

GEOCRES - 31G-210
No:



Golder Associates Ltd.
CONSULTING ENGINEERS

DRAFT REPORT TO

McCORMICK RANKIN

FOUNDATION INVESTIGATION
PROPOSED CPR OVERPASS
HIGHWAY 416
W.P. 313-19-01/03, SITE 16-319-1/2
DISTRICT (OTTAWA) EASTERN REGION
GEOCRES # 31G-210

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TABLE OF CONTENTS

	<u>Page No.</u>
1. INTRODUCTION	1
2. SITE DESCRIPTION AND GEOLOGY	1
3. PROCEDURE	2
4. SUBSURFACE CONDITIONS	3
4.1 General	3
4.2 Topsoil, Peat, Fill	5
4.3 Sandy Silt, Silty Sand, Sand	5
4.4 Sensitive Silty Clay	5
4.5 Sandy Silt with Clay, Gravel, Cobbles and Boulders	7
4.6 Silt	8
4.7 Bedrock	8
4.8 Groundwater	9
5. DISCUSSION AND RECOMMENDATIONS	10
5.1 General	10
5.2 Bridge Foundations	10
5.3 Abutment Wall Backfill and Earth Pressures	13
5.4 Approach Embankments	14
5.5 Additional Considerations	17

EXPLANATION OF TERMS AND SYMBOLS
RECORD OF BOREHOLE SHEETS
FIGURES 1 TO 11 AND DRAWINGS 3738902/03-A
AND 3738902/03-B

In order
following
page 17

LIST OF FIGURES

1. Plasticity Chart - Silty Clay (Weathered Crust)
2. Plasticity Chart - Silty Clay
3. Plasticity Chart - Silty Clay
4. Grain Size Distribution - Sandy Silt with Gravel, Clay, Cobbles and Boulders (Glacial Till)
5. Void Ratio - Pressure Curve, Consolidation Test
6. Void Ratio - Pressure Curve, Consolidation Test
7. Void Ratio - Pressure Curve, Consolidation Test
8. Void Ratio - Pressure Curve, Consolidation Test
9. Void Ratio - Pressure Curve, Consolidation Test
10. Unconsolidated Undrained Direct Shear Test Results
11. Summary of Vane Shear Strength vs Elevation

1. INTRODUCTION

Golder Associates Ltd. has been retained by McCormick Rankin, consultants to the Ministry of Transportation Ontario (MTO), to carry out a subsurface investigation at the site of a proposed overpass for Highway 416 at the CPR Railway line near Kemptville, Ontario (see Key Plan on Drawing 3738902/03-A). The purpose of this investigation was to determine the subsurface conditions at the site of the proposed overpass structures and approach embankments along the proposed Highway 416 between about stations 14+200 and 15+050.

2. SITE DESCRIPTION AND GEOLOGY

The site is located along the west side of Highway 16 some 1.6 kilometres south of the intersection of Highway 16 and County Road 19. The proposed approach embankment and bridge site has a flat topography and is mostly heavily wooded. Poor surficial drainage and numerous wet and swampy areas exist from just north of the CPR railway line to the south limit of the study area. Presently there are no structures within the proposed roadway alignment and overpass area. The CPR track is raised about 1.4 metres above the surrounding ground level.

A previous preliminary subsurface investigation was carried out by MTO along the existing Highway 16 at the CPR railway crossing. The results of that work are provided in MTO report entitled: "Preliminary Foundation Investigation for the Southbound and Northbound Lane Overhead Structures at the Crossing of Proposed Highway 416 (Alternate Alignments Line "B" and "C") and the CPR, Township of South Gower, County Grenville, District 9, Ottawa, W.J. 68-F-65, W.P. 6-66", dated October 31, 1968. During that investigation the subsurface conditions were found to consist of thin surficial deposits of peat, followed by silty sand extending to about 1.0 metre below ground surface, followed by a deposit of sensitive, grey silty clay. The

silty clay was indicated to be underlain by dense to very dense glacial till containing cobbles and boulders. Bedrock was not encountered in the boreholes.

3. PROCEDURE

The field work for this investigation was carried out between May 4, 1990 and January 23, 1991. During this time, four boreholes, numbered 2, 3, 5, and 6, were advanced in the area of the proposed overpass structures, and eighteen boreholes, numbered 1, 4, and 7 to 22 inclusive, were advanced within 340 metres of the proposed overpass along the proposed highway alignment for embankment design purposes. The boreholes were put down using a track mounted, hollow stem auger drill rig supplied and operated by a local contractor. All of the boreholes advanced for the proposed overpass structures were taken to bedrock and the bedrock was core drilled using BLX size diamond drilling equipment. Except for borehole 1 which was advanced to practical auger refusal within glacial till, the boreholes advanced for embankment design purposes were terminated in the upper part of the glacial till at depths ranging from 5.3 to 18.9 metres below existing ground surface. Standard penetration and in-situ vane shear strength tests were carried out in all of the boreholes and samples of the soils encountered were recovered using drive open sampling equipment. In addition, relatively undisturbed 73 millimetre diameter Shelby tube samples of the silty clay were recovered for oedometer consolidation testing and direct shear testing. Standpipes were sealed into most of the boreholes to determine the groundwater levels at the site. The field work was supervised throughout by a member of our engineering staff.

Samples of the soil and bedrock encountered in the boreholes were taken to our laboratory for examination and classification testing. Samples of the soil were tested for moisture content, liquid and plastic limit, and grain size distribution. Oedometer consolidation tests were carried out on five samples of the sensitive silty clay. An

unconsolidated, undrained direct shear test was carried out on a sample of the sensitive, grey silty clay.

