INTERBEDDED SEAMS/LAYERS OF CLAYEY SILT TO SILTY CLAY

FIG No 4

W P 114 - 87 - 00 B

78 12 M



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GRAIN SIZE DISTRIBUTION

CLAYEY SILT

WITH RANDOM LAYERS OF SILT

FIG No 5

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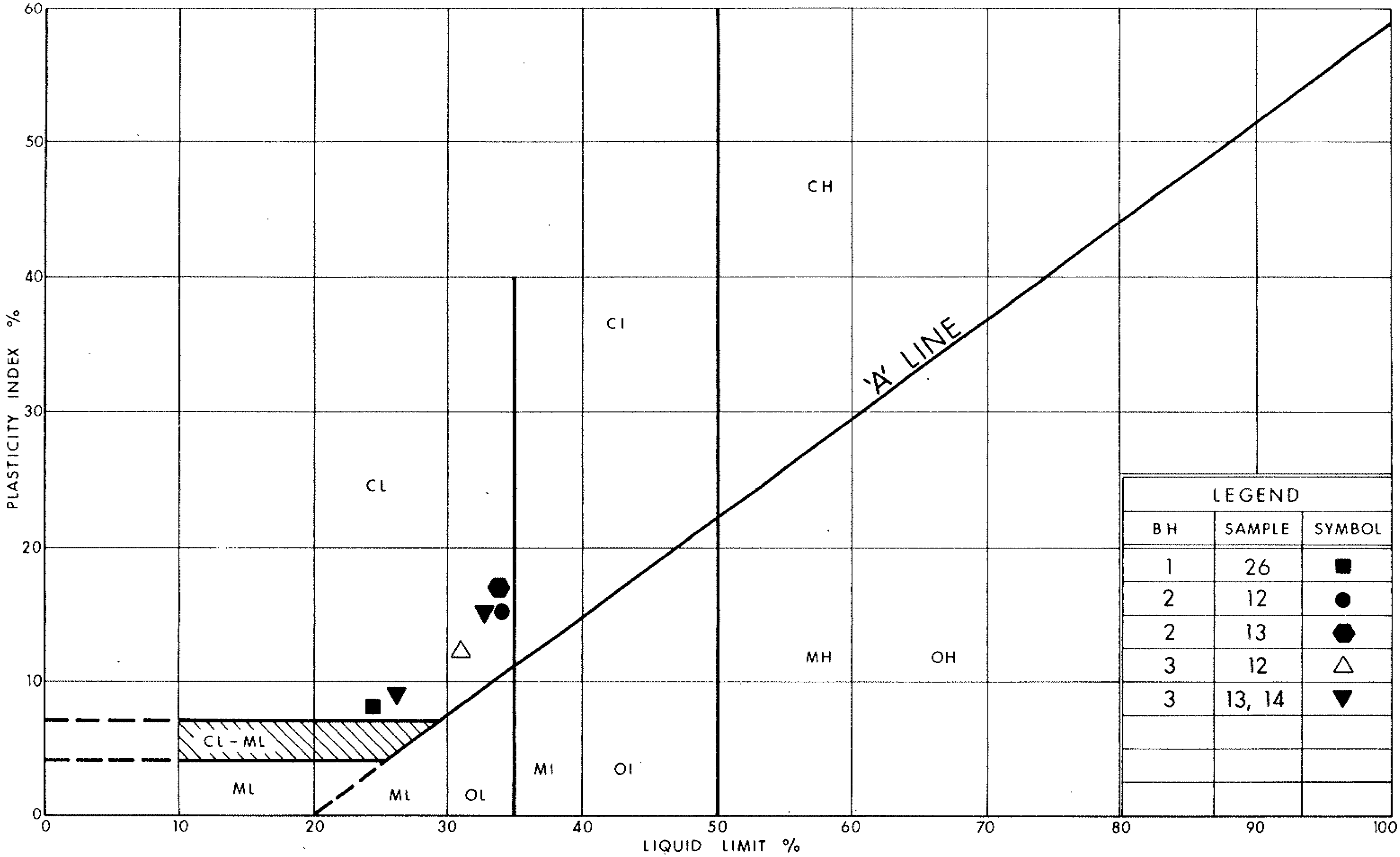

LEGEND		
BH	SAMPLE	SYMBOL
1	26	■
2	12	●
2	13	⬢
3	12	△
3	13, 14	▼

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PLASTICITY CHART

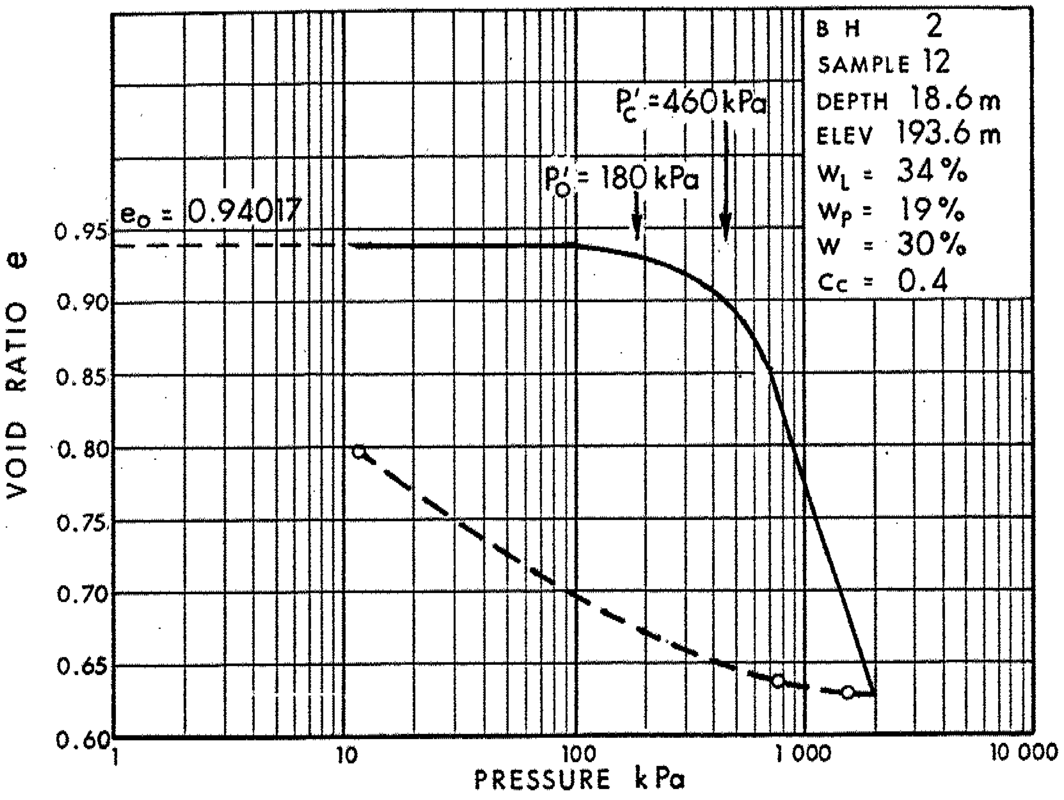
CLAYEY SILT

WITH RANDOM LAYERS OF SILT

FIG No 6

W P 114-87-00 B

VOID RATIO-PRESSURE CURVES



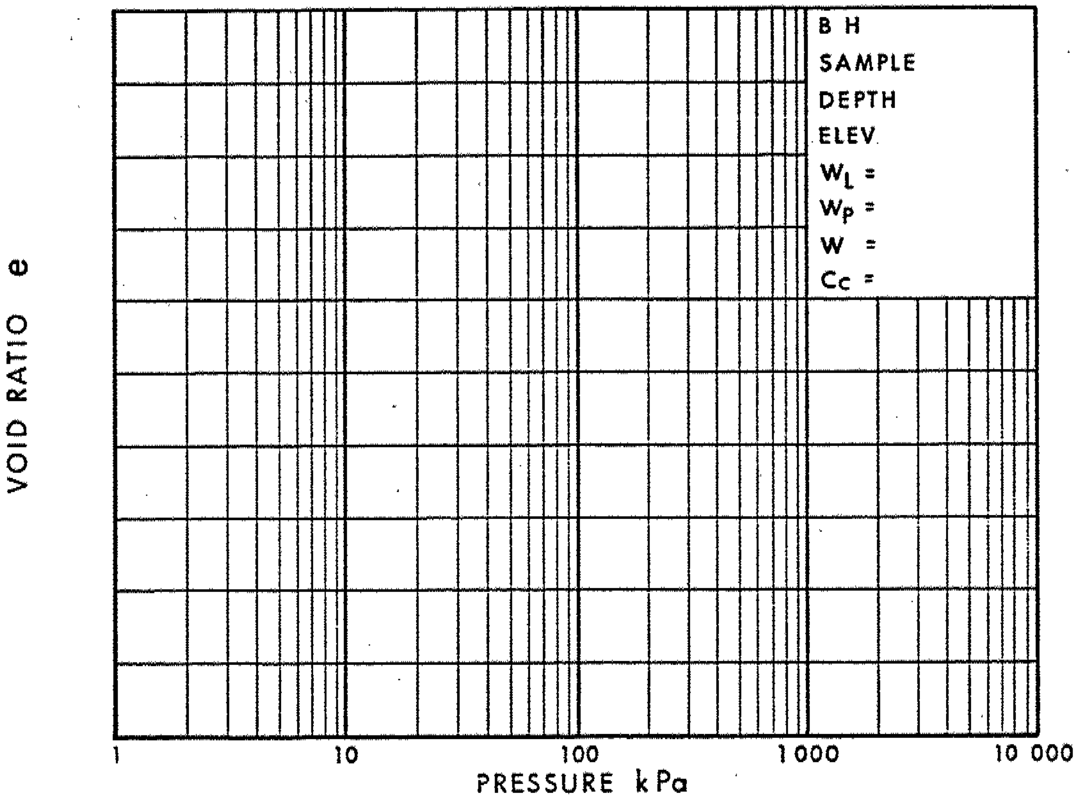


Fig 7

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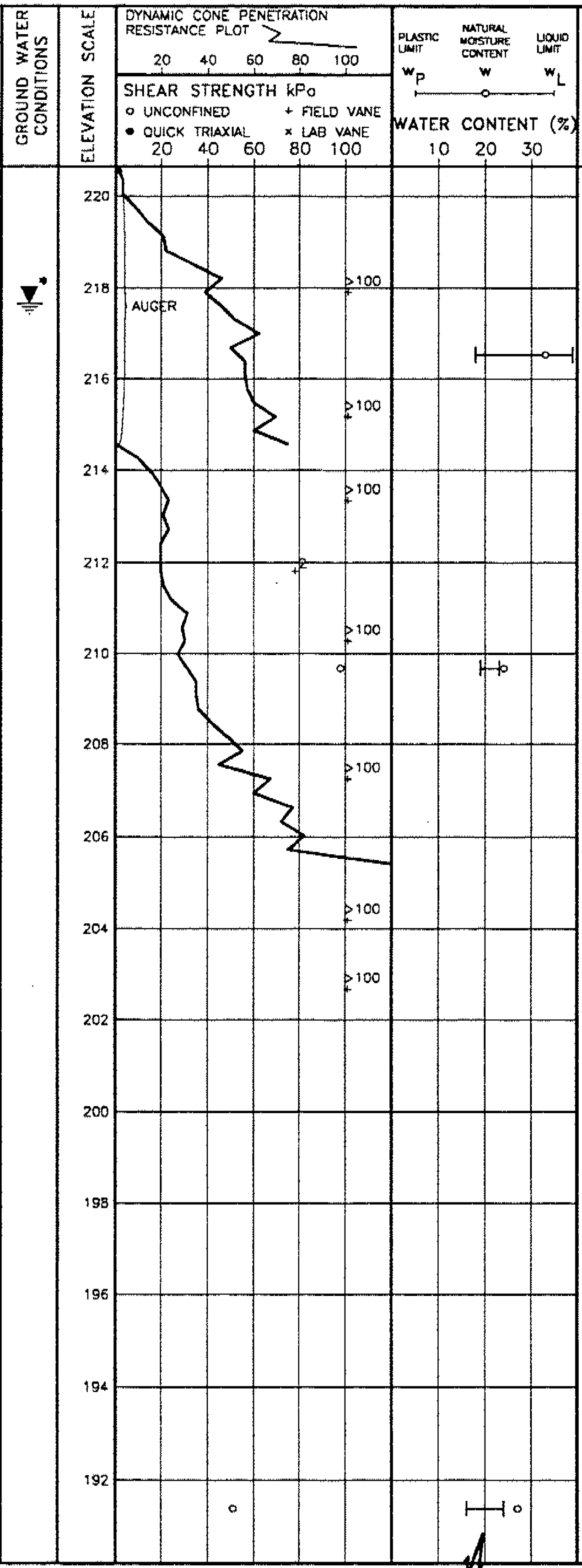
RECORD OF BOREHOLE No 1

(Formerly BH No 1 WP114-87-00)

1 OF 2 METRIC 52

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 438.0; E 255 868.0
ORIGINATED BY MP
DIST 4 HWY 403
BOREHOLE TYPE HS Auger & Dynamic Cone Test
COMPILED BY LD
DATUM Geodetic
DATE 91 02 18-22
CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
220.7	Ground Surface								
0.0	Clayey Silt to Silty Clay with random layers of Silt Stiff to Very Stiff Brown Grey	1	SS	3					
		2	SS	7					
		3	SS	10					
		4	SS	17					
		5	TW	PH	18.5	0	0	35	65
		6	SS	7					
		7	SS	12					
		8	SS	7					
211.6 9.1	Silt with interbedded seams/layers of Clayey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff	9	SS	7					
		10	TW	PH	19.4	0	0	90	10
		11	SS	15					
		12	SS	6					
		13	SS	9					
		14	TW	PH					
		15	SS	7					
		16	SS	7					
		17	SS	9					
		18	SS	9					
		19	SS	8					
		20	SS	9					
		21	SS	11					
		22	SS	10					
		23	SS	9					
195.9 24.8	Clayey Silt with random layers of Silt Grey, Stiff to Very Stiff	24	SS	13					
		25	SS	11					
		26	TW	PH	20.1	0	0	70	30
190.2 30.5									



Continued

Continued

+3, x5 : Numbers refer to Sensitivity

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

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RECORD OF BOREHOLE No 1

2 OF 2

METRIC 53

W.P. 114-87-00B
LOCATION Co-Ords: N 4 783 438.0; E 255 868.0
ORIGINATED BY MP
DIST 4 HWY 403
BOREHOLE TYPE HS Auger & Dynamic Cone Test
COMPILED BY LD
DATUM Geodetic
DATE 91 02 18-22
CHECKED BY PP

SOIL PROFILE			SAMPLES					DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE				
190.2	Continued										
30.5			27	SS	15		190				
			28	SS	18		188				
187.2											
33.5	Silt with interbedded layers of Clayey Silt to Silty Clay Grey, Compact		29	SS	11						
							186				
			30	SS	11						
							184				
			31	SS	12						
182.4			32	SS	25	/3cm					5 5 75 15
38.3	End of Borehole (Auger Refusal – Probable Bedrock) ▪ 91 02 23										

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

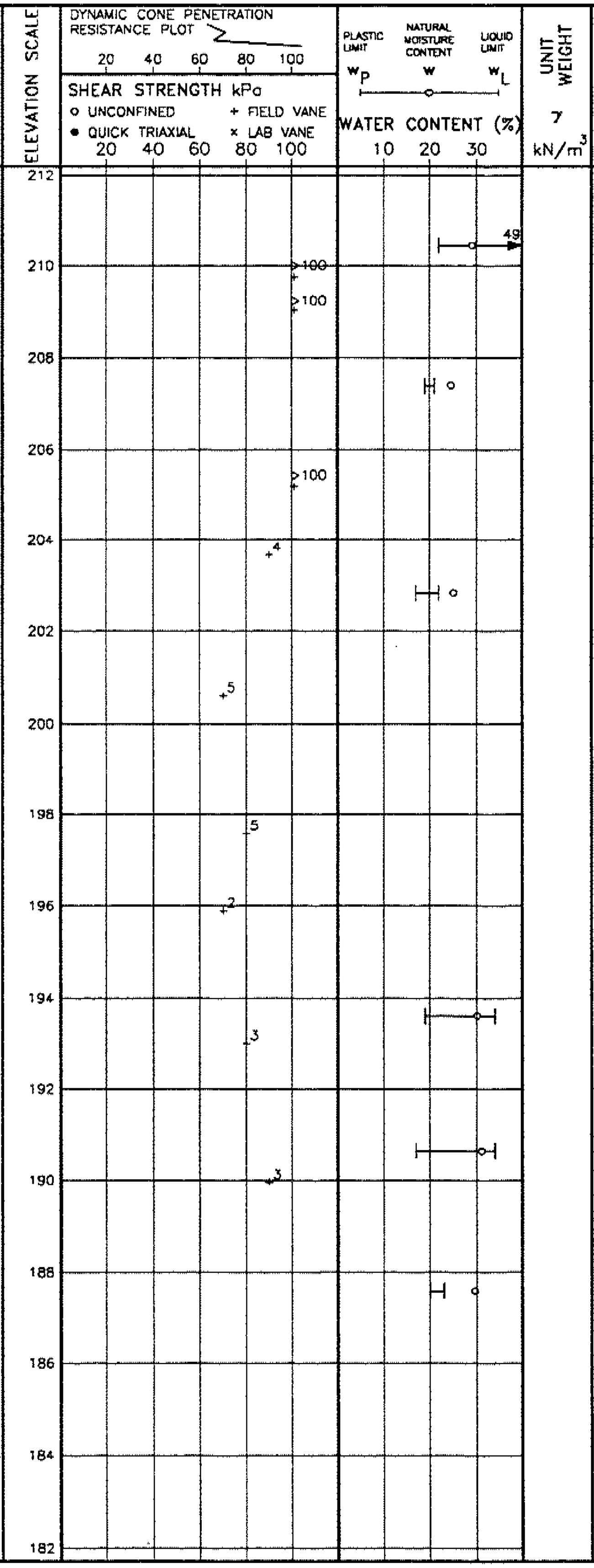
$15 \overset{20}{\underset{10}{\diamond}} 5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

1 OF 1 METRIC 54

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 449.3; E 255 908.1
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY LD
DATUM Geodetic
DATE 92 07 10
CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
212.2	Groud surface								
0.0	Clayey Silt to Silty Clay with random layers of Silt Brown, Very Stiff	1	SS	10	▼*				
		2	SS	6		0	0	45	55
		3	SS	8					
207.6 / 4.6	Silt with interbedded seams/layers of Clayey Silt to Silty Clay Grey, Very Loose to Compact/ Stiff to Very Stiff	4	SS	14		0	0	92	8
		5	SS	9					
		6	SS	5					
		7	SS	5		0	0	88	12
		8	SS	5					
		9	SS	6					
		10	SS	3					
		11	TW	PH					
193.9 / 18.3	Clayey Silt with random layers of Silt Grey, Stiff to Very Stiff	12	TW	PH		0	0	57	43
		13	SS	6		0	0	55	45
187.8 / 24.4	Silt with interbedded layers of Clayey Silt to Silty Clay Loose	14	SS	6		0	0	81	19
		15	SS	7					
181.7 / 30.5	End of Borehole * 92 07 10 (Auger Refusal – Probable Bedrock)								



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

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

Ministry of Transportation
Ontario

Foundation Design

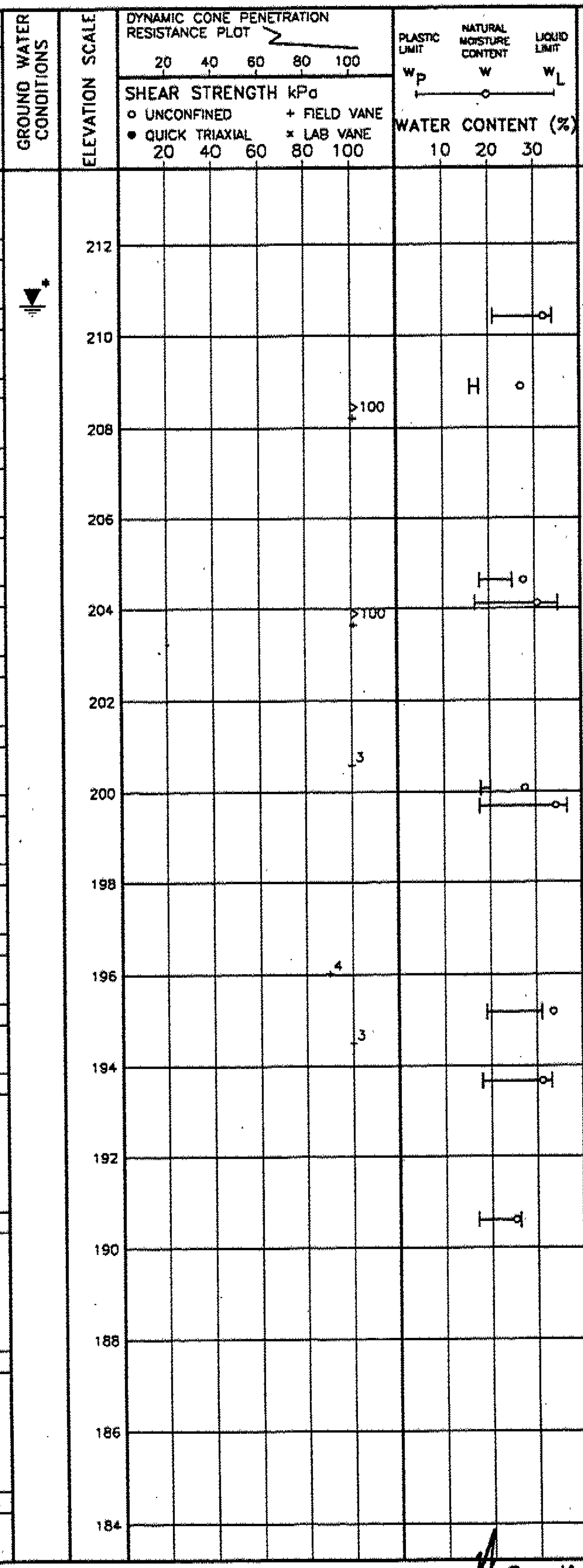
RECORD OF BOREHOLE No 3

1 OF 2 METRIC 55

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 494.0; E 255 936.7
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, Washbore - Tricone
COMPILED BY LD
DATUM Geodetic
DATE 92 07 09-10
CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE – DESCRIPTION
213.7	Ground Surface
209.1 / 0.0	Clayey Silt with random layers of Silt Brown, Very Stiff
195.4 / 4.6	Silt with interbedded seams/layers of Clayey Silt to Silty Clay Grey, Very Loose to Compact/ Stiff to Very Stiff seams layers
187.8 / 18.3	Clayey Silt with random layers of Silt Grey, Stiff to Very Stiff
183.2 / 25.9	Silt with interbedded layers of Clayey Silt to Silty Clay Compact
30.5	Continued

SAMPLES NUMBER	TYPE	'N' VALUES
1	SS	20
2	SS	25
3	SS	9
4	SS	7
5	SS	6
6	SS	10
7	SS	10
8	SS	7
9	SS	7
10	SS	11
11	SS	8
12	TW	PH
13	SS	17
14	SS	20
15	SS	16
16	SS	18



Sample	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
2		0	0	50	50
3		0	0	89	11
6		0	0	86	14
6		0	0	58	42
9		0	0	89	11
9		0	0	67	33
12	19.2	0	3	72	25
13		0	0	58	42
14		0	0	78	22

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued

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

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

Continued

RECORD OF BOREHOLE No 3   2 OF 2   METRIC   56

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 494.0; E 255 936.7
ORIGINATED BY TS
DIST 4   HWY 403
BOREHOLE TYPE HS Auger, Washbore – Tricone
COMPILED BY LD
DATUM Geodetic
DATE 92 07 09-10
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
183.2	Continued										
30.5											
181.8							182				
31.9	End of Borehole (Auger Refusal – Probable Bedrock) • 92 07 09										

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

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

RECORD OF BOREHOLE No 4

1 OF 1 METRIC 57

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 473.5; E 255 921.6
ORIGINATED BY PM
DIST 4 HWY 403
BOREHOLE TYPE Washboring, N Casing
COMPILED BY LD
DATUM Geodetic
DATE 92 07 20-21
CHECKED BY PP

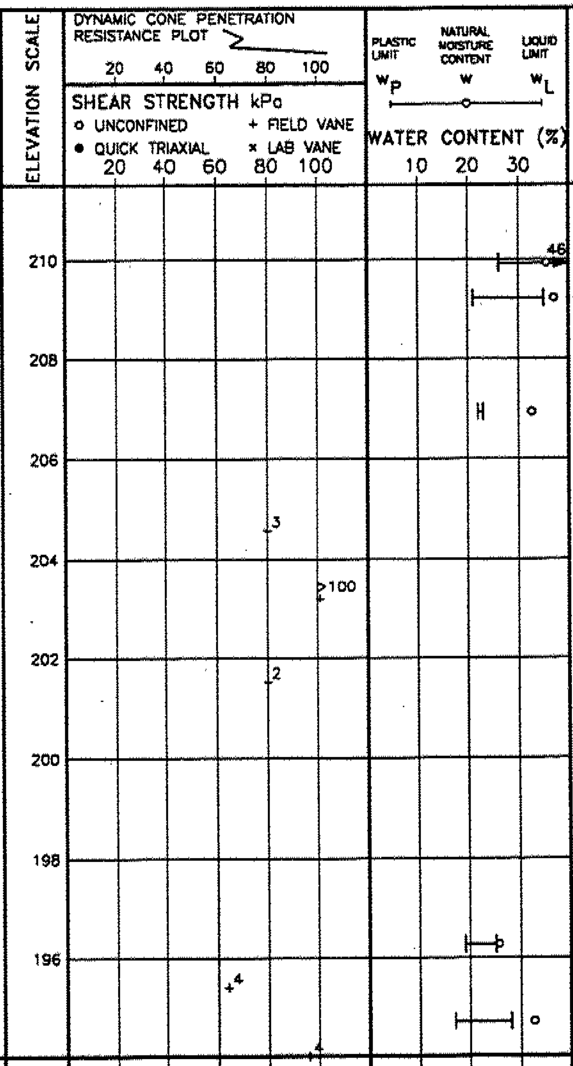
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
211.5	Water Surface
0.0	Water
210.0 / 1.5	Clayey Silt to Silty Clay with random layers of Silt trace Organics Brown, Very Stiff
207.0 / 4.5	Silt with interbedded seams/layers of Clayey Silt Brown / Grey Grey, Loose to Compact/ Stiff to Very Stiff
196.5 / 15.0	Clayey Silt with random layers of Silt Grey, Stiff to Very Stiff
194.1 / 17.4	End of Borehole • Sample 6, Wash Sample

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
1	SS	2	18.5	Org. 1.5%
2	SS	3	Org. 2.4%	0 0 40 60
3	WS	–		
4	TW	PH		
5	SS	15		
7	SS	13		0 0 92 8
8	WS	–		
9	SS	12		
10	WS	–		
11	SS	7		
12	WS	–		
13	SS	9		
14	WS	–		
15	TW	PH		
16	WS	–		
17	SS	10		
18	WS	–		
19	WS	–		
20	SS	9		
21	WS	–		
22	SS	11		

GROUND WATER CONDITIONS



+³, ×⁵ : Numbers refer to Sensitivity

20 15◇5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 5

1 OF 1 METRIC 58

W.P. 114-87-008
LOCATION Co-Ords: N 4 783 452.1; E 255 912.2
ORIGINATED BY PM
DIST 4 HWY 403
BOREHOLE TYPE Washboring, N Casing
COMPILED BY LD
DATUM Geodetic
DATE 92 07 22
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
211.5	Water Surface										
0.0	Water										
0.3	Clayey Silt to Silty Clay with random layers of Silt Grey – Brown, trace Organics, Very Stiff		1	SS	8		210		43	18.7	0 0 66 34
			2	WS	–			>100			Org. 1.9%
			3	SS	10						
			4	WS	–						
			5	TW	PH						
208.0			6	SS	23		208				
3.5	Silt, with interbedded seams/layers of Clayey Silt, Compact/Stiff to Very Stiff		7	WS	–						
206.7			8	SS	15						
4.8	End of Borehole										

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

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

RECORD OF BOREHOLE No 6

1 OF 1 METRIC 59

W.P. 114-87-008 LOCATION Co-Ords: N 4 783 488.4; E 255 928.5 ORIGINATED BY PM
DIST 4 HWY 403 BOREHOLE TYPE Washboring, N Casing COMPILED BY LD
DATUM Geodetic DATE 92 07 22 CHECKED BY PP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES						GR	SA	SI	CL
211.5	Water Surface												
0.0 210.3	Water												
1.2	Clayey Silt to Silty Clay with random layers of Silt Very Stiff Brown, trace Organics Grey	1	SS	4		210				0	0	62	38
		2	WS	–									
208.1		3	TW	PH									
3.4	Silt, with interbedded seams/layers of Clayey Silt	4	SS	30		208							
		5	WS	–									
206.7	Compac/ Stiff to Very Stiff	6	SS	16									
4.8	End of Borehole												

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

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

FOUNDATION INVESTIGATION REPORT

FOR

Twin Cell Culverts at the

Hwy 403 - Dunmark Lake East Crossing

WP 114-87-00C

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the Hwy 403 crossing at the northeastern "leg" of the Dunmark Lake. Twin cell culverts in combination with approach fills have been proposed to carry the highway over the lake. The structure is a component of the new Highway 403 that has been planned between Ancaster and Brantford.

SITE DESCRIPTION AND GEOLOGY

The site is located within and adjacent the northeastern area of the Dunmark Lake (hereafter identified as Dunmark Lake East) which is located between Dunmark Rd. to the south and Jerseyville Rd. to the north. The site, located within the Regional Municipality of Hamilton-Wentworth, is located approximately 1 kilometre east of Sunnyridge Rd.

The Dunmark Lake East is presently situated on private land bounded by agricultural farmland to the north and a recreational golf course (Heron Links) to the south. The lake is confined by tall deciduous tree forest to the north and to the east and west.

The waters of the Dunmark Lake East are murky and unclear. The depth of the water was approximately 1 metre at the time of the investigation, although this water level has been known to fluctuate throughout the year. In fact, the water level has been completely drawn down during past summers as a result of irrigation conducted at the Heron Links golf course. Wild grass and weed were present within the northern limits of the lake.

A drainage channel located north of Dunmark Lake East serves to drain the farmer's fields situated in this area. Existing native slopes immediately east and west of the Dunmark Lake East are approximately 16 metres to 10 metres in height respectively. The slopes are benched with gradients of approximately 4 to 5H:1V. The slopes, which are covered with trees show no signs of instability.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. The Dunmark Lake is located within a low lying basin created by glaciation. Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 30m.

INVESTIGATION PROCEDURE

GENERAL

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and laboratory testing program are discussed below.

Field Investigation

The fieldwork was carried out in two separate stages and hence within two different site mobilizations. In the initial stage, one borehole accompanied by two (2) dynamic cone penetration tests were advanced as part of a preliminary type investigation that occurred between 91 02 25-27. The borehole (BH5, formerly BH2, W.P. 114-87-00) was advanced to a depth of 33.4m, whilst the dynamic cone penetration test were advanced to depths of 6.1m and 18.3m. The deeper dynamic cone followed 6.1 metres of preaugering. The borehole and dynamic cone penetration test were advanced on land east of the existing Dunmark Lake employing a track mounted CME 55 equivalent drilling unit.

A more detailed investigation was conducted between 92 06 30 and 92 07 17 that included a total of four (4) additional boreholes. A dynamic cone penetration test also accompanied BH2 positioned at the proposed culvert outlet location. The boreholes were advanced to depths ranging from 15.4m to 30.2m. The two (2) boreholes advanced at the culvert inlet and outlet (BH1 and BH2) penetrated the bedrock. The two (2) other boreholes were advanced in conjunction with the proposed west approach embankment fills (BH3 and BH4) and represent the shallower boreholes. The dynamic cone penetration test accompanying BH2 was advanced to a depth of 15.5m.

The water in the Dunmark Lake at the time of the investigation necessitated a raft and a more portable, lighter diamond drill unit. The diamond drill used was a skid mounted Boyles Bros No. 1 unit that had a weight of approximately 900 kg. Conventional diamond drilling techniques were used to advance three (3) boreholes offshore. The process involves driving the casing with a 63.5 kg. hammer and washboring within the driven casing. NW casing was driven within the overburden.

The one borehole (BH4) on land west of the proposed culvert structure was advanced using a track mounted CME 75 equivalent drilling unit. Hollow stem augering techniques were used to penetrate the overburden at this location.

Both disturbed and undisturbed samples were retrieved in the overburden at the site generally at 1.5m intervals within the surficial 15 metres or so and at 3.0 metre intervals thereafter. Disturbed subsoil samples were retrieved using a 50mm diameter split spoon sampler driven in accordance with the Standard Penetration Test (SPT - ASTM D1586). Relatively undisturbed samples were also retrieved within the weaker cohesive materials using a 57mm diameter thin wall sampler. The thin wall sampler was pushed manually into the soil in accordance with procedures outlined in ASTM D1587. Wash samples were also randomly taken during the washboring process.

Rock core was also retrieved at two borehole locations using conventional rock coring techniques. A BXL core barrel within BW casing was used to retrieve up to 1.6 metres of rock core.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samplers were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

Rock core samples were also identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock core were placed in standard rock core boxes and carefully transported to the laboratory.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The tests were carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Groundwater levels were determined by monitoring the water levels in the open boreholes and the lake level was also monitored throughout the duration of the field investigation. All boreholes were backfilled upon completion of the fieldwork.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans. A boat was required to enable the borehole layout offshore. Long steel rods were used to stake the boreholes in the waters of Dunmark Lake East.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples. These tests are summarized in Table 1 below.

Table 1 - Physical/Mechanical Property Tests

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Test
2) Particle Size Analysis	
3) Natural Moisture Contents	
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Detailed rock core logging was conducted in the laboratory by an in-house resident geologist. The rock core logging included descriptions of colour, grain size, bedding, jointing and strength.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

GENERAL

Subsurface conditions across the site are uniform and generally consists of extensive stratifications of silt and clayey silt to silty clay. The surficial deposit which underlies the standing waters (approximately 0.7m to 1.0m at the time of the investigation) of Dunmark Lake consists of a cohesive clayey silt to silty clay. The thickness of this deposit ranges from 4.4 metres to 7.6 metres. The stratum has a stiff to very stiff consistency.

The surficial cohesive clayey silt to silty clay deposit is underlain by a plastic silt that has a loose to compact denseness and contains random interbedded layers of stiff to very stiff clayey silt to silty clay. The thickness of this stratum ranges from 9.0m to 12.2m.

The plastic silt stratum is in turn underlain by a second cohesive clayey silt to silty clay deposit which has a thickness ranging from 9.1m to 10.4m. This deposit also contains random layers of plastic silt. The cohesive material has a stiff to very stiff consistency.

A lower silt deposit with random layers of clayey silt to silty clay underlies the lower cohesive clayey silt to silty clay deposit. This deposit has a relatively shallow thickness of 1.5 to 3.2 metres.

Underlying the lower cohesionless silt deposit and overlying the bedrock exists a shallow deposit consisting of a heterogeneous mixture of silt, sand and gravel. This deposit is a glacial till and has a thickness of 1m to 2.9m. This deposit has a compact denseness.

The bedrock surface is uniform across the site and exists at an elevation of 182.6m to 182.8m. The bedrock is a medium strong dolostone.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700C-A.* A subsoil stratigraphical profile and a stratigraphical section at the proposed structure that illustrates the subsurface conditions at the site are also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and section and also on the individual Record of Borehole sheets in the Appendix.

Water

Approximately 0.7m to 1m of standing water was present in the Dunmark Lake East at the time of the investigation. The water was murky and calm at the time of the investigation.

Clayey Silt to Silty Clay

The surficial stratum at the site consists of a cohesive clayey silt to silty clay that extends for a thickness ranging from 4.4 metres to 7.6 metres below the ground surface. The deposit also contains traces of organics within the surficial three (3) metres. Inorganic silt extending approximately 0.6m in thickness also exists surficially at the site.

The colour of the deposit is primarily brown to mottled grey-brown but changes to grey at a depth as shallow as 3.7 metres at some locations. This varying colour is indicative of different depths of oxidation at the site and possible sedimentation in the Dunmark Lake.

* DWG NO 2 OF THE CONTRACT DWG'S

A grain size distribution envelope produced by mechanical sieve and hydrometer analysis for this material is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed primarily of grain sizes smaller than 75 micrometres. The grain size distribution envelope illustrates silt percentages ranging from 47% to 73% and clay percentages ranging from 24% to 53%. In general, the clay fraction is in the order of 24 to 28%. A grain size distribution curve illustrating the gradation of a representative sample of the surficial inorganic silt is also shown on Figure 1. The curve shows a large silt percentage (89%). In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below. Atterberg Limit Tests were carried out on the fine grained soil and the results are plotted on Figure 2 in the Appendix and summarized on Table 2 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 2 - Atterberg Limit Test Results
Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	28 - 35	4
Liquid Limit (w_L%)	34 - 49	4
Plastic Limit (w_P%)	19 - 20	4
Plasticity Index (Ip%)	15 - 29	4
Bulk Unit Weight (kN/m^3)	19	2

The test results clearly reveal that the soil has a plasticity ranging from low to intermediate and hence can be categorized as clayey silt (CL) to silty clay (CI). Natural moisture contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state. Figure 2 also illustrates that inorganic silt (MH) and organic clay of high plasticity was encountered within the surficial 1 to 2 metres of the deposit. The inorganic silt is perhaps an indication of some sedimentation within the lake and the organic clay is a reflection of the traces of organics in the material.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests. In general, the material exhibited sufficient shear strengths that inhibited the torquing of the vane. Hence, undrained shear strengths are generally in excess of 120 kPa.

The 'N' values as determined by the Standard Penetration Test ranged from 4 blows/0.3m to 19 blows/0.3m. Within the lake, the 'N' values were lower and generally less than 10 blows/0.3m. The larger 'N' values above 10 blows/0.3m were retrieved on land.

The compressibility characteristics of the clayey silt to silty clay stratum were determined by conducting a one dimensional consolidation tests on a representative sample. The results of the test are shown graphically on Figure 3 in the Appendix. The consolidations curve is plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load (log p). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (P_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The consolidation curve reveals a preconsolidation pressure of 290 kPa. The effective overburden pressure for the sample tested is approximately 35 kPa. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 255 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.16.

Silt with random layers of Clayey Silt to Silty Clay

A cohesionless silt of quick dilatancy interbedded with random layers of cohesive clayey silt to silty clay exists below the clayey silt to silty clay surficial deposit and extends to depths ranging from 13.9m to 19.8m below the ground or water surface. The thickness of this stratum ranges from 9.0m to 12.2m and the cohesive interbedded seams or layers are approximately 25mm to 150mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Grain size distribution envelopes as determined by mechanical sieve and hydrometer analysis for both the cohesionless host silt and cohesive layers of clayey silt to silty clay are shown on Figure 4 in the Appendix. The envelopes illustrate silt percentages ranging up to 85% with traces of clay for the silt material and for the cohesive layers, silt percentages range from 57% to 75%, but are generally in the 71 to 75% range with a clay fraction ranging from 20 to 43%, but generally in the 20 to 29% range. In accordance with the MTO Soil Classification system, materials with gradations of this nature are categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 5 and summarized in Table 3 below. Natural Moisture Contents are also included in the Table below.

Table 3 - Atterberg Limit Test Results
Silt with random layers of
Clayey Silt to Silty Clay

a) Silt

	Range	# of Tests
Natural Moisture Content (w%)	21 - 30	9
Liquid Limit (w_L%)	19 - 23	9
Plastic Limit (w_P%)	17 - 22	9
Plasticity Index (Ip%)	1 - 5	9

b) Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	24 - 35	8
Liquid Limit (w_L%)	23 - 34	8
Plastic Limit (w_P%)	15 - 18	8
Plasticity Index (Ip%)	6 - 21	8

The test results reveal that the main component of the deposit behaves as a plastic silt (ML to CL-ML). The interbedded cohesive layers have a low to intermediate plasticity (CL to CI).

In situ vane tests conducted within this deposit revealed undrained shear strength values ranging from 54 kPa to in excess of 120 kPa. Most of the undrained shear strength values were within the 100 kPa range. These larger undrained shear strength values are attributable to the significant silt percentages within the deposit. However, it can be concluded that the cohesive interlayers have a stiff to very stiff consistency.

The sensitivity of the soil also determined by the vane test ranged from 3 to 5 indicating a low to moderately sensitive cohesive material.

The 'N' values as derived from the Standard Penetration Test ranged from 5 blows/0.3m to 21 blows/0.3m. Based on these 'N' values it can be stated that the deposit has a loose to compact denseness.

Clayey Silt to Silty Clay with random layers of Silt

Underlying the plastic silt with random layers of clayey silt to silty clay, a second cohesive deposit consisting of clayey silt to silty clay exists. This deposit also contains random layers of plastic silt ranging in thickness from 50mm to 150mm. The thickness of the entire stratum ranges from 9.1m to 10.4m.

A grain size distribution envelope illustrating the gradation of the cohesive material of this deposit is shown on Figure 6 in the Appendix. The envelope clearly illustrates that the material is fine grained with grain sizes less than 75 micrometres. Clay percentages range from 17% to 53%, but generally between 17% and 38% and silt percentages range from 47% to 83%, but generally between 62% and 83% within the cohesive material.

In accordance with the MTO Soil Classification system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 4 below. Natural Moisture Contents are also included in the Table below.

Table 4 - Clayey Silt to Silty Clay with
random layers of Silt

	Range	# of Tests
Natural Moisture Content (w%)	25 - 43	7
Liquid Limit (w_L%)	22 - 39	7
Plastic Limit (w_P%)	16 - 19	7
Plasticity Index (Ip%)	6 - 20	7

The test results reveal that the cohesive soil has a low to intermediate plasticity and hence can be classified as a clayey silt to silty clay. Natural moisture contents are generally similar to the liquid limit of the soil.

The consistency and undrained shear strength of the soil was determined by conducting in situ vane tests and interpretation of SPT 'N' values. Undrained shear strengths were generally equal to or greater than 100 kPa indicating a stiff to very stiff consistency. The 'N' values as determined by the SPT ranged from 10 blows/0.3m to 36 blows/0.3m confirming the stiff to very stiff consistency.

Silt with random layers of Clayey Silt to Silty Clay

A second cohesionless deposit of plastic silt exists beneath the lower cohesive deposit of clayey silt to silty clay. This deposit has a relatively shallow thickness ranging from 1.5m to 3.2m. Once again, stratification is present within the deposit and random layers of cohesive clayey silt to silty clay ranging in thickness from 25mm to 100mm are present within the deposit. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Grain size distribution curves and Atterberg Limit Tests were conducted on representative samples of this material and are shown on Figures 8 and 9. The figures reveal that the host silt has large silt percentages (94%) and that the material behaves as an inorganic silt of low plasticity. The interbedded cohesive layer tested revealed a clay fraction of 69% and an intermediate plasticity (Cl).

Standard Penetration Tests conducted within this deposit reveal 'N' values ranging from 7 blows/0.3m to 20 blows/0.3m indicating a loose to compact state of denseness.

Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till)

Underlying the lower cohesionless silt deposit with random layers of clayey silt to silty clay and immediately overlying the bedrock, a deposit comprised of a heterogeneous mixture of silt, sand and gravel exists. This deposit is a glacial till and as is inherent of these types of materials, is unsorted and unstratified. The thickness of this deposit is relatively small and ranges from 1 to 2.9 metres.

The main component of this deposit is the silt material. Traces of sand and gravel are also present within the deposit. Although not encountered during the investigation boulders and cobbles are characteristic components of glacial till deposits and hence can exist in the deposit.

Bedrock

The bedrock consisting of a "vuggy" dolostone of the Amabel Formation underlies the heterogeneous mixture of silt, sand and gravel deposit at an elevation of approximately 182.6m to 182.8m. The bedrock was cored in BXL size up to 1.6m in depth.

The dolostone bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey to medium dark grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Description of Rock Core".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and physical index property testing. Recoveries were in the order of 92% to 93% and RQD's were in the order of 87% to 88% indicating that the rock is of good quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes and monitoring the lake level throughout the duration of the field investigation. The lake level ranged from Elevation 211 metres to 211.4 metres.

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, P. Martin and L. Dametto, Student Engineers utilizing equipment owned and operated by Atcost Soil Drilling. Logging of the rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by Mr. M. Devata, Chief Foundation Engineer.