Logs of the soil, bedrock, and groundwater conditions encountered in boreholes 1 to 22, inclusive are provided on the Record of Borehole Sheets following the text of this report. The locations of the boreholes are given on the Borehole Location and Soil Strata, Drawing 3738902/03-A. The subsurface profile together with the proposed bridge and approach embankment grades are provided on Drawings 3738902/03-A and 3738902/03-B. The results of the laboratory and field testing are provided on Figures 1 to 11, inclusive and on the Record of Borehole sheets.

The borehole locations were determined by Golder Associates Ltd. personnel relative to staked centrelines along the northbound and southbound lanes. The borehole elevations were determined by McCormick Rankin survey personnel and are referenced to Geodetic datum.

4. SUBSURFACE CONDITIONS

4.1 General

As previously indicated, the detailed soil, bedrock, and groundwater conditions determined from the boreholes are given on the Record of Borehole sheets following the text of this report.

The borehole logs indicate the subsurface conditions at the specific test locations only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The precision with which subsurface conditions are indicated depends on the method of boring, the frequency of sampling,

and the uniformity of the subsurface conditions. Subsurface conditions between the boreholes may vary significantly from conditions encountered in the boreholes.

The soil and bedrock descriptions in this report are based on commonly accepted methods of classification and identification employed in geotechnical practice. Classification and identification of soil and bedrock involves judgement and Golder Associates Ltd. does not guarantee descriptions as exact, but infers accuracy to the extent that is common in current geotechnical practice.

In general, the site was found to be underlain by surficial deposits of topsoil or peat up to 3.1 metres thick, followed by thin deposits of sand, sandy silt or silty sand and then by deposits of sensitive silty clay. Except for the areas where the silty clay is overlain by relatively thick deposits of peat, the upper part of the silty clay was found to be weathered to a stiff to very stiff grey brown crust. Beneath the relatively thick peat deposits and beneath the weathered silty clay crust, the silty clay is grey in colour and, in some areas, is mottled with black organic matter. The thickness of the silty clay varies considerably across the proposed overpass structure and embankment area, ranging from 3.4 to 18.1 metres, being greater at the north and south ends of the study area. Deposits of sandy silt containing gravel, clay, cobbles and boulders (glacial till) and a deposit of silt containing gravel and sand were encountered beneath the silty clay and above dolomitic limestone bedrock. The groundwater levels in the silty sand and silty clay deposits were found to range from 0.0 to 0.8 metres below the top of borehole levels.

The following sections present descriptions of the soil, bedrock, and groundwater conditions encountered in the boreholes.

4.2 Topsoil, Peat, Fill

Surficial deposits of topsoil, peat, and/or fill were encountered in all of the boreholes put down during this investigation. Surficial deposits of topsoil having a thickness of 0.1 to 0.2 metres were encountered in boreholes 1, 8, 9, 10, 11, 13, 14 and 22; a 0.3 metre thick layer of topsoil was also encountered beneath about 0.6 metres of silty sand fill at borehole 20.

Peat was encountered in boreholes 3 to 7 inclusive, 12, 15 to 19 inclusive, and 21. The peat has a thickness ranging from 0.2 to 2.7 metres, being thickest in the area south of the proposed overpass structures (average of 1.5 metres at boreholes 4, 7, 15, 16, and 17). In situ vane testing carried out in the peat at boreholes 4 and 7 gave shear strengths of about 6 to 20 kilopascals.

4.3 Sandy Silt, Silty Sand, Sand

Deposits composed of sandy silt, silty sand, and sand were encountered beneath the surficial topsoil, peat or fill at the borehole locations, with the exception of boreholes 14, 16 and 19. These deposits were found to have a thickness of about 0.1 to 0.7 metres (average of about 0.4 metres at nineteen borehole locations).

The moisture content of the silty sand at boreholes 3 and 5 was found to be 22 percent.

4.4 Sensitive Silty Clay

The surficial topsoil, peat, fill and sandy deposits are underlain by a thick deposit of sensitive silty clay. The thickness of the silty clay was found to range from about 3.4 metres at borehole 15 to about 18.1 metres at borehole 9. With the exception of

boreholes 4, 7, 15, 16, 17 where the silty clay is overlain by a relatively thick deposit of peat, the upper part of the silty clay deposit was found to be weathered to a grey brown crust. The thickness of the weathered crust was found to range from about 1.6 to 3.5 metres. Atterberg limit tests carried out on samples of the weathered silty clay gave liquid limit values of 32 to 36 percent and plastic limit values of 16 to 19 percent, which reflect a clay of low to intermediate plasticity. A summary of Atterberg limit results is provided on the Plasticity Chart, Figure 1. Standard penetration tests carried out within the grey brown silty clay gave N values ranging from 1 to 8 blows per 0.3 metres. In situ vane testing carried out within the weathered crust gave shear strength values ranging from 30 to 96 kilopascals, which reflect a firm to stiff consistency. The moisture content of the weathered silty clay ranges from about 25 to 38 percent.

Beneath the weathered crust and beneath the peat deposit at boreholes 4, 7, 15, 16, 17, the silty clay is grey and, in some areas, has a trace of black organic mottling and occasional sandy silt seams. Atterberg limit tests carried out on samples of the grey silty clay gave liquid limit values of 31 to 55 percent and plastic limit values of 18 to 25 percent, which reflect a clay of low to high plasticity. A summary of the Atterberg limit test results is provided on the Plasticity Charts, Figures 2 and 3. The moisture content of the grey silty clay ranges from about 28 to 82 percent, and is generally above the measured liquid limits.

For the most part, in situ vane testing carried out in the grey silty clay gave shear strengths of 17 kilopascals to about 42 kilopascals with the shear strength generally increasing with depth. Where the silty clay deposit is relatively thin and/or is overlain by a thick deposit of peat, such as at boreholes 4, 7, 15, 16 and 17, the strength of the silty clay is, on average higher than in other areas of the site, typically ranging from 21 to 96 kilopascals with values decreasing with depth. A summary of the vane shear strength information obtained during the investigation is provided on Figure 11.

An unconsolidated, undrained direct shear test on a sample of the grey silty clay obtained in borehole 3 gave a shear strength of 25.2 kilopascals, which agrees with the in situ vane results; these test results are provided on Figure 10.

Five oedometer consolidation tests were carried out on relatively undisturbed Shelby tube samples of the silty clay. The results of the consolidation tests are provided on the Void Ratio - Pressure Curves, Figures 5 to 9, inclusive. This testing shows that the apparent past preconsolidation pressure for the samples ranges from about 85 to 140 kilopascals, which is about 35 to 100 kilopascals in excess of the existing overburden pressure at the respective sample depths and locations.

4.5 Sandy Silt with Clay, Gravel, Cobbles and Boulders

A deposit of sandy silt containing clay, gravel, cobbles and boulders (glacial till) was encountered beneath the silty clay at all of the borehole locations. Where the deposit was fully penetrated with the sampling equipment (boreholes 2, 3, 5, and 6), the glacial till was found to have a thickness of about 6.2 to 9.8 metres and to extend to depths of 8.3 to 9.8 metres below the top of borehole level (elevation 70.0 to 73.1 metres).

The results of grain size distribution tests carried out on samples of the glacial till are given on Figure 4. It should be noted that the gradation tests were carried out on 38 millimetres I.D. split barrel samples and so do not reflect the presence of cobbles or boulders which exist with the glacial till. These results show that the glacial till contains about 15 to 25 percent sand, 55 to 74 percent silt, and 6 to 8 percent clay size particles by weight. The glacial till is slightly cohesive in nature.

Standard penetration tests carried out within the glacial till at the proposed overpass location gave N values of 3 to more than 100 blows per 0.3 metres. In general, however, the glacial till has a dense to very dense relative density.

In the two boreholes advanced for the south bound lane bridge (boreholes 5 and 6), it was necessary to use diamond drilling techniques in the glacial till due to the presence of cobbles and boulders.

The moisture content of the glacial till is between 5 and 16 percent.

4.6 Silt

A thin deposit of silt containing a trace of gravel and sand was encountered beneath the glacial till and above the bedrock at borehole 3. The thickness of this deposit was found to be about 1.3 metres at this location. One standard penetration test carried out in the silt gave an N value of 103 blows per 0.3 metres which reflects a very dense relative density. The moisture content of the silt was found to be about 15 percent.

4.7 Bedrock

The four cored boreholes advanced at the proposed bridge structures encountered dolomitic limestone bedrock at depths of 14.6 to 16.2 metres below the top of borehole level (elevation 70.0 to 71.8 metres). In general, the bedrock surface elevation decreases from south to north and from east to west across the proposed bridge structures.

The bedrock consists of fresh, thinly to thickly bedded dolomitic limestone with occasional shaly layers, typical of the Oxford formation.

A measure of the quality of the bedrock recovered from the boreholes is shown on the Record of Borehole sheets as the percent core recovery (REC) and Rock Quality Designation (RQD). The upper part of the bedrock at borehole 2 and the bedrock at borehole 5 was found to be fractured, as reflected in core recovery values of 50 to 100 percent (average of 79 percent) and RQD values of 0 to 77 percent (average of 29 percent). Beneath the fractured zone at borehole 2 and at boreholes 3 and 6, the bedrock was found to be, on average, of fair quality as reflected by recovery values of 88 to 100 percent (average of 98 percent) and RQD values of 27 to 85 percent (average of 54 percent).

4.8 Groundwater

Groundwater levels were obtained from standpipes sealed in the completed boreholes. On January 30, 1991, the groundwater levels in the silty sand and silty clay deposits were found to range from the borehole surface level to 0.8 metres below the top of the borehole level (elevation 85.6 to 86.5 metres). The water levels in the underlying glacial till were found to range from 0.3 to 1.9 metres below the borehole surface level (elevation 84.3 to 86.3 metres).

The ground water levels could be higher during wet periods of the year such as the early spring.

5. DISCUSSION AND RECOMMENDATIONS

5.1 General

This section of the report provides engineering guidelines on the geotechnical design aspects of the project based on our interpretation of the borehole information and the project requirements. It is stressed that the information in this portion of the report is provided for the guidance of the design engineers. Contractors bidding on or undertaking the work should examine the factual results of the investigation, satisfy themselves as to the adequacy of the information for construction and make their own interpretation of the factual data as it affects their proposed construction techniques, schedule and equipment capabilities.

It is understood that as presently proposed the northbound and southbound overpass structures will consist of three span concrete bridges, each having a total length of about 83 metres. The proposed maximum roadway level is understood to be elevation 96.5 metres, which will result in approach embankments with a height of up to about 10.5 metres above existing ground surface. The abutments for the bridge will likely be perched above existing ground surface.

5.2 Bridge Foundations

Due to the relatively low shear strength of the sensitive silty clay, the shallow overburden deposits are not considered suitable for the support of the proposed overpass structures on conventional spread footings. It is recommended therefore that the proposed bridges be founded on deep foundations, such as driven piles deriving support in end bearing.

Since the glacial till and underlying silt deposits contain cobbles and boulders, a heavy steel H pile is suggested to minimize pile bending problems. The piles should be equipped with a cast steel driving shoe (such as those manufactured by Titus Steel Company or by Associated Pile and Fitting Corporation) to minimize damage to the tips of the piles during driving.