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M. DEVATA
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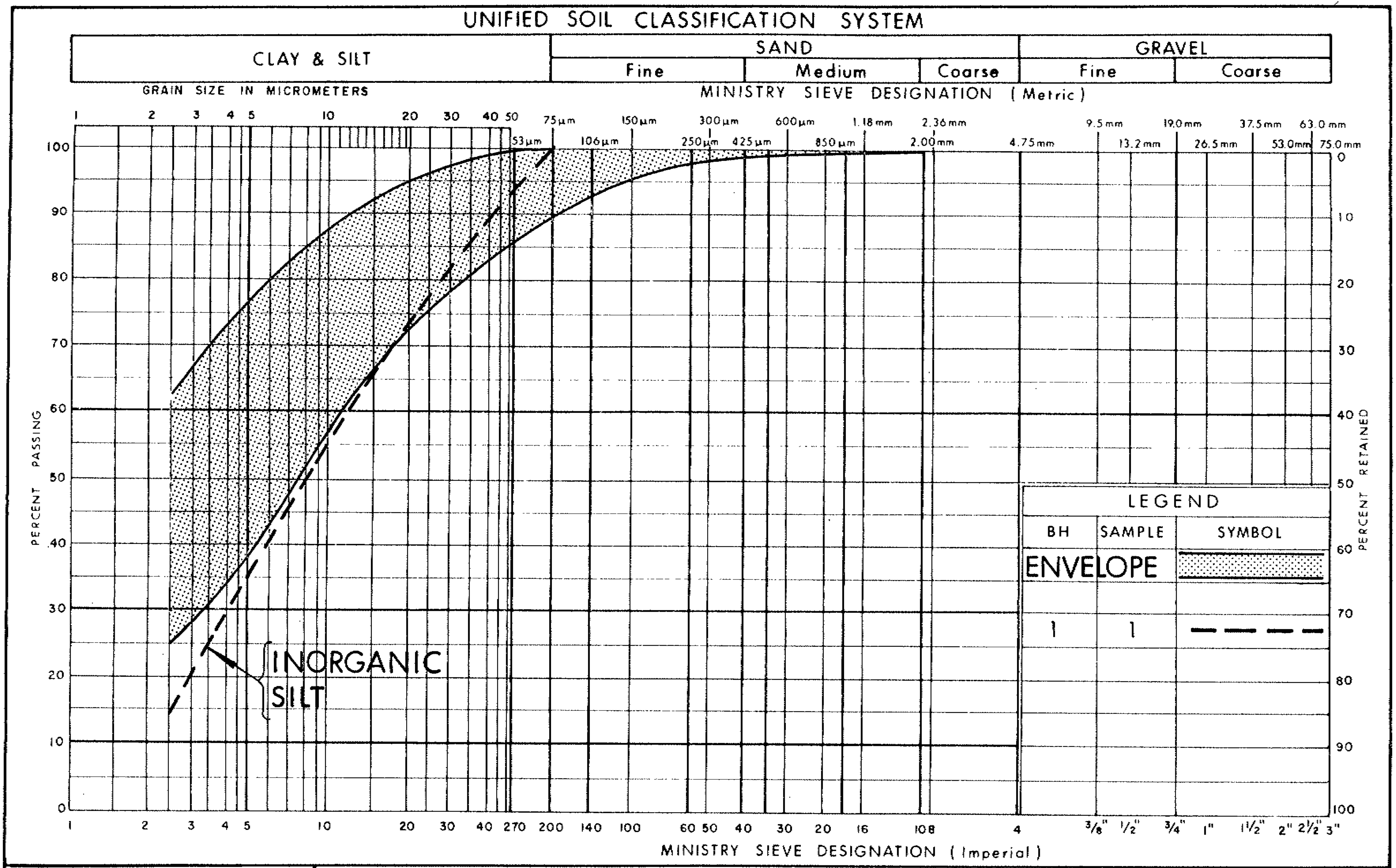
M. Devata

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

APPENDIX



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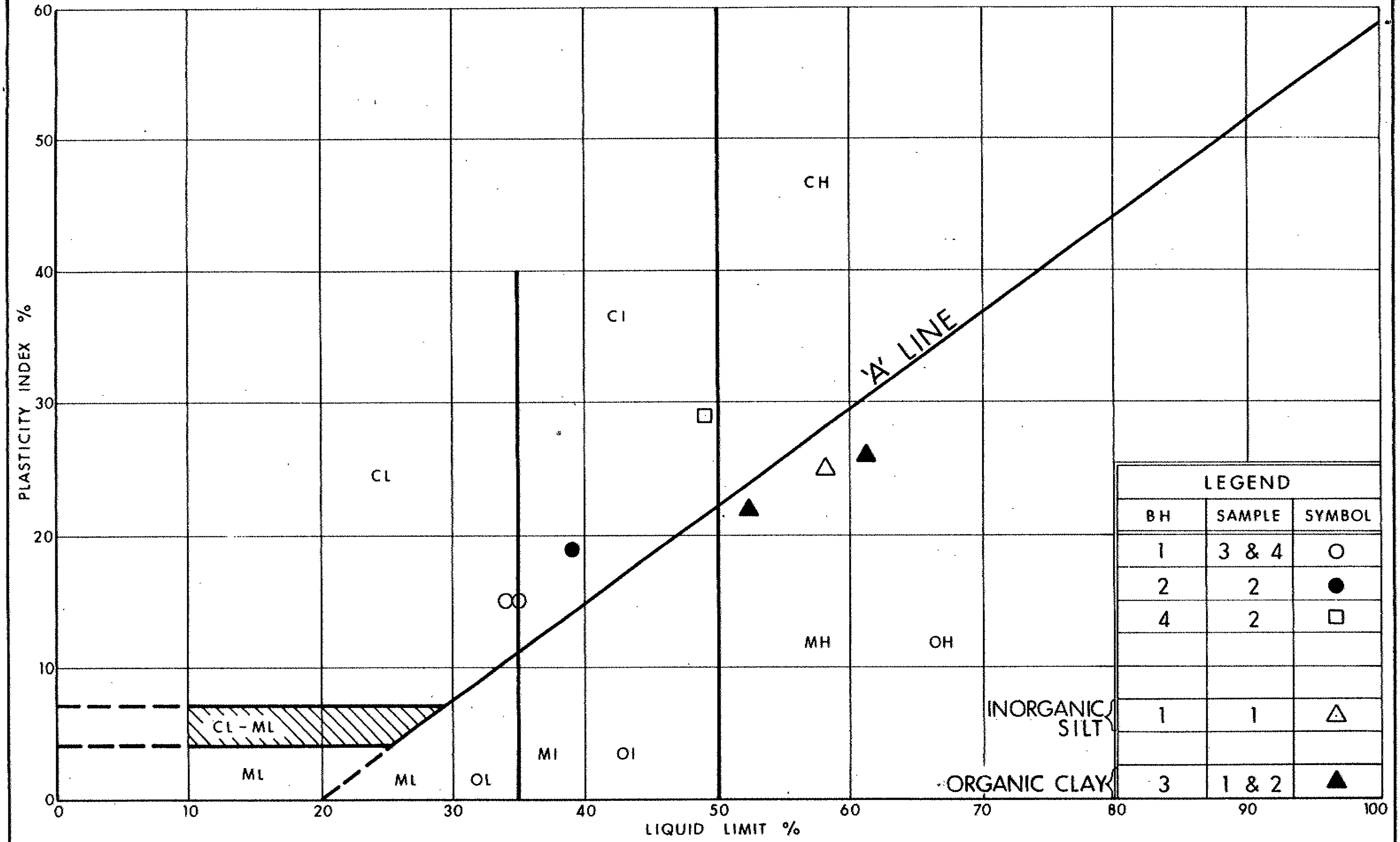
GRAIN SIZE DISTRIBUTION

CLAYEY SILT TO SILTY CLAY

FIG No 1

W P 114-87-00C



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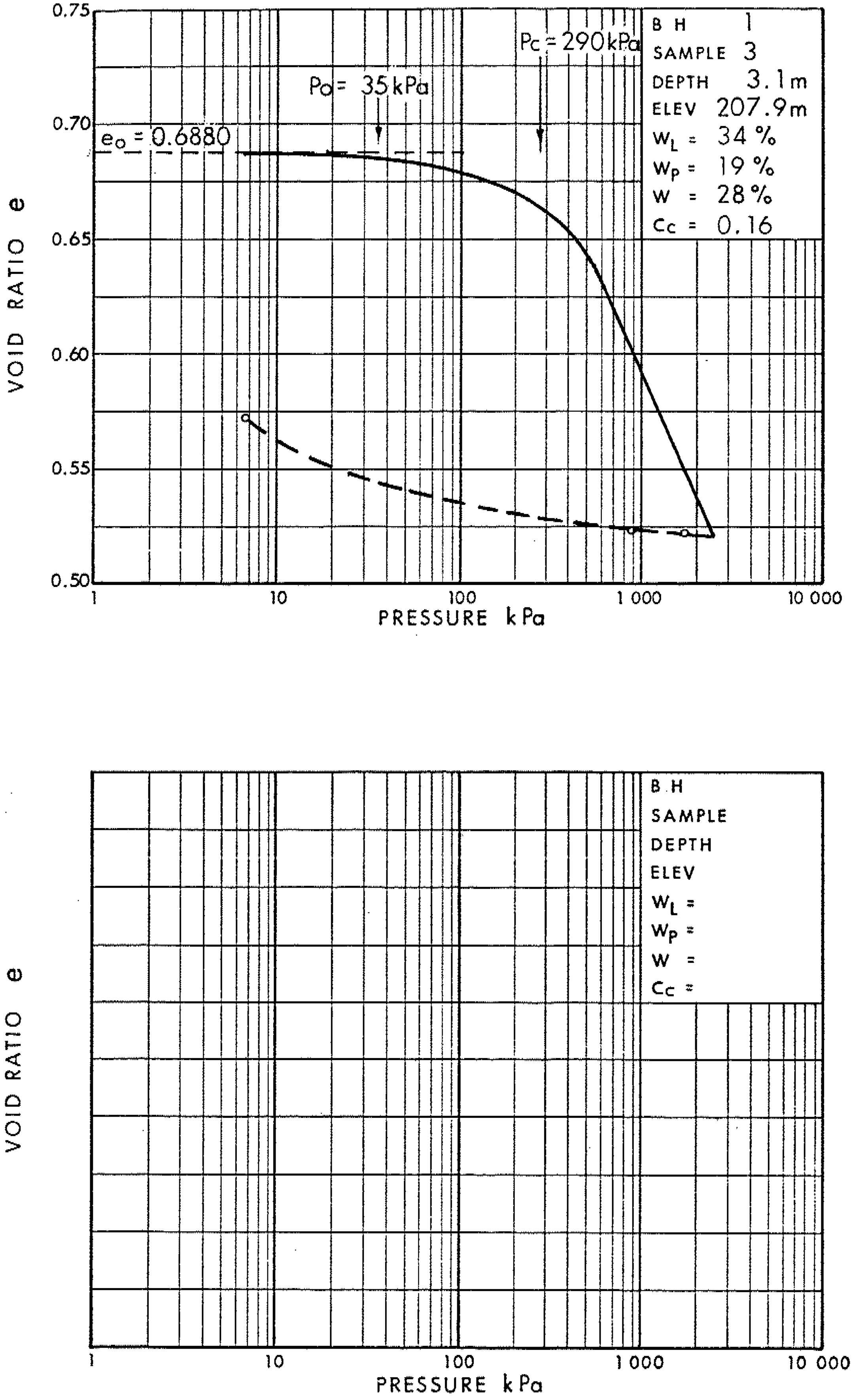
PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY

FIG No 2

W P 114 -87-00 C

VOID RATIO-PRESSURE CURVES

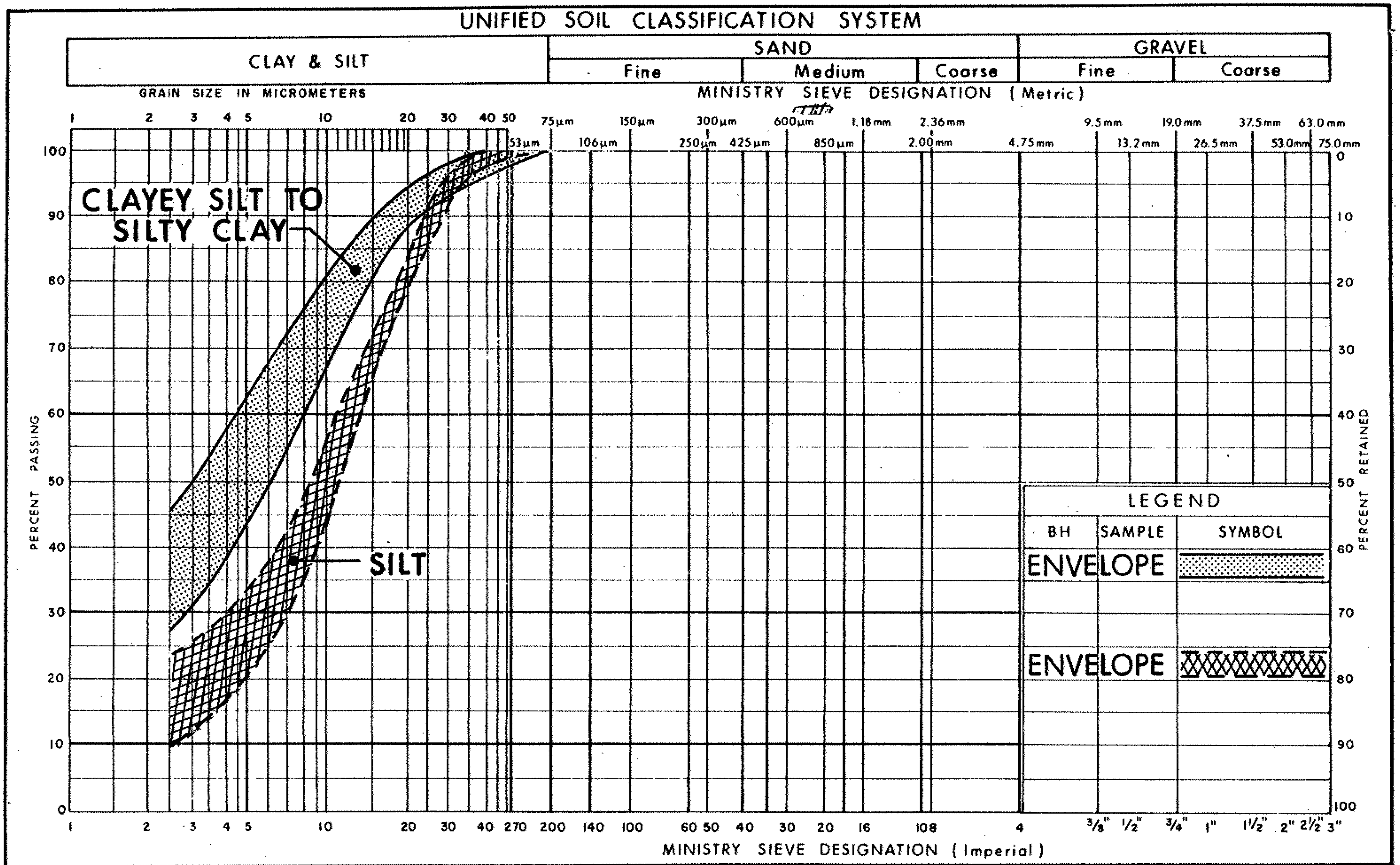


B H 1
SAMPLE 3
DEPTH 3.1m
ELEV 207.9m
W_L = 34 %
W_P = 19 %
W = 28 %
Cc = 0.16

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

Fig 3

78 12 M



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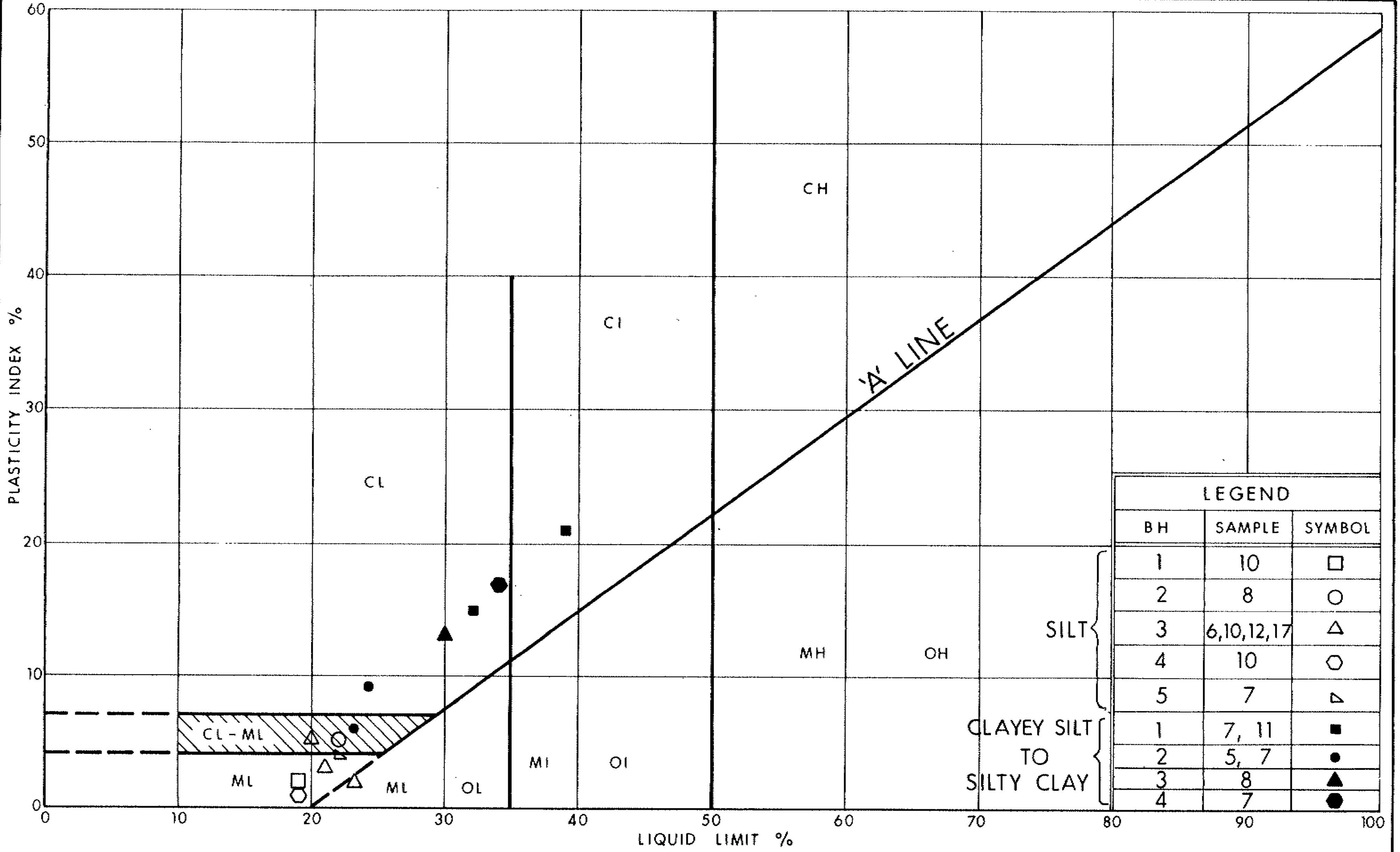
GRAIN SIZE DISTRIBUTION

SILT, WITH RANDOM LAYERS OF
CLAYEY SILT TO SILTY CLAY

FIG No 4

W P 114-87-00C



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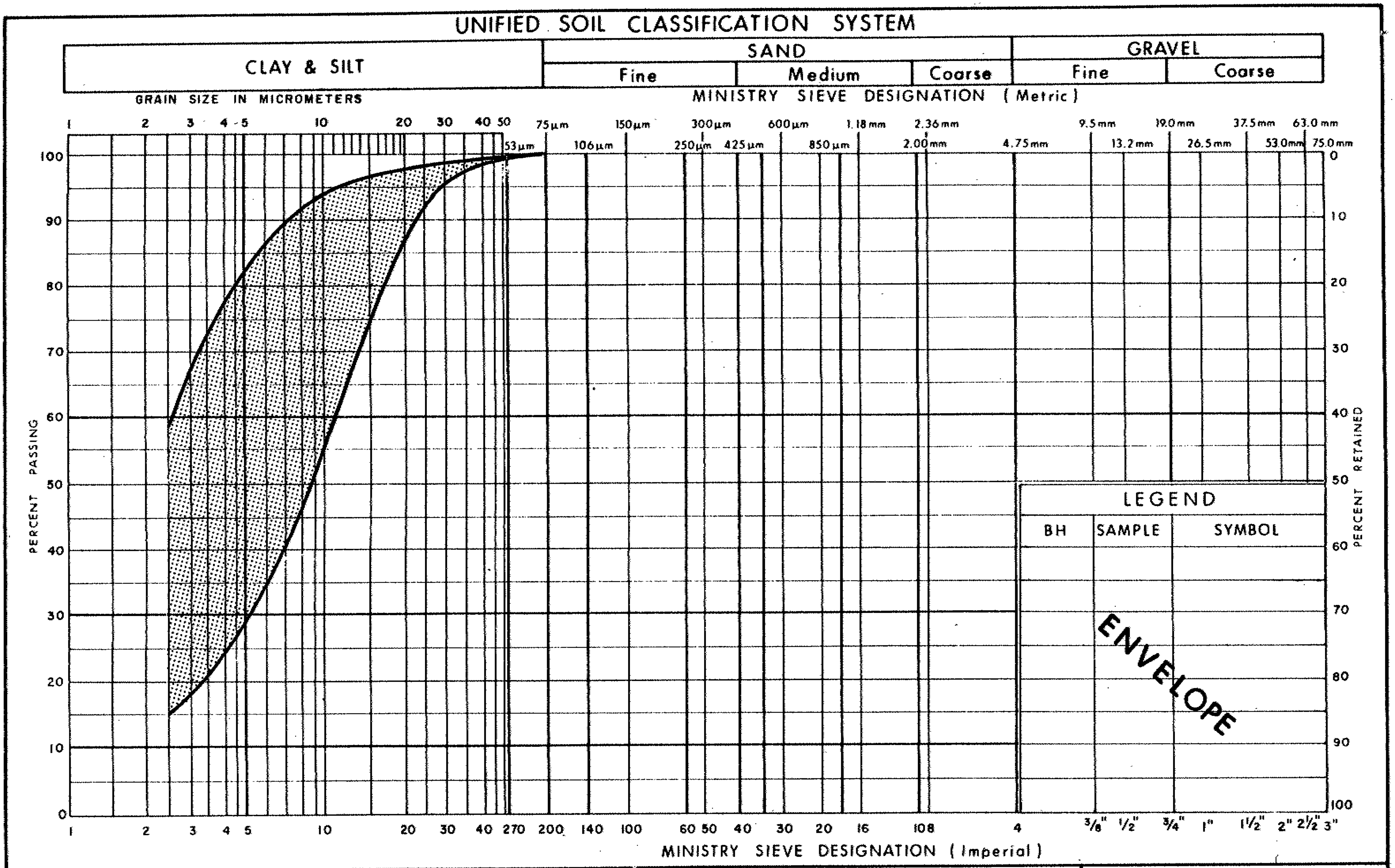
PLASTICITY CHART
SILT, WITH RANDOM LAYERS OF CLAYEY SILT TO SILTY CLAY

FIG No 5

W P 114-87-00C

78 12 M



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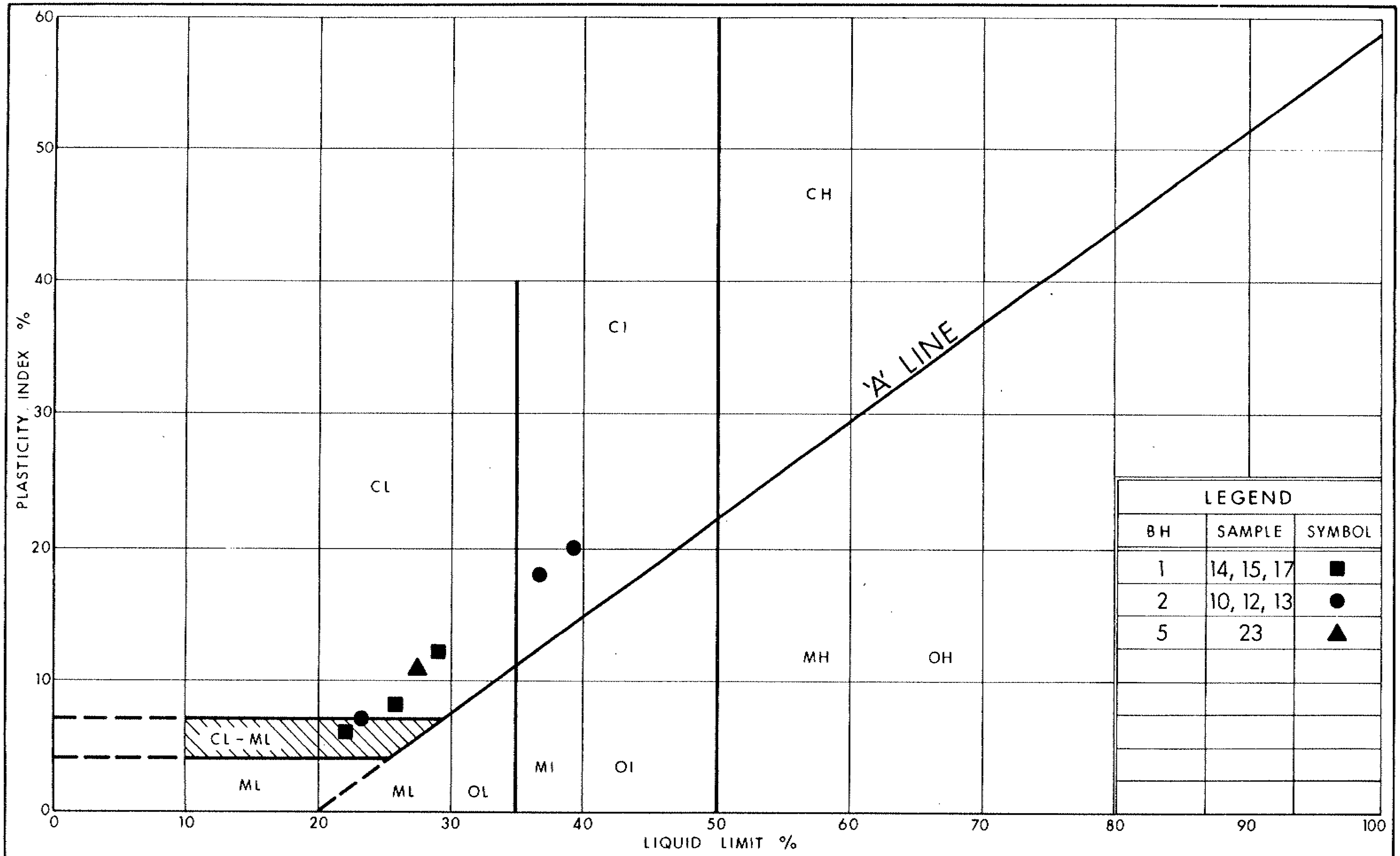
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM LAYERS OF SILT

FIG No 6

W P 114-87-00C

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
1	14, 15, 17	■
2	10, 12, 13	●
5	23	▲

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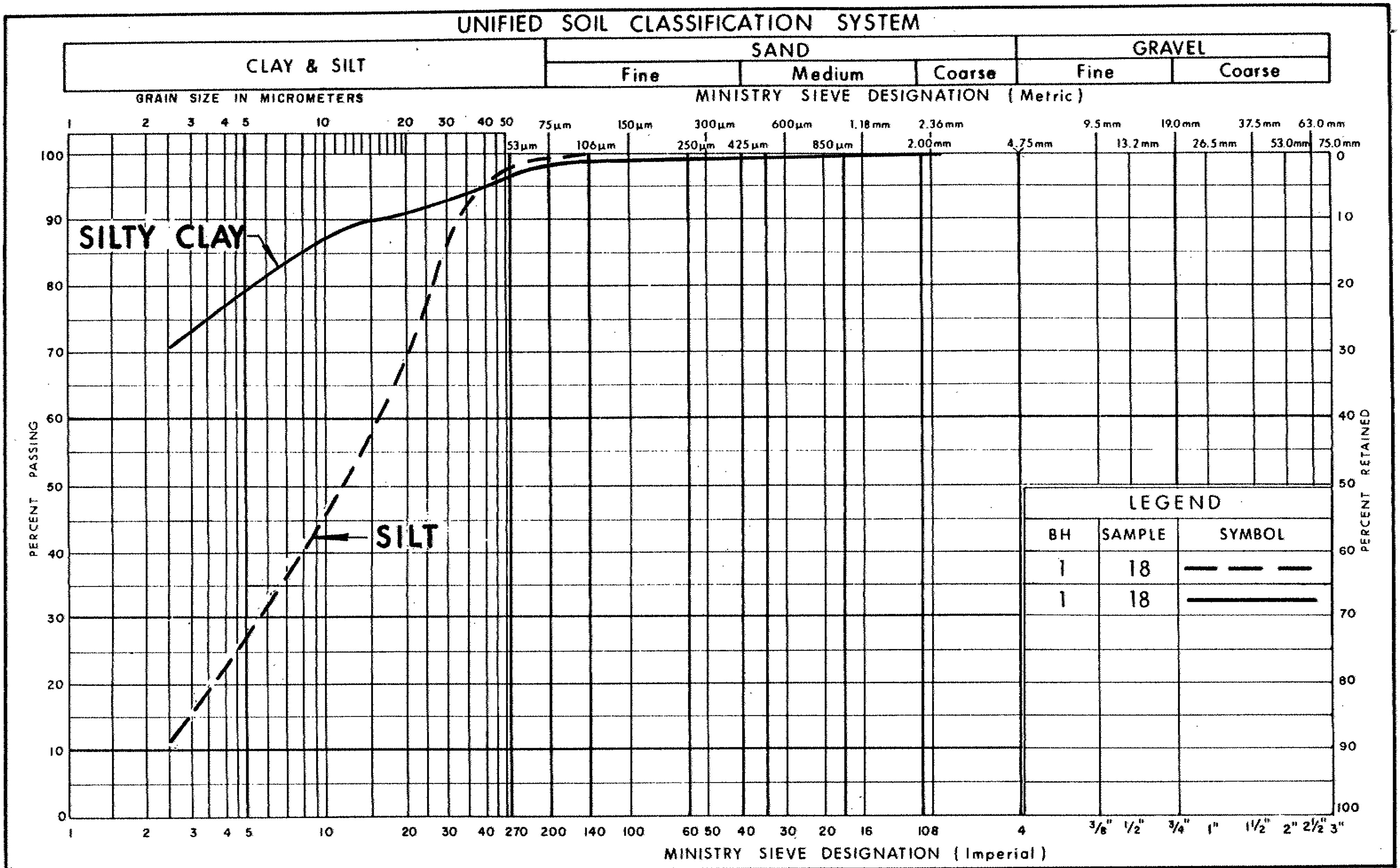
PLASTICITY CHART
CLAYEY SILT TO SILTY CLAY
WITH RANDOM LAYERS OF SILT

FIG No 7
W P 114-87-00 C

78 12 M



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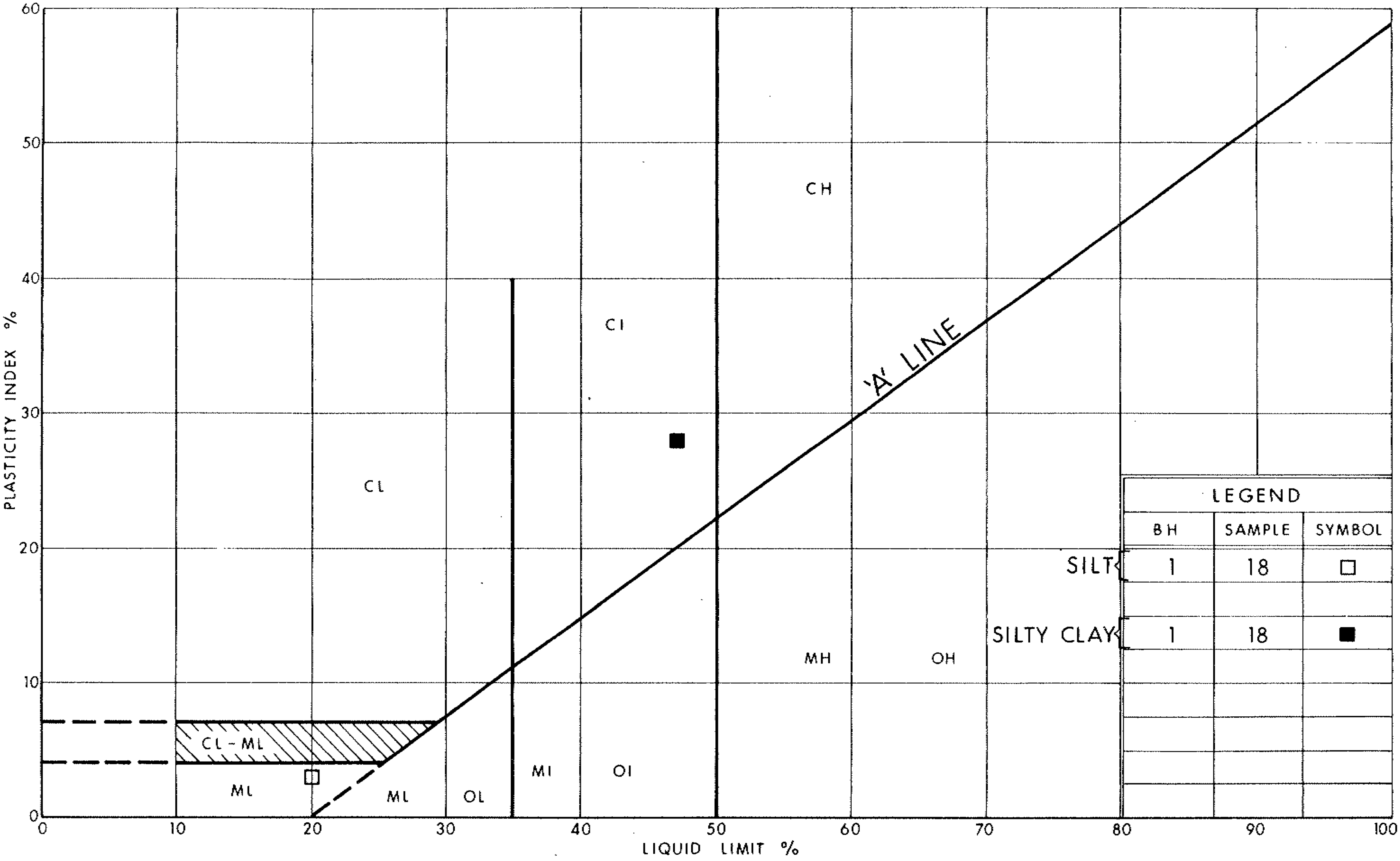
GRAIN SIZE DISTRIBUTION
SILT, WITH RANDOM LAYERS OF CLAYEY SILT TO SILTY CLAY

FIG No 8

W P 114-87-00 C

Oct 75, FF-S-21



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PLASTICITY CHART

SILT, WITH RANDOM LAYERS OF CLAYEY SILT TO SILTY CLAY

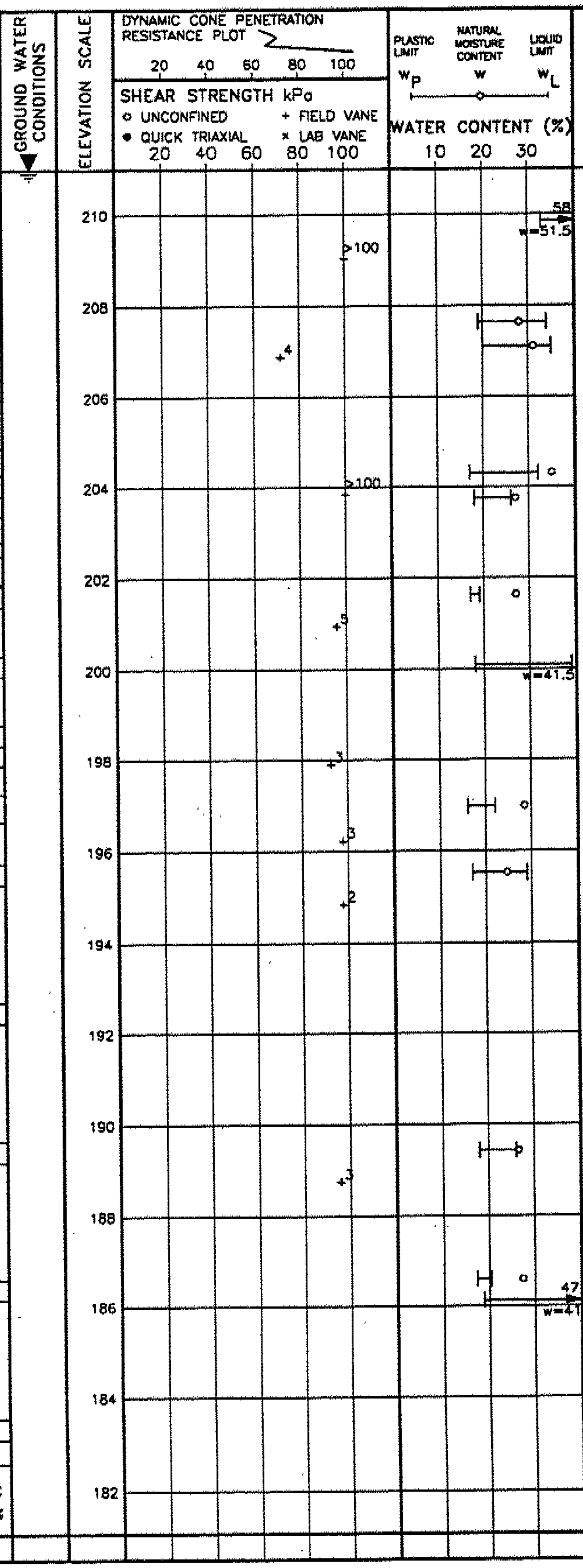
FIG No 9

W P 114-87-00 C

RECORD OF BOREHOLE No 1

1 OF 1 METRIC 87

W.P. 114-87-00C
LOCATION Co-ords: N 4 783 775.8 E 256 510.8
ORIGINATED BY PM
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, NW/BW Casing, Washbore, BXL Rock Core
COMPILED BY TS
DATUM Geodetic
DATE 92 07 09-15
CHECKED BY PP



ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
211.0	Water Surface								
0.0 210.3	Water								
0.7	Organic	1	SS	5	Org. 4.6%	0	0	89	11
	Grey	2	TW	PM					
	Clayey Silt to Silty Clay Stiff to Very Stiff				Org. 0.6%				
	Brown	3	TW	PM	19.1	0	12	65	23
206.4	Grey	4	SS	6		0	5	67	28
4.6	Silt with random layers of Clayey Silt to Silty Clay Grey, Loose to Compact with Stiff to Very Stiff Layers	5	SS	12					
		6	TW	PH		6	1	73	20
		7	SS	9		0	0	75	25
		8	TW	PM					
		9	SS	15					
		10	SS	10					
		11	SS	10					
		12	SS	9					
197.0		13	WS	–					
14.0	Clayey Silt to Silty Clay with random layers of Silt Grey, Stiff to Very Stiff	14	SS	14		0	0	83	17
		15	SS	14		0	0	80	20
		16	SS	17					
186.6		17	SS	12		0	0	94	6
24.4	Silt with random layers of Clayey Silt to Silty Clay Grey, Compact	18	SS	14		0	2	30	68
183.6 27.4	Het. Mixt. of Silt, Sand and Gravel (Glacial Till), Compact	19	SS	28					
182.6 28.4	Bedrock – Dolostone Light Grey, Unweathered Medium Strong	20	RC	REC 93%		RQD = 88%			
181.1 29.9	End of Borehole								

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

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

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 2

1 OF 1 METRIC 88

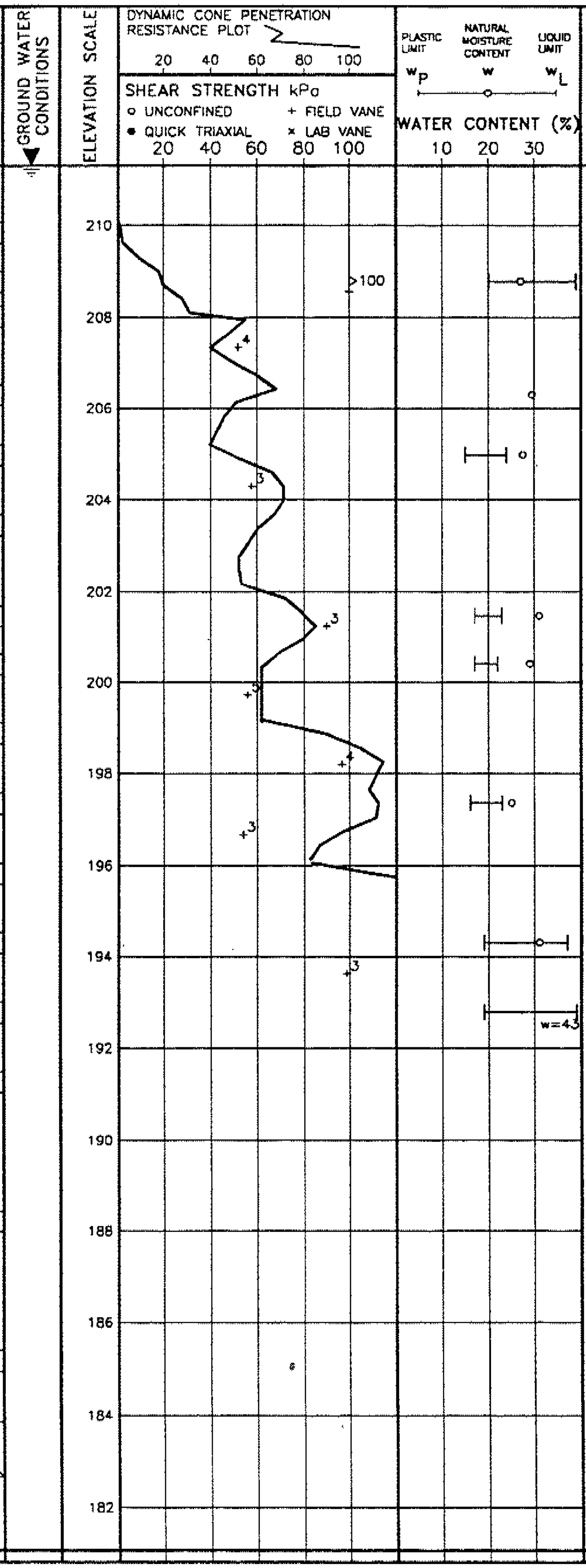
W.P. 114-87-00C	LOCATION Co-ords: N 4 783 696.2 E 256 522.6	ORIGINATED BY PM
DIST 4 HWY 403	BOREHOLE TYPE NW/BW Casing, Washbore, BXL Rock Core & Dynamic Cone Test	COMPILED BY TS
DATUM Geodetic	DATE 92 06 30 – 92 07 03	CHECKED BY PP

SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
211.3	Water Surface
0.0 210.3	Water
1.0	Clayey Silt to Silty Clay Stiff to Very Stiff Grey, Organic Brown Grey
206.4 4.9	Silt with random layers of Clayey Silt to Silty Clay Grey, Loose to Compact with Stiff to Very Stiff Layers
197.4 13.9	Clayey Silt to Silty Clay with random layers of Silt Grey, Stiff to Very Stiff
188.3 23.0	Silt with random layers of Clayey Silt to Silty Clay Compact
185.1 26.2	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till) Grey, Compact
182.7 28.6	Bedrock – Dolostone Grey, Unweathered Medium Strong
181.1 ~~30.2~~	~~End of Borehole~~

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL	REMARKS
1	SS	4						
2	SS	9	19.0	0	6	69	25	
3	SS	5						
4	SS	12		0	0	86	14	
5	SS	9		0	0	75	25	
6	SS	15						
7	SS	10		0	0	71	29	
8	SS	11		0	0	77	23	
9	SS	9						
10	SS	8		0	0	82	18	
11	SS	17						
12	SS	10		0	0	62	38	
13	SS	36		0	0	47	53	
14	SS	36						
15	SS	12						
16	SS	20						
17	WS	–						
~~18~~	~~SS~~	•						
19	RC	REC 92%						RQD = 87%



• Sampler Bouncing

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

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

RECORD OF BOREHOLE No 3

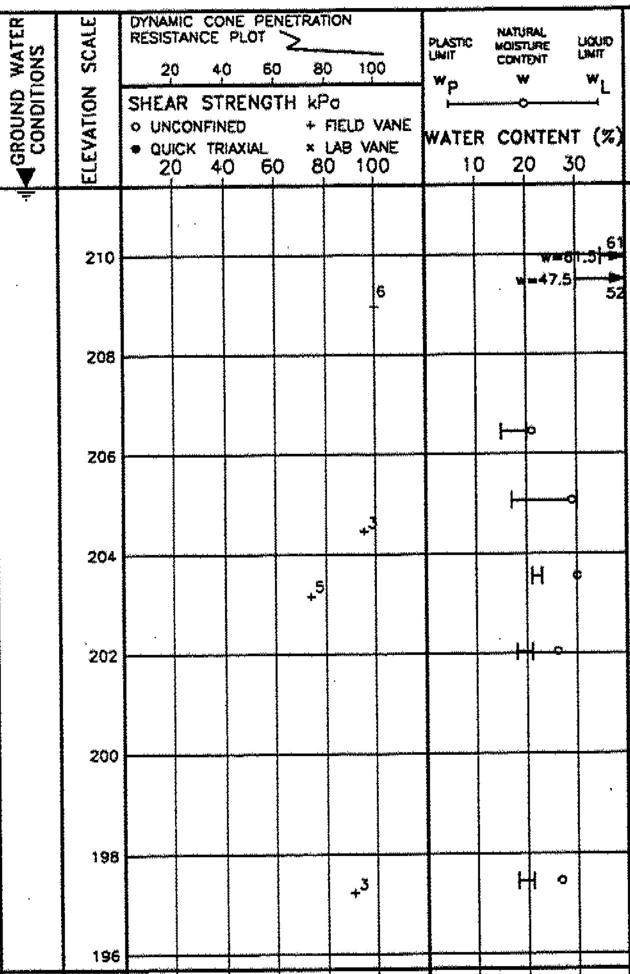
1 OF 1

METRIC

89

W.P. 114-87-00C
LOCATION Co-ords: N 4 783 749.8 E 256 483.6
ORIGINATED BY PM
DIST 4 HWY 403
BOREHOLE TYPE NW/BW Casing, Washbore
COMPILED BY TS
DATUM Geodetic
DATE 92 07 16-17
CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
211.4	Water Surface								
0.0	Water								
210.4 1.0	Clayey Silt to Silty Clay Brown, Stiff to Very Stiff	1	SS	4	Org 5.0%				
		2	SS	6	3.6%	0	2	73	25
		3	WS	-					
	Trace Organics	4	SS	9					
		5	WS	-					
206.7 4.7	Brown Grey	6	SS	9					
		7	WS	-					
		8	SS	7		0	0	57	43
	Silt with random layers of Clayey Silt to Silty Clay	9	WS	-					
		10	SS	12					
		11	WS	-					
	Loose to Compact with Stiff to Very Stiff Layers	12	SS	21		0	0	84	16
		13	WS	-					
		14	SS	18					
		15	WS	-					
		16	SS	20					
197.5 13.9	Clayey Silt to Silty Clay with random layers of Silt Grey, Stiff to Very Stiff	17	SS	11		0	0	85	15
195.7		18	SS	18					
15.7	End of Borehole								



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

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

RECORD OF BOREHOLE No 4

1 OF 1 METRIC 90

W.P. 114-87-00C	LOCATION Co-ords: N 4 783 697.1 E 256 469.2		ORIGINATED BY LD
DIST 4	HWY 403	BOREHOLE TYPE HS Auger	COMPILED BY TS
DATUM Geodetic	DATE 92 07 13		CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE: DESCRIPTION	STRAT PLOT	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L / WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
215.5	Ground Surface										
0.0	Clayey Silt to Silty Clay Brown, Very Stiff					*					
			1	SS	10		214				
								>100			
	trace Organics		2	SS	9				49		0 0 47 53
							212	>100			
211.1 4.4	Brown Grey		3	SS	11						
							210				
			4	SS	16						0 0 92 8
	Silt with random layers of Clayey Silt to Silty Clay		5	SS	9		208				
	Loose to Compact with Siff to Very Stiff Layers		6	SS	6		206	>100			
			7	SS	6						0 0 85 15
							204	>100			
			8	SS	7			>100			
							202				
			9	SS	7						
200.1			10	SS	5						0 0 88 12
15.4	End of Borehole * GWL Not Established										

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

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

RECORD OF BOREHOLE No 5

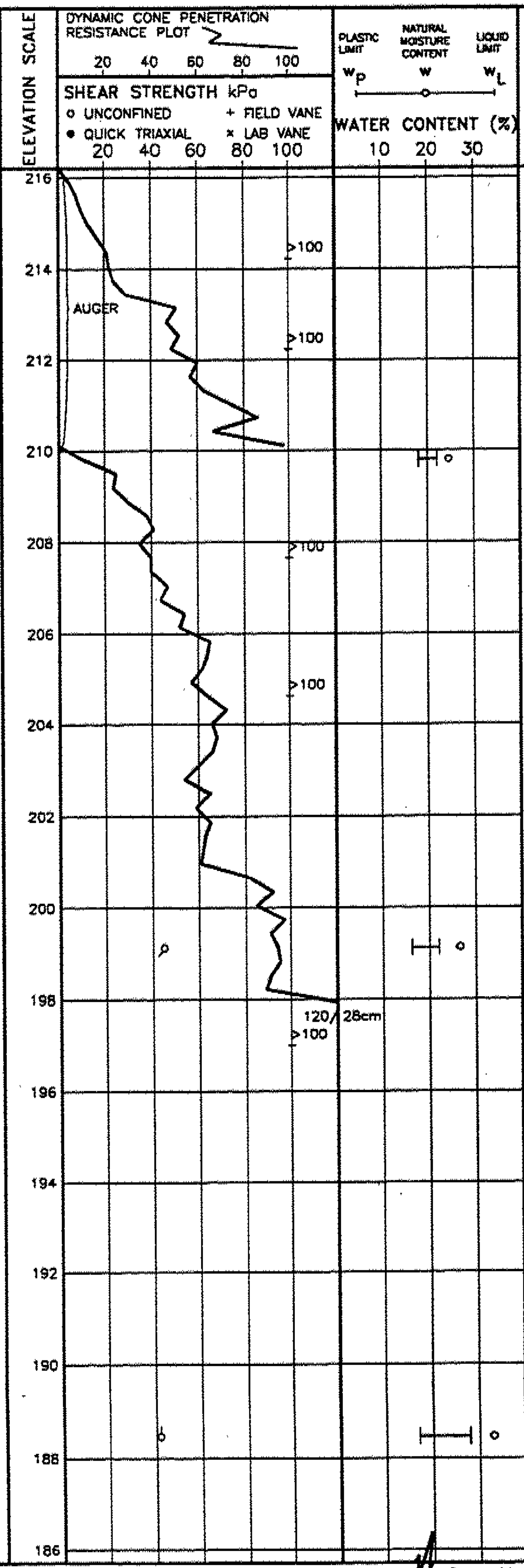
(Formerly BH2, W.P. 114-87-00)

1 OF 2

METRIC 91

W.P. 114-87-00C
LOCATION Co-ords: N 4 783 740.1 E 256 588.1
ORIGINATED BY MP
DIST 4 HWY 403
BOREHOLE TYPE HS Auger & Dynamic Cone Test
COMPILED BY TS
DATUM Geodetic
DATE 91 02 25-27
CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
216.2	Ground Surface									
0.0	Trace Organics	1	SS	6						
	Clayey Silt to Silty Clay Very Stiff	2	SS	14	▼*					
		3	TW	PH						
		4	SS	11						
	Brown Grey	5	SS	17						
		6	SS	19						
		7	TW	PH		19.8	0	0	92	8
208.6										
7.6	Silt with random layers of Clayey Silt to Silty Clay Loose to Compact with Very Stiff Layers	8	SS	8						
		9	SS	7						
		10	SS	8						
		11	SS	10						
		12	SS	6						
		13	SS	10						
		14	SS	7						
		15	SS	9						
		16	TW	PH		19.9				
		17	SS	6						
196.4										
19.8	Clayey Silt to Silty Clay with random layers of Silt Grey, Very Stiff	18	SS	11						
		19	SS	14						
		20	SS	18						
		21	SS	11						
		22	SS	13						
		23	TW	PH		19.9	0	0	67	33
187.2										
29.0	Silt with random layers of Clayey Silt to Silty Clay. Loose	24	SS	7						
185.7 30.5	Continued									



Continued

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

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

RECORD OF BOREHOLE No 5

(Formerly BH2, W.P. 114-87-00)

2 OF 2

METRIC 92

W.P. 114-87-00C

LOCATION Co-ords: N 4 783 740.1 E 256 588.1

ORIGINATED BY MP

DIST 4 HWY 403

BOREHOLE TYPE HS Auger & Dynamic Cone Test

COMPILED BY TS

DATUM Geodetic

DATE 91 02 25-27

CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
185.7	Continued										
30.5	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till)		25	SS	27						
			26	SS	22		184				
182.8	Grey, Compact				**						
33.4	End of Borehole • 91 02 28 ** Sampler Bouncing (Probable Bedrock)										

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

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

ROCK CORE DESCRIPTION
WP 114-87-00C

Page 1 of 1

	CORE RECOVERY				CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	20	28.40-29.92	93	88	28.40-29.92	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to dipping, undulating to planar, smooth to rough.
2	19	28.63-30.23	92	87	28.63-30.23	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderate to close spaced, flat, undulating to planar, smooth to rough.