As a design example, for an HP310x110 steel H-pile, the Serviceability Limit State (SLS) and Ultimate Limit State (ULS) loads could be taken as 1150 and 1600 kilonewtons, respectively. In this case the H piles should be set at a termination of 10 blows for the last 12 millimetres of penetration using a hammer transferring about 60 kilojoules of energy per blow to the pile. Based on previous piling experience in this area, it is possible that several rounds of restriking could be required to achieve permanence of the final set. Therefore, provision should be made for restriking all of the piles at least once to confirm the set. Piles that do not meet the design set criteria on the first restrike would require additional restriking. A minimum of two days should be allowed before restriking a pile.

Since the glacial till was found to have, on average, a dense to very relative density and to contain cobbles and boulders, it is expected that although some piles may reach bedrock most of the piles will terminate erratically within the glacial till.

Skin friction loads can be induced on the abutment piles due to consolidation settlement of the silty clay beneath the approach embankments. The negative skin friction loads on the piles can be determined using an effective stress approach as described in the Commentary to the Ontario Highway Bridge Design Code (OHBDC) Section C6-8.3.3.2. The skin friction force per unit area of pile can be determined by:

$$f_s = 0.25 p'_z$$

where p' = unit effective vertical stress at depth z .

For design purposes, the effective unit weight of the grey silty clay can be taken as 7 kilonewtons per cubic metre. The negative skin friction loads should be assumed to act only with the permanent (dead) loads.

As a design example, the negative skin friction load on a HP310x110 steel H pile driven through 6.5 metres of silty clay could be taken as 190 kilonewtons at SLS and 240 kilonewtons at ULS, if the adjacent embankment load is 50 kilopascals. The negative skin friction loads can be reduced by coating the pile section within silty clay with an asphalt emulsion (such as Bakelite 700-01).

Allowance should be made for pile load testing at the time of construction.

For snow cleared areas, the pile caps should be provided with at least 1.8 metres of earth cover for frost protection purposes.

To facilitate pile driving, the fill material used beneath the abutments should not contain cobble or boulder size material (i.e. not larger than 75 millimetres).

The soils at this site are highly susceptible to frost heaving. Therefore, the native soils around the piles should be protected from freezing during construction to prevent pile jacking due to adfreeze effects.

A licensed welding inspector should be retained during the pile driving to periodically inspect the welding procedures used by the contractor if welded pile splices are used.

5.3 Abutment Wall Backfill and Earth Pressures

The abutments should be backfilled with compacted non frost susceptible, free draining backfill such as that meeting Ontario Provincial Standard Specifications (OPSS) for Granular B Type I or II. The granular fill should extend at least 1.5 metres beyond the inside face of the abutments and should be compacted in thin lifts to at least 95 percent of the standard Proctor density. If lateral movement at the top of the abutment of about 0.05 percent of the retained height is expected to occur, "active" earth pressure coefficients (K_a) should be used in determining the horizontal loads on the abutments. If the wall movement is expected to be less, then "at rest" pressure coefficients (K_o) should be used.

Assuming that a well graded sand and gravel backfill material meeting OPSS Granular B Type I material is used behind the abutments, a material unit weight of 21.2 kilonewtons per cubic metre may be used together with the following earth pressure coefficients in determining the lateral loads on the abutments.

At Ultimate Limit State (ULS)	Earth Pressure Coefficient
"at rest" condition	0.55
"active" condition	0.38
At Serviceability Limit State (SLS)	
"at rest" condition	0.47
"active" condition	0.31

Earth pressure parameters for other materials could be provided if necessary.

To reduce compaction induced stress on the abutment walls, the granular fill near the abutments should be compacted with walk behind compaction equipment.

If light weight styrofoam fill is used near the abutments or wing walls, drainage of the wall section adjacent to the styrofoam could be provided by means of prefabricated wick drains, such as those manufactured by Alidrain, installed on 1 metre centres against the face of the wall.

5.4 Approach Embankments

As indicated, the proposed approach embankments would be up to about 10.5 metres in height with the present bridge configuration. As a basis for the design of the embankments, the maximum post construction (in service) settlement of the roadway has been taken as about 0.15 metres. With this post construction settlement constraint, the height that the embankment could be constructed depends on the type(s) of embankment fill material used and its bulk unit weight, the thickness of the silty clay layer and the consolidation characteristics of the silty clay, and the amount of preload time available.

If a limited preload period is available (say less than 1 year), it will not be possible to construct a conventional earth or slag fill embankment to the full design height while still maintaining the post construction settlements within acceptable limits. The maximum embankment height that can be obtained will be variable along the length of the proposed approach fill, due to the variable thickness and nature of the silty clay. As a guide, the following range in embankment heights could likely be achieved with clean sand fill, unprocessed pelletized slag, and structural coarse slag if a short (1 year) preload period is available.

<u>Embankment Fill Material Type</u>	<u>Bulk Unit Weight (kN/m³)</u>	<u>Range of Possible Embankment Heights Assuming a Preload Period of 1 Year (metres)</u>
Clean Sand Fill	18.6	2.5 to 5.5
Pelletized Slag	11.8	3.5 to 8.0
Structural Coarse Slag	10.8	3.5 to 8.5

In general, the lower range of embankment heights are applicable for the areas where the silty clay is soft to firm and is relatively thick, and the upper range of embankment heights can be achieved just south of the proposed overpass in the area of thin, stiff grey silty clay (see boreholes 16, 17, and 18).

The above embankments heights include an allowance for pavement granular materials and asphalt and assume that the topsoil and peat are removed from beneath the embankment area.

To achieve the required approach fill grade with a limited preload period, the bridge structure would have to be extended or, as an alternative to extending the overpass structure, consideration could also be given to structurally supporting the fill loads on deep foundations bearing on or within the underlying glacial till. Due to the quantities of fill required, it is not considered practical to use light weight fill (such as styrofoam) to achieve the required embankment grades.

If a long preload period is available (say 5 to 10 years or more), several design options could be considered for the proposed embankment construction; these are as follows:

- single stage construction with large berms to control overall rotational stability, with or without vertical drains to increase the rate of consolidation settlement.
- staged construction with or without supplementary vertical drains.

Staged construction entails constructing the embankments in stages at controlled rates so that consolidation of the silty clay (and hence soil strengthening) occurs prior to the next stage of embankment loading. Vertical drains, such as sand drains or manufactured filter wrapped, plastic wick drains, are installed at close spacing (say at 1.5 metre centre to centre) to increase the rate of consolidation settlement and, therefore, to increase the rate of possible embankment construction and to reduce the in service settlement.

Since the silty clay is relatively thick in some areas, and since there are property constraints, staged construction with supplementary vertical drains is considered to be the best option from a geotechnical point of view.

During staged construction of the embankment, it will be necessary to carefully monitor the consolidation and settlement behaviour of the silty clay so that the embankment design (amount of loading and time rate of loading) can be modified as necessary. The field instrumentation should consist of the following: settlement plates and extensometers to provide information on the settlement and variations of settlement with depth, piezometer installations to provide information on the porewater pressure in the silty clay between the vertical drains and beneath the embankment, and inclinometer installations to measure lateral deformations beneath the fill. Accurate measurement of the fill unit weights and fill heights must also be included as part of the monitoring. Details on the embankment loading requirements, side slope requirements, spacing of vertical drains, time rate of loading, etc., could be provided if required, when and if the preload period is known.

5.5 Additional Considerations

It is recommended that the pile driving equipment proposed by the contractor be reviewed in light of the contract pile type and set criteria and accepted by the geotechnical engineer well in advance of any pile driving operations. Also, all piling operations should be inspected throughout by qualified geotechnical personnel.

Excavation and removal of the peat deposits will be carried out below the groundwater level. Groundwater inflow into the excavation could be substantial and should be handled by pumping from sumps in the excavation. The excavated areas should be backfilled with sand or sand and gravel material, compacted in maximum 300 millimetre thick lifts to at least 95 percent of the standard Proctor density.

The recommendations provide in this report are for preliminary design purposes only; further recommendations could be provided if and when the final design of the overpass structures and embankments proceeds.

Yours truly,

GOLDER ASSOCIATES LTD.

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Disk 30

EXPLANATION OF TERMS USED IN REPORT

N VALUE: THE STANDARD PENETRATION TEST (SPT) N VALUE IS THE NUMBER OF BLOWS REQUIRED TO CAUSE A STANDARD 51mm O.D SPLIT BARREL SAMPLER TO PENETRATE 0.3m INTO UNDISTURBED GROUND IN A BOREHOLE WHEN DRIVEN BY A HAMMER WITH A MASS OF 63.5kg, FALLING FREELY A DISTANCE OF 0.76m. FOR PENETRATIONS OF LESS THAN 0.3m N VALUES ARE INDICATED AS THE NUMBER OF BLOWS FOR THE PENETRATION ACHIEVED. AVERAGE N VALUE IS DENOTED THUS \bar{N} .

DYNAMIC CONE PENETRATION TEST: CONTINUOUS PENETRATION OF A CONICAL STEEL POINT (51mm O.D. 60° CONE ANGLE) DRIVEN BY 475 J IMPACT ENERGY ON 'A' SIZE DRILL RODS. THE RESISTANCE TO CONE PENETRATION IS MEASURED AS THE NUMBER OF BLOWS FOR EACH 0.3m ADVANCE OF THE CONICAL POINT INTO THE UNDISTURBED GROUND.

SOILS ARE DESCRIBED BY THEIR COMPOSITION AND CONSISTENCY OR DENSENESS.

CONSISTENCY: COHESIVE SOILS ARE DESCRIBED ON THE BASIS OF THEIR UNDRAINED SHEAR STRENGTH (c_u) AS FOLLOWS:

c_u (kPa)	0 - 12	12 - 25	25 - 50	50 - 100	100 - 200	> 200
	VERY SOFT	SOFT	FIRM	STIFF	VERY STIFF	HARD

DENSENESS: COHESIONLESS SOILS ARE DESCRIBED ON THE BASIS OF DENSENESS AS INDICATED BY SPT N VALUES AS FOLLOWS:

N (BLOWS/0.3m)	0 - 5	5 - 10	10 - 30	30 - 50	> 50
	VERY LOOSE	LOOSE	COMPACT	DENSE	VERY DENSE

ROCKS ARE DESCRIBED BY THEIR COMPOSITION AND STRUCTURAL FEATURES AND / OR STRENGTH.

RECOVERY: SUM OF ALL RECOVERED ROCK CORE PIECES FROM A CORING RUN EXPRESSED AS A PERCENT OF THE TOTAL LENGTH OF THE CORING RUN.