***CR** = CORE RECOVERY
***RQD** = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

FOUNDATION INVESTIGATION REPORT

FOR

BIG CREEK CULVERT

WP 114-87-00(D), Hwy 403

District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted in conjunction with the proposed triple cell culvert and associated embankment fills at the Hwy 403 - Big Creek crossing. The Big Creek crossing is one of many structures proposed in connection with the new Hwy 403 between Ancaster and Brantford.

SITE DESCRIPTION AND GEOLOGY

The site is situated along the proposed Hwy 403 alignment between Jerseyville Rd. and Hwy 2 in the north-south direction and between Alberton Rd. and Sunnyridge Rd. in the east-west direction. The site is located within the Town of Ancaster, Regional Municipality of Hamilton-Wentworth.

The site is located within a pronounced valley that houses the existing meandering Big Creek. The Big Creek which is approximately 3 metres in width and 2 metres in depth, flows in a southerly direction. At the time of the investigation, the water level in the creek was approximately 1 metre.

Ridges of overburden confine the relatively flat valley terrain. The ridges are approximately 15 to 20 metres higher than the valley floor. The ridges are covered by either agricultural crops, tall deciduous trees or grassland. The valley terrain is covered by tall grasses.

The area surrounding the site is occupied by farmland. Both dairy farming and agricultural farming is evident on this farmland.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound. Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 25m.

INVESTIGATION PROCEDURE

General

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and the laboratory testing program are discussed below.

Field Investigation

The fieldwork for this project was carried out under two separate stages. The initial stage was planned as part of a preliminary investigation study and consisted of one (1) sampled borehole advanced to a depth of 24.8 metres. The borehole was advanced between 76 03 23 and 76 03 24.

A more detailed investigation was recently conducted between 92 07 06 and 92 07 08. The investigation consisted of a total of five (5) sampled boreholes. Two of the boreholes were positioned at the proposed culvert structure location. One of these boreholes (BH3) was accompanied by a dynamic cone penetration test. The three (3) remaining boreholes were advanced at the proposed embankment fill locations adjacent the culvert structure. The boreholes were advanced to depths ranging from 24.1m to 28.3m below the ground surface. The dynamic cone penetration test was advanced to a depth of 22.1 metres.

All boreholes were advanced using track mounted drilling units equivalent to Central Mining Equipment (CME) 55 machines. Conventional hollow stem augering techniques were used to advance the boreholes in the overburden. Conventional rock coring techniques using BW and NW casing and BXL and NXL core barrels were used to retrieve up to 3 metres of rock core at the two (2) structure foundation locations.

Subsoil samples were generally retrieved at 1.5m intervals for the surficial 18m or so and at 3m intervals thereafter. Both disturbed and undisturbed subsoil samples were retrieved throughout the overburden. Disturbed subsoil samples were retrieved in accordance with the Standard Penetration Test (ASTM D1586) using a standard split spoon sampler driven into the soil and undisturbed subsoil samples were retrieved using a thin wall sampler pushed hydraulically into the soil in accordance with procedures outlined in ASTM D1587.

All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

In situ vane tests were also carried out to determine the undrained shear strength at selected intervals between the subsoil sample retrieval. The test was carried out in accordance with ASTM D2573 employing the standard MTO 'N' vane. Remoulded shear strengths were also obtained allowing the determination of soil sensitivity.

Rock core samples were also identified in the field and physical index properties were determined by visual examination and also by measurement of rock quality designations (RQD's) and rock core recovery. All rock core were placed in standard rock core boxes and carefully transported to the laboratory.

Groundwater levels were determined by monitoring the water levels in the open boreholes throughout the duration of the field investigation. All boreholes were backfilled upon completion of the fieldwork.

The survey related to the location and elevation of the individual boreholes was provided by Central Region Surveys and Plans.

Laboratory Analyses

All subsoil samples were carefully visually examined in the laboratory in accordance with the procedures outlined in the Visual Method described in Chapter 2 of the MTO Soil Classification Manual. The behaviour, gradation and other pertinent physical and mechanical properties of the soil were determined by conducting the appropriate laboratory tests on representative samples as identified in Table 1 below.

Table 1 - Physical/Mechanical Property Tests

Physical Properties	Mechanical Properties
1) Atterberg Limit Tests	1) Consolidation Tests
2) Particle Size Analysis	2) Unconfined Compression Tests
3) Natural Moisture Contents	3) Undrained Unconsolidated Tests
4) Bulk Unit Weights	

Sample preparation and testing were conducted in accordance with the MTO Laboratory Testing Manual.

Detailed rock core logging was conducted in the laboratory by an in-house resident geologist. The rock core logging includes descriptions of colour, grain size, bedding, jointing and strength.

Laboratory test results have been summarized below in the subsequent section of this report entitled "Subsurface Conditions" and are illustrated on the corresponding boreholes and figures included in the Appendix to this report.

SUBSURFACE CONDITIONS

General

Subsurface conditions across the site are uniform and consist of four (4) distinct layers of overburden overlying bedrock. The surficial deposit consists of a shallow veneer of cohesive clayey silt that extends to depths ranging from 2.7m to 5.0m below the ground surface. The deposit which has a firm to very stiff consistency also contains random interbeds of plastic silt approximately 25mm to 100mm in thickness.

The surficial cohesive clayey silt deposit is underlain by a plastic silt that has a very loose to loose denseness and contains random interbedded seams or layers of cohesive clayey silt. This deposit has a thickness ranging from 7.2m to 10.7m.

The plastic silt stratum is in turn underlain by a deposit consisting of layers of plastic silt interbedded with a cohesive clayey silt to silty clay. Pronounced and distinct stratified layers up to 300mm are present within this deposit. The deposit has a thickness ranging from 9.1m to 12.2m.

A very thin deposit comprised of a heterogeneous mixture of silt, sand and gravel underlies the layered silt and clayey silt to silty clay stratum. The deposit has a thickness of approximately

0.4m to 2.8m and extends to the bedrock surface which exists at an elevation of 183.0m to 184.4m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 1148700D-A*. A subsoil stratigraphical profile and a stratigraphical section at the proposed structure that illustrates the subsurface conditions at the site are also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and section and also on the individual Record of Boreholes sheets in the Appendix.

Clayey Silt with random layers of Silt

The surficial stratum at the site consists of a cohesive clayey silt that extends for a thickness ranging from 2.7 to 5.0 metres. The deposit also contains thin layers or seams of plastic silt generally 25mm to 100mm in thickness. The deposit has been oxidized for the surficial 2.3 to 4.3 metres, which is most of the deposit, and is brown in colour within this depth. Below this depth, the deposit is unoxidized and grey in colour. A grain sized distribution envelope produced by mechanical sieve and hydrometer analysis is shown in Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed primarily of grain sizes smaller than 75 micrometres. The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 62% to 85% and clay percentages ranging from 15% to 38%. In general, silt percentages exceed 75% and the clay fraction is in the order of 15% to 22%. In view of the fact that more than 50% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below.

* DWG NO 2 OF THE CONTRACT DWG'S

Atterberg Limit Test were carried out on the fine grained soil (less than 425 micrometres) and the results are plotted on Figure 2 in the Appendix and summarized on Table 2 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 2 - Atterberg Limit Test Results - Clayey Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	23 - 31	8
Liquid Limit (w_L%)	23 - 42	8
Plastic Limit (w_P%)	16 - 20	8
Plasticity Index (Ip%)	7 - 23	8
Bulk Unit Weight (kN/m^3) γ	18.8 - 20	4

The test results clearly reveal that the soil has a liquid limit ranging from 23% to 42% but generally, the liquid limit is less than or equal to 30%. Therefore, the soil generally has a low plasticity and can hence be categorized as a clayey silt (CL). Natural moisture contents are generally close to the liquid limit of the soil.

Random layers of silt are also present within the surficial deposit. The silt interbeds typically display quick dilatancy, no toughness and a low dry strength.

The consistency and undrained shear strength of the soil were determined by conducting in situ vane tests. The results of these tests are plotted on the individual Record of Borehole Sheets and summarized on the Undrained Shear Strength vs. Elevation graph shown on Figure 3 in the Appendix. In situ vane test results are erratic and undrained shear strengths ranged from as low as 24 kPa, determined in isolated zones only, to as high as exceeding 120 kPa (depths at which the vane could not be torqued). It is believed that the lower values may have been the result of disturbance induced during the testing and the larger values were the result of silt interbeds. As Figure 3 illustrates, undrained shear strengths generally range from 50 kPa to 100 kPa, indicating a stiff consistency.

The sensitivity of the soil is defined by the ratio of the undrained strength in the undisturbed state to the undrained strength, at the same water content, in the remoulded state. Sensitivities of this soil ranged from 2 to 5 indicating a low to moderately sensitive material.

The 'N' values as determined by the Standard Penetration Test ranged from 1 blow/0.3m to 8 blows/0.3m suggesting a low penetration resistance and hence confirming the lower strengths and weaker consistencies of this soil.

Silt with interbedded seams/layers of Clayey Silt

A cohesionless silt of quick dilatancy interbedded with thin seams and also layers of cohesive clayey silt exists below the surficial clayey silt deposit and extends to depths ranging from 12.2m to 13.7m below the ground surface. The thickness of this stratum ranges from 7.2m to 10.7m and the cohesive interbedded seams are approximately 25mm to 75mm in thickness, whilst the layers are up to 150mm in thickness. The cohesive interbedded layers are distinct and easily recognized and determined by visual index property identification tests. The layers have a darker grey colour, low plasticity, medium toughness, stickiness, shine and medium to high dry strength.

Random thin layers of sand and gravel are also present within this deposit. These layers are generally less than 0.5 metres in thickness.

Grain size distribution envelopes as determined by mechanical sieve and hydrometer analysis illustrating the gradations of the cohesionless silt material and the cohesive seams/layers are shown on Figure 4 in the Appendix. The envelope illustrates that the host silt has percentages of silt ranging between 83% and 89% with clay fractions ranging from 10% to 16%. The cohesive interlayers and seams have silt percentages ranging from 39% to 83% and clay fractions ranging from 13% to 61%. The silty soil does however exhibit plasticity and the results of Atterberg Limit Tests carried out on some representative samples of this material and also the cohesive interbeds are summarized in Table 3 below and illustrated in Figure 4.

Table 3 - Atterberg Limit Test Results - Silt with interbedded seams/ layers of Clayey Silt

a) Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	22 - 29	6
Liquid Limit (w_L%)	19 - 24	6
Plastic Limit (w_P%)	16 - 20	6
Plasticity Index (Ip%)	2 - 5	6
Liquidity Index (I_L%)	0.5 - 3.5	6

b) Clayey Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	26 - 42	7
Liquid Limit (w_L%)	21 - 34	7
Plastic Limit (w_P%)	14 - 18	7
Plasticity Index (Ip%)	7 - 16	7
Liquidity Index (I_L%)	1.1 - 1.9	7

The test results reveal that the host soil is a plastic silt (ML to CL-ML categorization) and the interbedded seams/layers are of low plasticity and hence can be categorized as a clayey silt. Natural moisture contents exceed the liquid limit of the soil for both soils as reflected by liquidity indices exceeding unity.

Due to the percentages of clay and the seams/layers of interbedded clayey silt, vanes could be torqued and in situ tests were conducted. The results revealed undrained shear strength values ranging from approximately 60 to >120 kPa. The results, in general, were erratic and devoid of any pattern which is perhaps indicative of the high silt percentages.

The 'N' values as derived from the Standard Penetration test reveal values ranging from 3 to 10 blows/0.3m. This is representative of a very loose to loose state of denseness.

Layered Silt and Clayey Silt to Silty Clay

The plastic silt deposit is underlain by a deposit that consists of alternate layers of plastic silt and cohesive clayey silt to silty clay. The stratification of these layers is readily evident with the silt layers being lighter grey in colour and quickly dilatant. The cohesive layers, on the other hand, are darker grey in colour and exhibit no dilatancy.

The thickness of the entire stratum ranges from 9.1m to 12.2m across the site. The stratified layers range from approximately 100mm to 300mm in thickness.

Grain size distribution envelopes for both layered materials are shown on Figure 6 in the Appendix. The envelopes illustrate that the silt layers contain silt percentages ranging from 88% to 90% and clay percentages ranging from 9% to 12%. The cohesive interbeds, as expected have larger clay percentages ranging from 22% to 58% and smaller silt percentages ranging from 42% to 78%.

In accordance with the MTO Soil Classification system, materials with gradations of this nature are categorized by their behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 4 below. Natural Moisture Contents are also included in the Table below.

Table 4 - Atterberg Limit Test Results
Layered Silt and Clayey Silt to Silty Clay

a) Silt

Test	Range	# of Tests
Natural Moisture Content (w%)	25 - 29	3
Liquid Limit (w_L%)	20 - 24	3
Plastic Limit (w_P%)	18 - 22	3
Plasticity Index (Ip%)	2 - 3	3
Liquidity Index (I_L%)	3.3 - 5.5	3

b) Clayey Silt to Silty Clay

Test	Range	# of Tests
Natural Moisture Content (w%)	25 - 38	10
Liquid Limit (w_L%)	24 - 50	10
Plastic Limit (w_P%)	15 - 22	10
Plasticity Index (Ip%)	10 - 28	10
Liquidity Index (I_L%)	0.8 - 1.6	10

The test results reveal interbeds of inorganic silt of low plasticity (ML) and clayey silt to silty clay (CL to CI). Liquidity indices for both materials are close or exceed unity indicating that natural moisture contents are high and exceed the liquid limit of the soil.

In situ vane tests were conducted within this deposit to determine the consistency and undrained shear strength of the cohesive material. Undrained shear strengths ranged from 70 kPa to in excess of 120 kPa. Interpretation of the larger undrained shear strength values must consider the influence of the silt interbeds. These interbeds inhibit the advancement of the test and therefore erratic shear strength profiles are produced. In general, it can be concluded that the cohesive interbeds have a stiff to very stiff consistency.

The compressibility characteristics of the clayey silt to silty clay layers were determined by conducting a one dimensional consolidation test on a representative sample of the material. The results of the test are shown graphically on Figure 8 in the Appendix. The consolidation curve is plotted on semi-logarithmic paper with the void ratio (e) plotted against the applied load (log p). This form of plotting the load-deformation properties of the soil has the advantage of enabling the determination of the preconsolidation pressure (p_c) which is defined as the maximum pressure that the soil has experienced in its stress history. Considerable consolidation settlements can occur once the threshold preconsolidation pressure is exceeded.

The consolidation curve reveals a preconsolidation pressure of approximately 650 kPa. The effective overburden pressure for the sample tested is approximately 160 kPa. Therefore, the soil has been preconsolidated in the past to an effective pressure approximately 490 kPa in excess of the existing effective overburden pressure. The compression index of the material (C_c) is of small magnitude and equivalent to 0.64.

Heterogeneous Mixture of Silt, Sand, and Gravel (Glacial Till)

Underlying the layered silt and clayey silt to silty clay stratum and immediately overlying the bedrock, a deposit comprised of a heterogeneous mixture of silt, sand and gravel exists. This deposit is a glacial till and as is inherent of these types of materials, is unsorted and unstratified. The thickness of this deposit is relatively small and ranges from 0.4m to 2.8m.

The main component of this deposit is the silt material and this is illustrated on the grain size distribution curves shown on Figure 9 in the Appendix. The envelope includes particle sizes up to 26.5mm (coarse gravel) and hence excludes the boulder and cobble sizes. The envelope reveals that the silt material comprises up to approximately 76% of the deposit and the remainder of the deposit is comprised of traces of clay, some sand and traces/some gravel. Although boulders and cobbles were not encountered during the investigation, they are characteristic components of glacial tills and hence can be encountered in this deposit.

Atterberg Limit tests were conducted on the fine grained portion of the deposit (less than 425 micrometres) to determine if the material exhibits any plasticity. The results are plotted on the individual borehole logs (see BH's 2 and BH's 3) and confirm that the fine grained portion of the deposit has a low plasticity and can be categorized as a plastic silt (ML).

Bedrock

The bedrock, consisting of a "vuggy" dolostone of the Amabel Formation underlies the heterogeneous mixture of silt, sand and gravel deposit at an elevation of approximately 183m to 184.4m. The bedrock was cored at two borehole locations, BH1 and BH3 in BXL and NXL sizes respectively. Up to 3 metres of core was retrieved.

The dolostone bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey to medium dark grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Description of Rock Core".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and physical index property testing. Recoveries ranged from 97% to 100% and RQD's ranged from 83% to 98% indicating that the rock is of good to excellent quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of the more recent investigation were approximately 2 metres below the ground surface (Elevation 206.5m).

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto, Student Engineer, utilizing equipment owned and operated by Malone's Soil Samples and Dominion Soil Investigation. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by Mr. M. Devata, Chief Foundation Engineer.

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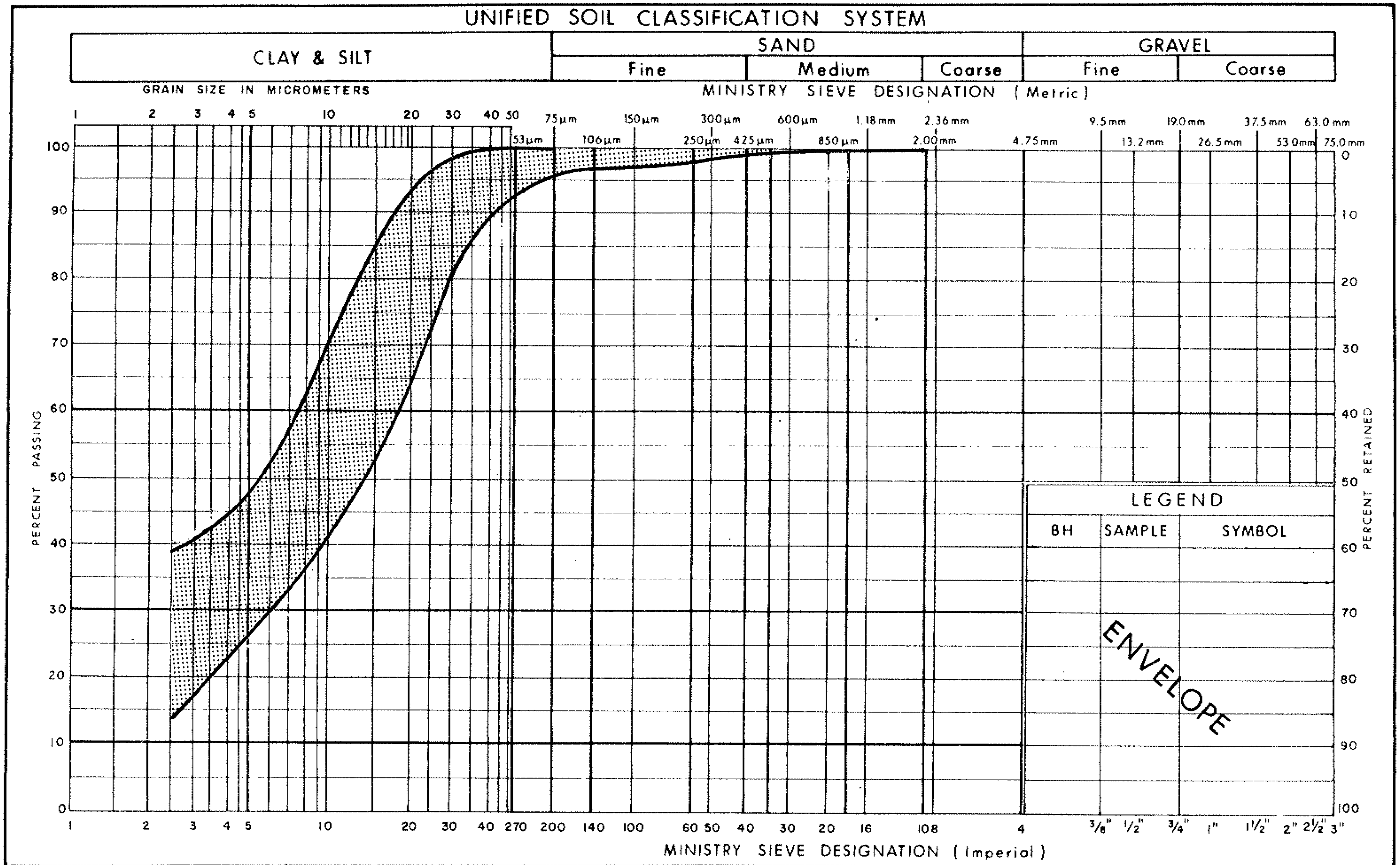
APPENDIX



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GRAIN SIZE DISTRIBUTION

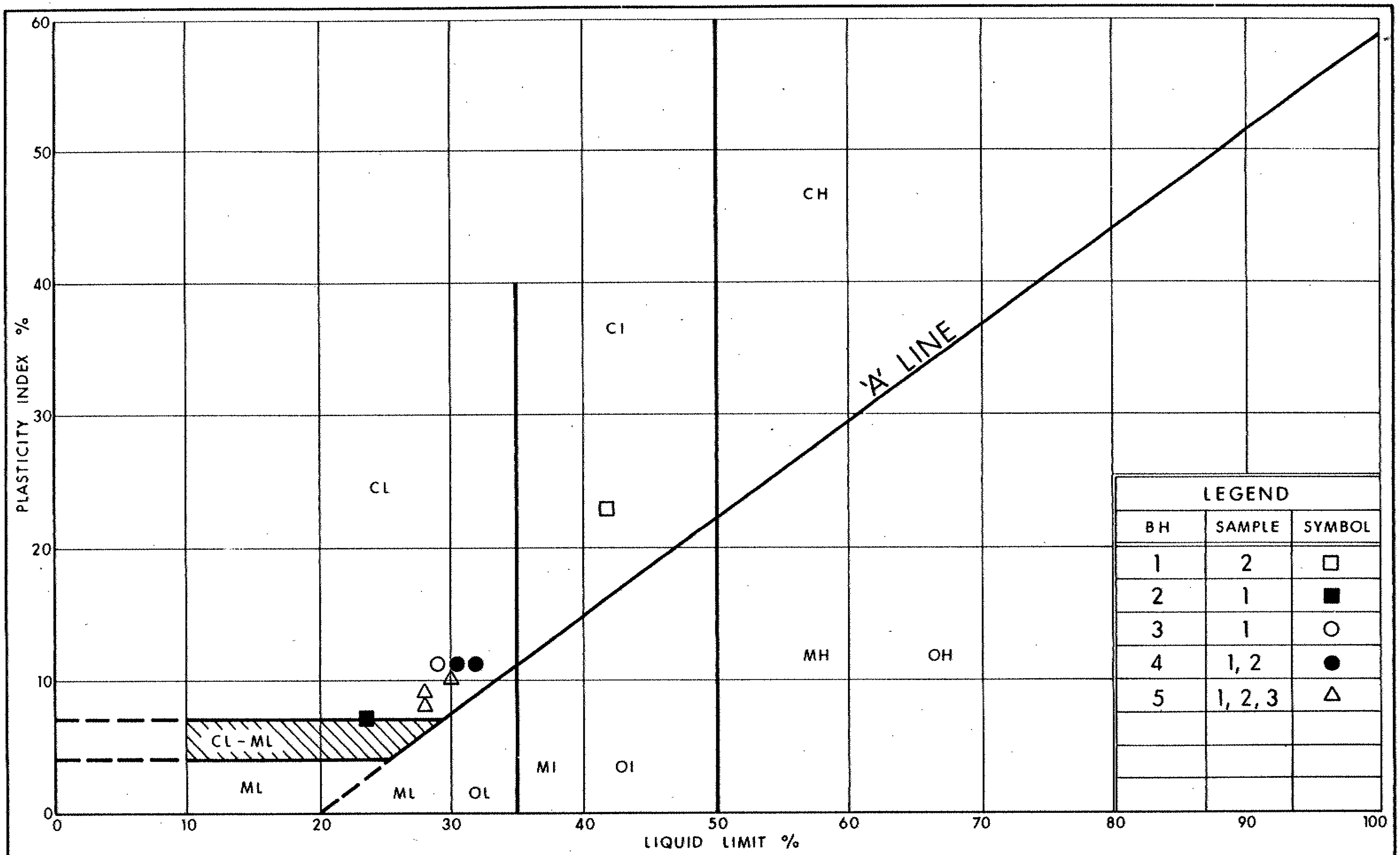
CLAYEY SILT

WITH RANDOM LAYERS OF SILT

FIG No 1

W P 114-87-00(D)

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
1	2	□
2	1	■
3	1	○
4	1, 2	●
5	1, 2, 3	△

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PLASTICITY CHART

CLAYEY SILT

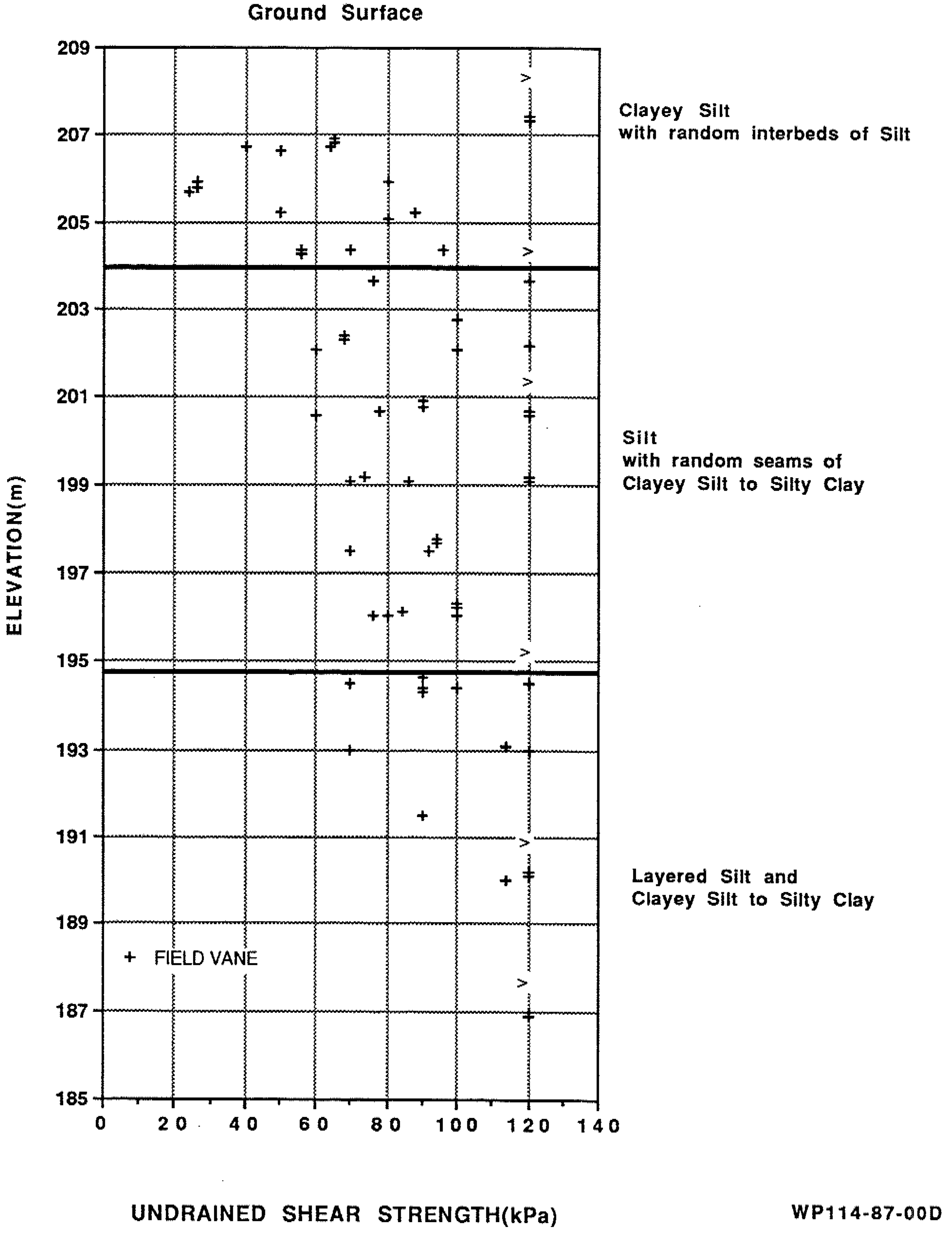
WITH RANDOM LAYERS OF SILT

FIG No 2

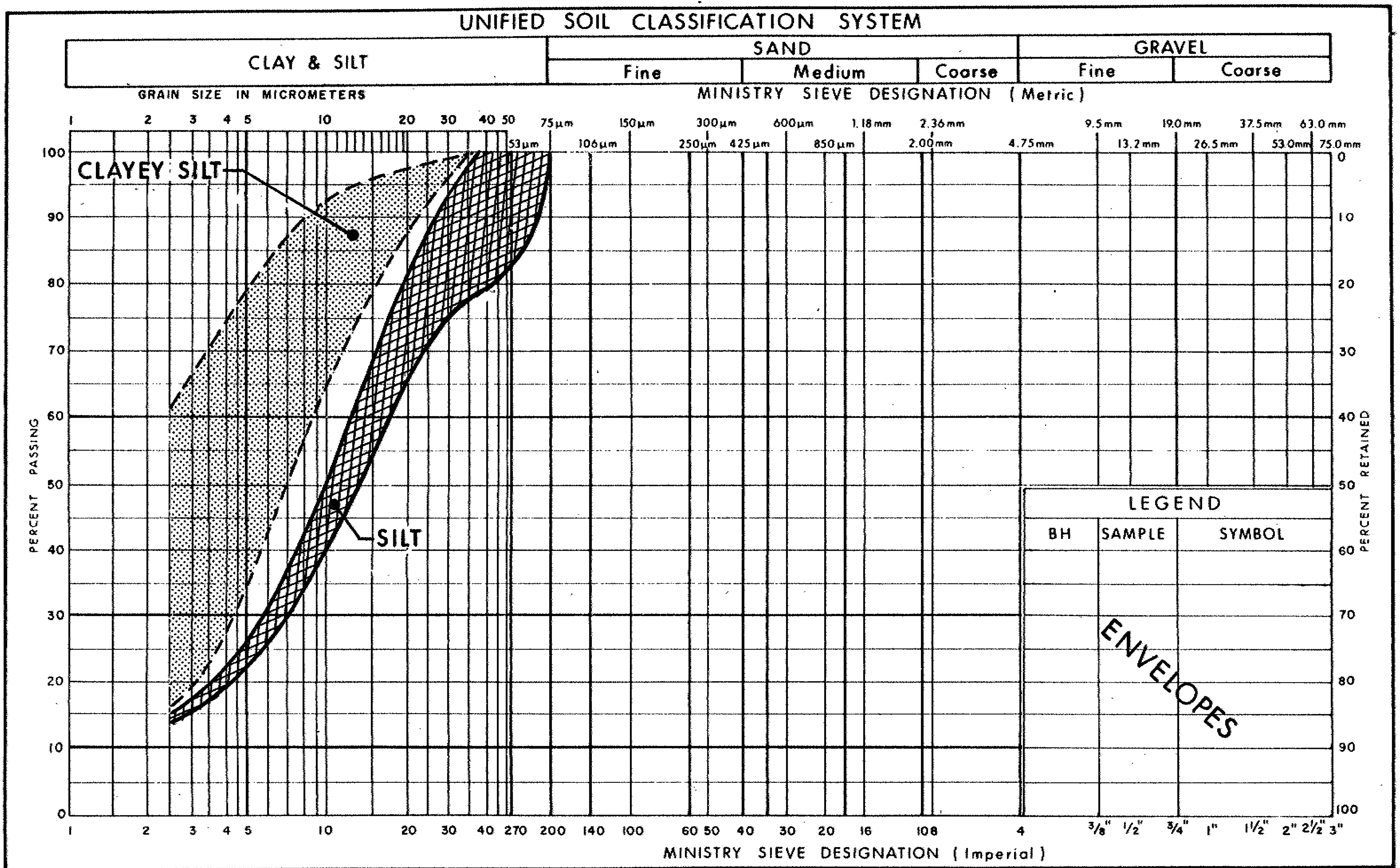
W P 114-87-00(D)

113

FIGURE 3
ELEVATION VS SHEAR STRENGTH PROFILE



78 12 M



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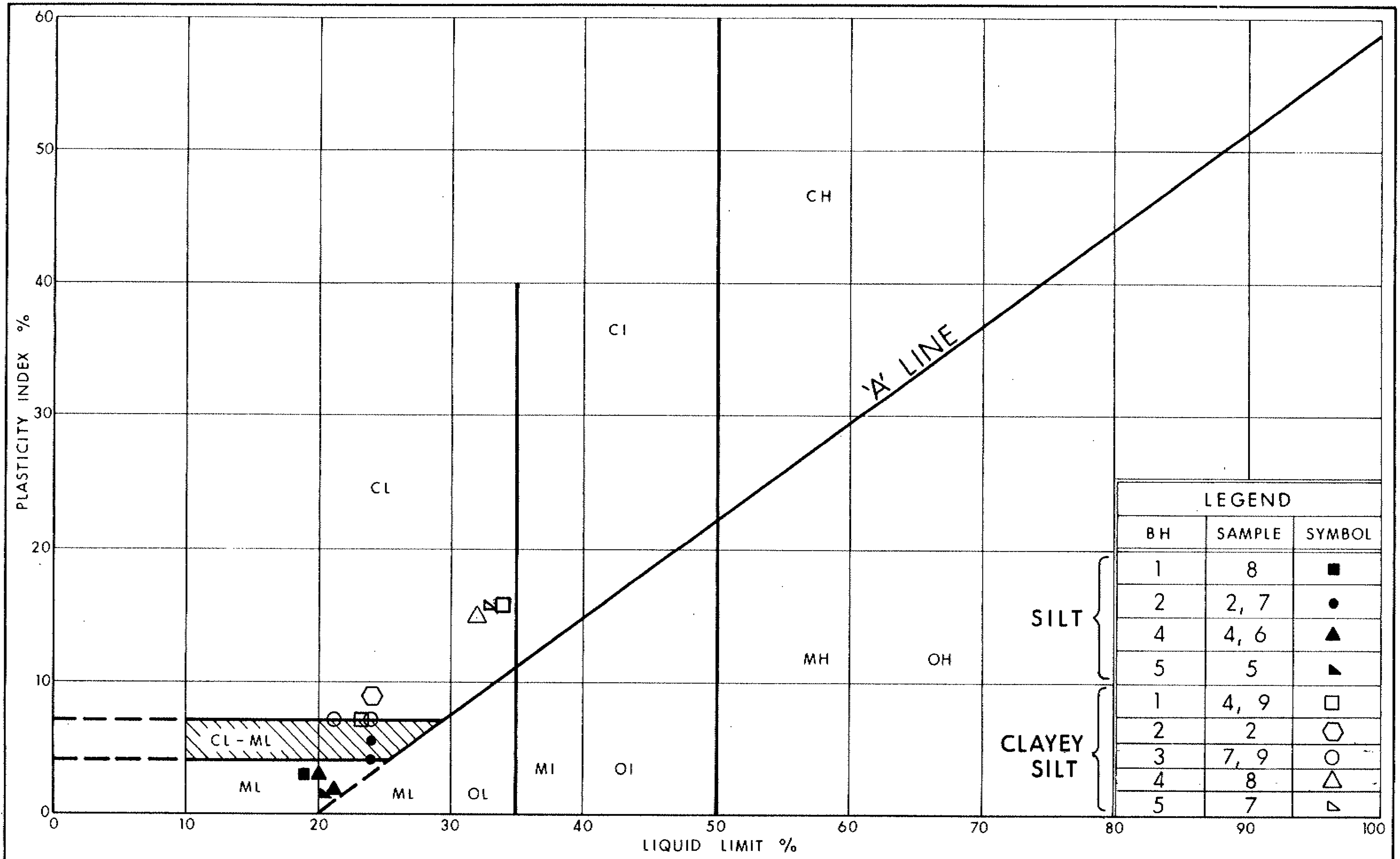
GRAIN SIZE DISTRIBUTION
SILT
WITH INTERBEDDED SEAMS / LAYERS OF CLAYEY SILT

FIG No 4

W P 114 - 87 - 00 (D)

Oct 75, FF-S-21



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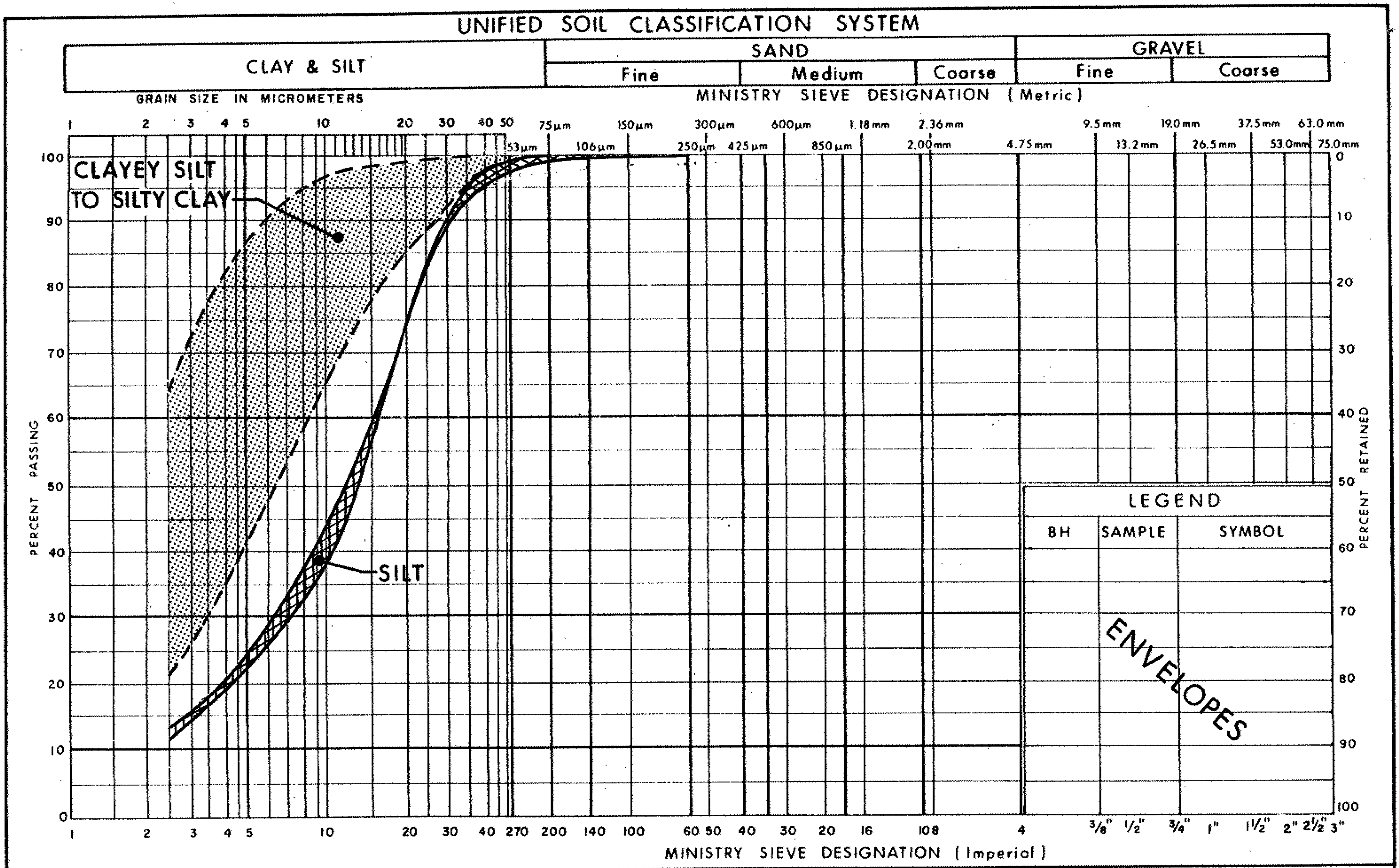
PLASTICITY CHART
SILT
WITH INTERBEDDED SEAMS/LAYERS OF CLAYEY SILT

FIG No 5

W P 114-87-00(D)

78 12 M



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GRAIN SIZE DISTRIBUTION

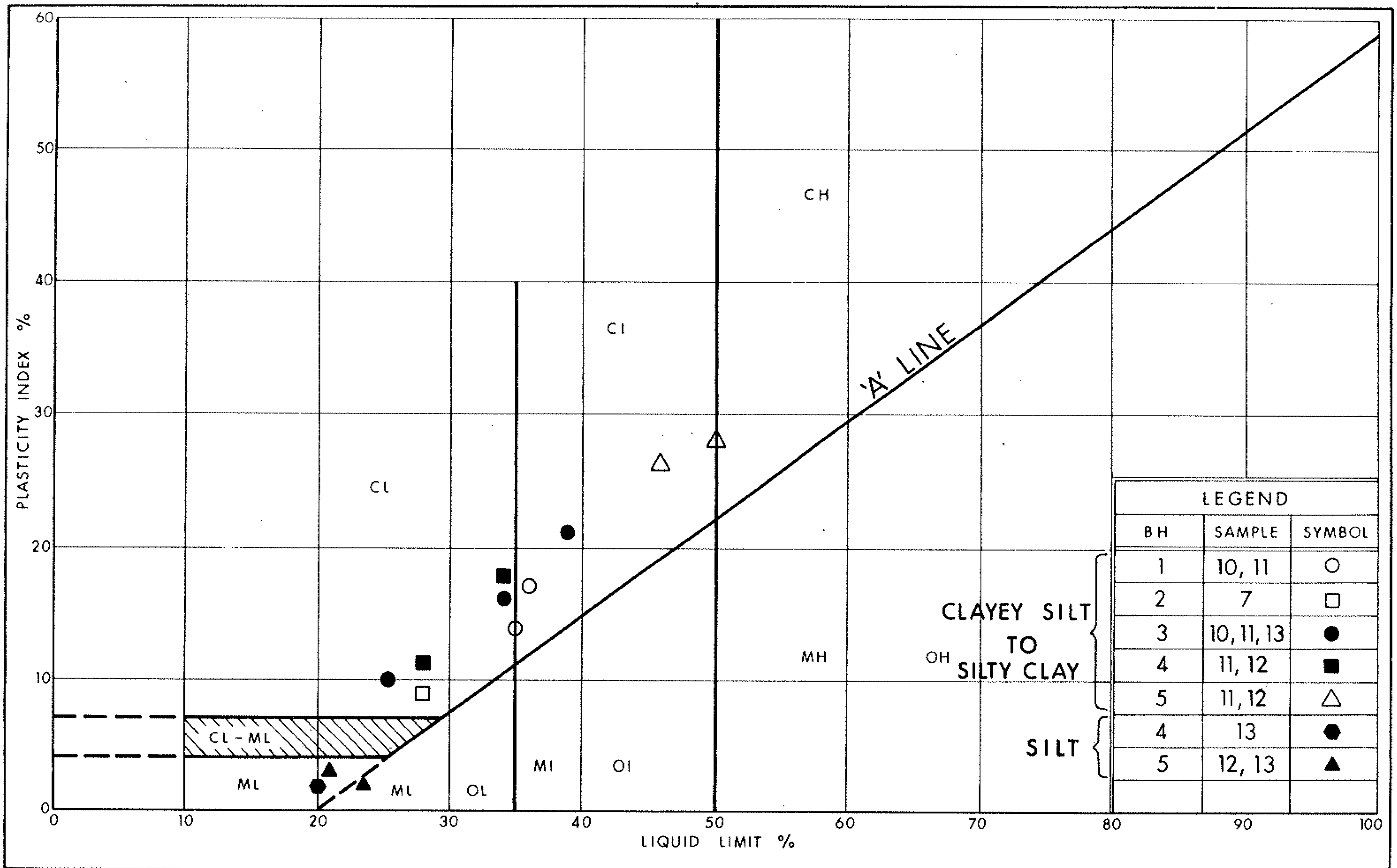
LAYERED SILT & CLAYEY SILT TO SILTY CLAY

FIG No 6

W P 114 - 87 - 00 (D)