MODIFIED RECOVERY: SUM OF THOSE INTACT CORE PIECES, 100mm+ IN LENGTH EXPRESSED AS A PERCENT OF THE LENGTH OF THE CORING RUN. THE ROCK QUALITY DESIGNATION (RQD), FOR MODIFIED RECOVERY, IS:

RQD (%)	0 - 25	25 - 50	50 - 75	75 - 90	90 - 100
	VERY POOR	POOR	FAIR	GOOD	EXCELLENT

JOINTING AND BEDDING:

SPACING	50mm	50 - 300mm	0.3m - 1m	1m - 3m	> 3m
JOINTING	VERY CLOSE	CLOSE	MOD. CLOSE	WIDE	VERY WIDE
BEDDING	VERY THIN	THIN	MEDIUM	THICK	VERY THICK

ABBREVIATIONS AND SYMBOLS

FIELD SAMPLING

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

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_l	1	SENSITIVITY = $\frac{c_u}{\tau_r}$

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

PHYSICAL PROPERTIES OF SOIL

ρ_s	kg/m^3	DENSITY OF SOLID PARTICLES	e	1, %	VOID RATIO	e_{min}	1, %	VOID RATIO IN DENSEST STATE
γ_s	KN/m^3	UNIT WEIGHT OF SOLID PARTICLES	n	1, %	POROSITY	I_D	1	DENSITY INDEX = $\frac{e_{max} - e}{e_{max} - e_{min}}$
ρ_w	kg/m^3	DENSITY OF WATER	w	1, %	WATER CONTENT	D	mm	GRAIN DIAMETER
γ_w	KN/m^3	UNIT WEIGHT OF WATER	S_r	%	DEGREE OF SATURATION	D_n	mm	n PERCENT - DIAMETER
ρ	kg/m^3	DENSITY OF SOIL	w_L	%	LIQUID LIMIT	C_u	1	UNIFORMITY COEFFICIENT
γ	KN/m^3	UNIT WEIGHT OF SOIL	w_p	%	PLASTIC LIMIT	h	m	HYDRAULIC HEAD OR POTENTIAL
ρ_d	kg/m^3	DENSITY OF DRY SOIL	w_s	%	SHRINKAGE LIMIT	q	m^3/s	RATE OF DISCHARGE
γ_d	KN/m^3	UNIT WEIGHT OF DRY SOIL	I_p	%	PLASTICITY INDEX = $w_L - w_p$	v	m/s	DISCHARGE VELOCITY
ρ_{sat}	kg/m^3	DENSITY OF SATURATED SOIL	I_L	1	LIQUIDITY INDEX = $\frac{w - w_p}{I_p}$	i	1	HYDRAULIC GRADIENT
γ_{sat}	KN/m^3	UNIT WEIGHT OF SATURATED SOIL	I_C	1	CONSISTENCY INDEX = $\frac{w_L - w}{I_p}$	k	m/s	HYDRAULIC CONDUCTIVITY
ρ'	kg/m^3	DENSITY OF SUBMERGED SOIL	e_{max}	1, %	VOID RATIO IN LOOSEST STATE	j	KN/m^2	SEEPAGE FORCE
γ'	KN/m^3	UNIT WEIGHT OF SUBMERGED SOIL						

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 342; E 373 805

ORIGINATED BY LQ

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic DATE May 4, 1990

CHECKED BY AFC

[illegible]

+3, x5 : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 1

METRIC

W P 173-89-02/03 LOCATION Co-ords N 4 992 342; E 373 805 ORIGINATED BY LO
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY APC
DATUM Geodetic DATE May 4, 1990 CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa									
								20	40	60	80	100					
	Continued																
	Sandy silt, some gravel trace clay with cobbles and boulders (glacial till)						72										
	Compact to very dense	Grey															
70.1																	
16.2	Auger refusal End of hole						70										
	*Sank under weight of hammer																

RECORD OF BOREHOLE No 2

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 317; E 373 811 ORIGINATED BY D.M.
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY AFC
DATUM Geodetic DATE January 9 and 19, 1991 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N VALUES			20	40	60	80	100					
86.2	Water Level																
85.9	Ice																
0.3	Peat																
85.5	Dark brown																
0.7	Silty sand Grey Brown																
0.8	Silty clay, some sandy silt seams (weathered crust)		1	SS	3												
			2	SS	7												
83.2	Grey brown Stiff to to grey very stiff																
3.0	Silty clay, occasional sandy silt seam																
	Soft to firm Grey		3	TW	WR*												
			4	SS	WR*												
78.7																	
7.5	Sandy silt, trace of some gravel and clay, with cobbles and boulders (glacial till)		5	SS	3												
			6	SS	58												
			7	SS	110												
	Very loose to very dense Grey		8	SS	80 for 18 cm												
	Continued																

+3, x5: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 2

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 317; E 373 811
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core
 DATUM Geodetic DATE January 9 and 10, 1991
 ORIGINATED BY D.M.
 COMPILED BY AFC
 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa										WATER CONTENT (%)		
								20	40	60	80	100						20	40	60
	Continued		9	SS	77		74													
							Bentonite													
			10	SS	22		Pea gravel backfill													
							Standpipe B													
							72													
70.2			11	SS	24															
16.0	Dolomite limestone bedrock, fractured, thinly bedded, occ. planar smooth joint		12	RC BXL	REC= 92%		70										RQD = 50% **			
69.4			13	RC BXL	REC= 59%												RQD = 0%			
			14	BXL	100%												RQD = 0%			
16.8	Dolomite limestone bedrock, fresh, thinly to thickly bedded, some shaly layers		15	RC BXL	REC= 100%												RQD = 46%			
	Grey		16	RC BXL	REC= 100%		68										RQD = 66%			
66.8																				
19.4	End of hole						66													
	* Sank under weight of rods.																			
	**REC = Recovery BQD = Rock Quality Designation																			

+3, x5: Numbers refer to
Sensitivity

20
15 ± 5 (%) STRAIN AT FAILURE
10

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 268; E 373 849

ORIGINATED BY LQ

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core

COMPILED BY AFC

DATUM Geodetic DATE January 11, 1991

CHECKED BY AFC

[illegible]

+³, x⁵: Numbers refer to Sensitivity

20
15-5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 3

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 268; E 373 849 ORIGINATED BY LO
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY APC
 DATUM Geodetic DATE January 11, 1991 CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPo									WATER CONTENT (%)		
								20	40	60	80						100	20	40
	Continued																		
73.1	Sandy silt, trace to some gravel and clay, with cobbles and boulders (glacial till) loose to very dense		11	SS	36		74												
13.3	Grey						Native Backfill												
71.8	Silt, trace gravel and sand		12	SS	103														
	Very dense Grey						72												
14.6	Dolomitic limestone bedrock, fresh, thinly to thickly bedded, some shaly layers and seams. Soil filled, near vertical joint from 14.8 to 15.1 metres depth		13	RC BXL	REC= 98% RQD= 27%														
			14	RC BXL	REC= 100% RQD= 61%		70												
			15	RC BXL	REC= 100% RQD= 85%		Bentonite Sand backfill												
67.4	Grey						68												
							Standpipe												
19.0	End of Hole						66												

RECORD OF BOREHOLE No 4

METRIC

W P 373-89-02/03 LOCATION Co-ords N 4 992 231; E 373 857

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY APC

DATUM Geodetic DATE January 28, 1991

CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPo								WATER CONTENT (%)		
								20 40 60 80 100										
86.2	Water Level																	
0.0	Ice														GR SA SI CL			
0.2	Peat																	
84.8	Dark Brown		1	SS	WH*		86	+ S=2										
1.4	Silty sand							+ S=6										
1.5	Grey Brown							+ S=4										
			2	SS	2													
	Silty clay, some sandy silt seams						84											
			3	SS	3													
	Stiff	Grey						+ S=9										
81.6							82	+ S=6										
4.6	Silty clay, occasional sandy silt seam		4	SS	PM			+ S=5										
	Soft to firm	Grey	5	SS	PM		80	+ S=16										
								+ S=8										
								+ S=10										
79.0																		
7.2	Sandy silt, trace to some gravel and clay (glacial till)							+ S=8										
78.0	Loose	Grey	6	SS	5													
8.2	End of hole						78											
	* Sank under weight of hammer																	
	**Water level not established						76											

+³, x⁵: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10

METRIC

W P 373-89-02/03

LOCATION _____ Co-ords N 4 992 257; E 373 799

ORIGINATED BY DM

DIST 2

HWY 416

BOREHOLE TYPE Hollow Stem Auger, BXL, Rock Core

COMPILED BY AFC

DATUM Geodetic

DATE January 3 to 9, 1991

CHECKED BY AFC

[illegible]

+³, x⁵ : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 5

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 257; E 373 799 ORIGINATED BY DM
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY AFC
 DATUM Geodetic DATE January 3 to 9, 1991 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	N° VALUES			SHEAR STRENGTH kPa									
								20 40 60 80 100									
	Continued		14	SS	105		74										
	Sandy silt, some gravel, trace clay, with cobbles and boulders (glacial till)		15	RC BXL	REC = 19%												
			16	SS	60 for 15 cm												
	Compact to very dense		17	RC BXL	REC = 11%		72										
	Grey		18	SS	89									9 25 59 8			
70.0			19	RC BXL	REC = 66%												
			20	RC BXL	REC = 100%		70							** RQD=26%			
16.2	Dolomitic limestone bedrock, fresh, thinly to thickly bedded, some shaly seams and layers, fractured core from 16.3 to 16.4, 16.8 to 16.8, and 19.2 to 19.3 metres depth.		21	RC BXL	REC = 50%									RQD=0%			
			22	RC BXL	REC = 84%									RQD=42%			
			23	RC BXL	REC = 100%		68							RQD=70%			
65.9			24	RC BXL	REC = 75%									RQD=0			
	Grey		25	RC BXL	REC = 50%									RQD=0			
			26	RC BXL	REC = 98%		66							RQD=77%			
20.3	End of hole																
	* Sank under weight of rods						64										
	** REC=Recovery RQD=Rock Quality Designation																

RECORD OF BOREHOLE No 6

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 209; E 373 836 ORIGINATED BY DM
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger, BXL Rock Core COMPILED BY APC
 DATUM Geodetic DATE January 15 and 15, 1991 CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								20 40 60 80 100	20 40 60 80 100						
86.3	Water Level														
0.0	Ice														
0.2	Peat														
85.4	Dark Brown		1	AS*	-		86								
0.9	Siltsand, occasional		2	SS	PM										
84.8	silty clay layers														
	Grey Brown														
1.5	Silty clay, some sandy silt seams (weathered crust)		3	TW	PM										
	Stiff Grey brown to grey														
81.7															
4.6	Silty clay, occasional sandy silt seams		4	TW	PM										
	Firm Grey														
79.4			5	SS	PM										
6.9	Sandy silt, some gravel, trace clay, with cobbles and boulders (glacial til)		6	SS	5										
	Loose to very dense Grey		7	SS	43										
			8	RC BXL	REC=93%										
			9	SS	19 for 23 cm										
			10	RC BXL	REC=21%										
			11	RC BXL	REC=36%										
			12	SS	30 for 8 cm										
			13	RC BXL	REC=16%										
	Continued														

METRIC

W P 373-89-02/03

LOCATION Co ords N 4 992 209; E 373 836

ORIGINATED BY DM

DIST 9 HWY 416

BOREHOLE TYPE Hollow Stem Augering BXL Rock Core

COMPILED BY AFC

DATUM Geoditic

DATE January 15 and 16, 1991

CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)			
								20 40 60 80 100										
							○ UNCONFINED + FIELD VANE											
							● QUICK TRIAXIAL x LAB VANE											
							20 40 60 80 100					20 40 60						
71.1	<div>Continued</div> <div>Sandy silt, some gravel, trace clay, with cobbles and boulders (glacial till)</div> <div>Loose to very dense Grey</div>	<div>13 RC REC=16% 14 SS 30 for 13 cm</div> <div>15 RC BXL REC=4%</div> <div>16 SS 64</div> <div>17 RC BXL REC=54%</div>				74												
15.2	Dolomitic limestone bedrock, fresh, thinly to thickly bedded, some faintly weathered shaly layers	<div>18 RC BXL REC=100% RQD=64%</div> <div>19 RC BXL REC=98% RQD=42%</div> <div>20 RC BXL REC=88% RQD=44%</div>				72												
68.0	Grey					70												
18.3	End of hole *Auger Sample **REC=Recovery RQD=Rock Quality Designation					68												
						66												