117

Oct 75, FF-S-21



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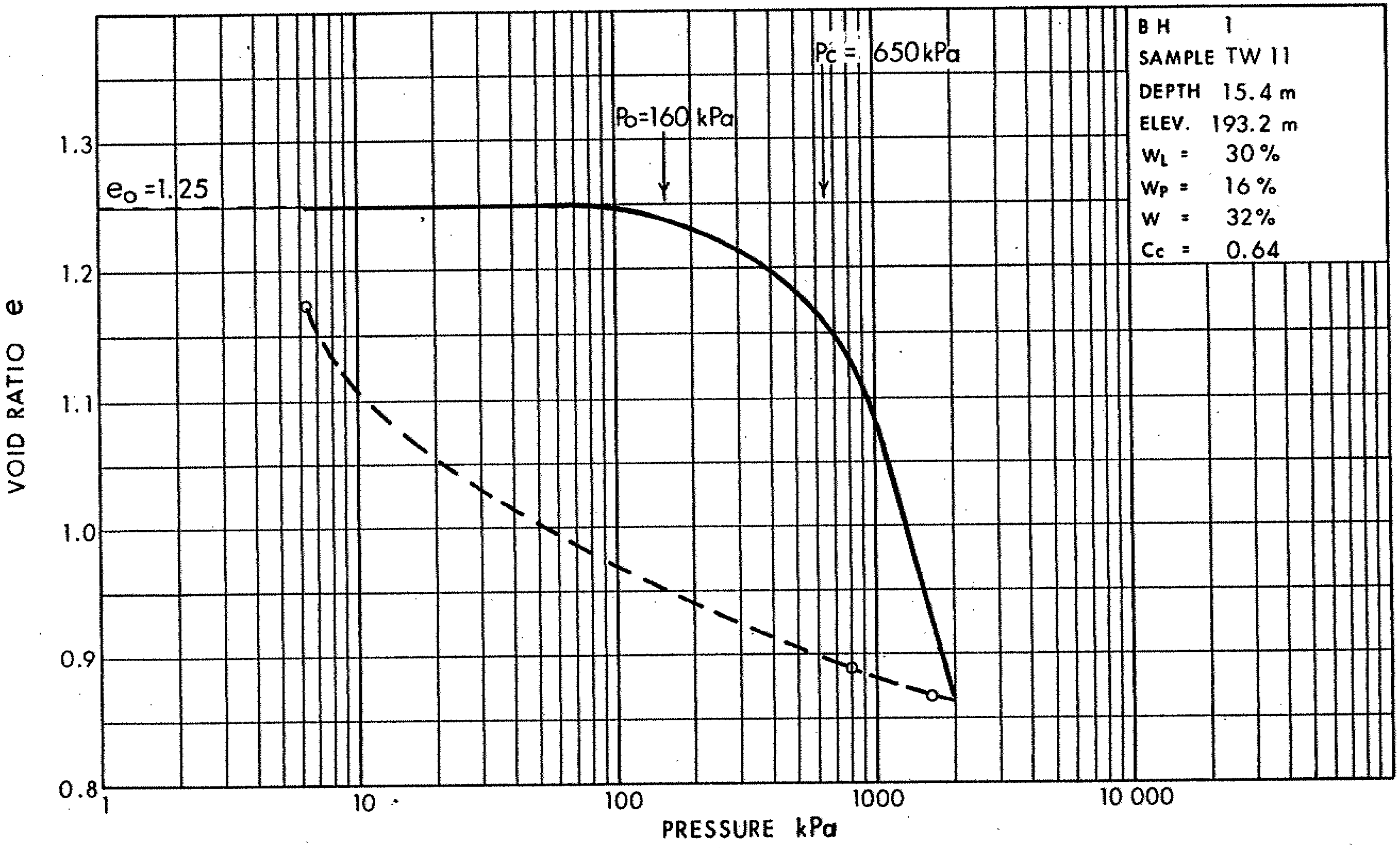
PLASTICITY CHART

LAYERED SILT & CLAYEY SILT TO SILTY CLAY

FIG No 7

W P 114-87-00(D)

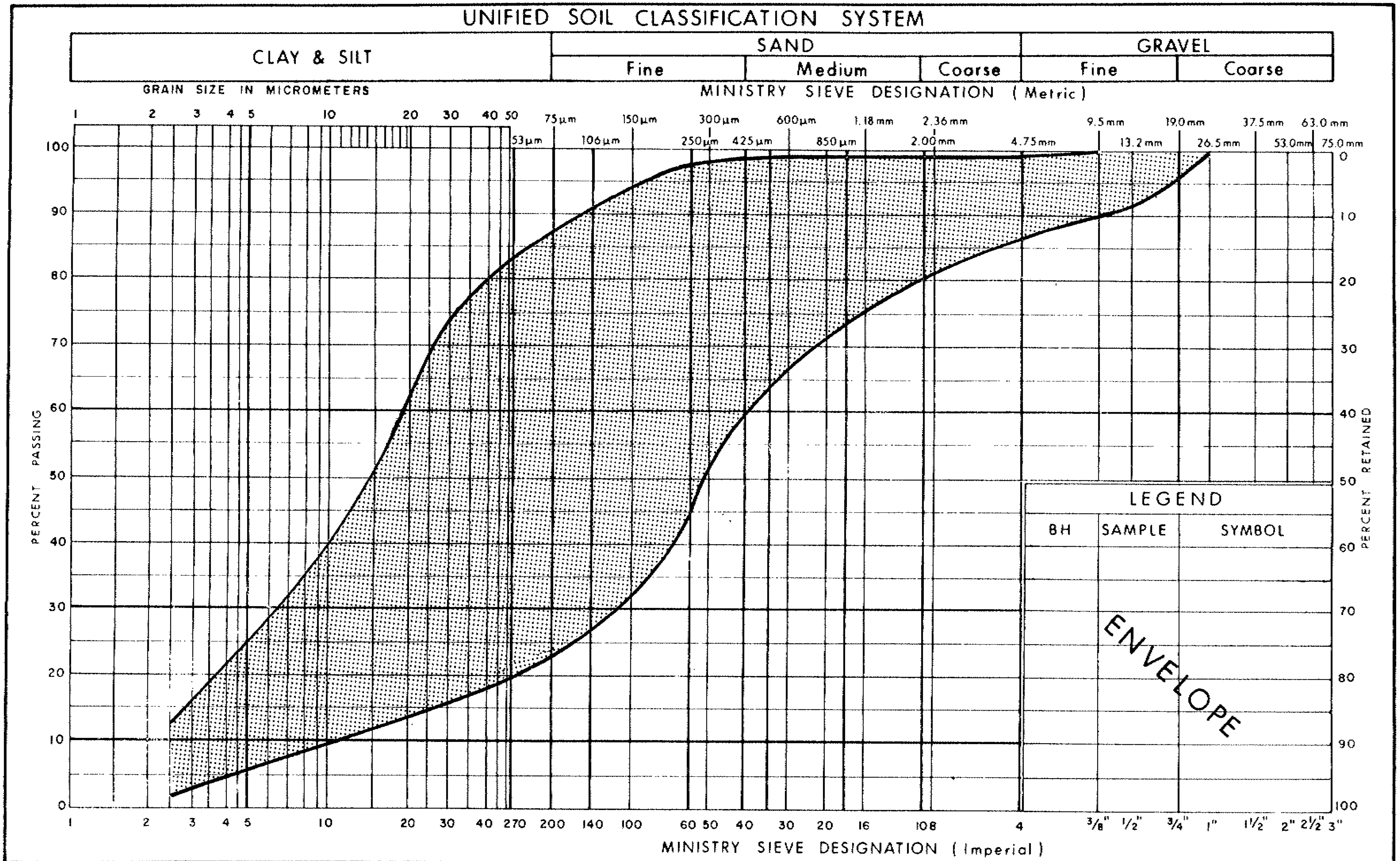
VOID RATIO - PRESSURE CURVE



WP 114-87-00(D)

FIG No 8

78 12 M



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GRAIN SIZE DISTRIBUTION

HET MIXTURE OF

SILT, SAND & GRAVEL (Glacial Till)

FIG No 9

W P 114-87-00(D)

RECORD OF BOREHOLE No 1

1 OF 1 METRIC

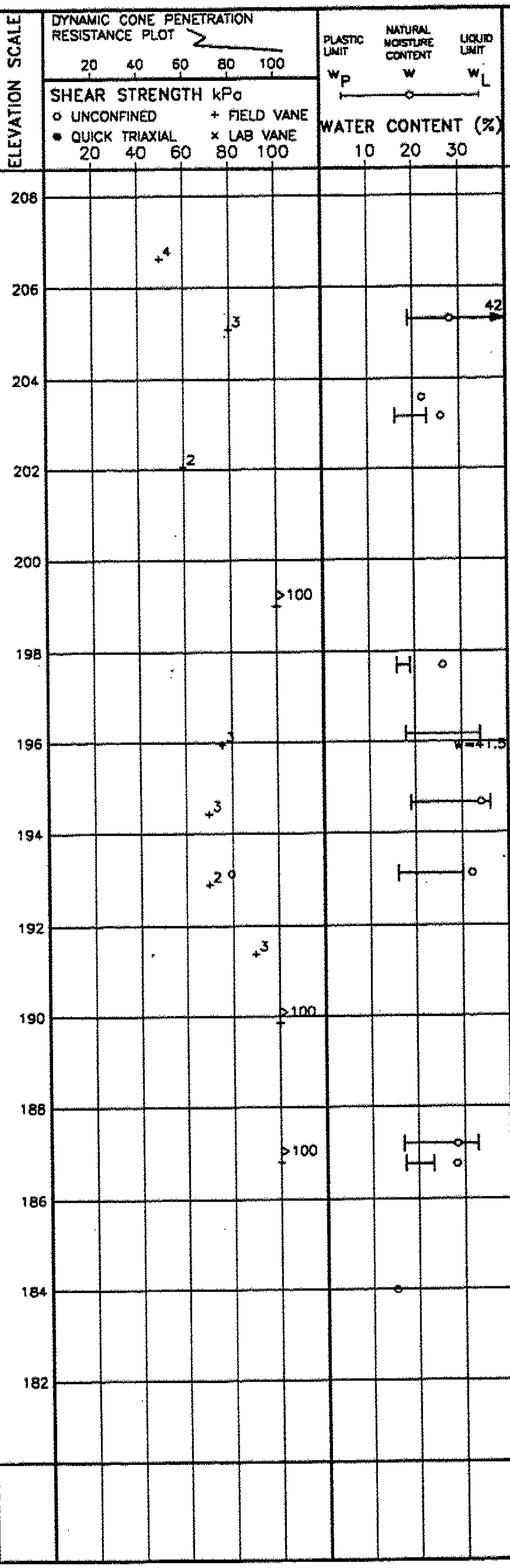
W.P. 114-87-00(D)
LOCATION Co-ords: N 4 783 650.6 E 257 227.6
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, BXL Core
COMPILED BY TS
DATUM Geodetic
DATE 92 07 06-07
CHECKED BY PP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
208.6	Ground Surface
0.0	Clayey Silt to Silty Clay with random layers of Silt Brown Grey Stiff
204.0 4.6	Silt with interbedded seams/layers of Clayey Silt Grey, Loose to Compact / Stiff to Very Stiff
194.9 13.7	Layered Silt and Clayey Silt to Silty Clay Grey, Loose/Stiff to Very Stiff
184.5 24.1	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till), Dense
183.3 25.3	Bedrock – Dolostone Light Grey, Unweathered Medium Strong
180.3 28.3	End of Borehole * 92 07 07

SAMPLES

NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	7	▼*					
2	SS	6		18.9	0	0	62	38
3	TW	PH			0	82	8	10
4	SS	10			0	2	83	15
5	TW	PH						
6	SS	8						
7	SS	5						
8	SS	6			0	0	88	12
9	SS	6			0	0	39	61
10	SS	7			0	0	50	50
11	TW	PH		19.6	0	0	45	55
12	TW	PH						
13	SS	9						
14	SS	9			0 0	2 2	57 71	41 27
15	SS	36			1	16	74	9
16	RC	REC 97%			RQD = 84%			
17	RC	REC 97%			RQD = 87%			



+³, ×⁵ : Numbers refer to Sensitivity

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

RECORD OF BOREHOLE No 2

(Formerly BH No 11, WP 65-67-01)

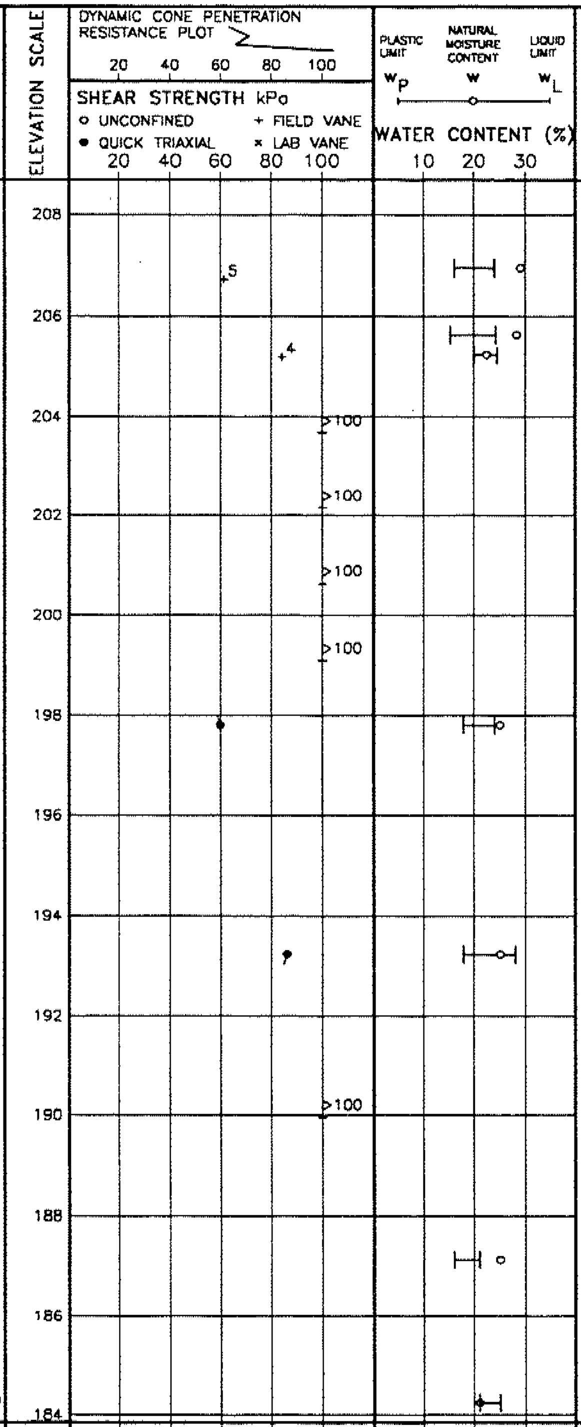
1 OF 1

METRIC

W.P. 114-87-00(D)
LOCATION Co-ords: N 4 783 691.6 E 257 277.1
ORIGINATED BY MK
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY MK
DATUM Geodetic
DATE 76 03 23-24
CHECKED BY PP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
208.7	Ground Surface										
0.0	Clayey Silt with random layers of Silt Brown, Stiff					▼					
			1	SS	5			0	0	92	8
205.7 3.0	Silt with interbedded seams/layers of Clayey Silt Grey, Loose/Stiff to Very Stiff		2	SS	7			0	0	79	21
			3	TW	PH						
			4	SS	6						
			5	TW	PH						
			6	SS	7						
			7	TW	PH		19.6				
			8	SS	8						
195.0 13.7	Layered Silt and Clayey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff		9	SS	10						
			10	TW	PH		19.8				
			11	SS	9						
			12	TW	PH						
184.3 183.9	*		13	SS	64	/15cm		8	25	61	6
24.8	End of Borehole (Auger Refusal – Probable Bedrock)										

- * Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till) Very Dense



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

20
15 ◇ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3

1 OF 1 METRIC

W.P. 114-87-00(D)
LOCATION Co-ords: N 4 783 740.0 E 257 281.0
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, NW Casing, NXL Core and Cone Test
COMPILED BY TS
DATUM Geodetic
DATE 92 07 06-07
CHECKED BY PP

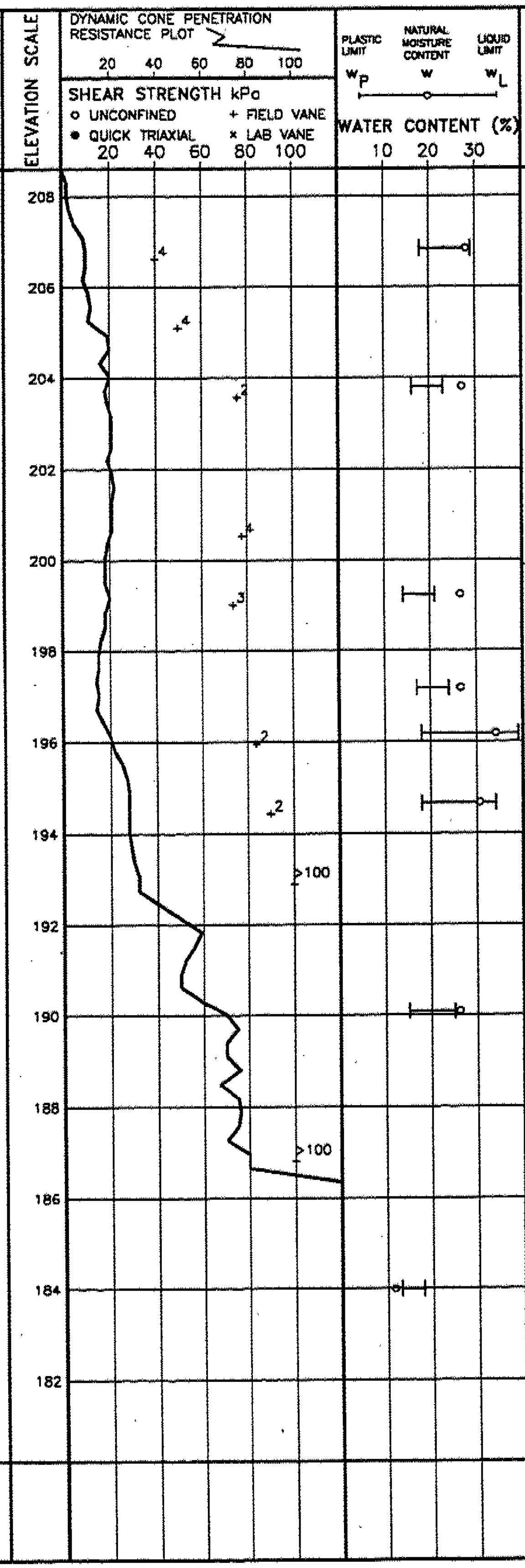
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
208.6	Ground Surface
0.0 … 203.6	Clayey Silt with random layers of Silt Brown / Grey Firm to Stiff
5.0 … 196.4	Silt with interbedded seams/layers of Clayey Silt Grey, Very Loose to Loose / Stiff to Very Stiff
12.2 … 184.2	Layered Silt and Clayey Silt to Silty Clay Grey, Loose to Compact / Stiff to Very Stiff
24.4 … 183.0	Heterogenous Mixture of Silt, Sand and Gravel (Glacial Till), Very Dense
25.6 … 180.3	Bedrock – Dolostone Light Grey, Unweathered Medium Strong
28.3	End of Borehole * GWL not established ** Sampler Bouncing

GROUND WATER CONDITIONS: *

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL	REMARKS
1	SS	3	20.0	0	2	81	17	
2	SS	1						
3	SS	5		0	0	85	15	
4	SS	3						
5	TW	PH						
6	SS	3						
7	SS	4		0	0	87	13	
8	SS	4						
9	TW	PH		0	0	87	13	
10	SS	7						
11	SS	9		0	0	63	37	
12	SS	7						
13	SS	16		0	0	78	22	
14	TW	PH						
15	SS	6						
16	SS	62		5	9	76	10	
~~17~~	~~SS~~	**						
18	RC	REC 100%						RQD = 98%
19'	RC	REC 100%						RQD = 83%



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

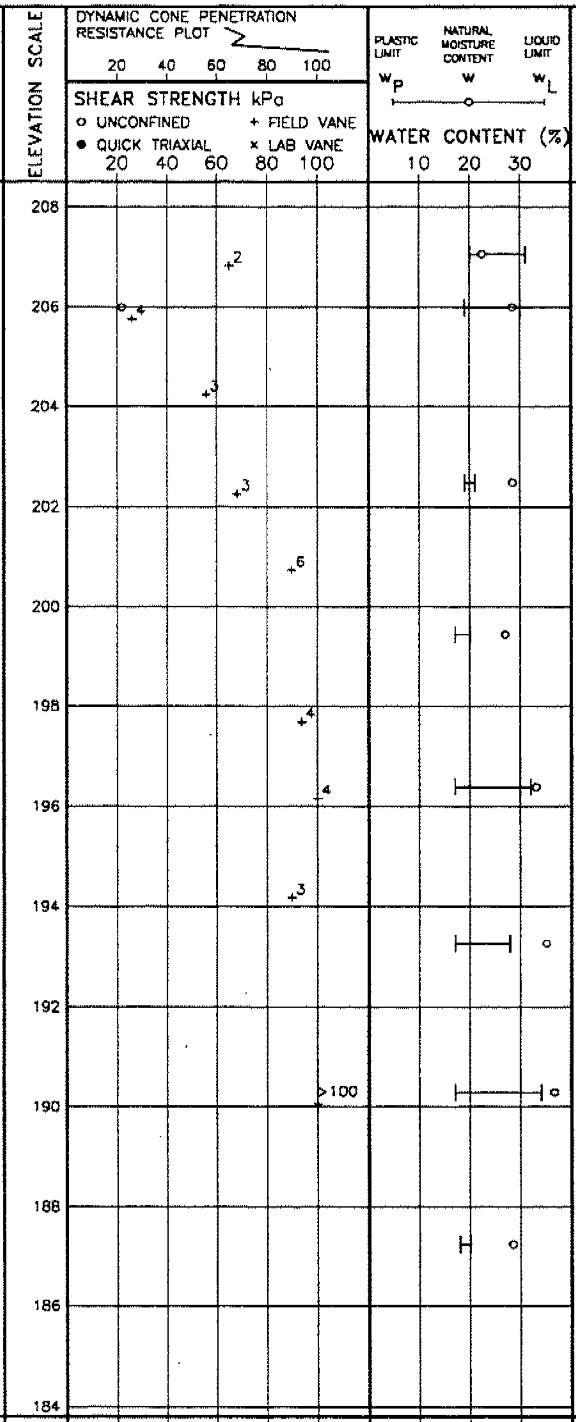
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 4 1 OF 1 METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 681.0 E 257 167.2 ORIGINATED BY LD
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 92 07 07 CHECKED BY PP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
208.5	Ground Surface										
0.0	Clayey Silt with random layers of Silt Brown, Firm to Stiff		1	SS	7	▼*	20.0	0	10	74	16
			2	TW	PH		18.8	0	2	80	18
204.7 3.8	Silt with interbedded seams/layers of Clayey Silt Grey, Very Loose to Compact / Stiff to Very Stiff		3	SS	6						
			4	SS	4			0	1	83	16
			5	SS	10						
			6	SS	6			0	0	89	11
			7	SS	6						
			8	SS	8			0	0	50	50
195.1 13.4	Layered Silt and Clayey Silt to Silty Clay Grey, Very Loose to Compact/ Stiff to Very Stiff		9	SS	8						
			10	TW	PH						
			11	TW	PH			0	0	53	47
			12	SS	9			0	0	42	58
			13	SS	4			0	1	90	9
184.7 23.8 183.8	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till)		14	SS	**						
24.7	End of Borehole										

* 92 07 09
** Sampler Bouncing (Probable Bedrock)



+3, ×5 : Numbers refer to Sensitivity

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

Ministry of Transportation
Ontario

RECORD OF BOREHOLE No 5

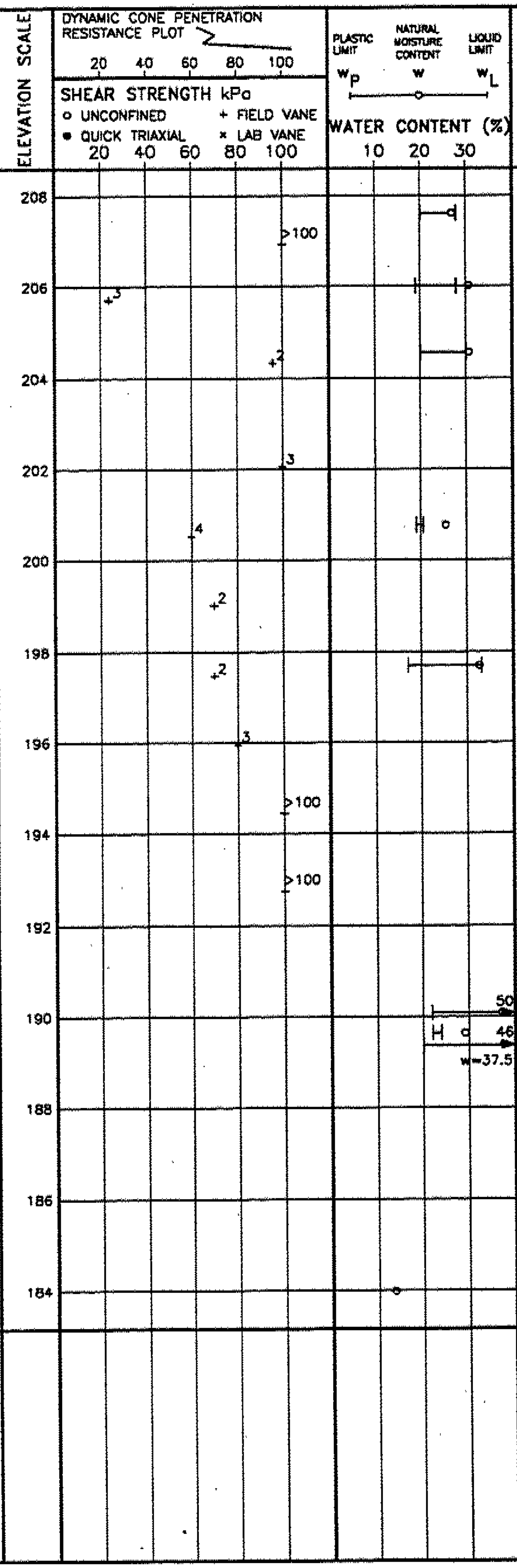
1 OF 1 METRIC

W.P. 114-87-00(D)
LOCATION Co-ords: N 4 783 719.1 E 257 221.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY TS
DATUM Geodetic
DATE 92 07 07-08
CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION
208.6	Ground Surface
0.0	Clayey Silt Brown, Very Stiff
204.3 / 4.3	Silt with interbedded seams/layers of Clayey Silt Grey, Very Loose to Loose/ Stiff to Very Stiff
194.9 / 13.7	Layered Silt and Clayey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff
184.2 / 24.4	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till), Loose
183.1 / 25.5	End of Borehole (Auger Refusal – Probable Bedrock) * 92 07 09

SAMPLES NUMBER	TYPE	'N' VALUES	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
1	SS	5	0	3	76	21
2	TW	PH	0	2	76	22
3	SS	5	0	0	78	22
4	SS	4				
5	SS	7	0	0	88	12
6	SS	6				
7	SS	5	0	0	53	47
8	SS	4				
9	SS	10				
10	TW	PH				
11	SS	5				
12	TW	PH				
13	SS	5				
14	SS	9	15	62	22	1

STRAT PLOT
GROUND WATER CONDITIONS
UNIT WEIGHT γ kN/m³



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

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

RECORD OF BOREHOLE No 6

1 OF 1 METRIC

W.P. 114-87-00(D) LOCATION Co-ords: N 4 783 708.2 E 257 119.3 ORIGINATED BY LD
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 92 07 08 CHECKED BY PP

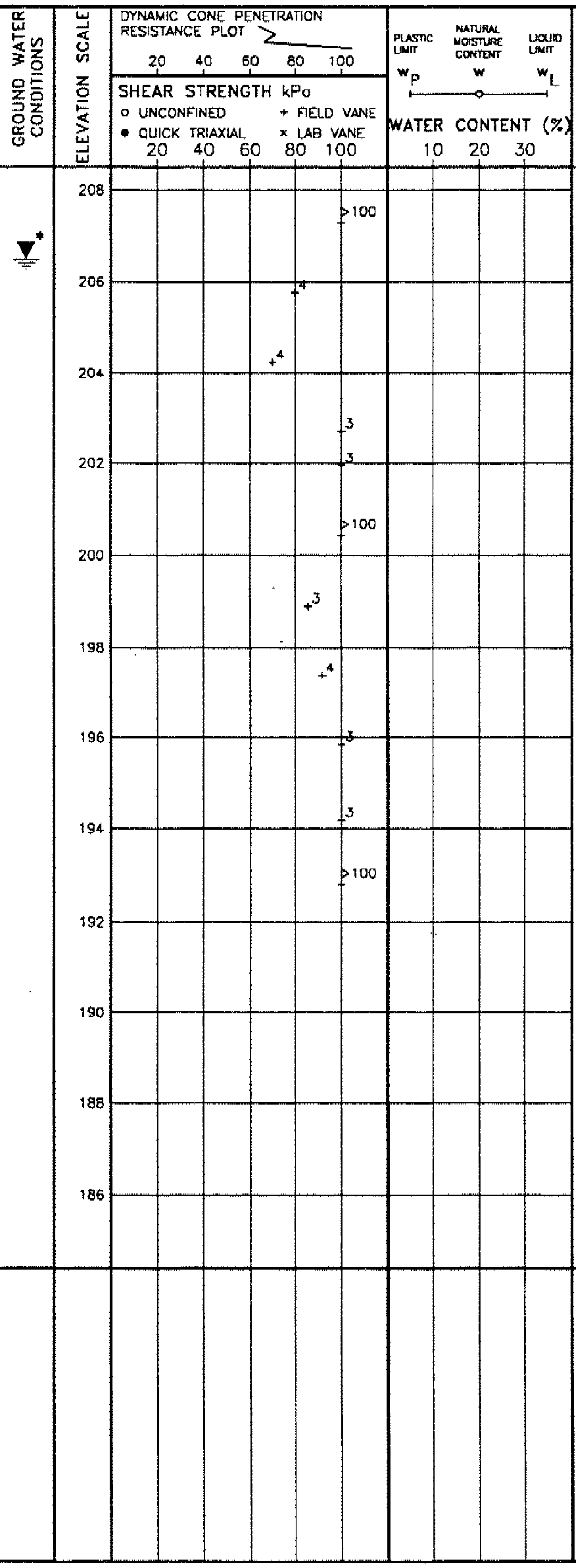
SOIL PROFILE

ELEV DEPTH	DESCRIPTION
208.5	Ground Surface
0.0	Clayey Silt with random layers of Silt Very Stiff Brown / Grey
205.8 2.7	Silt with interbedded seams/layers of Clayey Silt Grey, Loose/Stiff to Very Stiff
196.3 12.2	Layered Silt and Clayey Silt to Silty Clay Grey, Loose to Compact/ Stiff to Very Stiff
187.2 21.3	Heterogeneous Mixture of Silt, Sand and Gravel (Glacial Till) Compact
184.4 24.1	End of Borehole (Auger Refusal – Probable Bedrock) * 92 07 09

SAMPLES

NUMBER	TYPE	'N' VALUES
1	SS	8
2	SS	4
3	SS	5
4	SS	5
5	SS	6
6	SS	9
7	SS	6
8	SS	5
9	SS	8
10	TW	PH
11	SS	6
12	SS	14
13	SS	15

GROUND WATER CONDITIONS: ▼*



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+3, ×5 : Numbers refer to Sensitivity

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

ROCK CORE DESCRIPTION
WP 114-87-00D

Page 1 of 1

	CORE RECOVERY				CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	16	25.30-26.82	97	84	25.30-28.35	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	17	26.82-28.35	97	87		
3	18	25.60-27.13	100	98	25.60-28.35	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	19	27.13-28.35	100	83		

***CR** = CORE RECOVERY *(NOTE: Depths are approximated where core recovery is less than 100%)*

***RQD** = ROCK QUALITY DESIGNATION

Logged by: DAW, Soils and Aggregates Section

FOUNDATION INVESTIGATION REPORT
For
Hwy. 403 & Hwy. 52 Underpass
W.P. 65-67-04, Site 36-260
District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted at the abovementioned site.

SITE DESCRIPTION AND GEOLOGY

The site is located at Hwy. 52 situated approximately at mid-distance between Hwy. 2 and Jerseyville Road in the Town of Ancaster, Regional Municipality of Hamilton-Wenthworth. At the site, Hwy. 52, an existing two lane asphaltic highway with narrow shoulders is supported on an earth embankment that spans an existing valley. The embankment is approximately 100 m in length and varies in height above the original valley ground surface up to a maximum of approximately ten (10) m. Side slopes are constructed at 2H:1V and generally covered by grassland and low lying shrubs. However, some historical surficial slope instabilities is indicated by coarse gravel present at the surface of the east embankment slope. It is suspected that the gravel revetment was placed subsequent to some embankment surface erosion that took place.

The valley continues on either side of the Hwy. 52 embankment location with a maximum depth and width equivalent approximately to the maximum dimensions of the embankment. The slopes are relatively flat and estimated at approximately flatter than 5H:1V. The valley slopes are generally covered by crop vegetation and grassland. At the southeast portion of the site, tall trees are present on the existing valley slope. The valley floor contains a small meandering creek that was dry at the time of the investigation. Water in the creek is transmitted beneath the Hwy. 52 via a circular steel corrugated pipe culvert. The valley floor is covered by a combination of tall grasses and tall deciduous trees.

The terrain beyond the site area consists of rolling hills and valleys. Land use is primarily agricultural and both corn and alfalfa were crops noticed in the area.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound.

Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 37 m.

INVESTIGATION PROCEDURE

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and laboratory program are discussed below.

Field Investigation

The fieldwork for this project was carried out under two separate stages. The initial stage, was implemented between 76 03 25 to 76 03 26 inclusive and consisted of one sampled borehole (BH 6, formerly BH 13) advanced to a depth of 37.3 m. This initial first stage provided information to facilitate the planning and design of the proposed Hwy. 403 route between the towns of Ancaster and Brantford.

The second stage of the fieldwork was carried out between 91 07 08-16 inclusive and consisted of a total of seven (7) sampled boreholes reflecting the greater extent of this subsequent fieldwork. The scope of the second stage of the fieldwork was to provide detailed soils/rock data to facilitate the design and construction of the proposed structure and related earthworks. Two (2) boreholes were advanced at the proposed north abutment structure foundation location, and one (1) borehole was advanced at each of the proposed pier and south abutment foundation locations. Two approach boreholes were also advanced for purposes of the proposed Hwy. 52 north and south approach widening. The boreholes at the structure locations were advanced to depths ranging from 38.5 m to 39.9 m whilst the dynamic cone penetration test advanced at the structure foundation locations were driven to depths ranging from 3.4 m to 5.7 m. The approach boreholes were advanced to depths of 12.6 m.

The boreholes were advanced through overburden using track mounted boring units employing conventional continuous flight hollow stem augering techniques. Conventional rock coring techniques were used to retrieve up to 3 m of rock core.

In general, subsoil samples were retrieved at 0.7 m to 1.5 m for the surficial 15 m and at 3.0 m intervals thereafter. At the approach locations, subsoil samples were retrieved at 1.5 m intervals within the existing approach fills and at 0.7 m intervals within the native subsoil.

Subsoil samples were generally retrieved in accordance with the Standard Penetration Test (ASTM D 1586) and hence were disturbed during the testing. All subsoil samples were identified in the field and then properly sealed in plastic containers to preserve natural moisture contents. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted.

Rock core samples were also identified in the field and rock recoveries and Rock Quality Designations (RQD) measured. The rock cores were then transported to the laboratory in conventional core boxes and detailed rock core logs were produced by an in-house geologist.

In situ vane tests were also carried out to determine the undrained shear strength of the weaker cohesive soils at the site. The test was carried out in accordance with ASTM D 2573 using the standard MTO 'N' vane. Remoulded shear strengths were also obtained where applicable.

Groundwater levels were obtained by monitoring the levels in the open boreholes throughout the duration of the field investigation. All open boreholes were backfilled at the completion of the fieldwork.

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

Laboratory Analyses

To determine the pertinent physical properties of the soil, various laboratory tests were conducted. These tests included:

1) Natural Moisture Contents
2) Atterberg Limits
3) Grain Size Analyses

Laboratory test results are shown on the borehole logs and corresponding figures attached in the Appendix. These results have been summarized in the subsequent section of this report entitled 'Subsurface Conditions'.

SUBSURFACE CONDITIONS

The variation of the subsurface conditions at the site are a reflection of the rolling terrain that consists of alternating hills and valleys present in the area. At the proposed north abutment location, a ridge of native soil exists covered by a shallow thickness of fill material. The fill material varies in thickness from approximately 3.5 m at the western location (BH 1) to approximately 2 m at the eastern location (BH 2). Beyond this ridge, extensive thicknesses of fill material spanning previously existing valleys are present. South of the ridge, the fill material has a thickness ranging up to 9.3 m. North of the ridge, the fill material has a thickness ranging up to 4.7 m.

The composition of the fill material varies from a sand with a trace to some silt and a trace gravel located within approximately 2 to 3 m of the surface underlain by a fill material composed primarily of silt with random zones of clayey silt. The fill material denseness ranges from very loose to dense but generally is in a loose to compact state of denseness.

The fill material has been placed on a native deposit of cohesionless silt with traces of sand and clay. This silt stratum has a thickness ranging from approximately 1.5 m to 7.9 m and has a loose to very dense denseness.

The silt stratum is underlain by a thin layer of a very stiff clayey silt material. This layer is approximately 0.7 m to 1.6 m in thickness.

A second lower deposit of silt underlies the cohesive clayey silt stratum and extends for thicknesses in the order of 20 m. The deposit contains random layers of silty sand to sandy silt approximately 0.7 m in thickness and also contains interbeds of clayey silt of 12.5 mm to 25 mm in thickness within approximately the lower 6 metres of the deposit. The denseness of the cohesionless material varies generally from loose to compact with random dense to very dense zones.

The lower silt deposit is underlain by a second cohesive stratum of clayey silt. This stratum extends to bedrock and has a thickness of approximately 6 m.

Bedrock exists at an elevation ranging from 193.0 m to 194.1 m, at depths ranging from 36 to 37.8 m below existing ground surface. Bedrock consists of dolostone of the Amabel Formation.

A contour plan of the site illustrating the locations and elevations of the boreholes is shown on Drawing No. 656704-A*. A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Borehole sheets in the Appendix.

* DWG NO 2 OF THE CONTRACT DWG'S

Sand, trace/and Silt, trace Gravel, trace Clay (Fill Material)

At the boreholes advanced within the existing Hwy. 52 right-of-way, a cohesionless, brown sand with traces of gravel and silt percentages varying from traces (0-10%) to approximately equal silt and sand percentages exists beneath the asphaltic road surface. This fill material serves as a subbase and base for the existing highway and has a thickness of 2 to 3.5 m. Traces of organics, clay and asphalt are also present within this fill material. Grain size distribution curves as determined by mechanical sieve analysis, representative of the gradation of this material is shown on Figure 1 in the Appendix. Natural moisture contents of the material range from 11 to 13%.

Based on 'N' values derived from the Standard Penetration Test ranging from 6 blows/0.3 m to 35 blows/0.3 m, it appears that this material has been placed and compacted to a denseness ranging from loose to dense. In general, 'N' values are between 10 blows/0.3 m and 30 blows/0.3 m and hence the material is in a compact state of denseness.

Silt with Random Zones of Clayey Silt (Fill Material)

The cohesionless sand with traces/and silt and traces of gravel fill material is underlain by a fill material consisting of primarily silt with random zones of clayey silt at the existing embankment fill locations beyond the abovementioned ridge located at the proposed north abutment location. Traces of black asphalt, organics and gravel were also found within this fill material. The thickness of this fill varies between 4.1 m and 7.3 m within the embankment south of the ridge and has a thickness of up to 2.7 m north of the ridge. Approximately 2 m of this fill material was also found at the surface of the ridge (BH 2). A grain size distribution envelope illustrating the range of the gradation of this fill material is shown on Figure 2 in the Appendix. The colour of this material is brown with random zones of grey and natural moisture contents ranged from 15 to 27%.

Atterberg Limit Tests were also carried out to determine the plasticity of the random cohesive zones within the non-plastic silt material. These results are illustrated on Figure 3 in the Appendix. The results reveal that the random cohesive zones are of low plasticity and hence can be classified as a clayey silt.

The denseness and consistency of the cohesionless silt and cohesive clayey silt was determined by the evaluation of 'N' values derived from the Standard Penetration Test. Based on 'N' values ranging from 8 blows/0.3 m to 39 blows/0.3 m in the cohesionless silt, this material can be described as having a loose to very dense denseness. In the cohesive material, 'N' values ranged from 17 blows/0.3 m to 23 blows/0.3 m revealing a very stiff consistency.

Silt, trace/some Sand to Silt

The fill material is underlain by a stratum of native silt to a silt that contains traces to some sand and also traces of clay. This cohesionless deposit is primarily oxidized and hence brown in colour although the lower 2 m of the deposit has been oxidized to a grey colour at some locations. The thickness of this deposit ranges from 1.5 m at the original valley location (BH 4) to 7.9 m at the ridge of the valley (BH 2). A grain size distribution envelope as determined by mechanical sieve and hydrometer analysis is shown on Figure 4 in the Appendix.

The 'N' values measured by carrying out the Standard Penetration Test in this stratum varied between 7 blows/0.3 m and 80 blows/0.3 m, indicating a denseness ranging from loose to very dense. The 'N' values at the ridge located at the north abutment location were generally larger and greater than 30 blows/0.3 m and consequently, the silt material at this location can be defined as having a dense to very dense denseness. Elsewhere within this stratum 'N' values are generally less than 30 blows/0.3 m. The lower 'N' values obtained in this material across the site were generally measured beneath the groundwater table in the open borehole. Hence, it is suspected that the low 'N' values may be attributable to the unbalanced hydrostatic head conditions and are not necessarily representative of the state of denseness of this deposit that arise. It is therefore concluded that the material beyond the ridge is in a compact state of denseness.

Clayey Silt

The native silt deposit is underlain by a thin stratum of cohesive clayey silt. This stratum is grey in colour and has a thickness in the order of 0.7 m to 1.6

m. The surface of this stratum exists at an elevation ranging from 220.0 m to 220.8 m.

A grain size distribution envelope illustrating the gradation of this material is shown on Figure 5 in the Appendix. The envelope illustrates that this soil is composed of fine grained material and hence, in accordance with the MTO Soil Classification System categorized according to its behaviour. Atterberg Limit Tests were carried out on representative samples to determine the behaviour and plasticity of this material and the results are plotted on Figure 6 in the Appendix and summarized in Table 1 below. The results reveal that the soil is of low plasticity and hence is identified as a clayey silt.

Table 1 - Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	24-30	4
Liquid Limit (w_L%)	32-35	4
Plastic Limit (wp%)	15-18	4
Plasticity Index (I_P%)	15-19	4

The 'N' values as measured in accordance with the Standard Penetration Test ranged from 10 blows/0.3 m to 24 blows/0.3 m. In Situ Vane Tests attempted in this material could not be torqued and hence, it is concluded that this stratum has an undrained shear strength exceeding 100 kPa and therefore of very stiff consistency.

Silt with Random Layers of Silty Sand and Layers of Clayey Silt

The cohesive clayey silt stratum is underlain by a deposit comprised of material ranging from silt to silt with traces to some sand. The deposit also contains random layers of silty sand to sandy silt and within the lower 3 to 9 metres of the deposit random layers of clayey silt also exist. The deposit has a thickness ranging from 16.3 m to 19.8 m extending to an elevation ranging from 199.6 m to 202.9 m. The layers of silty sand to sandy silt are approximately 0.8 m in thickness and the clayey silt layers are generally 10 to 50 mm in thickness. A grain size distribution envelope illustrating the silt deposit is shown on Figure 7 in the Appendix. Grain size distribution curves depicting the gradation of a typical sandy silt layer and clayey silt layer is also shown on Figure 7.

An Atterberg Limit Test was carried out on a representative sample of the cohesive interlayers at the lower depth of the deposit (BH 2, SS16). The results of the test reveal a liquid limit (w_L) equivalent to 25% and a plasticity index (I_P) equivalent to 10%. This confirms that the interlayer is of low plasticity and hence can be identified as clayey silt.

Based on the interpretation of Standard Penetration Test 'N' values ranging from 6 blows/0.3 m to 83 blows/0.3 m, the silt with random layers of silty sand to sandy silt can be described as having a denseness ranging from loose to very dense. In general, 'N' values range from 10 blows/0.3 m to 50 blows/0.3 m indicating a compact to dense state of denseness.

Lower 'N' values were measured in the lower depths of the deposit where the silt is interbedded with layers of clayey silt. The 'N' values ranged from 6 blows/0.3 m to 26 blows/0.3 m suggesting a loose to compact silt with interbeds of stiff to very stiff clayey silt.

Clayey Silt

The silt deposit with layers of silty sand to sandy silt and layers of clayey silt is underlain by the lowermost overburden stratum at the site consisting of a cohesive clayey silt. This stratum, which also contains seams of silt approximately 25 mm in thickness extends to the bedrock surface. A grain size distribution envelope for the deposit as determined by mechanical sieve and hydrometer analysis is provided on Figure 8 in the Apppendix.

Atterberg Limit Tests were carried out to define the behaviour and plasticity of this fine grained stratum and the results are illustrated on Figure 9 in the Appendix and summarized in Table 2 below. The results reveal that the soil has a low plasticity and hence can be described as a clayey silt in accordance with the MTO soil classification system. Natural moisture contents are generally within the Plastic Limit (w_P)-Liquid Limit (w_L) range and hence the soil is in a plastic state of condition.

Table 2 - Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	26-30	7
Liquid Limit (w_L%)	21-34	7
Plastic Limit (w_P%)	15-18	7
Plasticity Index (I_P%)	6-18	7

The 'N' values measured in accordance with the Standard Penetration Test ranged from 12 blows/0.3 m to 20 blows/0.3 m. In situ vane tests conducted within this material revealed undrained shear strengths ranging from 90 kPa to values exceeding 100 kPa. In general, the vane could not be torqued within the limits of the test and hence, undrained shear strengths generally exceed 100 kPa. It can therefore be concluded from the in situ testing carried out within this stratum, that the soil has a stiff to very stiff consistency.

Bedrock

The overburden at the site is underlain by dolostone bedrock of the Amabel Formation at an elevation of approximately 193 m to 194.1 m. The bedrock surface is relatively flat and uniform across the site. The bedrock was cored in BQ and BXL size up to 3 m in depth at the proposed structure foundation locations.

The dolostone bedrock is a fine to medium grained chemical sedimentary rock that typically is composed of magnesium carbonate compounds and calcite crystals. The rock is unweathered, that is featured by a porous 'vug' texture and stylolites. The rock is light to medium dark grey in colour and contains thin horizontal beds and closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled 'Description of Rock Core'.

An assessment of the quality and strength of the rock was carried out by measuring Core Recoveries and Rock Quality Designation (RQD) in the field and hardness testing in the laboratory. Recoveries ranged from 94% to 100% and RQD's ranged from 80% to 95% indicating that the rock is of good to excellent quality. Rock strengths can be described as medium strong.

Groundwater Conditions

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of investigation ranged from approximately 6.3 m to 9.4 m below the existing ground surface (elevation 224.3 m to 221.3 m). This groundwater elevation appears to coincide approximately with the native soil-fill material interface at the proposed pier and south abutment and approach locations. These elevations including the groundwater elevations at the north abutment ridge, also appear to be at the valley floor elevation.

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto, Engineering Student, utilizing equipment owned and operated by Atcost Soil Drilling Ltd. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by M. Devata, Chief Foundation Engineer.

REGISTERED PROFESSIONAL ENGINEER
P. PAYER
PROVINCE OF ONTARIO

P. Payer

P. Payer, P. Eng.
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CIVIL
M. DEVATA
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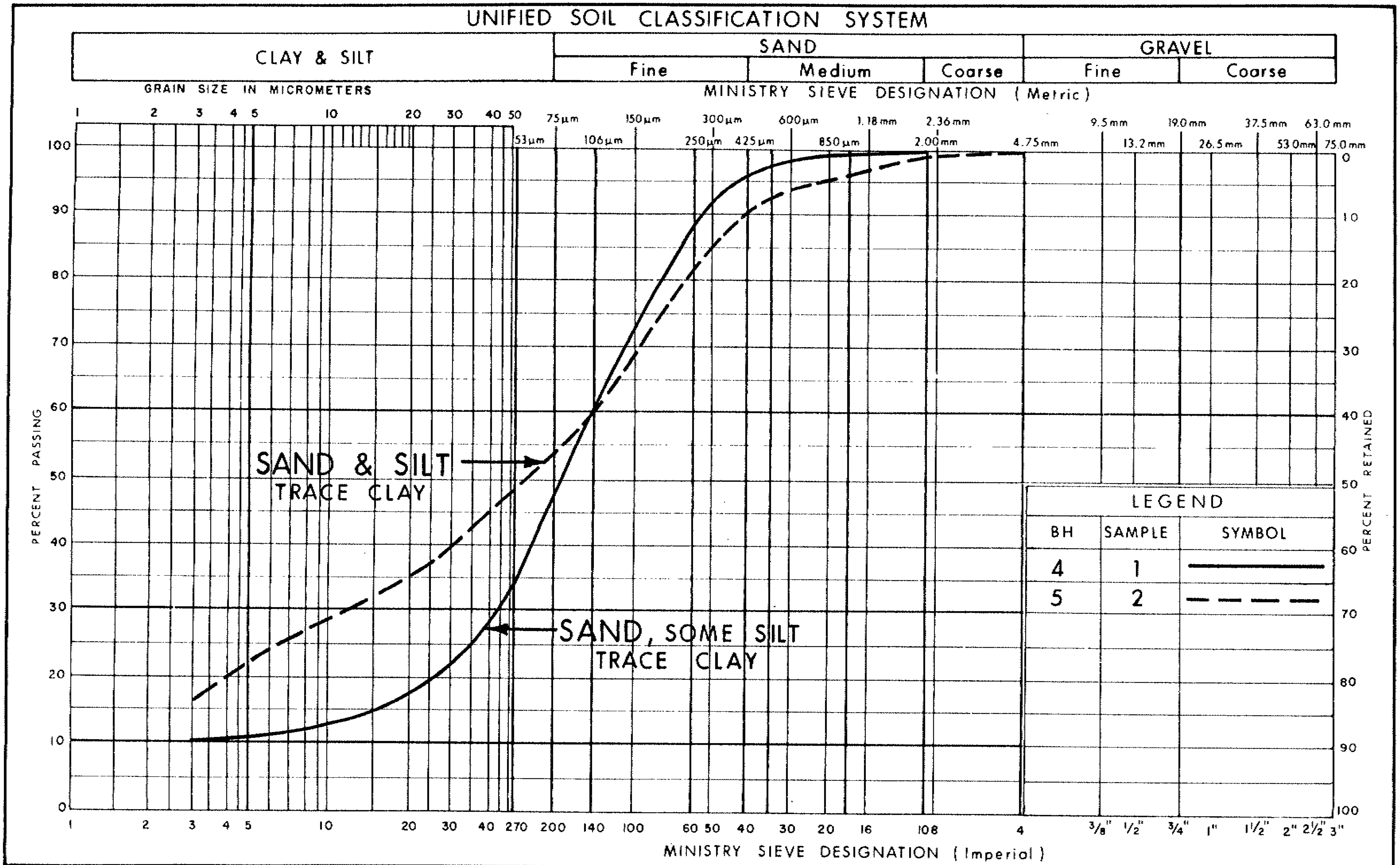
M.S. Devata, P. Eng.
Chief Foundation Engineer

APPENDIX

78 12 M



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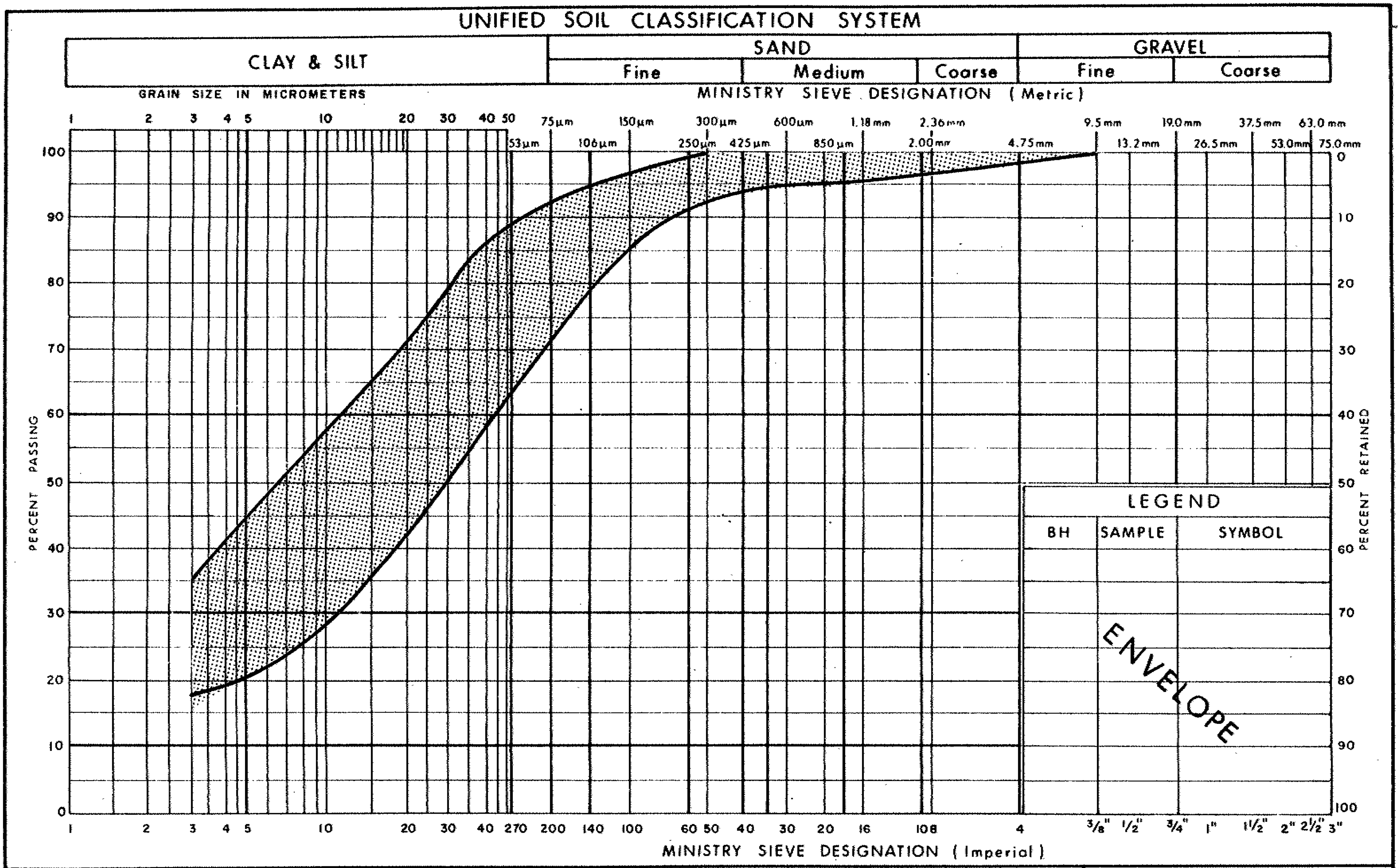
GRAIN SIZE DISTRIBUTION
SAND, SOME/AND SILT, TRACE CLAY, GRAVEL
(FILL MATERIAL)

FIG No 1

W P 65-67-04

78 12 M



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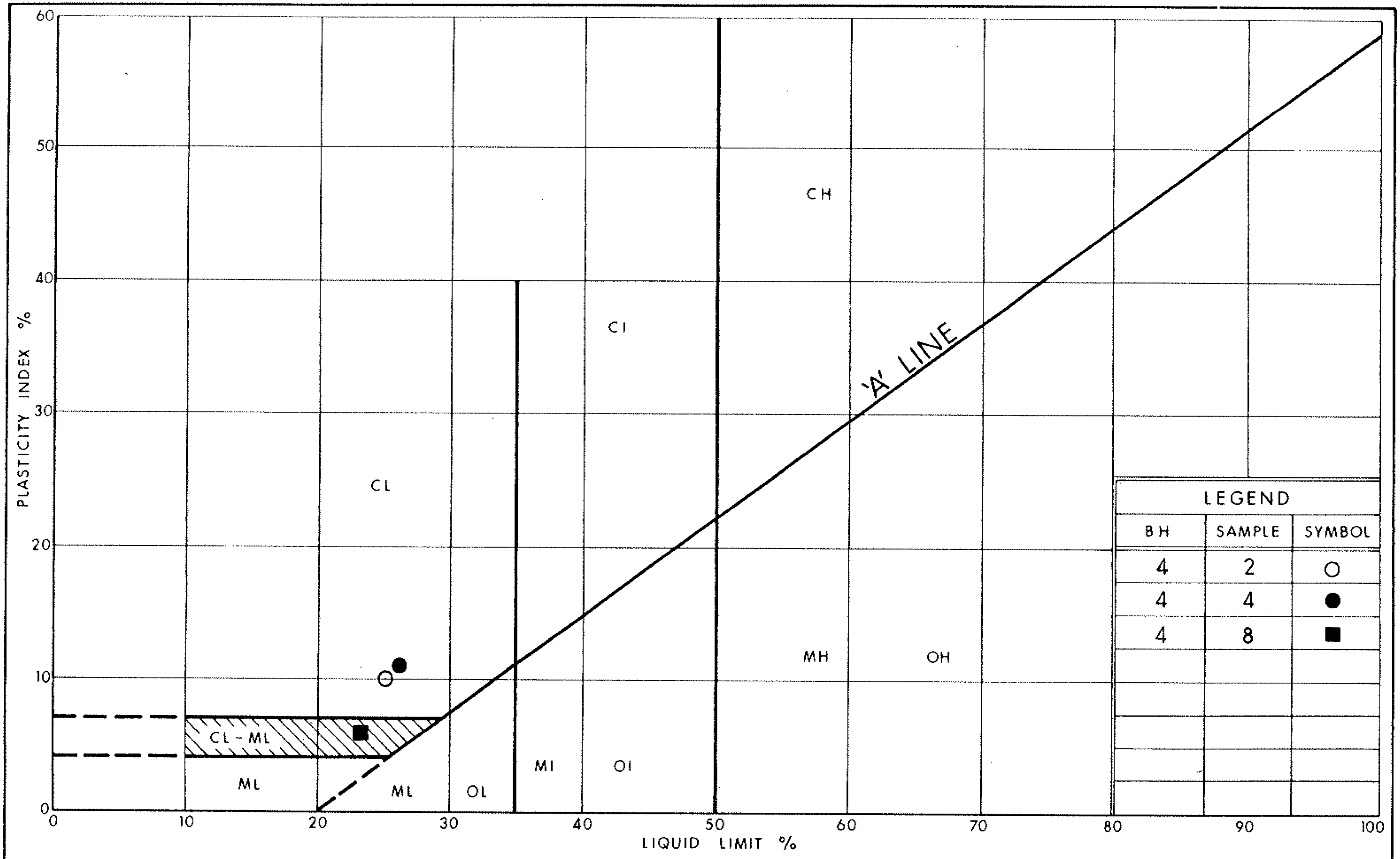
GRAIN SIZE DISTRIBUTION
SILT WITH RANDOM ZONES OF CLAYEY SILT
(FILL MATERIAL)

FIG No 2

W P 65-67-04



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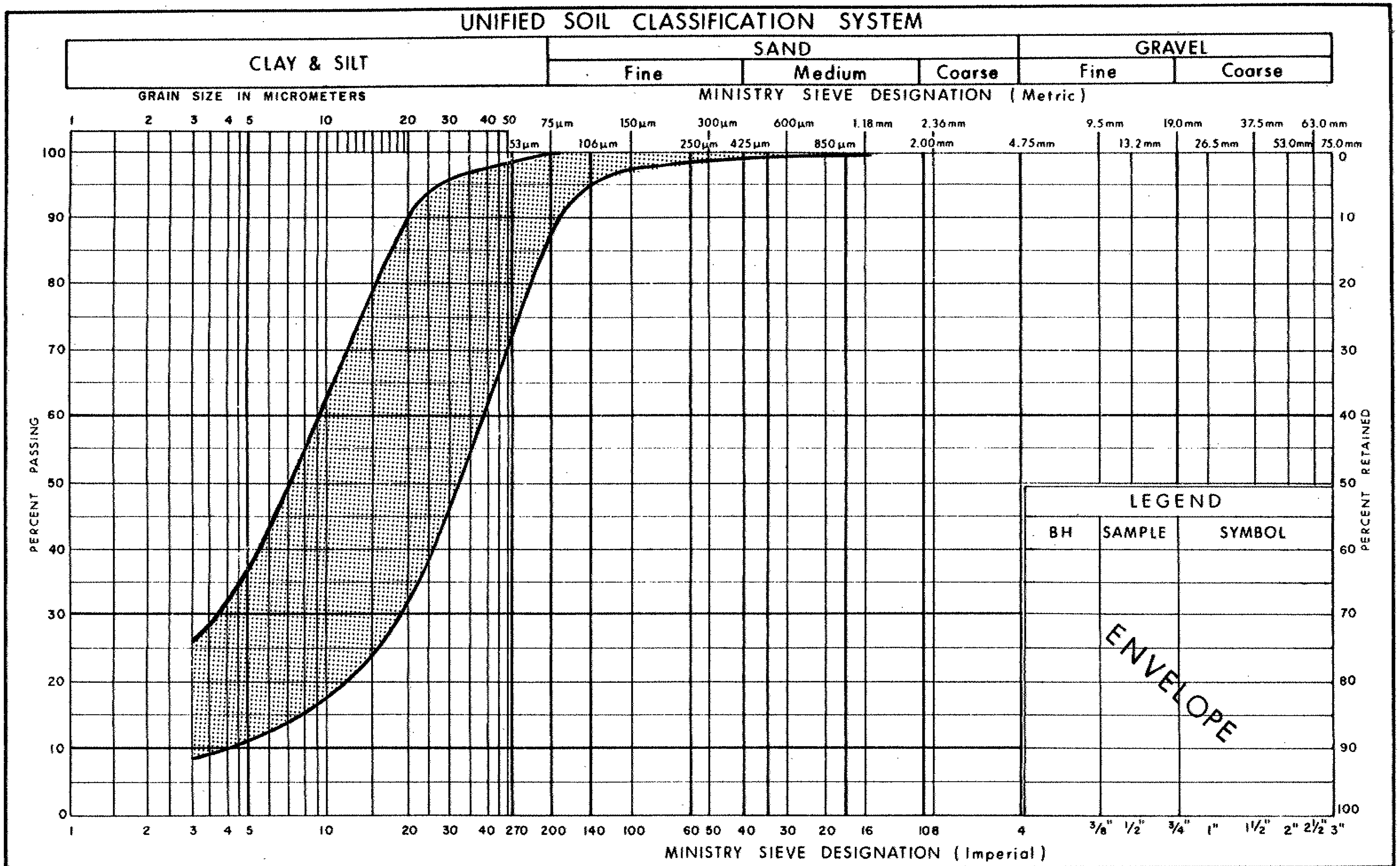
PLASTICITY CHART
SILT WITH RANDOM ZONES OF CLAYEY SILT
(FILL MATERIAL)

FIG No 3

W P 65-67-04

78 12 M



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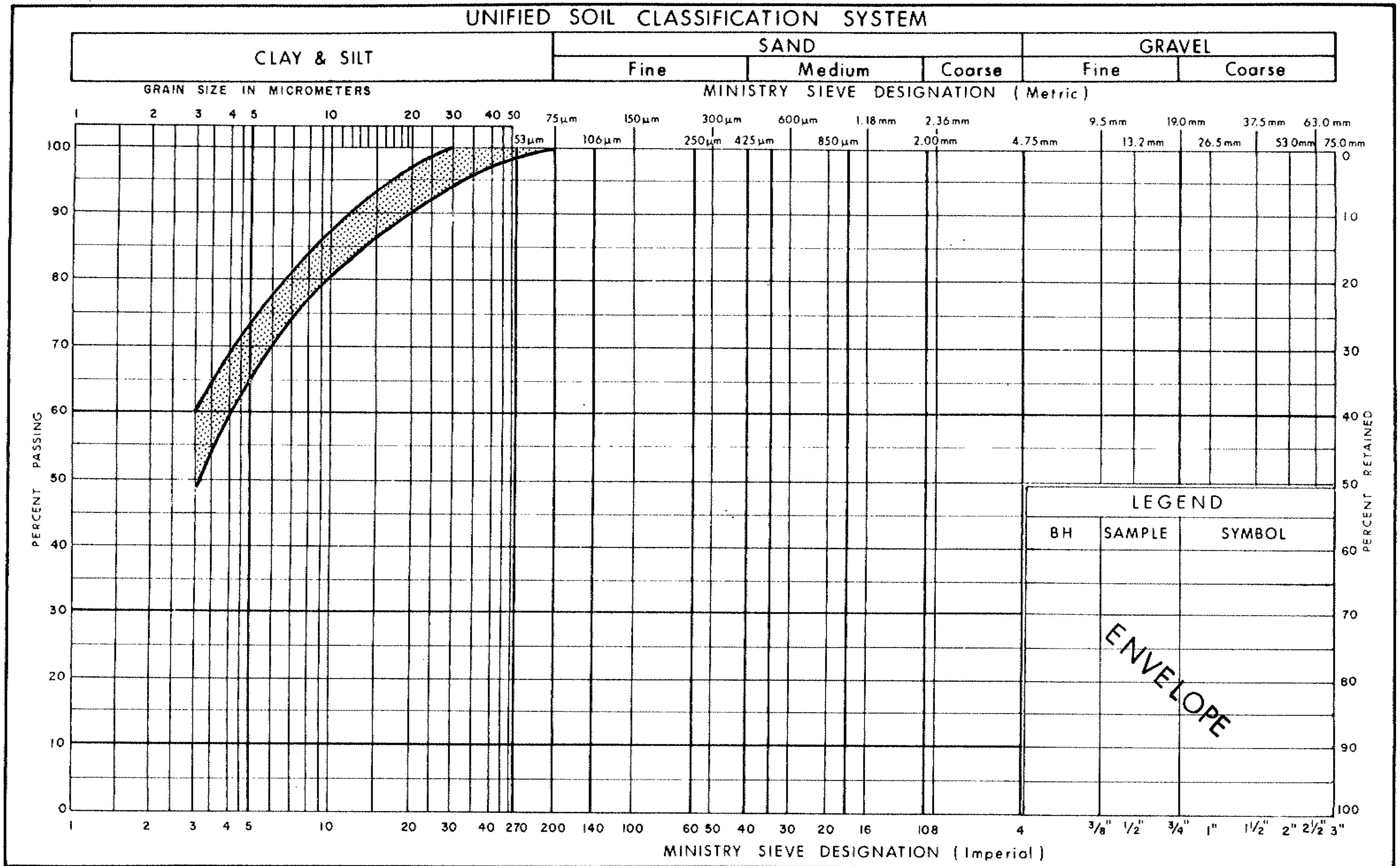
GRAIN SIZE DISTRIBUTION

SILT, TRACE / SOME SAND TO SILT

FIG No 4

W P 65-67-04

78 12 M



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GRAIN SIZE DISTRIBUTION

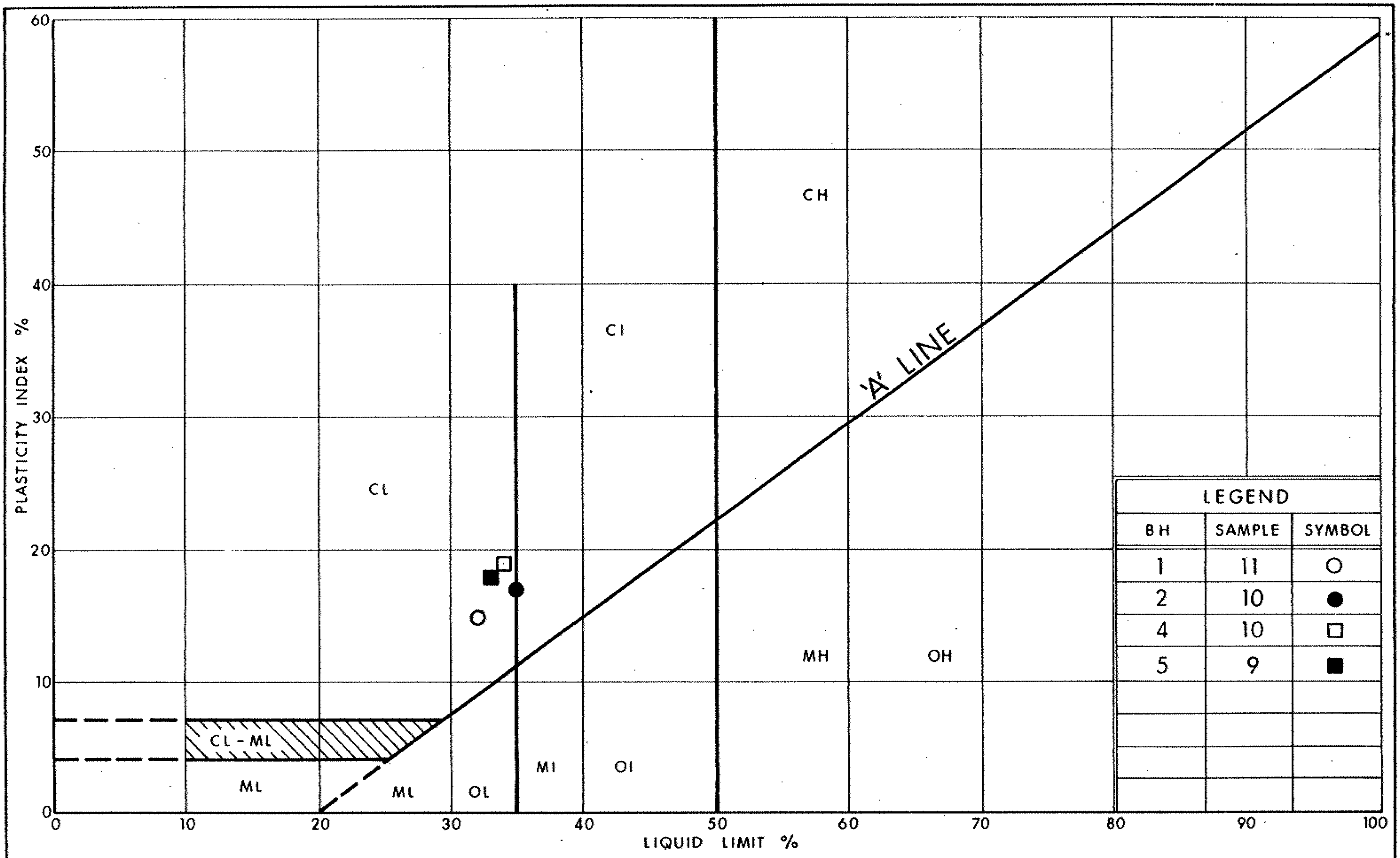
CLAYEY SILT

FIG No 5

W P 65-67-04

144

Oct 75, FF-S-21



BH	SAMPLE	SYMBOL
1	11	○
2	10	●
4	10	□
5	9	■

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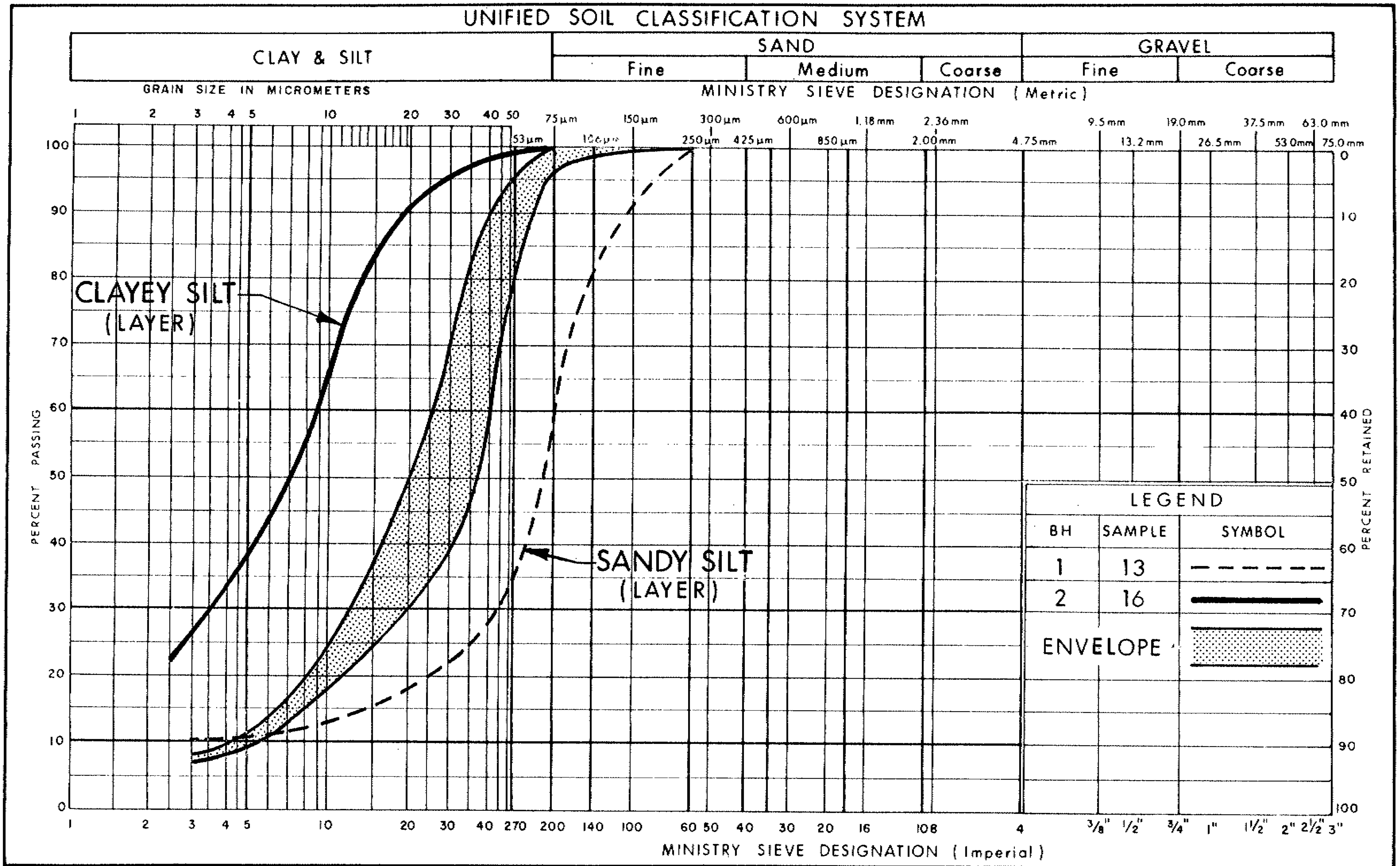
PLASTICITY CHART
CLAYEY SILT

FIG No 6

W P 65-67-04

78 12 M



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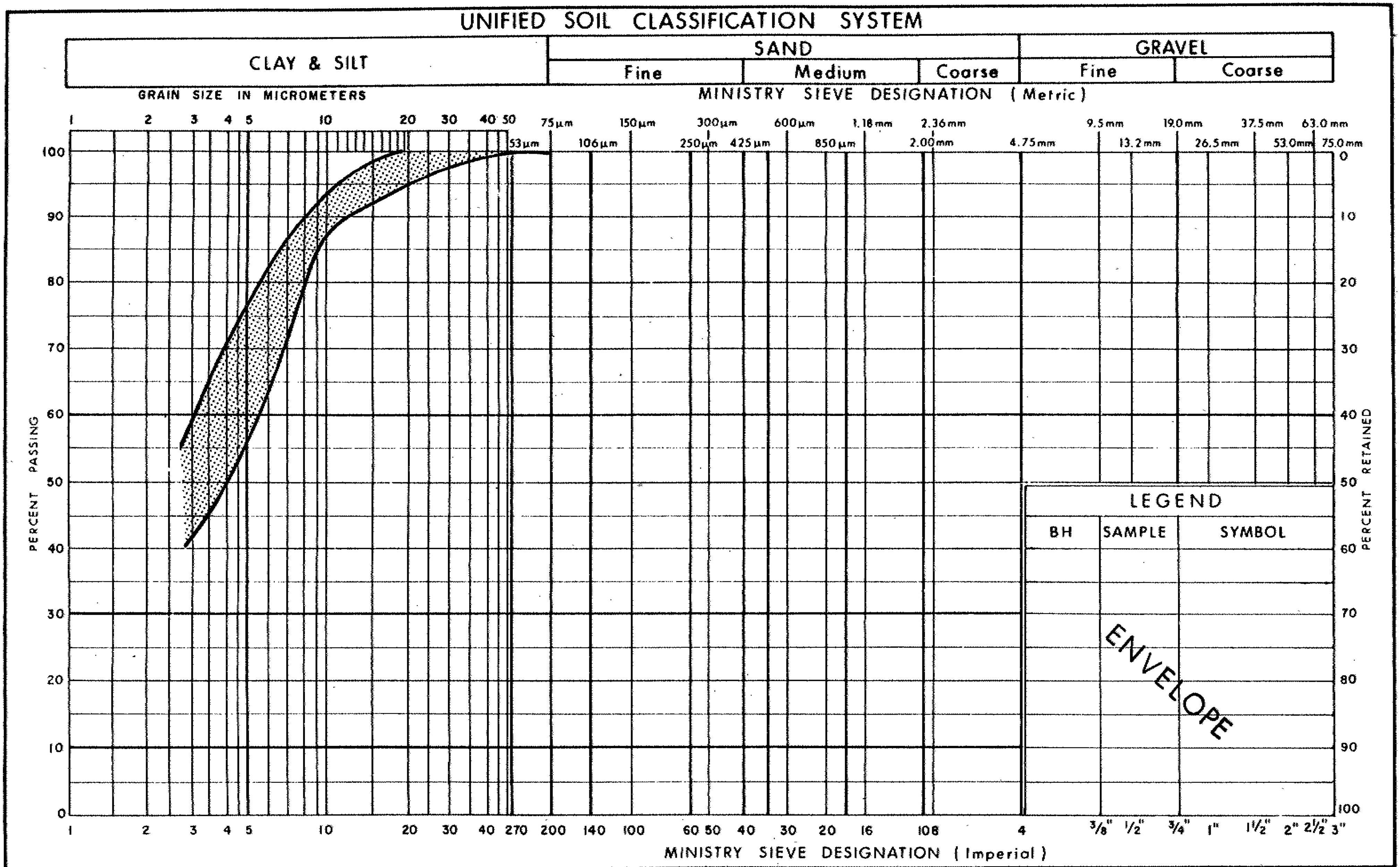
GRAIN SIZE DISTRIBUTION

SILT, WITH RANDOM LAYERS OF SILTY SAND

FIG No 7

W P 65-67-04

78 12 M



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GRAIN SIZE DISTRIBUTION

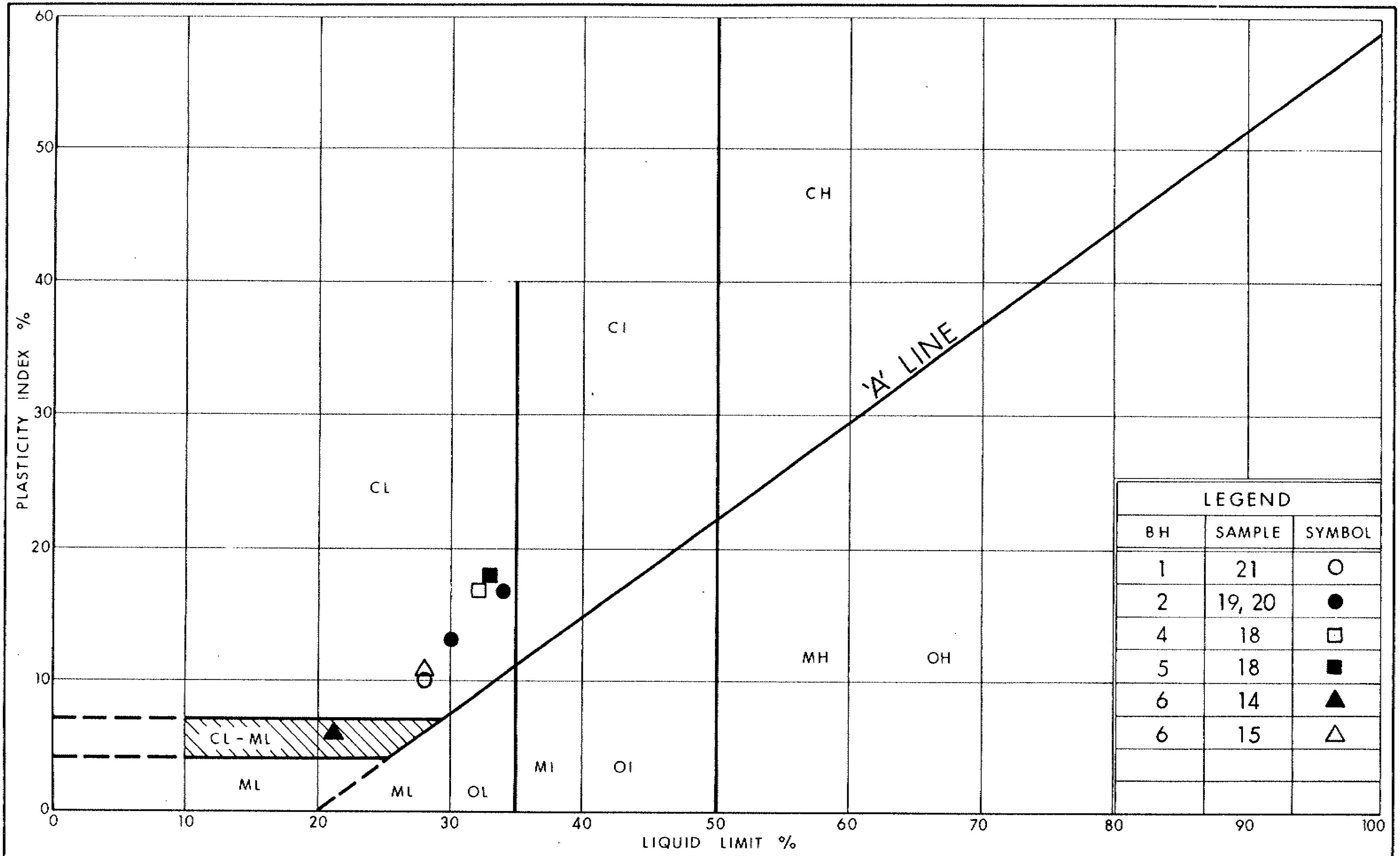
CLAYEY SILT

WITH RANDOM LAYERS OF SILT

FIG No 8

W P 65-67-04

Oct 75, FF-S-21



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PLASTICITY CHART

CLAYEY SILT
WITH RANDOM LAYERS OF SILT

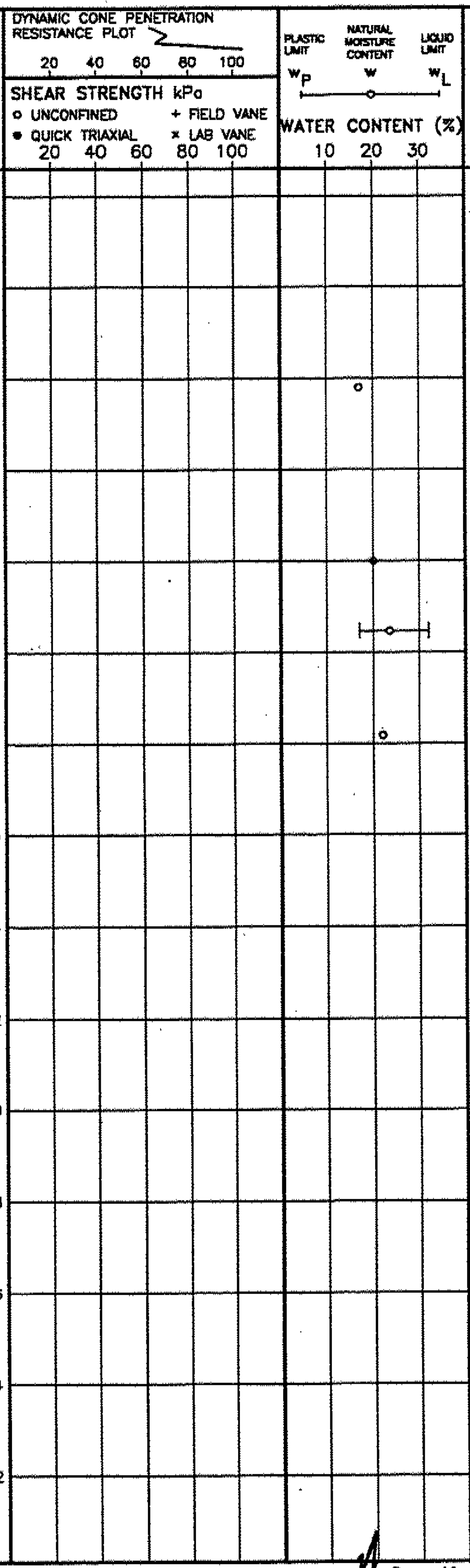
FIG No 9

W P 65-67-04

RECORD OF BOREHOLE No 1   1 OF 2   METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 548.0 E 260 498.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 07 10-11
CHECKED BY PP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES			GR	SA	SI	CL
230.6	Asphaltic Roadway Surface									
0.0	Sand, trace to some Silt trace Gravel, trace Organics, trace Asphalt (Fill Material)					230				
		1	SS	14						
	Brown with Black inclusions, Compact to Dense					228				
227.1		2	SS	35						
3.5	Silt	3	SS	48						
		4	SS	74		226	0	6	83	11
	Dense to Very Dense	5	SS	55						
		6	SS	38	▼	224				
	Compact Brown	7	SS	24						
	Grey	8	SS	13						
		9	SS	30		222	0	0	89	11
220.7		10	SS	12						
9.9 219.9	Clayey Silt Grey, Very Stiff	11	SS	24			0	0	60	40
10.7		12	SS	27		220				
	Sandy Silt	13	SS	42		218	0	43	47	10
		14	SS	14		216				
		15	SS	6		214				
		16	SS	7		212				
	Silt, trace Sand Loose to Compact					210				
		17	SS	18		208				
		18	SS	15		206				
						204				
	Random Interbedded Layers of Clayey Silt Stiff to Very Stiff	19	SS	7		202				
200.1 30.5										



Continued

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

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

Continued

Ministry of Transportation
Ontario

Foundation Design
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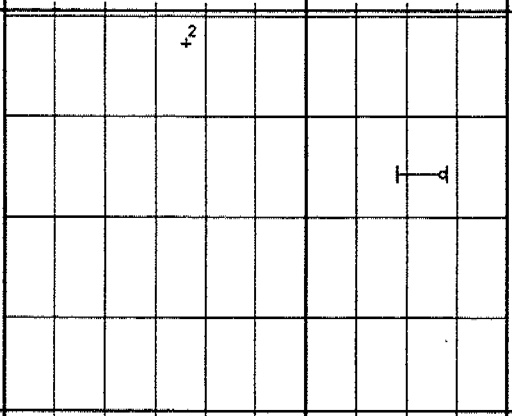
RECORD OF BOREHOLE No 1 2 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 548.0 E 260 498.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 07 10-11
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
200.1	Continued										
30.5	Clayey Silt Stiff to Very Stiff		20	SS	12		200	$+^2$			
			21	SS	17		198 196 194				
193.6 / 37.0	Bedrock – Dolostone Light to Medium Grey, Unweathered, Medium Strong		22	RC	REC 94%						RQD = 80%
192.1 / 38.5	End of Borehole										



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

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

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Ontario

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RECORD OF BOREHOLE No 1A

1 OF 1 METRIC

W.P. 65-67-04
DIST 4 HWY 403
DATUM Geodetic
LOCATION Co-ords: N 4 784 534.1 E 260 500.0
BOREHOLE TYPE HS Auger
DATE 91 07 16
ORIGINATED BY TS
COMPILED BY LD
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
230.6	Asphaltic Roadway Surface										
0.0	Sand trace Silt, trace Gravel						230				
229.1	(Fill Material)										
1.5			1	SS	12						
							228				
	Silt trace Sand, trace Gravel		2	SS	14						
	(Fill Material)						226				
	Compact		3	SS	*						
224.5	Brown										
6.1	Grey		4	SS	38	▼	224				
	Silt Compact to Dense										
222.5			5	SS	24						
8.1	End of Borehole * Probable Boulder										

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

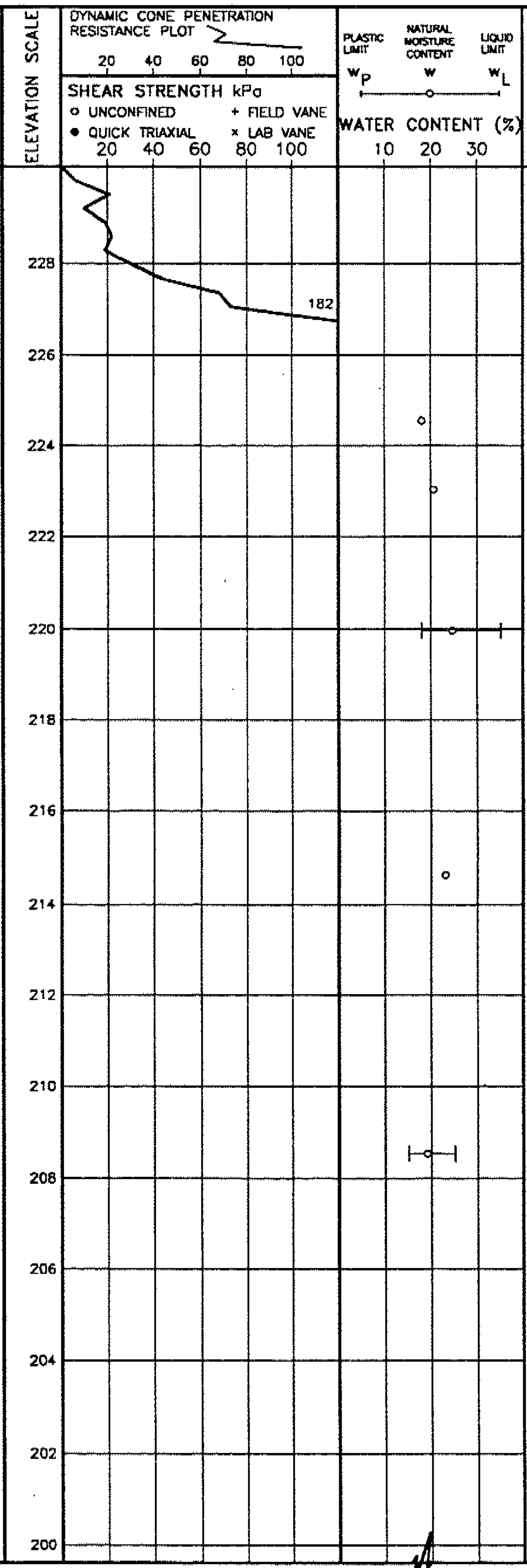
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

1 OF 2 METRIC

W.P. 65-67-04	LOCATION Co-ords: N 4 784 558.8; E 260 509.3	ORIGINATED BY LD
DIST 4 HWY 403	BOREHOLE TYPE HS Auger, BW Casing, Rock Coring	COMPILED BY LD
DATUM Geodetic	DATE 91 07 08-09	CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLE NUMBER	SAMPLE TYPE	'N' VALUES	GROUND WATER CONDITIONS	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR	SA	SI	CL
230.1	Ground Surface								
0.0	Silt with Random Zones of Clayey Silt (Fill Material)				*				
228.1	Brown, Compact	1	SS	23					
2.0	Silt, some Clay Dense to Very Dense	2	SS	40					
		3	SS	80					
		4	SS	81		1	7	78	14
	Brown Grey	5	22	36					
		6	SS	39		0	0	86	14
	Grey Brown	7	SS	68					
	Grey	8	SS	53					
220.2	Compact	9	SS	25					
9.9 219.4	Clayey Silt Grey, Very Stiff	10	SS	16		0	0	54	46
10.7	Silt with Random Layers of Silty Sand Dense to Very Dense	11	SS	38					
		12	SS	37					
		13	SS	42					
		14	SS	59		0	3	89	8
		15	SS	9					
	Random Interbedded Layers of Clayey Silt Stiff to Very Stiff	16	SS	11		0	0	80	20
		17	SS	26					
		18	SS	10					
199.6 30.5	Continued								



UNIT WEIGHT γ kN/m³

Continued

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

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

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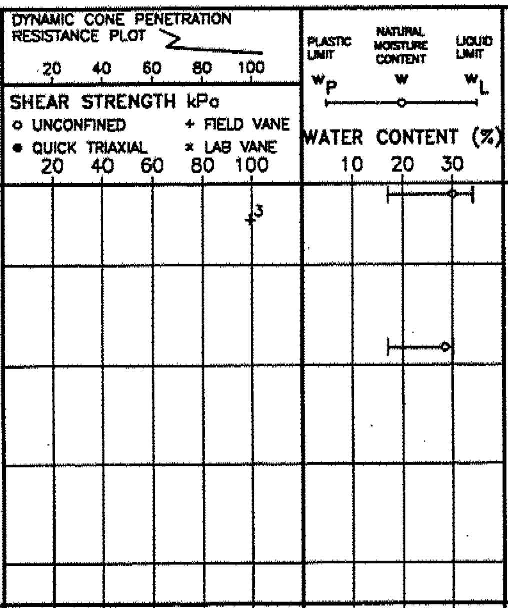
RECORD OF BOREHOLE No 2

2 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 558.8; E 260 509.3
ORIGINATED BY LD
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY LD
DATUM Geodetic
DATE 91 07 08-09
CHECKED BY PP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
199.6	Continued											
30.5	Clayey Silt with Random Layers of Silt Stiff to Very Stiff		19	SS	13				0	0	55	45
							198					
			20	SS	12				0	0	68	32
							196					
194.1												
36.0	Bedrock – Dolostone Light to Medium Grey, Unweathered, Medium Strong		21	RC	REC 100%		194		RQD = 89%			
			22	RC	REC 100%		192		RQD = 80%			
191.2 38.9	End of Borehole * G W L not Established											



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

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

RECORD OF BOREHOLE No 3

1 OF 1 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 455.2; E 260 516.2
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY TS
DATUM Geodetic
DATE 91 07 15
CHECKED BY PP

SOIL PROFILE ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
230.7	Asphaltic Roadway Surface									
0.0	Sand, trace Silt, trace Gravel (Fill Material)					230				
		1	SS	2						
227.7	Brown, Very Loose to Compact					228				
3.0	Silt with Random Zones of Clayey Silt (Fill Material)	2	SS	14						
		3	SS	7		226				
	Brown, Loose to Compact	4	SS	26		224				
		5	SS	*		222				
221.3		6	SS	10	▼					
9.4 220.0	Silt, trace Sand Black Organics Compact Brown	7	SS	20						
10.7 219.3	Clayey Silt Grey, Very Stiff	8	SS	14		220				
11.4	Silt with Layers of Silty Sand Grey, Compact to Dense	9	SS	49						
218.1		10	SS	28						
12.6	End of Borehole * Sampler Bouncing (Probable Boulder)									

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

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

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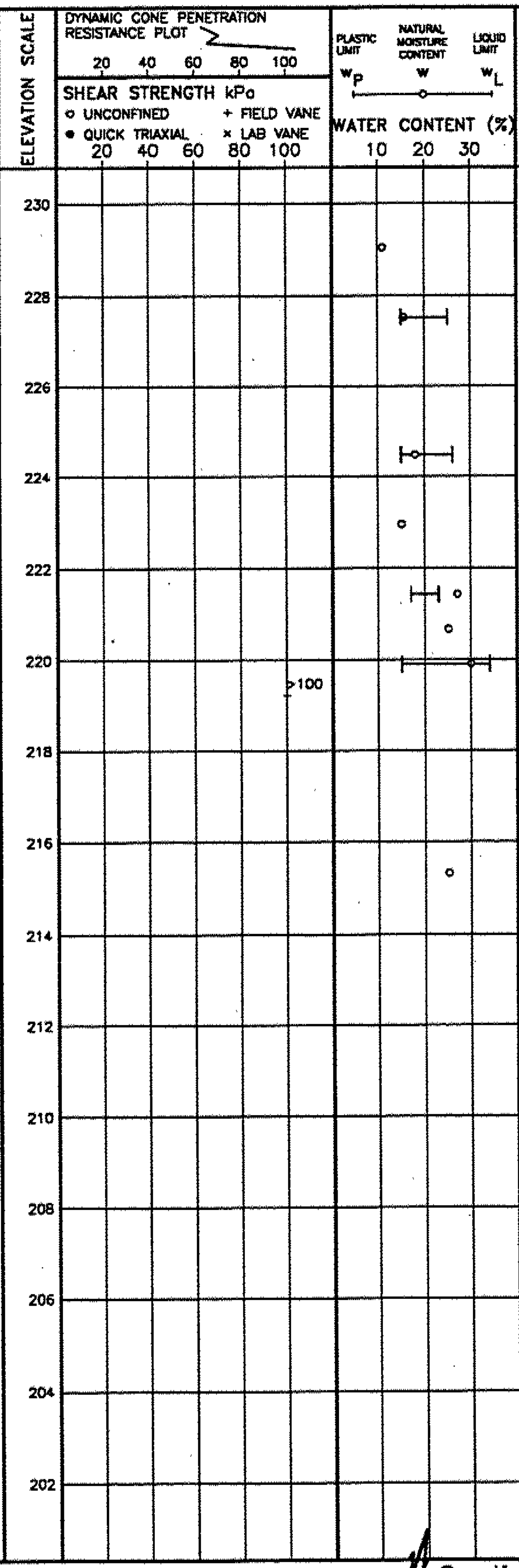
RECORD OF BOREHOLE No 4

1 OF 2 METRIC

W.P. 55-67-04
LOCATION Co-ords: N 4 784 484.0; E 260 520.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 07 10-11
CHECKED BY PP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
230.8	Asphaltic Roadway Surface								
0.0	Sand, some Silt, trace Clay (Fill Material)								
228.8	Compact	1	SS	28		0	50	40	10
2.0									
		2	SS	16		0	10	70	20
	Silt with Random Zones of Clayey Silt (Fill Material)	3	SS	46					
	Brown to Grey, Compact	4	SS	17		0	7	69	24
		5	SS	23					
		6	SS	25		2	28	53	17
		7	SS	23	▼				
221.5 / 9.3	Silt, trace Sand	8	SS	17		0	21	62	17
220.1	Brown, Compact	9	SS	20		0	2	88	10
10.7	Clayey Silt Grey, Very Stiff	10	SS	13		0	0	50	50
218.6 / 12.2	Silt with Random Layers of Silty Sand Grey, Compact	11	SS	29					
	Dense to Very Dense	12	SS	58					
		13	SS	32		0	1	90	9
		14	SS	16					
	Random Interbedded Layers of Clayey Silt Stiff to Very Stiff	15	SS	19					
		16	SS	12					
		17	SS	20					
200.3 / 30.5	Continued								



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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

RECORD OF BOREHOLE No 4 2 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 484.0; E 260 520.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 07 10-11
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
200.3	Continued										
30.5			18	SS	20		200				
	Clayey Silt with Random Layers of Silt Very Stiff						198				
			19	SS	17		196				
							194				
193.0 37.8	Bedrock – Dolostone Light Grey to Medium Grey, Unweathered, Medium Strong		20	RC	REC 100%		192				RQD = 80%
191.5 39.3	End of Borehole										

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

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

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Ontario

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RECORD OF BOREHOLE No 5

1 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 513.2; E 260 503.3
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY LD
DATUM Geodetic
DATE 91 07 08-09
CHECKED BY PP

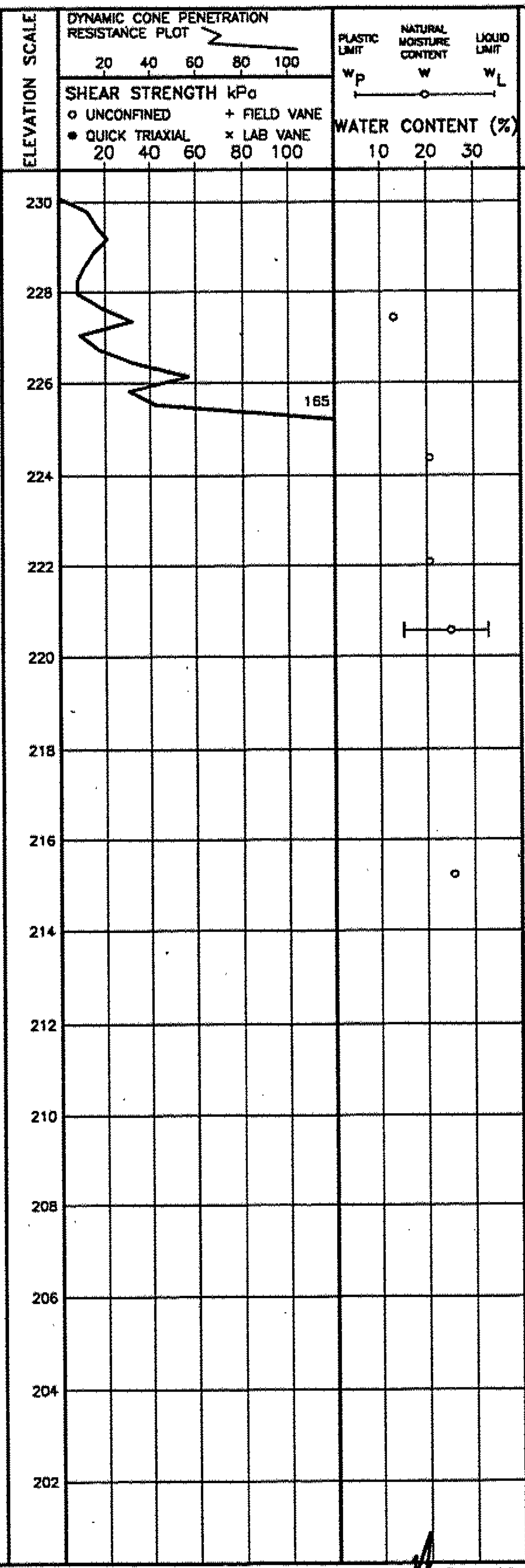
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
230.7	Ground Surface
0.0	Sand and Silt, trace Gravel (Fill Material) Brown, Loose to Compact
227.2 / 3.5	Silt with Random Zones of Clayey Silt (Fill Material) Brown, Loose to Dense
223.1 / 7.6	Silt, trace Sand Brown, Loose to Compact
220.8 / 9.9	Clayey Silt Grey, Very Stiff
219.9 / 10.8	Silt with Random Layers of Silty Sand Loose to Compact - - - - - - - Random Interbedded Layers of Clayey Silt Stiff to Very Stiff
200.2 / 30.5	

SAMPLES

NUMBER	TYPE	'N' VALUES	GR	SA	SI	CL
1	SS	6				
2	SS	13	0	46	42	12
3	SS	34				
4	SS	12	0	10	60	30
5	SS	9				
6	SS	7				
7	SS	21	0	11	81	8
8	SS	21				
9	SS	10	0	0	60	40
10	SS	24				
11	SS	22				
12	SS	20				
13	SS	16	0	0	93	7
14	SS	16				
15	SS	18				
16	SS	8				
17	SS	8				

GROUND WATER CONDITIONS
ELEVATION SCALE



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)
GR SA SI CL

Continued

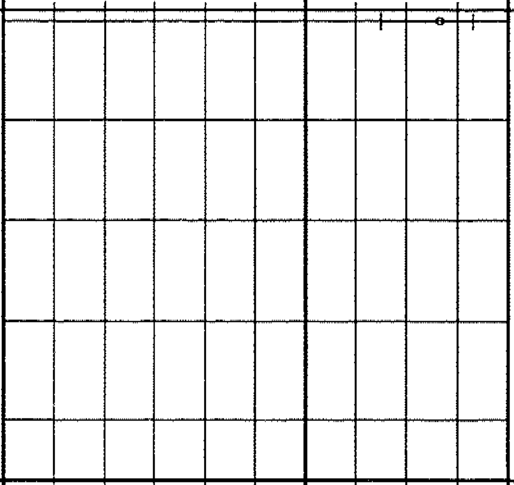
Continued

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

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

RECORD OF BOREHOLE No 5 2 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 513.2; E 260 503.3
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY LD
DATUM Geodetic
DATE 91 07 08-09
CHECKED BY PP



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						GR	SA	SI	CL
200.2	Continued													
30.5	Clayey Silt with Random Layers of Silt Stiff to Very Stiff		18	SS	15		200				0	0	55	45
							198							
			19	TW	PH									
							196							
193.7							194							
37.0	Bedrock – Dolostone Light to Medium Grey, Unweathered, Medium Strong		20	RC	REC 95%						RQD = 95%			
							192							
190.8			21	RC	REC 96%						RQD = 85%			
39.9	End of Borehole * G W L not Established													

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

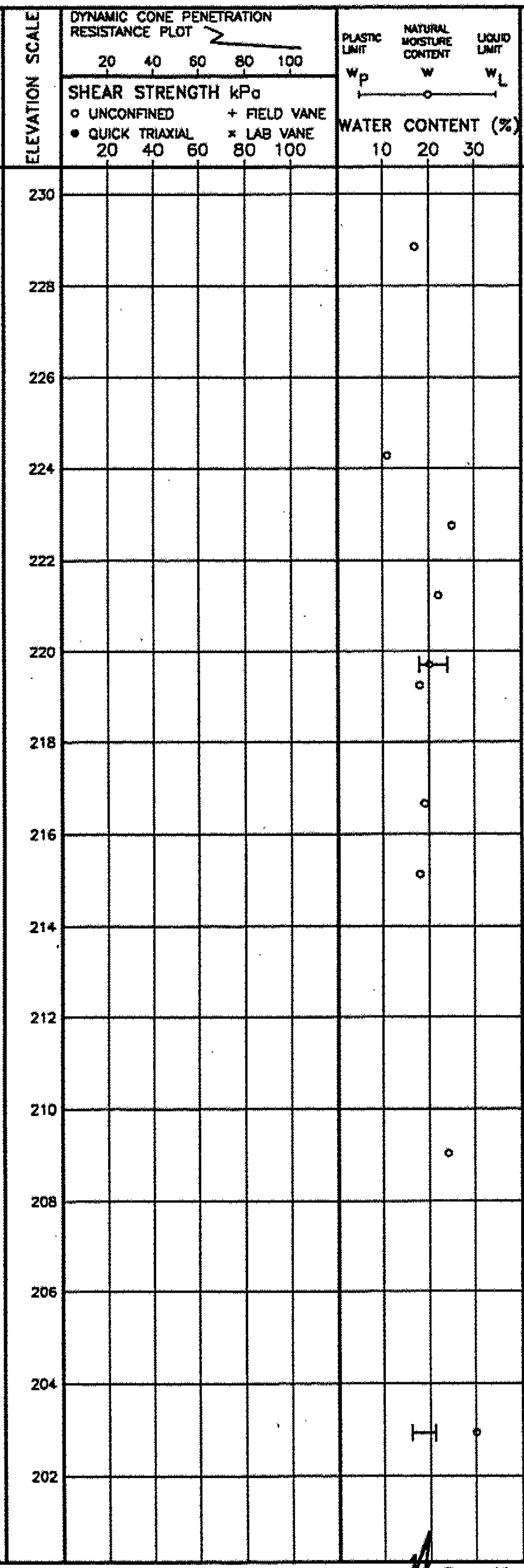
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 6*

1 OF 2 METRIC

W.P. 65-67-04
LOCATION Co-ords: N 4 784 515.7; E 260 511.0
ORIGINATED BY MK
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY MK
DATUM Geodetic
DATE 76 03 25-26
CHECKED BY PP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	GR	SA	SI	CL
230.6	Ground Surface								
0.0	Silt, some Sand, to Silty Sand (Fill Material) Loose to Dense	1	SS	8		0	20	74	6
		2	SS	39					
		3	SS	17					
		4	SS	33		6	47	41	6
223.3 7.3	Silt, some Sand Loose to Compact	5	SS	9	▼	0	17	76	7
		6	SS	17		0	18	76	6
219.9 10.7	Clayey Silt Very Stiff	7	SS	19		0	1	69	30
219.2 11.4	Silt, some Sand to Silt with Random Layers of Clayey Silt Loose to Very Dense					0	0	92	8
		8	SS	39		0	0	99	1
		9	SS	54		0	0	98	2
		10	SS	83		0	7	87	6
		11	SS	20					
		12	SS	24		0	0	95	5
		13	SS	6					
202.9 27.7		14	SS	9					
200.1 30.5									



UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%)

Continued

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

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

Continued

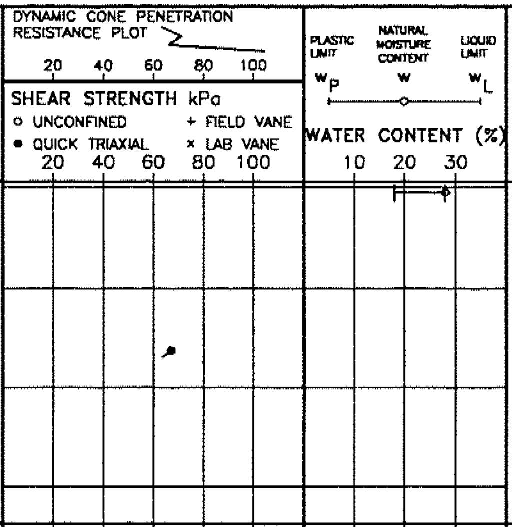
RECORD OF BOREHOLE No 6* 2 OF 2 METRIC

W.P. 65-67-04 LOCATION Co-ords: N 4 784 515.7; E 260 511.0 ORIGINATED BY MK

DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY MK

DATUM Geodetic DATE 76 03 25-26 CHECKED BY PP

ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
200.1	Continued							
30.5	Clayey Silt with Random Layers of Silt Stiff to Very Stiff	▨	15	SS	11		200	
		▨					198	
		▨	16	TW	PH		196	
193.3		▨	17	SS	9		194	
37.3	End of Borehole * Formerly BH No 13 (WP 65-67-01)							



UNIT WEIGHT γ kN/m³

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

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

RECORD OF BOREHOLE No 7

1 OF 1 METRIC

W.P. 65-67-04 LOCATION Co-ords: N 4 784 578.0; E 260 498.0 ORIGINATED BY LD

DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 91 07 15 CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS
230.6	Asphaltic Roadway Surface				
0.0	Sand, trace Silt, trace Gravel (Fill Material) Brown, Dense	1	SS	38	
228.6 2.0	Silt, with Random Zones of Clayey Silt, some Organics (Fill Material) Brown to Black, Loose	2	SS	9	
225.9 4.7	Silt, some Sand Brown, Compact	3	SS	9	
		4	SS	12	
		5	SS	12	▼
		6	SS	15	
	Grey, Dense	7	SS	38	
		8	SS	30	
221.5 9.1	Clayey Silt Grey, Very Stiff	9	SS	12	
219.9 10.7	Silt, some Sand with Layers of Silty Sand Grey, Dense to Very Dense	10	SS	51	
		11	SS	56	
218.0 12.6	End of Borehole	12	SS	46	

ELEVATION SCALE: 230, 228, 226, 224, 222, 220

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100

PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L

WATER CONTENT (%) 10 20 30

UNIT WEIGHT γ kN/m^3

REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

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

ROCK CORE DESCRIPTION
WP 65-67-04

Page 1 of 1

	CORE RECOVERY				CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	22	36.96-38.48	94	80	36.96-38.48	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to light olive grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to close spaced, flat to dipping, undulating, smooth to rough.
2	21 22	35.97-37.39 37.39-38.91	100 100	89 80	35.97-38.91	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to light olive grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to dipping, undulating, smooth to rough.
4	20	37.80-39.32	100	80	37.80-39.32	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to light olive grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to close spaced, flat to dipping, undulating, smooth to rough.
5	20 21	37.03-38.56 38.56-39.93	95 96	95 85	37.03-39.93	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to light olive grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to close spaced, flat to dipping, undulating, smooth to rough.

***CR** = CORE RECOVERY

***RQD** = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

FOUNDATION INVESTIGATION REPORT
For
Hwy. 403 and Alberton Road Underpass
W.P. 65-67-05, Site 36-261
District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted at the abovementioned site. It is proposed to construct a two span structure that will carry the existing Alberton Road along its present alignment over the proposed Hwy. 403.

SITE DESCRIPTION AND GEOLOGY

The site is located along the existing Alberton Road approximately 1 km north of Hwy. 2 and 3 km west of Hwy. 52 within the Town of Ancaster, Regional Municipality of Hamilton-Wentworth.

The existing Alberton Road is a two lane asphaltic roadway with narrow gravel shoulders. The shoulders, in turn, are adjoined by a flat lying grassland. The gravel shoulders were at some locations also covered with grass and weeds.

The terrain at the site has a gently rolling and hilly topography. Ground surface elevations hence vary significantly. Elevations immediately west of the proposed structure are approximately 1 to 2 m higher and similarly elevations east of the structure are approximately 1 m lower in elevation. Land use in the area is predominantly agricultural farmland and both corn and barley were being cultivated at the time of the investigation. In addition, a milk holstein, evidence, of dairy farming is located approximately 0.5 km north of the site and some forestland exists approximately 1 km east of the site beyond the abovementioned agricultural farmland.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound.

Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of weak to medium strong dolostones of the Paleozoic era. At the site, the overburden has a thickness of approximately 28 to 29 m.

INVESTIGATION PROCEDURES

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and laboratory testing program are discussed below.

Field Investigation

The fieldwork for this project was carried out under two separate stages. The initial stage, was implemented between 76 03 24-25 inclusive and consisted of one sampled borehole (BH 5, formerly BH 12) advanced to a depth of 29.7 m and one dynamic cone penetration test advanced to a depth of 12.8 m. This initial first stage provided information to facilitate the planning and design of the proposed Hwy. 403 route between the Towns of Ancaster and Brantford.

The second stage of the fieldwork was carried out between 91 06 24-27 inclusive and consisted of a total of four sampled boreholes reflecting the greater extent of this subsequent fieldwork. The scope of the second stage of the fieldwork was to provide detailed soils/rock data to facilitate the design and construction of the proposed structure and related earthworks. Two (2) boreholes were advanced at the proposed abutment structure foundation locations and one borehole was advanced at either proposed approach fills north and south of the structure. The boreholes at the structures were advanced to depths of 31.2 m (BH 1) and 30.8 m (BH 2) and were accompanied by dynamic cone penetration tests driven to depths ranging from 7.9 m to 9.8 m. The approach fill boreholes were advanced to depths ranging from 12.6 m to 20.7 m.

The boreholes were advanced through the overburden using track mounted boring units employing conventional continuous flight hollow stem augering techniques. Conventional rock coring techniques were used to retrieve 3 m of rock core at BH 1 and 1.5 m at BH 2.

In general, subsoil samples were retrieved at 0.7 m intervals for the surficial 4.6 m to 6.0 m, at 1.5 m intervals beyond this surficial depth to approximately 15 m and at 3 m intervals thereafter. Subsoil samples were taken at 1.5 m intervals at the approach locations.

Subsoil samples were generally retrieved in accordance with the Standard Penetration Test (ASTM D1586) and hence were disturbed during the testing. Relatively undisturbed subsoil samples were randomly retrieved in cohesive soils using a thin wall sampler in accordance with procedures outlined in ASTM D 1587. All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents. Disturbed samples were placed in plastic containers and the thin wall samples were capped and waxed at the ends of the shelby tubes. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

Rock core samples were also identified in the field and rock recoveries and Rock Quality Designations (RQD) measured. The rock cores were then transported to the laboratory in conventional core boxes and detailed rock core logs were produced by an in-house geologist.

In situ vane tests were also carried out to determine the undrained shear strength of the weaker cohesive soils at the site. The test was carried out in accordance with ASTM D2573 using the Standard MTO 'N' vane. Remoulded shear strengths were also obtained where applicable.

Groundwater levels were obtained by monitoring the levels in the open boreholes throughout the duration of the field investigation. All open boreholes were backfilled at the completion of the fieldwork.

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

Laboratory Analyses

To determine the pertinent physical properties and behaviour of the soil, various laboratory tests were conducted. These tests included:

1) Natural Moisture Contents
2) Atterberg Limits
3) Grain Size Analyses
4) Bulk Unit Weights
5) Consolidation Tests

Laboratory test results are shown on the borehole logs and corresponding figures attached in the Appendix. These results have been summarized in the subsequent section of this report entitled "Subsurface Conditions".

SUBSURFACE CONDITIONS

General

The ground surface elevation at the boreholes advanced at the site ranged from 221.3 m to 222.1 m.

The subsurface conditions are generally uniform across the site and underlying a sand and gravel roadway base fill material approximately 0.8 m in thickness consists of three (3) distinct soils strata. The surficial native deposit extending to depths ranging from 5 to 6.6 m below the ground surface consists of a stiff to very stiff clayey silt to silty clay material with occasional seams of silt. This stratum is underlain by an extensive deposit of plastic silt interbedded with layers of clayey silt. The clayey silt interbeds range in thickness from approximately 25 mm to 2 m. The silt material is in a loose to compact state of denseness and the clayey silt layers are generally stiff to very stiff in consistency. This deposit has a thickness ranging from 19.1 m to 20.9 m. A third soil stratum consisting of a clayey silt with interbedded layers of silt underlies the silt deposit with interbeds of clayey silt and extends to the bedrock surface. The thickness of this stratum ranges from 3.4 m to 3.8 m. This stratum has a stiff to very stiff consistency. The bedrock surface exists at an elevation ranging from 191.7 m to 193.1 m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. 656705-A*. A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Borehole sheets in the Appendix.

Sand and Gravel (Fill Material)

A cohesionless sand and gravel exists as the base of the existing Alberton Roadway and has a thickness in the order of 0.8 m. This bedding material is brown in colour and appears to be in a compact state of denseness.

Clayey Silt to Silty Clay with random seams of Silt

The surficial native stratum at the site consists of a cohesive clayey silt to silty clay material that contains random seams of interbedded silt. The stratum which is unstructured and without any distinct layering has a thickness ranging 4.2 to 5.8 m.

The stratum has been oxidized to a penetration depth of approximately 3 to 4.6 m beneath the existing ground surface and hence is brown in colour within this depth. Beneath this depth, the stratum is unoxidized and grey in colour.

A grain size distribution envelope produced by mechanical sieve and hydrometer anlayses is shown on Figure 1 in the Appendix. The envelope clearly illustrates that the stratum is composed of grain sizes smaller than 75 micrometres.

* DWG NO 2 OF THE CONTRACT DWG'S

The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 55% to 82% and clay percentages ranging from 15% to 45%. A grain size distribution curve representing the gradation of a typical silt seam is also shown on Figure 1.

In view of the fact that more than 80% of the material is finer than 75 micrometres, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil. The results are plotted on Figure 2 in the Appendix and summarized on Table 1 below. Natural moisture contents and the bulk unit weight of the soil have also been included in the table.

Table 1 - Atterberg Limit Test Results

	Range	# of Tests
Natural Moisture Content (w%)	22-27	8
Liquid Limit (w_L%)	24-40	8
Plastic Limit (w_P%)	17-21	8
Plasticity Index (I_P%)	5-21	8
Bulk Unit Weight (kN/m^3)	19.6-20.3	2

The test results clearly reveal that the soil has a plasticity ranging from low to intermediate and hence can be classified as a clayey silt to silty clay with seams of plastic silt. Natural Moisture Contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state.

The consistency and undrained shear strength of the soil was determined based on the evaluation of the 'N' values derived from the Standard Penetration Tests and by conducting in situ vane tests. The 'N' values ranged from 7 blows/0.3 m to 24 blows/0.3 m and averaged 15 blows/0.3 m based on twenty-two (22) Standard Penetration Tests. In situ vane tests were also attempted within the weaker zones of the stratum. In generally, the vanes could not be torqued within the limitations of the test and hence it can be concluded from this observation that the material has undrained shear strengths exceeding 100 kPa and hence the soil has a stiff to very stiff consistency.

Silt with interbedded layers of Clayey Silt

An extensive cohesionless deposit of plastic silt interbedded with layers of clayey silt underlies the surficial native clayey silt to silty clay with interbedded seams stratum at the site. The surface of this deposit is present at an elevation ranging from 214.5 m to 217.1 m and the deposit has a thickness ranging from 19.1 m to 20.9 m.

The deposit has a distinct layered structure with predominant silt thickness interbedded with layers or seams of cohesive clayey silt ranging in thickness from 25 mm to 2 m. The silt material is light grey in colour whilst the clayey silt is dark grey in colour. The silt material exhibits a quick dilatancy. Grain size distribution envelopes representing the gradation of the silt material as well as the clayey silt interlayers are shown on Figure 3 in the Appendix.

Atterberg Limit Tests were also carried out to determine the behaviour and plasticity of the cohesive interbeds and also to verify any plasticity in the silty material. The results of these tests are shown on Figure 4 in the Appendix. The results reveal that this silt deposit is a plastic material and the cohesive interbeds are of low plasticity. These results are also summarized in Table 2 below.

Table 2 - Atterberg Limits

Silt

	Range	# of Tests
Natural Moisture Content (w%)	26-28	8
Liquid Limit (w_L%)	20-26	8
Plastic Limit (w_P%)	16-20	8
Plasticity Index (I_P%)	1-6	8

Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	20-30	6
Liquid Limit (w_L%)	23-35	6
Plastic Limit (w_P%)	14-19	6
Plasticity Index (I_P%)	7-21	6

The compressibility characteristics of the clayey silt interbeds was determined by conducting a one dimensional consolidation test on a representative sample. The results of the test (e-log curve) is illustrated on Figure 5 in the Appendix. The results reveal that the material has been preconsolidated in the past to an effective pressure approximately 500 kPa in excess of the existing effective overburden pressure. The compression index of the material (Cc) was of small magnitude and equivalent to approximately 0.4.

Some borehole sloughing was observed during the penetration and sampling within this deposit. This soil cave-in can be attributed to unbalanced hydrostatic head.

The denseness of the silt material was determined by evaluating the 'N' values derived by the Standard Penetration Test. Based on 'N' values ranging from 7 blows/0.3 m to 30 blows/0.3 m, the silt material has a denseness ranging from loose to compact. In view of the influence of unbalanced hydrostatic head conditions in producing lower 'N' values, the denseness of the silt material can be described as compact.

The consistency of the clayey silt interbeds was determined by attempting to conduct in situ vane tests. In many cases, the presence of the silt material confining the clayey silt layers inhibited the execution of the test. However, vane tests were successfully executed in the thicker layers of clayey silt. Undrained shear strengths measured ranged from approximately 60 kPa to in excess of 120 kPa. Based on this information, the cohesive clayey silt can be described as having a stiff to very stiff consistency.

Clayey Silt with layers of Silt

Underlying the silt with interbedded layers of clayey silt stratum a deposit consisting of a clayey silt with layers of silt extending to the bedrock surface exists. The surface of the deposit exists at an elevation ranging from 195.3 m to 196.9 m and the deposit has a thickness in the order of magnitude of 3.4 m to 3.8 m. The silt layers are typically 50 mm to 100 mm in thickness.

A grain size distribution curve illustrating the gradation of a representative sample of this material is shown on Figure 6 in the Appendix. The curve illustrates that the material is fine grained with grain sizes less than 75 micrometres.

In accordance with the MTO soil classification system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 3 below. Natural Moisture Contents are also included in the table below.

Table 3 - Clayey Silt to Silty Clay

	Range	# of Tests
Natural Moisture Content (w%)	28-30	2
Liquid Limit (w_L%)	28-29	2
Plastic Limit (W_p%)	18-19	2
Plasticity Index (I_p%)	10-11	2

The test results reveal that the soil has a low plasticity and hence can be classified as a clayey silt. Natural moisture contents are approximately equivalent to the liquid limit of the soil revealing liquidity indices (I_L) exceeding unity.

The 'N' values as derived from the Standard Penetration Test reveal values ranging from 8 blows/0.3 m to 14 blows/0.3 m. Based on these 'N' values the consistency of the soil is estimated as stiff to very stiff.

Bedrock

The bedrock consists of dolostone of the Amabel Formation and underlies the clayey silt with layers of silt deposit at an elevation of approximately 191.7 m to 193.1 m. The bedrock was cored in BQ and BXL size up to 3 m in depth at the proposed structure foundation locations.

The dolostone bedrock is a fine to medium grained chemical sedimentary rock that typically is composed of magnesium carbonate compounds and calcite crystals. The rock is unweathered that is featured by a porous "vug" texture and stylolites. The rock is light grey to medium dark grey in colour and contains thin horizontal beds and wide spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix entitled "Description of Rock Core".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and hardness testing in the laboratory. Recoveries ranged from 87% to 100% and RQD's ranged from 70% to 83% indicating that the rock is of good to excellent quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of the recent investigation were approximately 3 m below the ground surface (elevation 218.9 m to 219.1 m).

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto, Engineering Student, utilizing equipment owned and operated by Atcost Soil Drilling Ltd. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.
The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by M. Devata, Chief Foundation Engineer.

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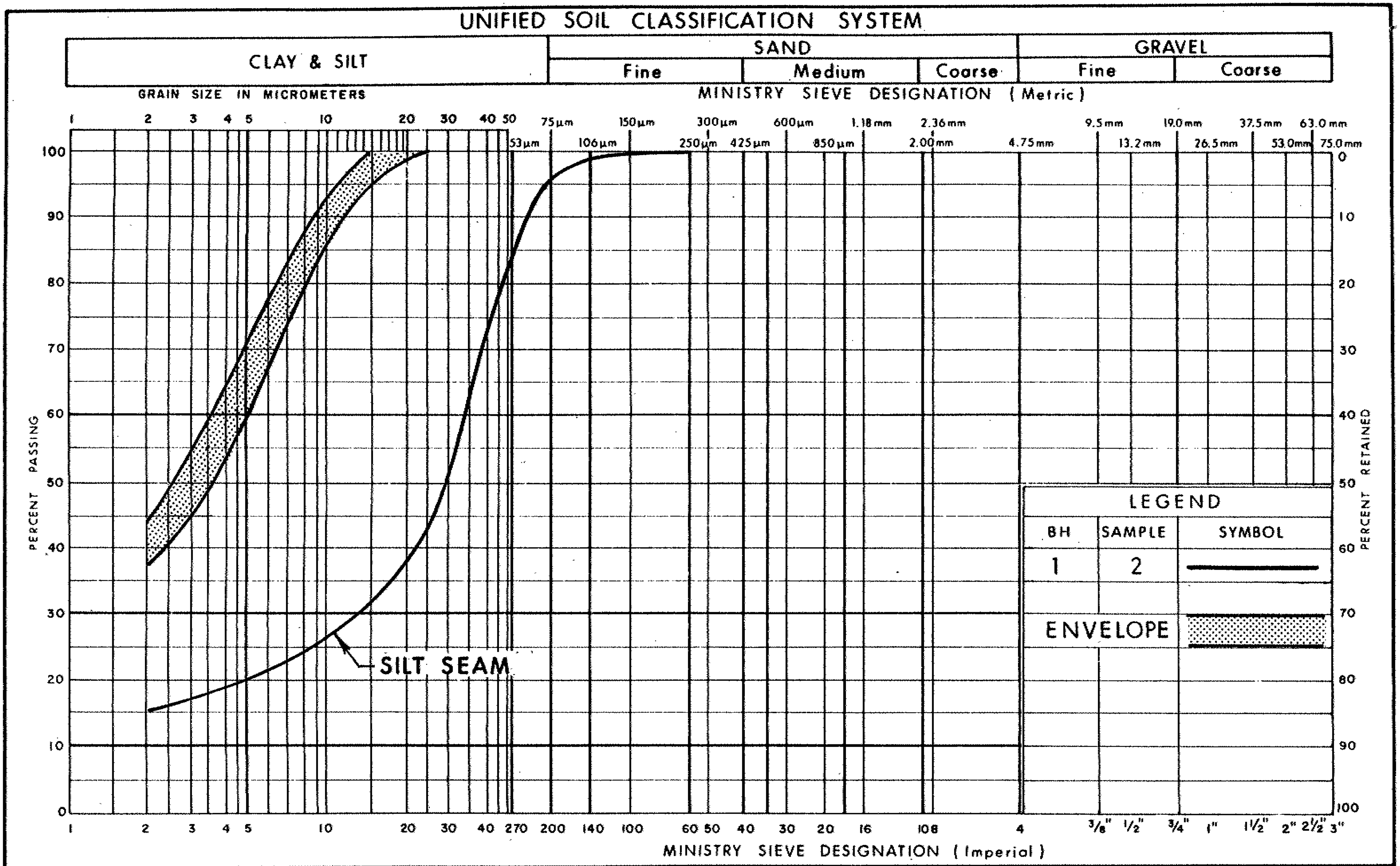
APPENDIX

78 12 M



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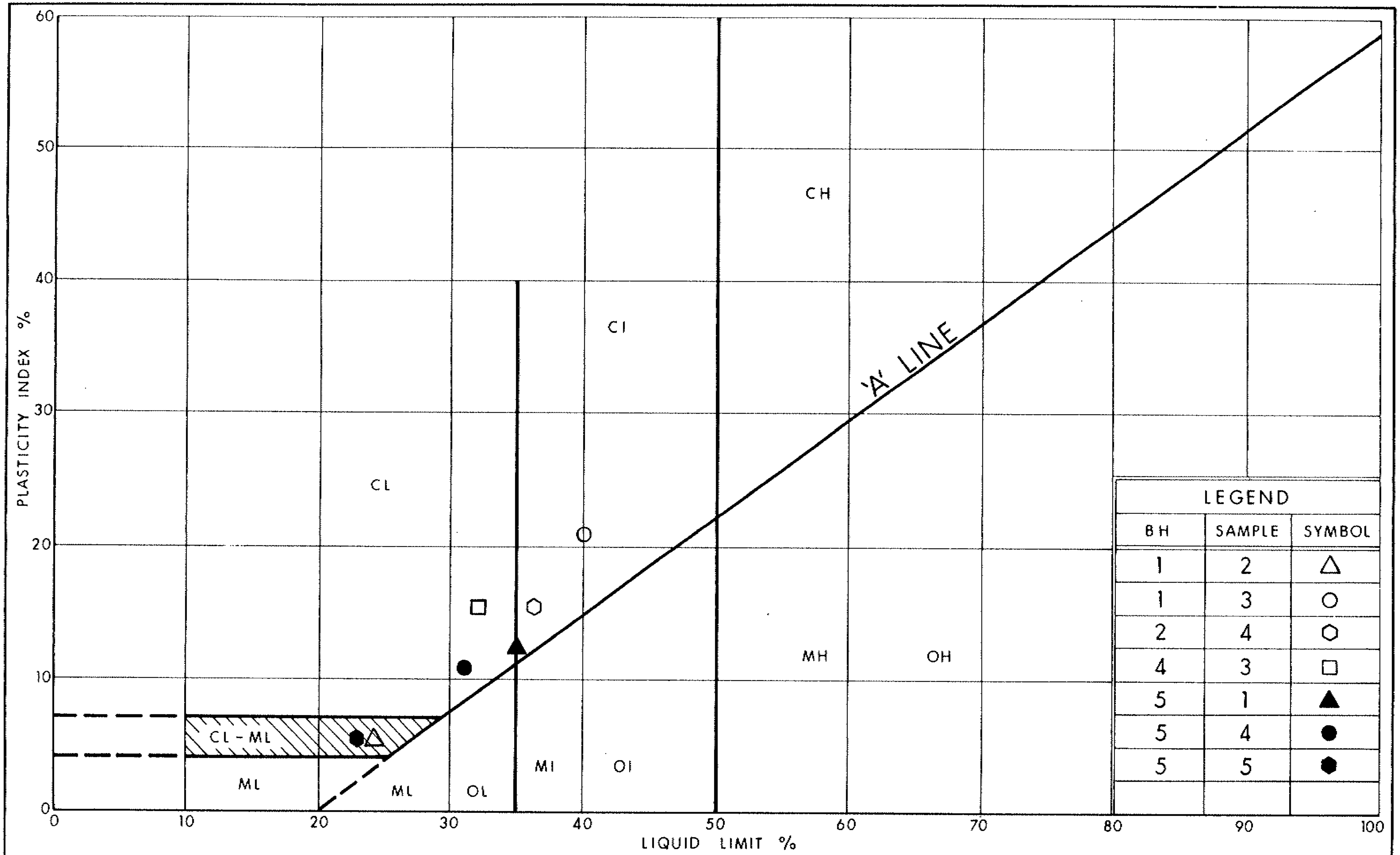
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM SEAMS OF SILT

FIG No 1

W P 65-67-05

Oct 75, FF-S-21



LEGEND

BH	SAMPLE	SYMBOL
1	2	△
1	3	○
2	4	⬡
4	3	□
5	1	▲
5	4	●
5	5	⬢

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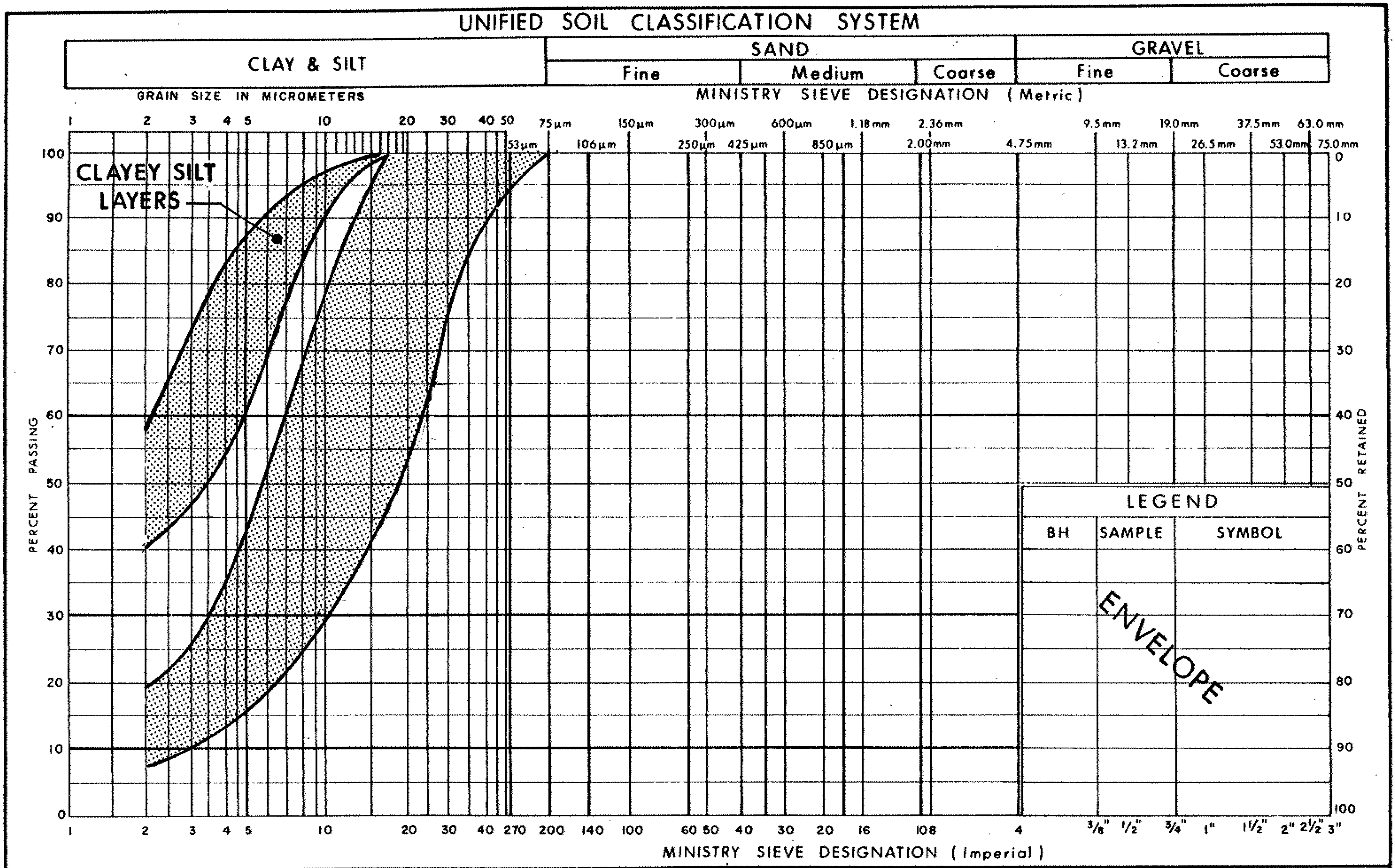
PLASTICITY CHART

CLAYEY SILT TO SILTY CLAY
WITH RANDOM SEAMS OF SILT

FIG No 2

W P 65-67-05

78 12 M



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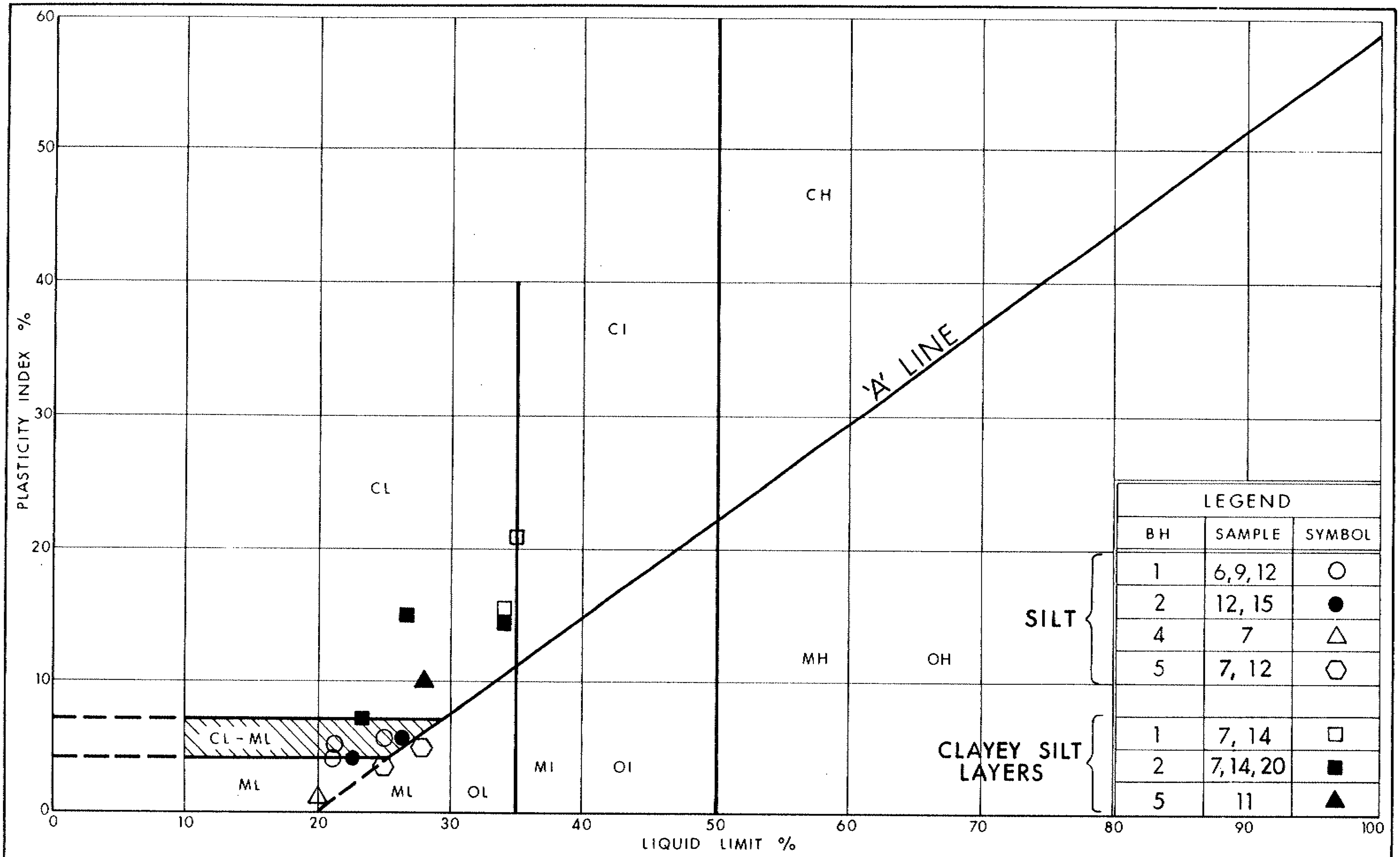
GRAIN SIZE DISTRIBUTION

SILT, WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 3

W P 65-67-05

Oct 75, FF-S-21



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PLASTICITY CHART

SILT, WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 4

W P 65-67-05

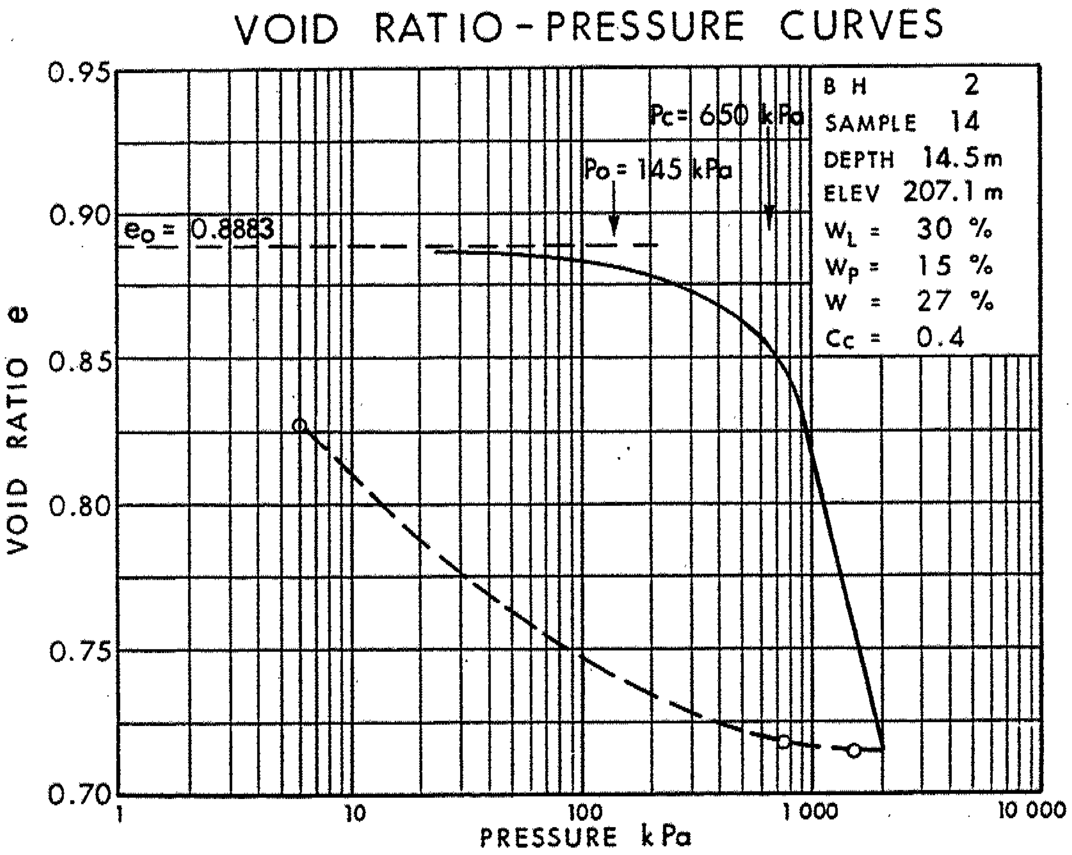
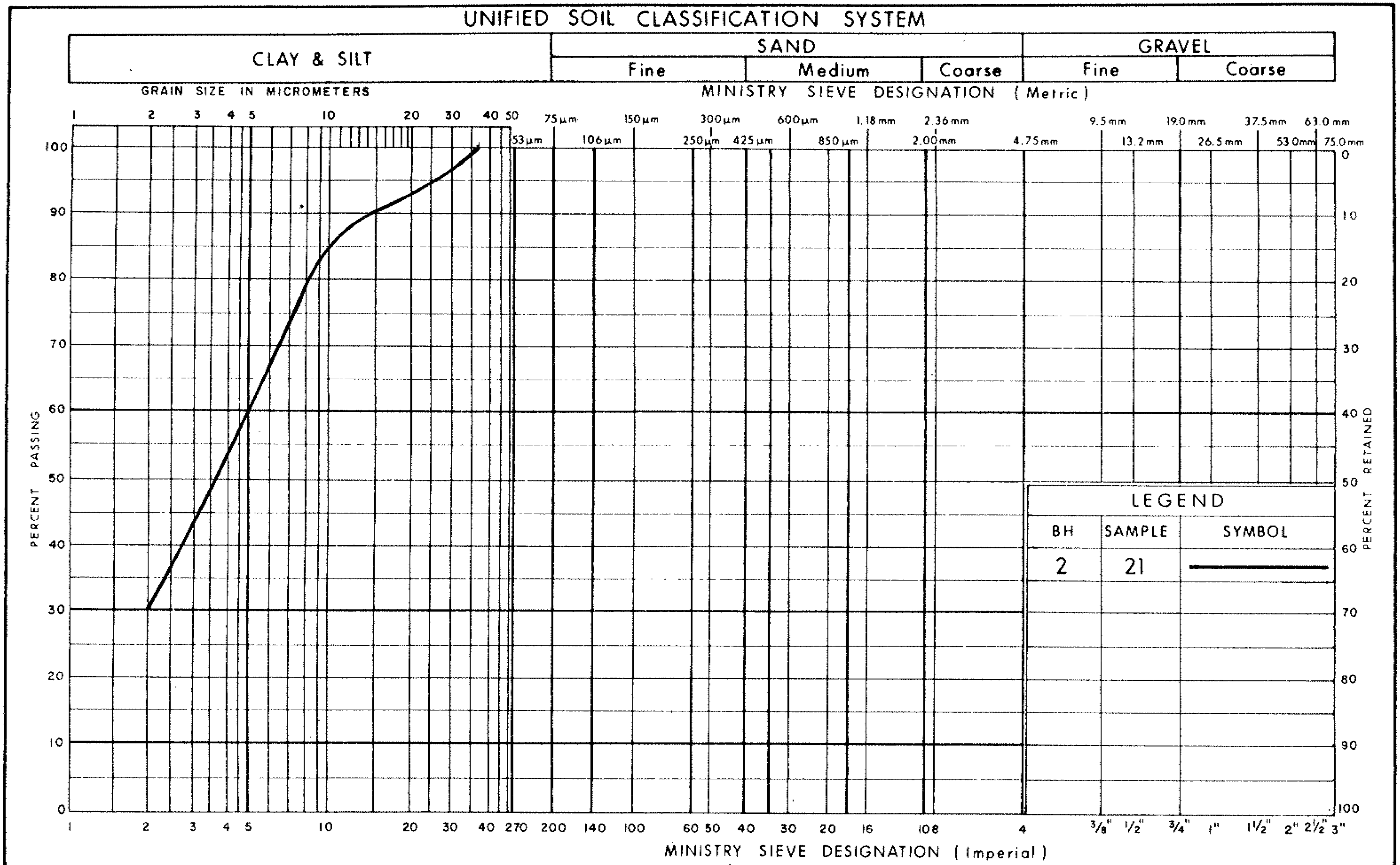


Fig 5

WP 65-67-05

78 12 M



LEGEND		
BH	SAMPLE	SYMBOL
2	21	━━━

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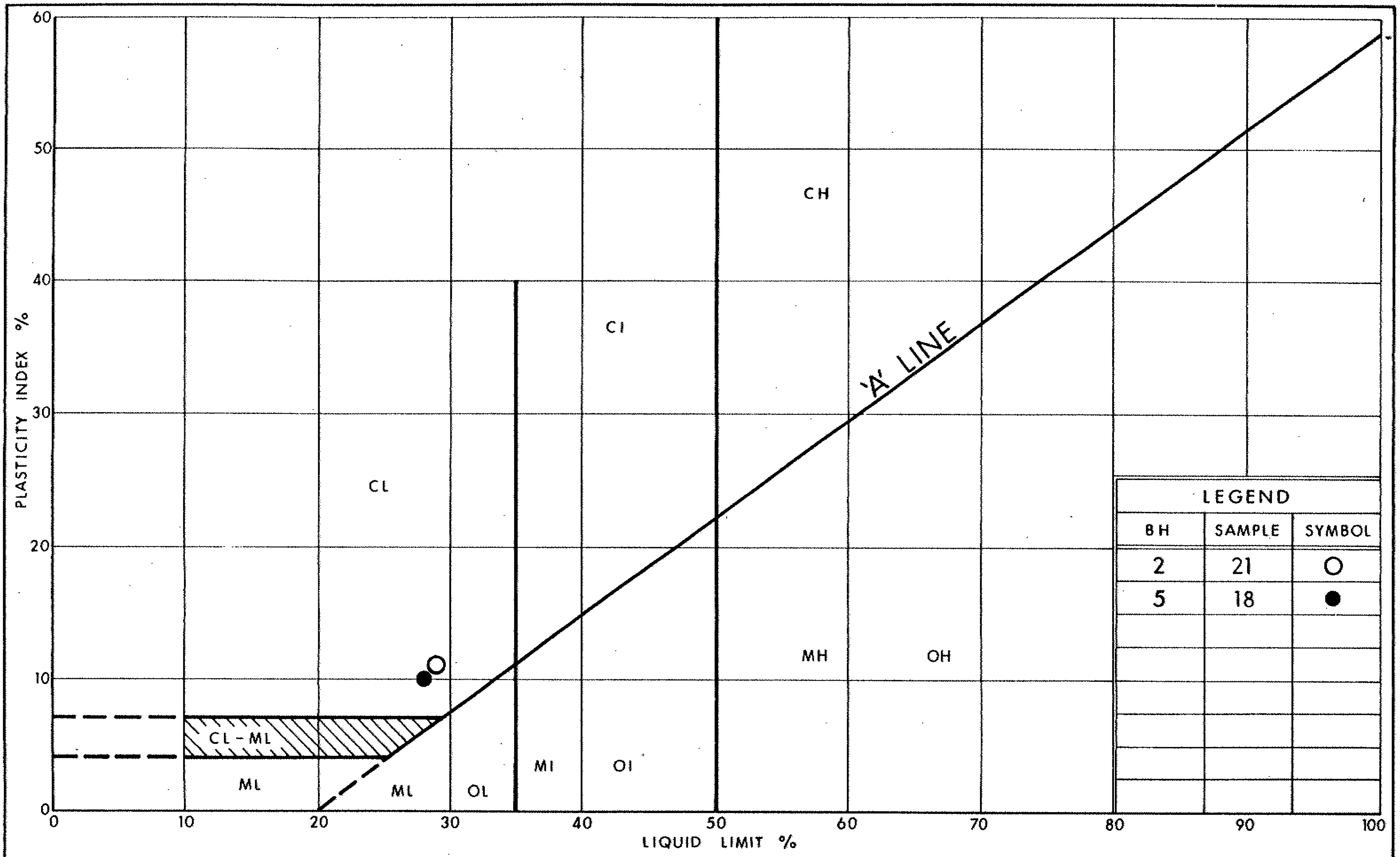
GRAIN SIZE DISTRIBUTION

CLAYEY SILT, WITH LAYERS OF SILT

FIG No 6

W P 65-67-05

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
2	21	○
5	18	●

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PLASTICITY CHART

CLAYEY SILT, WITH LAYERS OF SILT

FIG No 7

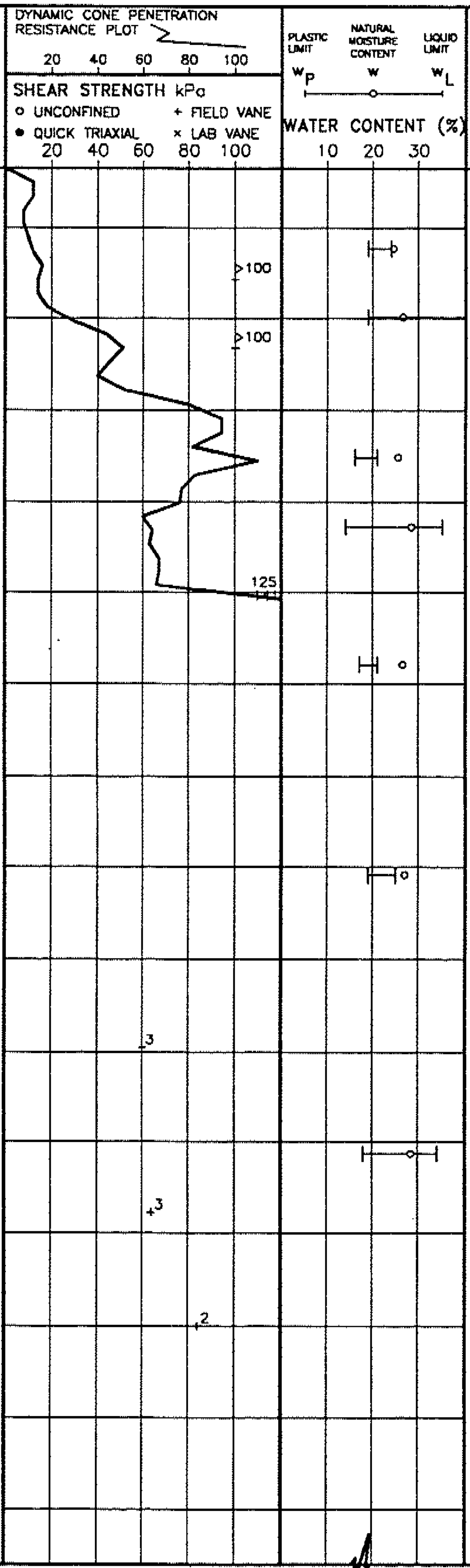
W P 65-67-05

RECORD OF BOREHOLE No 1

1 OF 2 METRIC

W.P. 65-67-05	LOCATION Co-ords: N 4 783 630.4; E 258 154.8	ORIGINATED BY TS
DIST 4 HWY 403	BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring	COMPILED BY LD
DATUM Geodetic	DATE 91 06 24	CHECKED BY PP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL	REMARKS
221.3	Ground Surface										
220.5 0.0	Sand and Gravel (Fill Material) Brown, Compact				*						
0.8	Clayey Silt with random seams of Silt, Brown / Grey, Very Stiff	1	SS	10							
		2	SS	8			0	3	82	15	
		3	SS	13		20.3	0	0	55	45	
216.0		4	SS	16							
5.3	Silt with interbedded layers of Clayey Silt, Grey, Loose to Compact	5	SS	22							
		6	SS	14			0	0	84	16	
		7	SS	11			0	0	43	57	
		8	SS	18							
		9	SS	12			0	0	88	12	
		10	SS	9							
		11	SS	10							
		12	SS	18			0	0	76	24	
		13	SS	8							
		14	SS	12			0	0	60	40	
196.9		15	TW	PH							
24.4	Clayey Silt with layers of Silt, Grey, Stiff to Very Stiff	16	SS	14							
193.1		17	SS	11							
28.2	Bedrock – Dolostone, Light Grey, Unweathered, Medium Strong	18	RC	REC 95%							RQD = 77%
190.8 30.5		19	RC	REC 100%							RQD = 83%



Continued

+³, ×⁵ : Numbers refer to Sensitivity

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

Continued

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RECORD OF BOREHOLE No 1 2 OF 2 METRIC

W.P. 65-67-05
LOCATION Co-ords: N 4 783 630.4; E 258 154.8
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring
COMPILED BY LD
DATUM Geodetic
DATE 91 06 24
CHECKED BY PP

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 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
190.8	Continued										
30.5 190.1		▨	19	RC	REC 100%						RQD = 83%
31.2	End of Borehole * GWL not established										

$+^3, \times^5$: Numbers refer to Sensitivity $15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

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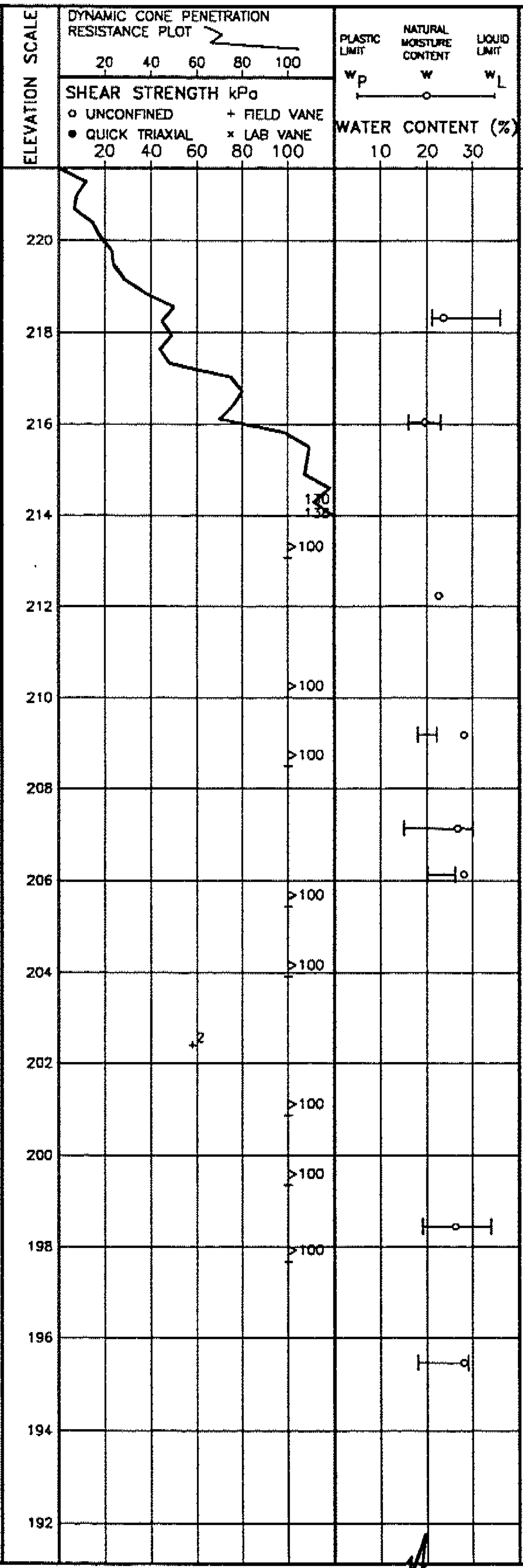
RECORD OF BOREHOLE No 2

1 OF 2 METRIC

W.P. 65-67-05
DIST 4 HWY 403
DATUM Geodetic
LOCATION Co-ords: N 4 783 686.8; E 258 142.0
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
DATE 91 06 26-27
ORIGINATED BY TS
COMPILED BY TS
CHECKED BY PP

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES			GR	SA	SI	CL
221.6	Ground Surface									
0.0 220.8	Sand and Gravel (Fill Material) Brown, Compact									
0.8	Clayey Silt to Silty Clay with random seams of Silt	1	SS	9						
		2	SS	19						
		3	SS	16						
	Very Stiff Brown	4	SS	24	▼	19.6	0	0	63	37
	Grey	5	TW	PH						
216.6		6	SS	23						
5.0		7	SS	30			0	0	79	21
		8	SS	29						
		9	SS	10						
		10	SS	24			0	0	92	8
		11	SS	10						
	Silt with interbedded layers of Clayey Silt	12	SS	8			0	0	85	15
	Grey, Loose to Compact	13	SS	9						
		14	TW	PH			0	0	55	45
		15	SS	8			0	0	82	18
		16	SS	8						
		17	SS	6						
		18	SS	11						
		19	SS	10						
		20	TW	PH						
195.7										
25.9		21	SS	10			0	0	70	30
	Clayey Silt with layers of Silt Grey, Very Stiff									
192.3		22	SS	* 3	/15cm					
29.3	Bedrock – Dolostone Light Grey, Medium Strong, Unweathered	23	RC	REC 87%			RQD = 70%			
191.1										
30.5	Continued									



+³, ×⁵ : Numbers refer to Sensitivity

20 15-○-5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 2

2 OF 2 METRIC

W.P. 65-67-05
LOCATION Co-ords: N 4 783 686.8; E 258 142.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 06 26-27
CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV / DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
191.1	Continued										
190.8		▨	23	RC	REC	= 87%					RQD = 70%
30.8	End of Borehole										
	* Sampler Bouncing										

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

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

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RECORD OF BOREHOLE No 3

1 OF 1 METRIC

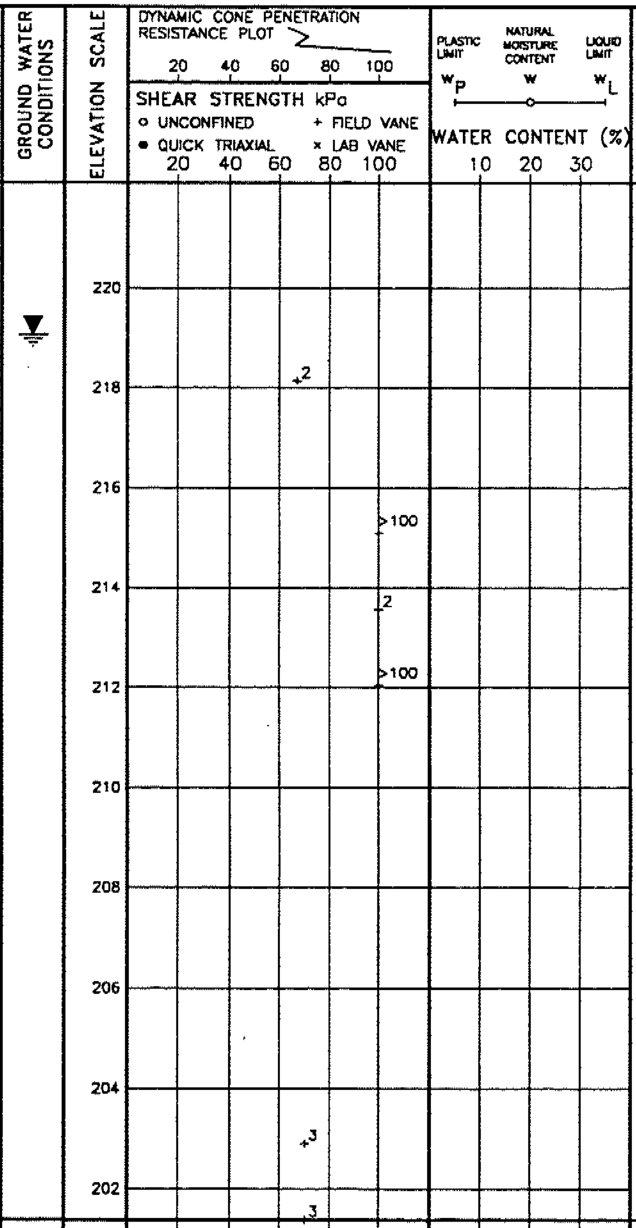
W.P. 65-67-05
LOCATION Co-ords: N 4 783 606.6; E 258 167.6
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY TS
DATUM Geodetic
DATE 91 06 26
CHECKED BY PP

SOIL PROFILE

ELEV DEPTH	DESCRIPTION
222.1	Ground Surface
0.0 221.3	Sand and Gravel (Fill Material) Brown, Compact
0.8	Clayey Silt with random seams of Silt Brown / Grey Stiff to Very Stiff
217.1 5.0	Silt with interbedded layers of Clayey Silt Grey, Loose to Compact
201.4 20.7	End of Borehole

SAMPLES

NUMBER	TYPE	'N' VALUES
1	SS	16
2	SS	10
3	SS	7
4	SS	9
5	SS	7
6	SS	12
7	SS	18
8	SS	8
9	SS	10
10	SS	8
11	TW	PH
12	SS	18
13	SS	15



UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

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

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

RECORD OF BOREHOLE No 4

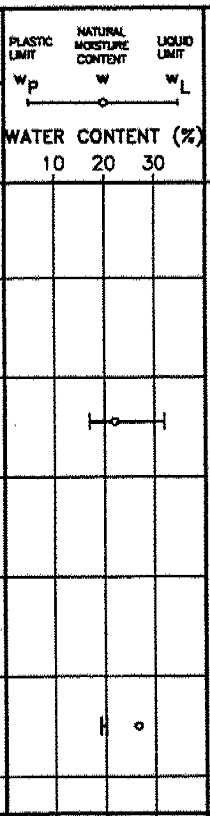
1 OF 1 METRIC

W.P. 65-67-05
LOCATION Co-ords: N 4 783 714; E 258 145.2
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY TS
DATUM Geodetic
DATE 91 06 26
CHECKED BY PP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
221.9	Ground Surface										
221.1 0.0	Sand and Gravel (Fill Material)										
0.8	Clayey Silt with random seams of Silt Brown	1	SS	11		220					
		2	SS	24	▽						
	Grey					218					
	Very Stiff	3	SS	13				0	0	60	40
						216					
215.3		4	SS	22							
6.6	Silt with interbedded layers of Clayey Silt	5	SS	15		214					
		6	SS	21							
	Grey, Compact					212					
		7	SS	13				0	0	88	12
						210					
209.3		8	SS	10							
12.6	End of Borehole										

DYNAMIC CONE PENETRATION RESISTANCE PLOT
20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100



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

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

RECORD OF BOREHOLE No 5 * 1 OF 1 METRIC

W.P. 65-67-05
LOCATION Co-ords: N 4 783 662.2; E 258 159.5
ORIGINATED BY BW
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Rock Coring, Cone Test
COMPILED BY BW
DATUM Geodetic
DATE 76 03 24-25
CHECKED BY PP

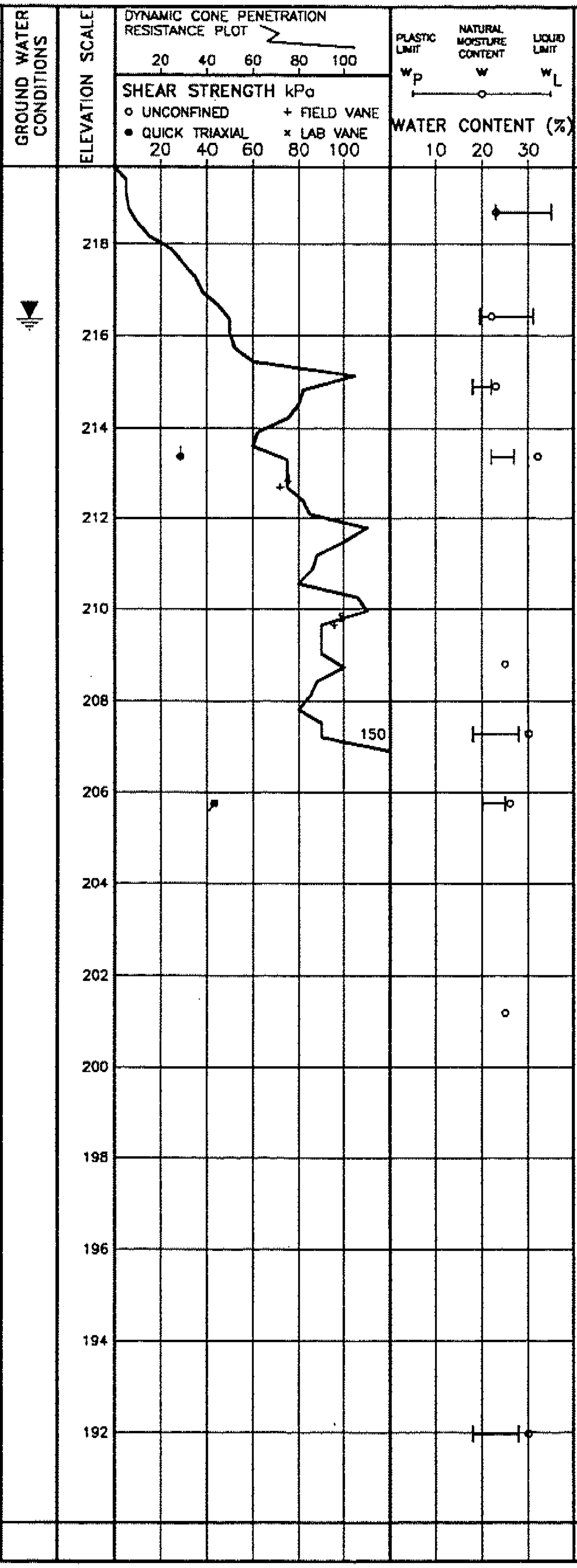
SOIL PROFILE

ELEV DEPTH	DESCRIPTION	STRAT PLOT
219.7	Ground Surface	
0.0	Clayey Silt with random seams of Silt trace of organics, Brown Grey Stiff to Very Stiff	▨
214.5 5.2	Silt with interbedded layers of Clayey Silt Grey, Loose to Compact	
195.3 24.4	Clayey Silt with layers of Silt Stiff to Very Stiff	▨
191.7 28.0	Bedrock – Dolostone Light Grey, Medium Strong, Unweathered	▨
190.0 29.7	End of Borehole * Formerly BH 12 (WP 65-67-01)	

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	SS	23					
2	SS	12					
3	SS	14					
4	SS	16					
5	SS	17		0	0	92	8
6	SS	7					
7	TW	PH	18.9				
8	TW	PH					
9	SS	7					
10	SS	7		0	0	93	7
11	SS	9					
12	TW	PH	19.0				
13	SS	8					
14	SS	9					
15	SS	10					
16	SS	9					
17	SS	10					
18	SS	8		0	1	80	19
19	RC	REC 100%					

REMARKS & GRAIN SIZE DISTRIBUTION (%)



+³, ×⁵: Numbers refer to Sensitivity
20
15-○-5 (%) STRAIN AT FAILURE
10

ROCK CORE DESCRIPTION
WP 65-67-05

Page 1 of 1

	CORE RECOVERY				CORE DESCRIPTION	
BH#	**RC#**	**DEPTH (m)**	**% CR***	**% RQD***	**DEPTH (m)**	**DESCRIPTION**
1	18	28.19-29.72	95	77	28.19-31.24	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to near vertical, undulating to planar, smooth to rough.
	19	29.72-31.24	100	83		
2	23	29.26-30.78	87	70	29.26-30.78	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey to medium dark grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures moderately close to very close spaced, flat to near vertical, undulating to planar, smooth to rough.

***CR** = CORE RECOVERY

***RQD** = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section

FOUNDATION INVESTIGATION REPORT
For
Hwy. 403 & Sunnyridge Road Underpass
W.P. 65-67-07, Site 36-263
District 4, Burlington

INTRODUCTION

This report summarizes the results of a foundation investigation conducted at the abovementioned site. It is proposed to construct a two span structure that will carry Sunnyridge Road over the proposed Hwy. 403. The structure is a component of the proposed Hwy. 403 roadway between Ancaster and Brantford.

SITE DESCRIPTION AND GEOLOGY

The site is situated at and adjacent to the existing Sunnyridge Road, between Hwy. 2 south of the site and Jerseyville Road north of the site. The site area is located in the Town of Ancaster within the Regional Municipality of Hamilton-Wentworth.

The existing Sunnyridge Road that divides the site is a two lane paved roadway. Adjoining grass-covered ditches provide surface-runoff drainage on either side of the roadway. A ridge approximately 1 m in height exists adjacent to the ditch on the west side of Sunnyridge Road.

The terrain at the site, apart from the abovementioned ridge, is generally flat. Land use in the general site area is primarily agricultural farmland and residential. Two neighbouring single storey residential homes are located east of the existing Sunnyridge Road and agricultural farmland consisting of corn crops exists west of the existing Sunnyridge Road.

Physiographically, the site is located within the geological domain known as the Haldimand clay plain. The Haldimand clay plain occupies the area lying between the Niagara Escarpment and Lake Erie. The entire area was submerged in Lake Warren, a glacial lake formed during the retreat of the Wisconsinan Glaciation (approximately 12,000 years ago). Lacustrine clays and silts were deposited as the lake gradually receded due to the deposition of sediments during isostatic land rebound.

Drainage of this belt is controlled by the Grand River which has cut a deep valley in the clay and silt. Consequently, there has been much dissection by tributary drainage.

The underlying bedrock at the site consists of hard dolomites of the Paleozoic era. At the site, the overburden has a thickness of approximately 42 m.

INVESTIGATION PROCEDURES

Soil and rock data and inherent properties were obtained by conducting both an in situ field investigation and laboratory analyses. Details of the field investigation and laboratory testing program are discussed below.

Field Investigation

The field work for this project was carried out under two separate stages. The initial stage, was implemented between 76 02 27 to 76 03 04 inclusive and consisted of one sampled borehole (BH 2, formerly BH 8) advanced to a depth of 27.9 m and two dynamic cone penetration tests. One dynamic cone test was driven from the ground surface to a depth of 15.2 m. A second cone test was driven at the bottom of the sampled borehole and advanced to a depth of 42.4 m below the original ground surface (Elevation 180.9 m). This initial first stage provided information to facilitate the planning and design of the proposed Hwy. 403 route between the cities of Ancaster and Brantford (see W.P. 65-67-01).

The second stage of the field work was carried out between 91 06 17 to 91 06 21 inclusive and consisted of a total of six sampled boreholes reflecting the greater extent of this subsequent field work. The scope of the second stage of the field work was to provide detailed soils/rock data to facilitate the design and construction of the proposed structure and related earthworks. Two (2) boreholes were advanced at the proposed abutment structure foundation locations and a total of four (4) boreholes were advanced at the proposed approach cuts on either side of the structure. The boreholes at the structure locations were advanced to depths of 44.8 m (BH 1) and 43.4 m (BH 3) whilst the dynamic cone penetration tests advanced at the structure foundation locations were driven to depths ranging from 8.8 m to 9.4 m. Approach cut boreholes were advanced to depths ranging from 11.1 m to 12.7 m.

The boreholes were advanced through overburden using track mounted boring units employing conventional continuous flight hollow stem augering techniques and also casing/washboring methods. The casing/washboring methods were applied to facilitate penetration of the deeper boreholes (BH's 1 and 3). Conventional rock coring techniques were used to retrieve upto 3 m of rock core at BH 1.

In general, subsoil samples at the proposed structure foundation locations were retrieved at 0.7 m intervals for the surficial 4.6 m to 6.0 m, at 1.5 m intervals beyond this surficial depth and up to a depth of 15.2 m to 18.3 m, and at 3 m intervals thereafter. Subsoil samples were taken at 1.5 m intervals at the approach locations.

Subsoil samples were generally retrieved in accordance with the Standard Penetration Test (ASTM D1586) and hence were disturbed as a result of the testing procedure. Relatively undisturbed subsoil samples were randomly retrieved in cohesive soils using a thin wall sampler in accordance with procedures outlined in ASTM D 1587. All subsoil samples were identified in the field and then properly sealed to preserve natural moisture contents in the soil. Disturbed samples were placed in sealed plastic containers and thin wall samples were capped and waxed. The samples were then transported to the laboratory where additional visual classifications were carried out and pertinent laboratory tests were conducted as described in the next section below.

Rock core samples were also identified in the field and rock recoveries and Rock Quality Designations (RQD) measured. The rock cores were then transported to the laboratory in conventional core boxes and detailed rock core logs were produced by an in-house geologist.

In situ vane tests were also carried out to determine the undrained shear strength of the weaker cohesive soils at the site. The test was carried out in accordance with ASTM D 2573 using the standard MTO 'N' vane. Remoulded shear strengths were also obtained where applicable.

Groundwater levels were obtained by monitoring the levels in the open boreholes throughout the duration of the field investigation. All open boreholes were backfilled at the completion of the fieldwork.

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

Laboratory Analyses

To determine the pertinent physical and strength properties of the soil, various laboratory tests were conducted. These tests included:

1) Natural Moisture Contents
2) Atterberg Limits
3) Grain Size Analyses
4) Bulk Unit Weights
5) Unconfined Compression
6) Consolidated Undrained

Laboratory test results are shown on the borehole logs and corresponding figures attached in the Appendix. These results have been summarized in the subsequent section of this report entitled "Subsurface Conditions".

SUBSURFACE CONDITIONS

General

The subsurface conditions are generally uniform across the site. Underlying a 1.2 m thick sand with a trace of silt roadway base fill material located beneath the asphaltic Sunnyridge Road and present surficially elsewhere at the site exists a stratum of cohesionless compact silt. This stratum has been oxidized to a brown colour and has a thickness up to 1.5 m. This stratum is underlain by a deposit of unoxidized grey clayey silt to silty clay that contains random intermittent layers of plastic silt. The stiff to very stiff clayey silt with compact silt layers has a thickness ranging from 12.9 m to 14.9 m. The surficial native deposit is in turn underlain by a cohesionless silt stratum that contains then interbeds of clayey silt. This stratum has a loose to compact denseness and has a thickness ranging from 9.6 m to 12.2 m. A second extensive deposit of cohesive clayey silt underlies the silt with thin interbeds of clayey silt stratum. This deposit extends to the bedrock surface and has a thickness of approximately 14.5 m. The bedrock surface exists at an elevation of approximately 180.6 m to 180.9 m.

A plan of the site illustrating the locations and elevations of the boreholes is shown on Dwg. No. 656707-A.* A subsoil stratigraphical profile illustrating the subsurface conditions at the site is also provided. The boundaries between the various soil types, in situ and laboratory test results as well as groundwater levels established at the time of investigation are shown on the stratigraphical profile and also on the individual Record of Boreholes sheets in the Appendix.

Sand, trace Silt, trace Gravel (Fill Material)

A cohesionless sand with traces of silt and gravel encountered at BH 3 indicates that the base of the existing Sunnyridge Road asphaltic roadway is composed of this material. The material is primarily brown in colour but also contains black organic impurities. The base material is approximately 1.2 m in thickness and has a loose denseness.

Silt

The surficial native stratum across the site consists of a cohesionless silt that has a thickness of up to 1.5 m. The deposit is primarily brown in colour with mottled grey inclusions revealing varying degrees of oxidation. Traces of organics are also present within this stratum.

A grain size distribution curve produced by mechanical sieve and hydrometer analysis is shown in Figure 1 in the Appendix. The curve illustrates a primarily silt percentage composition with minor traces of clay.

Standard Penetration Test 'N' values ranging between 14 blows/0.3 m to 18 blows/0.3 m indicate that the silt has a compact state of denseness.

* DWG NO 2 OF THE CONTRACT DWG'S

Clayey Silt to Silty Clay with random layers of Silt

The silt stratum is underlain by a cohesive clayey silt deposit that also contains random layers of plastic silt. The deposit has a thickness ranging from 12.9 m to 14.9 m and is unoxidized and hence grey in colour. The silt layers are generally 25 mm to 100 mm in thickness.

A grain size distribution envelope produced by mechanical sieve and hydrometer analysis is shown in Figure 2 in the Appendix. The envelope clearly illustrates that the stratum is composed of grain sizes smaller than 75 micrometre. The grain size distribution envelope for this material illustrates large percentages of silt, ranging from 35% to 74% and clay percentages ranging from 26% to 65%. In view of the fact that more than 50% of the material is finer than 75 micrometre, the soil is categorized according to its behaviour in accordance with the MTO Soil Classification Manual. Atterberg Limit Tests were hence conducted to define the behaviour and plasticity of the soil as discussed below.

Atterberg Limit Tests were carried out on the fine grained soil and the results are plotted on Figure 3 in the Appendix and summarized on Table 1 below. Natural Moisture Contents and the Bulk Unit Weight of the soil have also been included in the table.

Table 1 - Atterberg Limit Test Results

	Range	# of Tests
Natural Moisture Content (w%)	20-35	14
Liquid Limit (w_L%)	25-45	14
Plastic Limit wp%)	14-21	14
Plasticity Index (Ip%)	11-26	14
Bulk Unit Weight (kN/m^3)	18.8-20.6	7

The test results clearly reveal that the soil has a plasticity ranging from a low to intermediate and hence can be categorized as clayey silt to silty clay. Natural moisture contents are generally within the plastic and liquid limits of the soil and hence the soil is in a plastic state. Silt layers present within the deposit generally exhibited a slow dilatant reaction.

The consistency and strength of the soil was determined by conducting in situ vane tests and consolidated undrained tests. The results of these tests have been plotted on the individual Record of Borehole sheets. The undrained shear strength of the soil determined by the in situ vane test revealed values ranging from 60 kPa to in excess of 120 kPa. However, generally speaking undrained shear strengths exceed 120 kPa. Consequently, the soil can be categorized as having a very stiff consistency.

The 'N' values as determined by the Standard Penetration Test ranged from 7 blows/0.3 m to 23 blows/0.3 m confirming a stiff to very stiff soil consistency with loose to compact silt layers.

Silt with interbeds of Clayey Silt

A cohesionless silt of quick dilatancy interbedded with thin layers of cohesive clayey silt exists below the clayey silt to silty clay with layers of silt and extends to a depth of 27.4 m. The thickness of this stratum ranges from 9.6 m to 12.2 m.

A grain size distribution envelope as determined by mechanical sieve and hydrometer analysis is shown on Figure 4 in the Appendix. The envelope illustrates primarily silt percentages with some clay. The silty soil does however exhibit plasticity as illustrated by the results of Atterberg Limit tests carried out on some representative samples of the material. These results are illustrated on Figure 5 in the Appendix and reveal that liquid limits (w_L%) range between 20% and 24% and plasticity indices (I_p%) are generally less than 5%. Natural moisture contents range between 26% and 28%, hence exceeding the liquid limits of the soil.

The interbedded cohesive thin layers are of low plasticity as determined by visual index property identification tests (dry strength, toughness, shine, rolling, miscellaneous) and hence can be categorized as clayey silt. The thickness of these layers are generally in the order of 25 mm.

Some borehole sloughing was observed during the penetration and sampling within this deposit. This soil cave-in can be attributed to unbalanced hydrostatic head.

Many of the residential homes in the site area are known to have water wells installed in this stratum because the recharge permeability is faster than both the overlying and underlying cohesive deposit. However, water recharge in this silty material is not at a substantial rate and most wells have to be replenished by an external supply source.

Based on the interpretation of Standard Penetration Test 'N' values ranging from 8 blows/0.3 m to 17 blows/0.3 m determined in the deposit, this silty soil can be categorized as having a loose to compact denseness. In general, however, 'N' values exceed 10 blows/0.3 m and hence the soil has a compact denseness. The interbedded clayey silt layers can be categorized as having a stiff consistency.

Clayey Silt with random seams of interbedded Silt

Underlying the cohesionless silt with interbeds of clayey silt stratum a second cohesive deposit consisting of a clayey silt extending to the bedrock surface exists. The surface of the deposit exists at an elevation ranging from 197.4 m to 195.4 m and the deposit has a thickness in the order of magnitude of 14.5 m to 14.9 m. Traces of gravel were found in the deposit immediately overlying the bedrock.

A grain size distribution envelope illustrating the gradation of the material of this deposit is shown on Figure 6 in the Appendix. The envelope clearly illustrates that the material is fine grained with grain sizes less that 75 micrometres. Typically, clay percentages range from 29% to 56% and silt percentages range from 44% to 71%.

In accordance with the MTO Soil Classifications system, a deposit with gradations of this nature is categorized by its behaviour and hence Atterberg Limit Tests were conducted to evaluate the plasticity of the soil. The results of these tests are illustrated on Figure 7 and summarized in Table 2 below. Natural Moisture Contents are also included in the Table below.

Table 2 - Clayey Silt

	Range	# of Tests
Natural Moisture Content (w%)	27-32	5
Liquid Limit (w_L%)	26-34	5
Plastic Limit w_P%)	14-18	5
Plasticity Index (I_P%)	12-16	5

The test results reveal that the soil has a low plasticity and hence can be classified as a clayey silt. Natural moisture contents generally exceed the liquid limit of the soil.

The 'N' values as derived from the Standard Penetration Test reveal values ranging from 9 blows/0.3 m to 29 blows/0.3 m. Based on these 'N' values the consistency of the soil is estimated as stiff to very stiff.

Bedrock

The bedrock consisting of a "vuggy" dolomite of the Amabel Formation underlies the clayey silt with random seams of interbedded silt deposit at an elevation of approximately 180.6 m to 180.9 m. The bedrock was cored in BQ and BXL size up to 2.9 m in depth at the proposed abutment structure foundation locations and was inferred via a dynamic cone penetration test at BH 2 (formerly BH 8).

The dolomite bedrock is a chemical sedimentary rock that typically is composed of magnesium carbonate compounds and is fine to medium grained. The rock is unweathered that is featured by a porous "vug" texture. The rock is light-grey in colour and contains thin horizontal beds and very close to closely spaced vertical fractures. Detailed descriptions of the bedrock are attached in the Appendix in a report entitled "Description of Rock Core".

An assessment of the quality and strength of the rock was carried out by measuring core recoveries and Rock Quality Designations (RQD) in the field and hardness testing in the laboratory. Recoveries were generally 100% and RQD's ranged from 81% to 98% indicating that the rock is of good to excellent quality. Rock strengths can be described as medium strong.

GROUNDWATER CONDITIONS

Observation of the groundwater level was carried out by measuring the water levels in the open boreholes throughout the duration of the field investigation. Groundwater levels determined at the time of investigation were approximately 2 m below the ground surface (elevation 220.8 m to 221.4 m).

As previously discussed, water wells in the area have been installed to the silt deposit generally at a depth of approximately 15 m. However, the recharge rate of groundwater flow in this material is insufficient to satisfy a continuous water supply and hence the wells are periodically replenished with external water sources.

Groundwater levels in general, are subject to seasonal fluctuations and hence can vary from the values given in this report.

MISCELLANEOUS

The fieldwork for this investigation was carried out under the supervision of T. Sangiuliano, Foundation Engineer, and L. Dametto, Engineer Student, utilizing equipment owned and operated by Atcost Drilling Ltd. Logging of rock core in the laboratory was carried out by D. Williams, Petrographer.

The project was carried out by T. Sangiuliano under the general supervision of P. Payer, Senior Foundation Engineer. The report was written by T. Sangiuliano, reviewed by P. Payer and approved by Mr. M. S. Devata, Chief Foundation Engineer.

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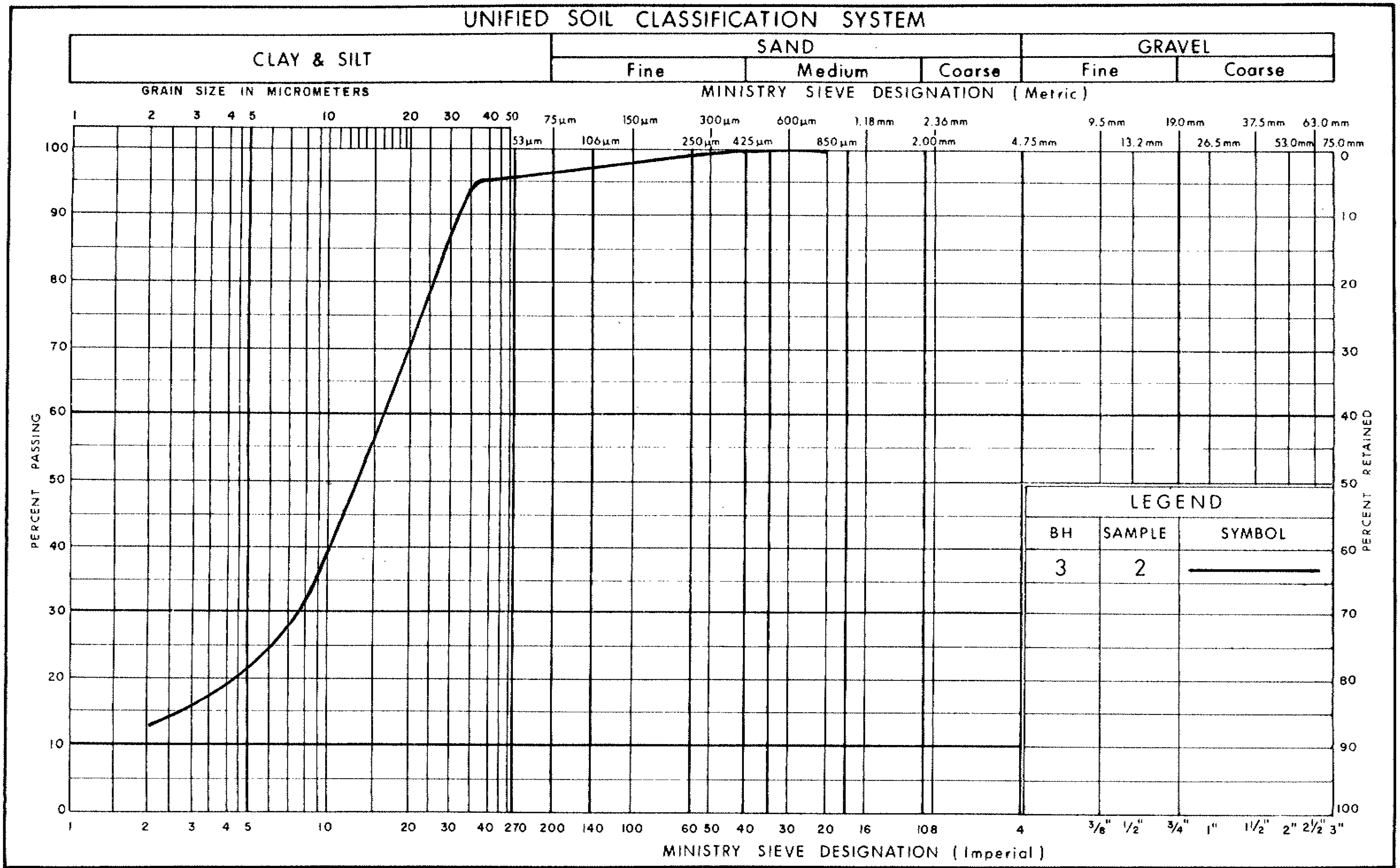
Chief Foundation Engineer

APPENDIX

78 12 M



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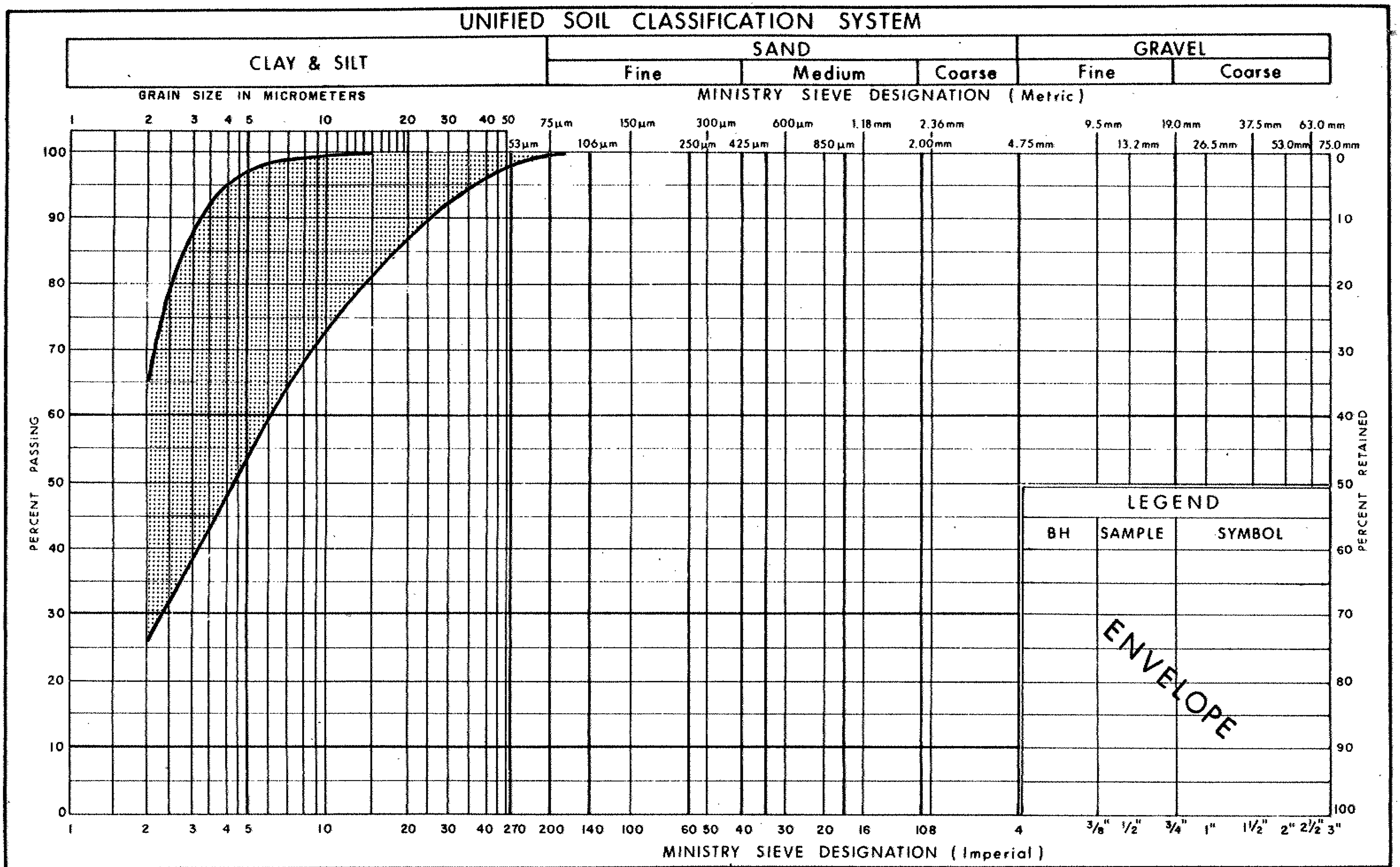
GRAIN SIZE DISTRIBUTION

SILT

FIG No 1

W P 65 - 67 - 07

78 12 M



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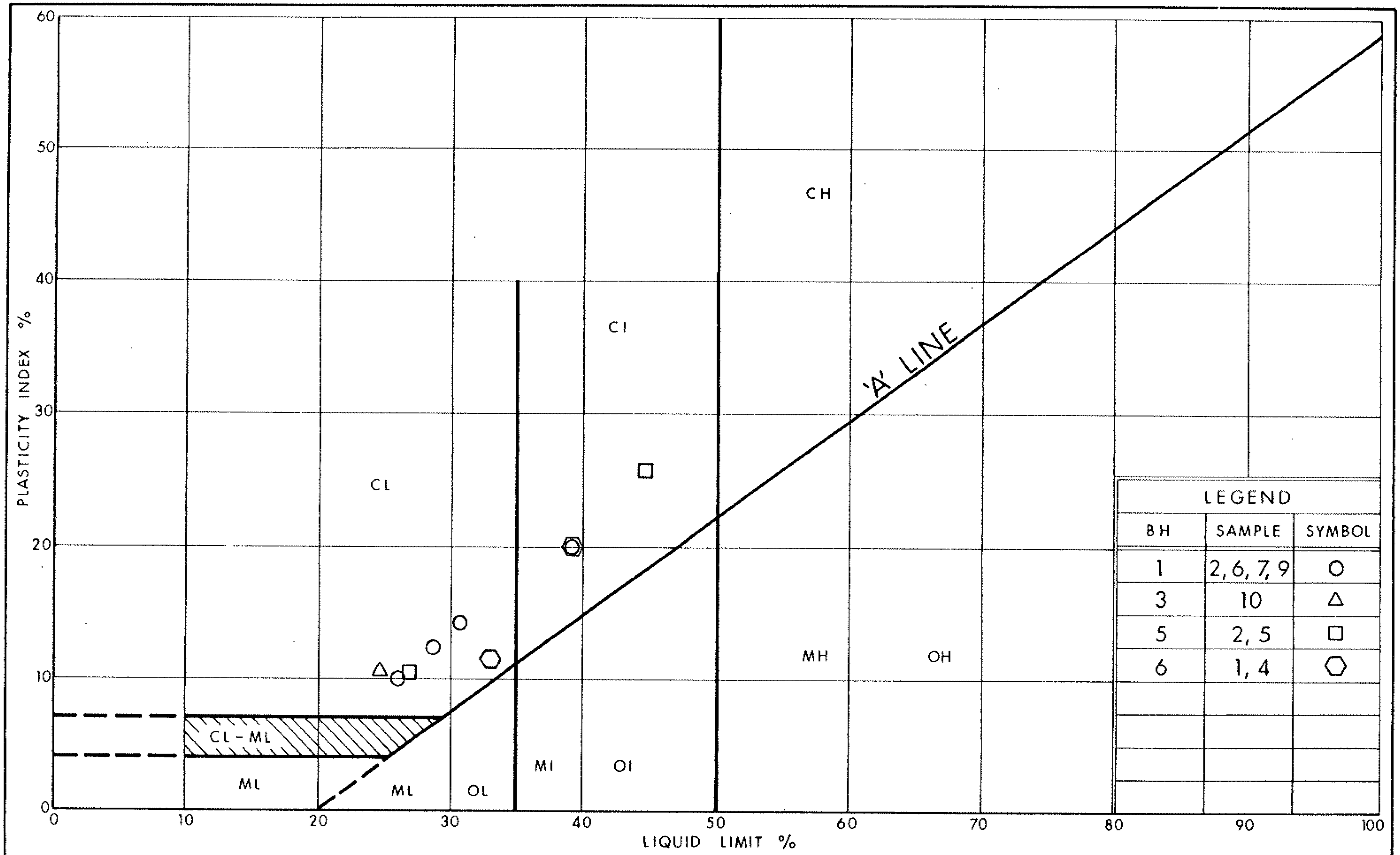
GRAIN SIZE DISTRIBUTION
CLAYEY SILT TO SILTY CLAY
WITH RANDOM LAYERS OF SILT

FIG No 2

W P 65-67-07



LEGEND

BH	SAMPLE	SYMBOL
1	2, 6, 7, 9	○
3	10	△
5	2, 5	□
6	1, 4	⬡

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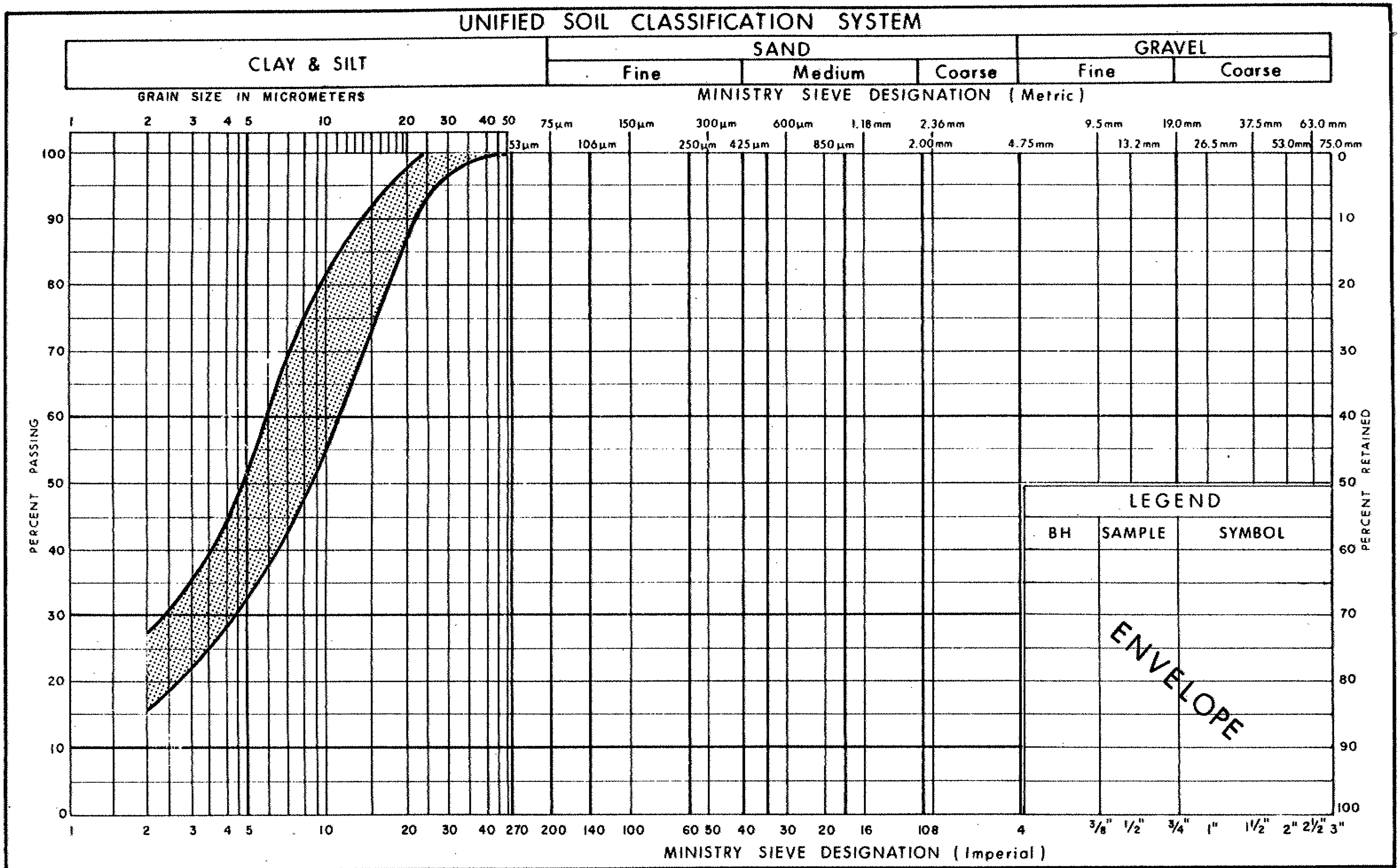
PLASTICITY CHART
CLAYEY SILT TO SILTY CLAY
WITH RANDOM LAYERS OF SILT

FIG No 3
W P 65-67-07

78 12 M



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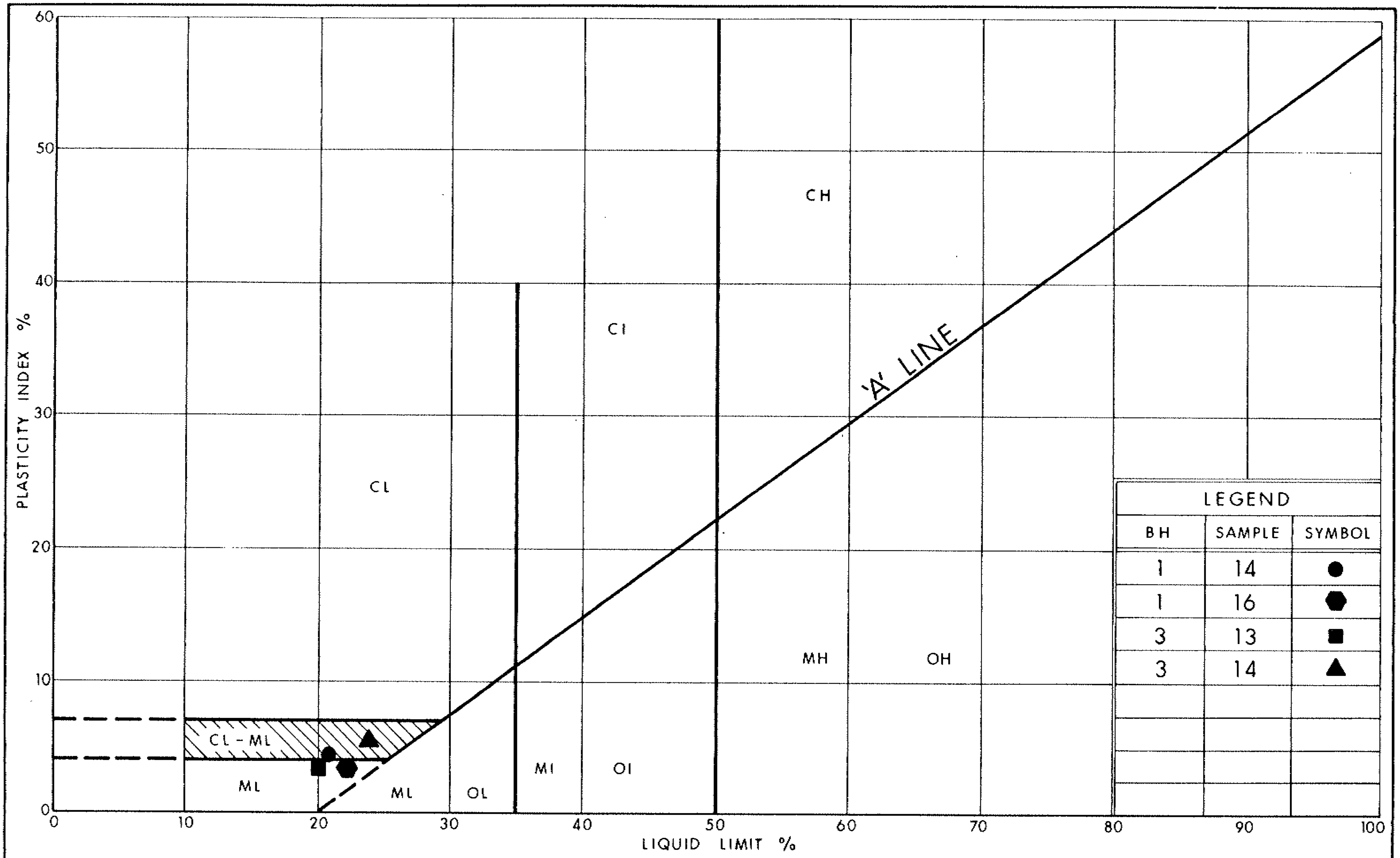
GRAIN SIZE DISTRIBUTION
SILT
WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 4

W P 65-67-07

Oct 75, FF-S-21



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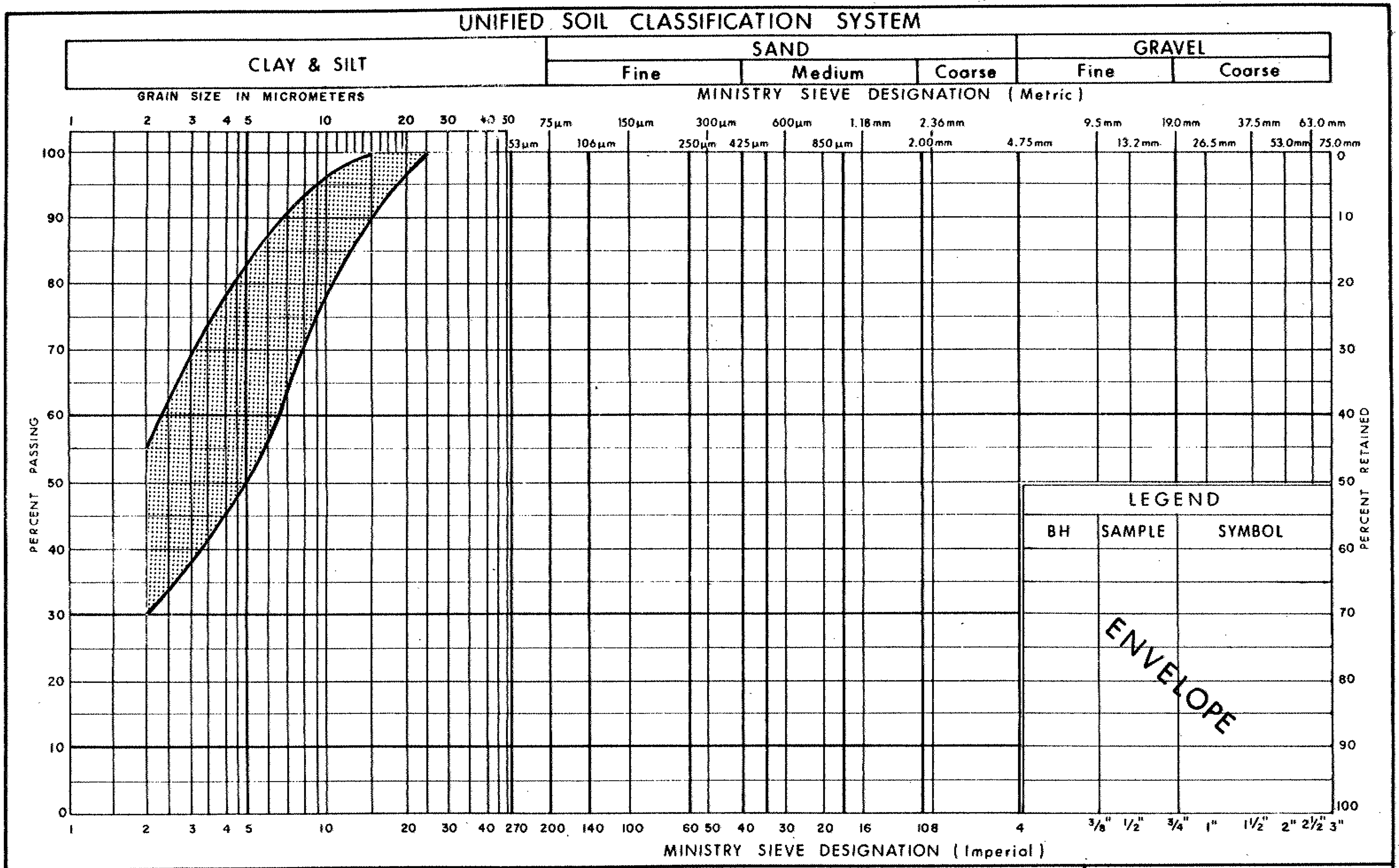
PLASTICITY CHART
SILT
WITH INTERBEDDED LAYERS OF CLAYEY SILT

FIG No 5
W P 65-67-07

206

78 12 M



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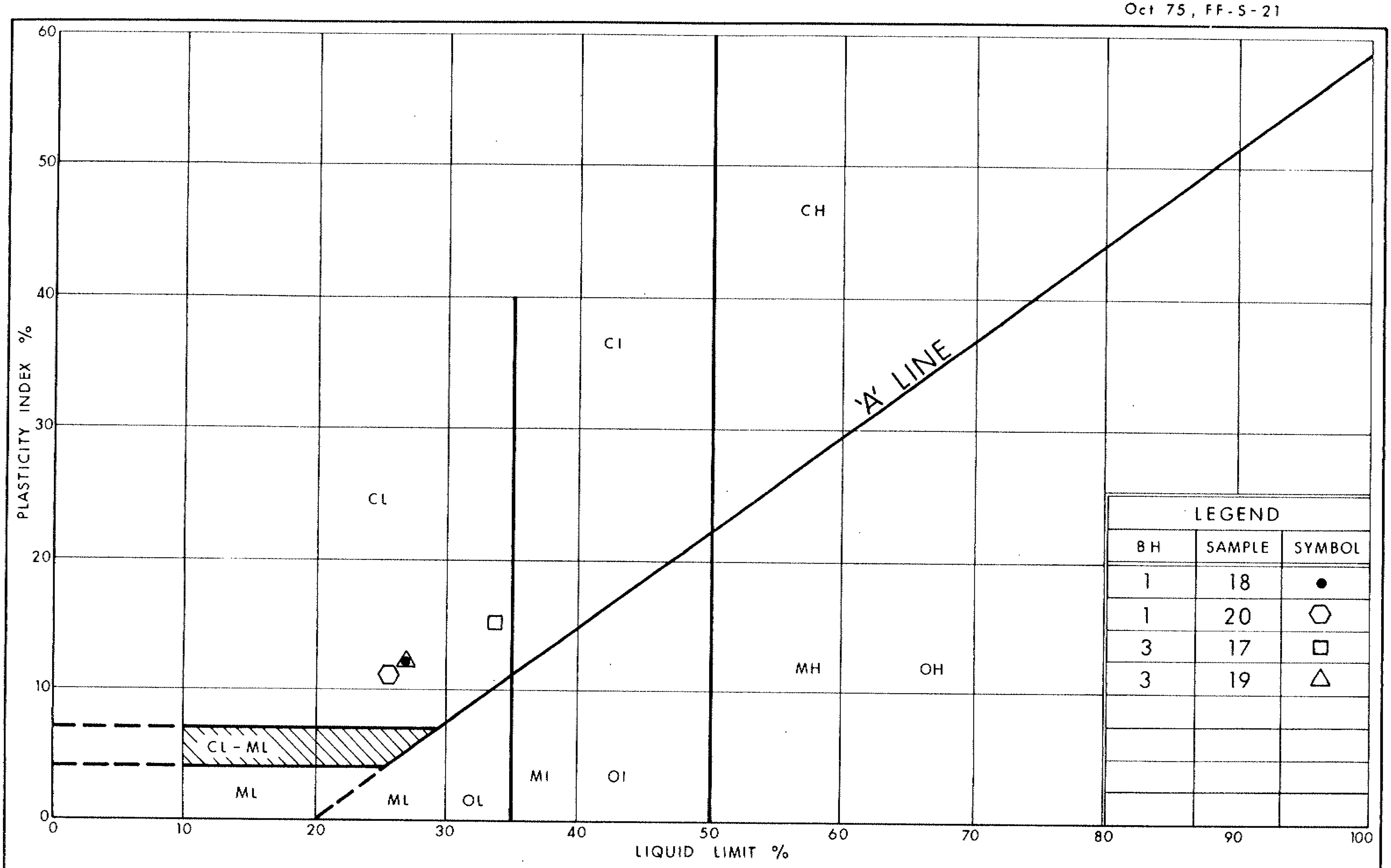
GRAIN SIZE DISTRIBUTION
CLAYEY SILT
WITH RANDOM SEAMS OF INTERBEDDED SILT

FIG No 6

W P 65 - 67 - 07

Oct 75, FF-S-21



LEGEND		
BH	SAMPLE	SYMBOL
1	18	●
1	20	⬡
3	17	□
3	19	△

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PLASTICITY CHART
CLAYEY SILT
WITH RANDOM SEAMS OF INTERBEDDED SILT

FIG No 7
W P 65-67-07

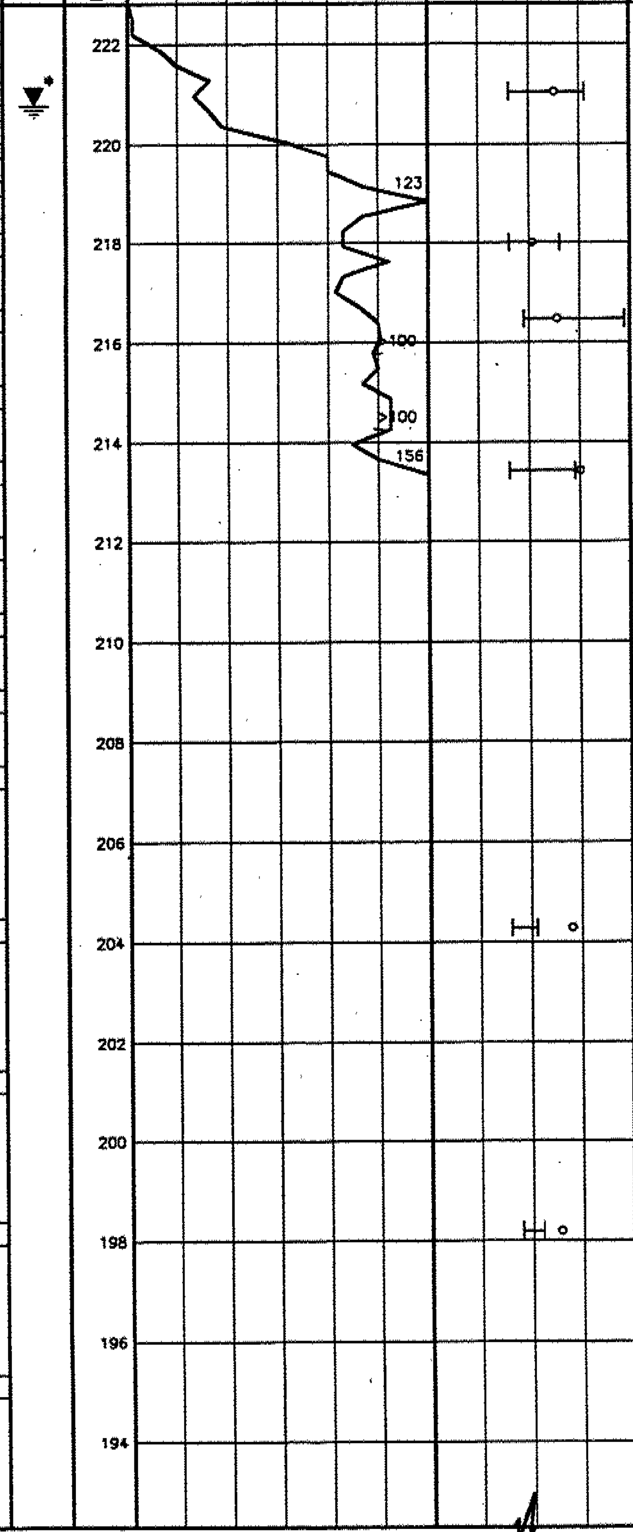
Ministry of Transportation Ontario

RECORD OF BOREHOLE No 1 1 OF 2 METRIC

W.P. 65-67-07 LOCATION Co-ords: N 4 783 272.0; E 255 679.0 ORIGINATED BY TS
DIST 4 HWY 403 BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring COMPILED BY TS
DATUM Geodetic DATE 91 06 17-19 CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
222.8	Ground Surface								
0.0	Silt Brown, Compact	1	SS	14					
221.3 1.5	Clayey Silt to Silty Clay with random layers of Silt Stiff to Very Stiff Brown / Grey	2	SS	13	18.8	0	1	64	35
		3	SS	22					
		4	SS	17					
		5	SS	19					
		6	SS	22	19.9	0	0	61	39
		7	SS	9	20.7	0	0	44	56
		8	SS	12					
		9	SS	16	20.3	0	0	64	36
		10	SS	11					
		11	SS	16					
		12	SS	12					
207.6 15.2	Silt with interbedded layers of Clayey Silt Grey, Compact	13	SS	11					
		14	SS	14		0	0	78	22
		15'	SS	17					
		16	SS	11		0	0	85	15
195.4 27.4		17	SS	22					
192.3 30.5									

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 20 40 60 80 100 | PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30



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+³, ×⁵ : Numbers refer to Sensitivity

20 15◇5 10 (%) STRAIN AT FAILURE

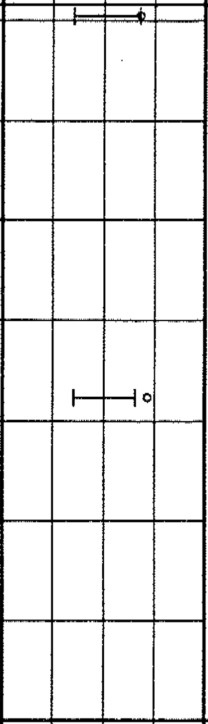
Continued

RECORD OF BOREHOLE No 1

2 OF 2 METRIC 210

W.P. 65-67-07
LOCATION Co-ords: N 4 783 272.0; E 255 679.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 06 17-19
CHECKED BY PP

SOIL PROFILE ELEV / DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.3	Continued										
30.5			18	SS	17		192				0 0 71 29
							190				
	Clayey Silt with random seams of interbedded Silt Grey, Very Stiff		19	SS	19		188				
							186				
			20	SS	25		184				0 0 65 35
			21	SS	29		182				
180.9			22	SS	**						
41.9	Bedrock – Dolostone Light Grey, Unweathered Medium Strong		23	RC	REC 100%		180				RQD = 81%
178.0			24	RC	REC 100%						RQD = 97%
44.8	End of Borehole										



* 91 06 21

** Sampler Bouncing

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

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

Ministry of Transportation
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RECORD OF BOREHOLE No 2 *

1 OF 2 METRIC 211

W.P. 65-67-07	LOCATION Co-ords: N 4 783 311.5; E 255 672.0
DIST 4 HWY 403	BOREHOLE TYPE HS Auger, Cone Test,
DATUM Geodetic	DATE 76 02 27, 76 03 01-04
ORIGINATED BY TS	COMPILED BY TS
CHECKED BY PP	

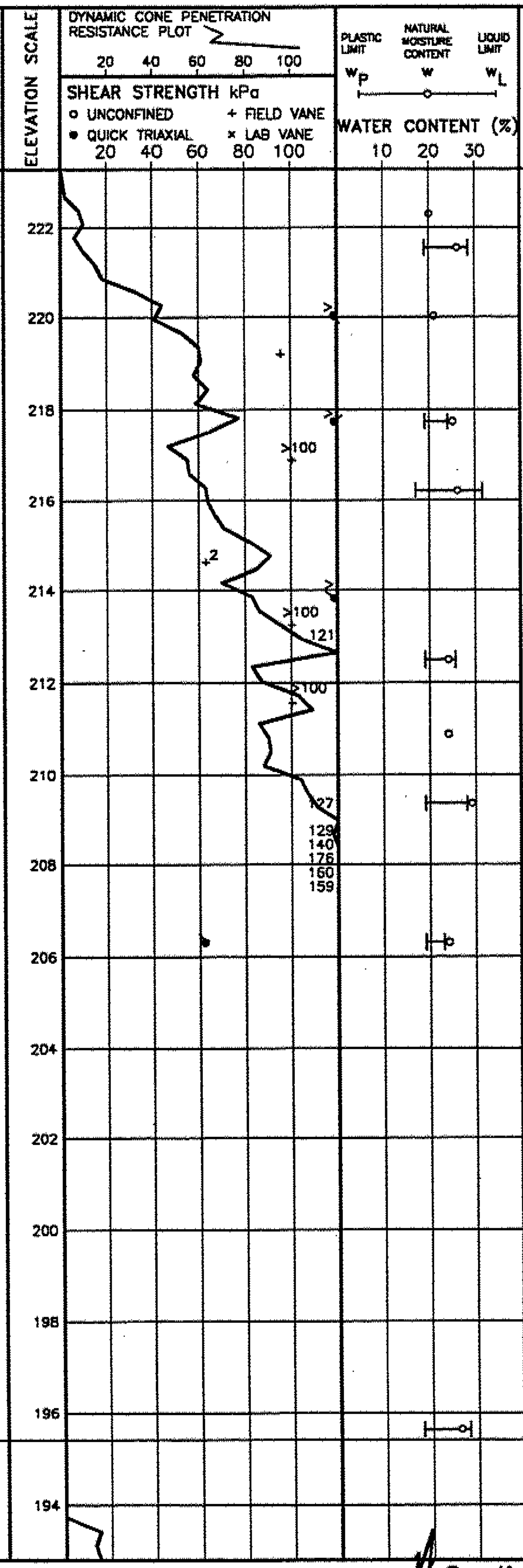
SOIL PROFILE

ELEV / DEPTH	DESCRIPTION
223.3	Ground Surface
0.0	Sand, some Silt Brown, Loose
221.9 / 1.4	Clayey Silt with random layers of Silt Trace Organics, Brown Grey Stiff to Very Stiff
207.0 / 16.3	Silt with interbedded layers of Clayey Silt Grey, Loose to Compact
197.4 / 25.9	Clayey Silt with random seams of interbedded Silt Grey, Very Stiff
195.4 / 27.9	End of Borehole
192.8 / 30.5	Continued

SAMPLES

NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
1	SS	8		0	60	29	11
2	SS	14		0	0	92	8
3	SS	14					
4	TW	PH	20.1				
5	SS	9					
6	TW	PH	19.3				
7	SS	11					
8	TW	PH					
9	TW	PH	19.8				
10	SS	8					
11	SS	9		0	0	94	6
12	SS	9		0	0	65	35
13	SS	9					
14	TW	PH	19.3				
15	SS	8					
16	SS	13					
17	SS	9					
18	TW	PH					

GROUND WATER CONDITIONS ▼



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

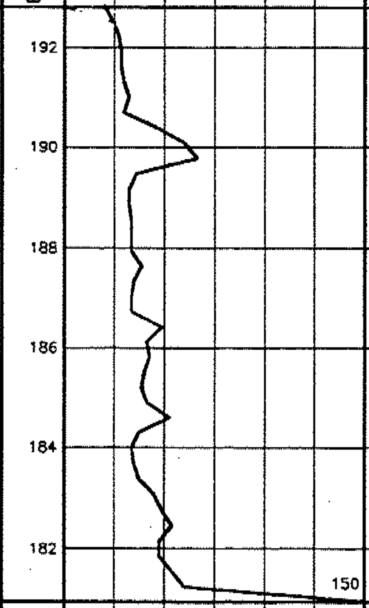
$15\overset{20}{\underset{10}{\diamond}}5$ (%) STRAIN AT FAILURE

Continued

RECORD OF BOREHOLE No 2 * 2 OF 2 METRIC 212

W.P. 65-67-07 LOCATION Co-ords: N 4 783 311.5; E 255 672.0 ORIGINATED BY TS
DIST 4 HWY 403 BOREHOLE TYPE HS Auger, Cone Test, COMPILED BY TS
DATUM Geodetic DATE 76 02 27, 76 03 01-04 CHECKED BY PP

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 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
192.8	Continued										
30.5	Probable Clayey Silt with random seams of interbedded Silt						192 190 188 186 184 182				
180.9 42.4	End of Cone Test (Probable Bedrock) * (Formerly Borehole No 8 WP 65-67-01)										



$+^3$, $\times^5$: Numbers refer to Sensitivity   15 $\overset{20}{\underset{10}{\diamond}}$ 5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

1 OF 2

METRIC 213

W.P. 65-67-07

LOCATION Co-ords: N 4 783 329.0; E 255 656.0

ORIGINATED BY TS

DIST 4 HWY 403

BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring

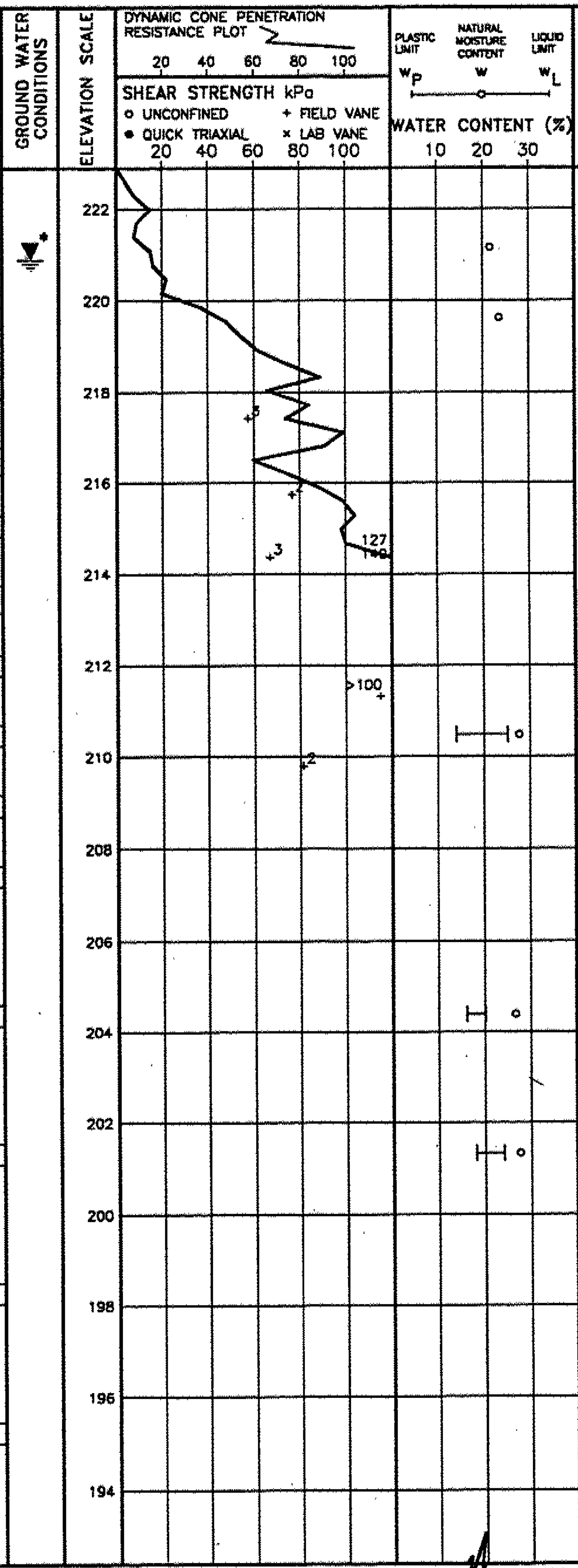
COMPILED BY TS

DATUM Geodetic

DATE 91 06 17-20

CHECKED BY PP

ELEV / DEPTH	SOIL PROFILE DESCRIPTION	SAMPLES NUMBER	TYPE	'N' VALUES	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
222.9	Ground Surface								
0.0 221.7	Sand, trace silt trace gravel (Fill Material) Brown with Black inclusions, Loose	1	SS	6					
1.2 220.6	Silt Brown, Compact	2	SS	18		0	4	83	13
2.3	Brown / Grey Clayey Silt of Silty Clay with random layers of Silt Stiff to Very Stiff	3	SS	15					
		4	SS	14		0	0	69	31
		5	SS	9					
		6	TW	PH					
		7	SS	11					
		8	TW	PH					
		9	SS	12					
		10	SS	12		0	0	64	36
207.7		11	SS	14					
15.2	Silt with interbedded layers of Clayey Silt Grey, Loose to Compact	12	SS	15					
		13	SS	15		0	0	78	22
		14	SS	11		0	0	74	26
195.5		15	SS	9					
27.4		16	SS	9					
192.4 30.5	Continued								



Continued

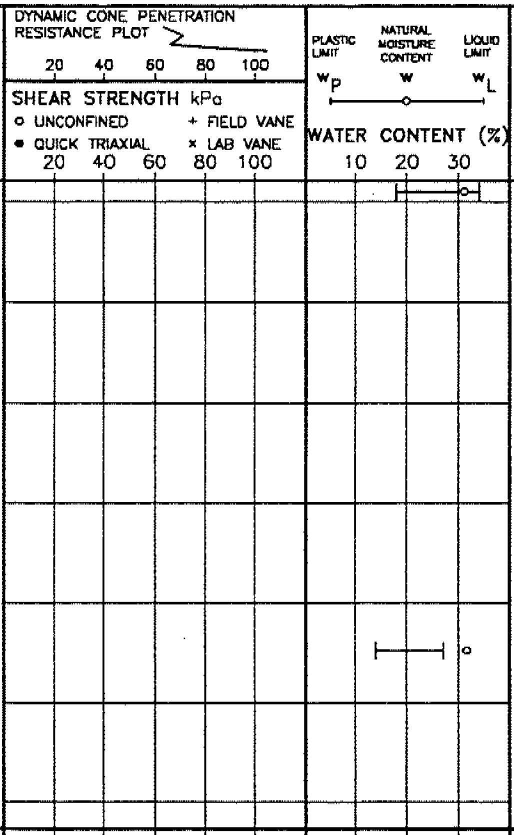
+3, x5: Numbers refer to Sensitivity

20 15-◇-5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 3

2 OF 2 METRIC 214

W.P. 65-67-07
LOCATION Co-ords: N 4 783 329.0; E 255 656.0
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger, BW Casing, Washboring, Rock Coring
COMPILED BY TS
DATUM Geodetic
DATE 91 06 17-20
CHECKED BY PP



SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			GR SA SI CL
192.4 30.5	Continued		17	SS	19		192	0 0 44 56
							190	
	Clayey Silt with random seams of Silt Grey, Stiff to Very Stiff		18	SS	13		188	
							186	
							184	
			19	SS	26			0 0 59 41
							182	
180.6	trace gravel		20	SS	20	/11cm		
42.3 179.5	Bedrock – Dolostone Light Grey, Unweathered, Medium Strong		21	RC	REC 98%		180	RQD = 98%
43.4	End of Borehole • 91 06 21							

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

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

Ministry of Transportation
Ontario

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RECORD OF BOREHOLE No 4

1 OF 1

METRIC 215

W.P. 65-67-07
LOCATION Co-ords: N 4 783 267.7; E 255 644.2
ORIGINATED BY TS
DIST 4 HWY 403
BOREHOLE TYPE HS Auger
COMPILED BY LD
DATUM Geodetic
DATE 91 06 21
CHECKED BY PP

SOIL PROFILE ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES 'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 / SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m^3	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
222.7	Ground Surface										
0.0	Silt Brown, Compact						222				
221.2 1.5	Brown Grey		1	SS	20	▼*					
							220				
			2	SS	17						
							218				
	Clayey Silt to Silty Clay with random layers of Silt Stiff to Very Stiff		3	SS	20						
			4	SS	8						
							216				
			5	SS	17						
							214				
			6	SS	30						
							212				
211.6			7	SS	12						
11.1	End of Borehole * 91 06 24										

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

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

Ministry of Transportation Ontario

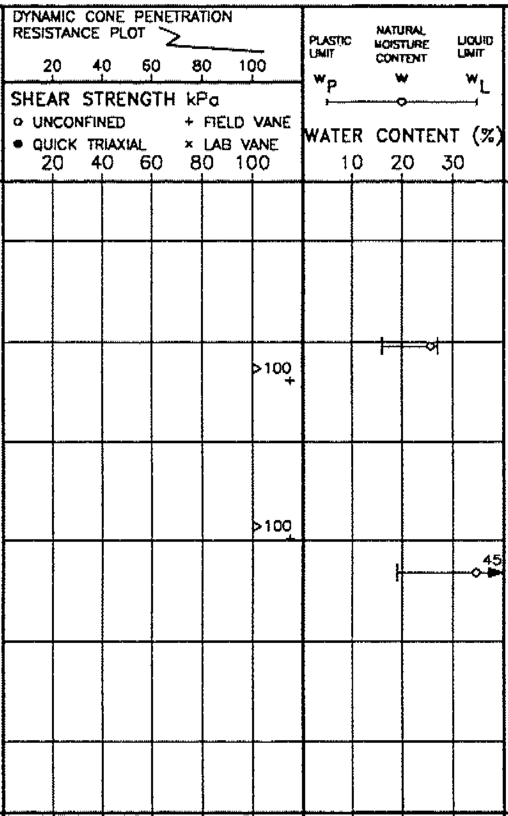
Foundation Design

RECORD OF BOREHOLE No 5

1 OF 1 METRIC 216

W.P. 65-67-07	LOCATION Co-ords: N 4 783 313.0; E 255 633.6		ORIGINATED BY TS
DIST 4	HWY 403	BOREHOLE TYPE HS Auger	COMPILED BY TS
DATUM Geodetic		DATE 91 06 19	CHECKED BY PP

ELEV DEPTH	SOIL PROFILE DESCRIPTION	STRAT PLOT	SAMPLES NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa	WATER CONTENT (%)	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
223.2	Ground Surface													
0.0	Silt Brown, Compact						222							
221.7 1.5	Clayey Silt to Silty Clay with random layers of Silt Very Stiff Brown Grey		1	SS	16	▼*								
			2	SS	8		220	>100 +			0	0	74	26
			3	SS	7		218							
			4	TW	PH		216	>100 +						
			5	SS	9				45		0	0	35	65
			6	SS	20		214							
			7	SS	10		212							
210.6			8	SS	10									
12.6	End of Borehole * 91 06 20													



REMARKS & GRAIN SIZE DISTRIBUTION (%)

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

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

RECORD OF BOREHOLE No 6

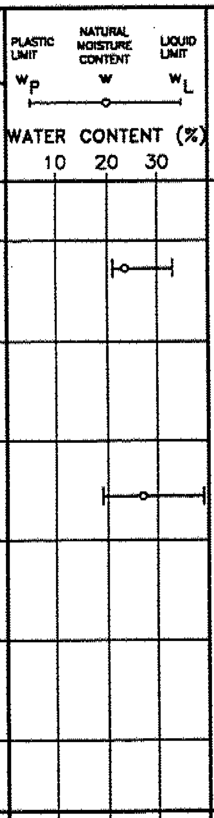
1 OF 1 METRIC 217

W.P. 65-67-07 LOCATION Co-ords: N 4 783 292.9; E 255 697.0 ORIGINATED BY TS
DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS
DATUM Geodetic DATE 91 06 20 CHECKED BY PP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	'N' VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	GR	SA	SI	CL
223.2	Ground Surface									
0.0	Silt Brown, Compact					222				
221.2		1	SS	17	▼*		0	1	65	34
2.0	Clayey Silt to Silty Clay with random layers of Silt Grey, Stiff to Very Stiff									
		2	SS	23		220				
		3	SS	13		218				
		4	SS	12			0	1	46	53
						216				
		5	TW	PH						
		6	SS	18		214				
		7	SS	13		212				
210.6		8	SS	16						
12.6	End of Borehole * 91 06 21									

DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100

SHEAR STRENGTH kPa
○ UNCONFINED + FIELD VANE
● QUICK TRIAXIAL × LAB VANE
20 40 60 80 100



UNIT WEIGHT γ kN/m³

REMARKS & GRAIN SIZE DISTRIBUTION (%)

+3, ×5: Numbers refer to Sensitivity

20 15◇5 10 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 7

1 OF 1 METRIC 218

W.P. 65-67-07 LOCATION Co-ords: N 4 783 348.1; E 255 685.8 ORIGINATED BY TS

DIST 4 HWY 403 BOREHOLE TYPE HS Auger COMPILED BY TS

DATUM Geodetic DATE 91 06 20 CHECKED BY PP

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100 SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL × LAB VANE 20 40 60 80 100	PLASTIC LIMIT w_P NATURAL MOISTURE CONTENT w LIQUID LIMIT w_L WATER CONTENT (%) 10 20 30	UNIT WEIGHT γ kN/m³	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES						
223.4	Ground Surface										
0.0	Silt Brown, Compact										
221.9 1.5	Clayey Silt to Silty Clay with random layers of Silt Grey, Very Stiff		1	SS	17	▼*	222				
			2	SS	23		220				
			3	SS	14		218				
			4	SS	9			>100 +			
			5	SS	13		216				
			6	SS	15		214				
			7	SS	10		212	>100 +			
210.8			8	SS	15						
12.6	End of Borehole * 91 06 21										

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

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

ROCK CORE DESCRIPTION
WP 65-67-07

Page 1 of 1

CORE RECOVERY					CORE DESCRIPTION	
BH#	RC#	DEPTH (m)	% CR*	% RQD*	DEPTH (m)	DESCRIPTION
1	23 24	41.91-43.28 43.28-44.81	100 100	81 97	41.91-44.81	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide to very close spaced, flat to near vertical, undulating, smooth.
3	21	42.32-43.43	98	98	42.32-43.43	**DOLOSTONE** with stylolites and abundant vugs containing calcite crystals, light grey; fine to medium grained; medium strong; unweathered to slightly weathered; fractures wide spaced, flat, undulating to planar, smooth.

***CR** = CORE RECOVERY

***RQD** = ROCK QUALITY DESIGNATION

(NOTE: Depths are approximated where core recovery is less than 100%)

Logged by: DAW, Soils and Aggregates Section