RECORD OF BOREHOLE No 7

METRIC

W P 373-84-02/03 LOCATION Co ords N 4 992 170; E 373 844
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger
 DATUM Geoditic DATE January 22, 1991
 ORIGINATED BY DM
 COMPILED BY AFC
 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	20 40 60 80 100	20 40 60 80 100		
86.4	Water level												
0.0	Ice												
0.2	Peat		1	AS*	-	**	86	+ S=1					
85.2	Dark brown		2	SS	PM			+ S=2					
1.2	Silty sand							+ S=4					
1.4	Grey brown		3	SS	2								
	Silty clay, some sandy silt seams						84						
	Stiff Grey		4	SS	4								
81.8								+ S=7					
4.6	Silty clay, occasional sand silt seam		5	SS	PM		82	+ S=6					
								+ S=5					
80.3	Firm Grey							+ S=9					
6.1								+ S=10					
80.0	Sandy silt, trace gravel and clay, with cobbles and boulders (glacial till)		6	SS	6 for 18 cm		80						
6.4	Grey												
	End of hole												
	*Auger sample						78						
	**Water level not established												



METRIC

ORIGINATED BY DM

COMPILED BY AFC

CHECKED BY _____ AFC

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 8

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 635; E 373 663 ORIGINATED BY DM
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
 DATUM Geodetic DATE December 17, 1990 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa						
	Continued							20 40 60 80 100						
	Silty clay, occasional sandy silt seam, trace black mottling		6	SS	WR			+ S=16						
	Soft to firm						72	+ S=35 + S=17						
	Grey		7	SS	WR			+ S=13 + S=15						
			8	SS	WR		70							
69.1														
17.8	Sandy silt, some gravel, trace clay (glacial till)							+ S=12						
68.0	Very loose		9	SS	WR									
	Grey						68							
18.9	End of hole													
	*Split spoon sank under weight of rods						66							

RECORD OF BOREHOLE No 9

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 571; E 373 640 ORIGINATED BY DM
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY APC
 DATUM Geodetic DATE January 2 and 3, 1991 CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT					PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%)
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20	40	60	80	100					
86.6	Ground Surface																
0.0	Topsoil																
0.2																	
0.3	Silty Sand Brown					**	86										
	Silty clay, occasional sandy silt seam (weathered crust)		1	SS	2												
83.9	Stiff Grey Brown						84										
2.7	Silty clay, occasional sandy silt seam, trace black mottling		2	SS	PM												
	Soft to firm Grey		3	SS	WR*		82										
			4	SS	WR												
							80										
			5	SS	WR												
							78										
			6	SS	WR												
							76										
			7	TW	PM												
			8	SS	WR		74										
							72										

+³, x⁵: Numbers refer to
Sensitivity

20
15
10
5 (%) STRAIN AT FAILURE

RECORD OF BOREHOLE No 9

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 571; E 373 640
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger
 DATUM Geodetic DATE January 2 and 3, 1991
 ORIGINATED BY DM
 COMPILED BY AFC
 CHECKED BY AFC

SOIL PROFILE		SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE			'N' VALUES	20 40 60 80 100					
	Continued												
	Silty clay, occasional sandy silt seam, trace black mottling		9	SS	WR		+ S=25 + S=38 + S=20						
	Soft to firm Grey		10	SS	WR								
			11	SS	WR		+ S=13 + S=10 + S=13						
68.2													
18.4 67.7	Silty sand, some gravel, trace clay (glacial till) Grey		12	SS	PM								
18.9	End of hole												
	*Split spoon sank under weight of rods												
	**Water level not established												

RECORD OF BOREHOLE No 10

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 517; E 373 723

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AEC

DATUM Gendetic DATE January 2, 1991

CHECKED BY AEC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPo							WATER CONTENT (%)			
								20 40 60 80 100										
86.5	Ground Surface																	
0.0	Topsoil																	
0.2	Silty sand																	
85.6	Brown																	
0.9	Silty clay, some sandy silt seams (weathered crust)		1	SS	2													
83.8	Stiff Grey brown																	
2.7	Silty clay, occasional sandy silt seam, trace black mottling		2	SS	PM													
	Soft to firm Grey																	
			3	SS	WR*													
			4	SS	WR													
			5	SS	WR													
			6	SS	WR													
			7	TW	PM													

RECORD OF BOREHOLE No 10

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 517; E 373 723 ORIGINATED BY DM
 DIST 4 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
 DATUM Geoditic DATE January 2, 1991 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa		W _p	W	W _L		
	Continued													
	Silty clay, occasional sandy silt seam trace black mottling		8	SS	WR		74	+ 27						
								+ 50						
								+ 36						
	Soft to firm		9	SS	WR		72	+ 19						
	Grey							+ 29						
70.8								+ 15						
15.7								+ 7						
15.9	Sandy silt, some gravel trace clay (glacial till)		10	SS	1									
	Grey													
	End of hole						70							
	*Split spoon sank under weight of rods													

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 455; E 373 699

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic DATE December 20, 1991

CHECKED BY AFC

[illegible]

+3, x5: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 11

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 455; E 373 699

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY APC

DATUM Geodetic DATE December 20, 1991

CHECKED BY APC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100					
	Continued													
	Silty clay, occasional sandy silt seam, trace black mottling		6	SS	WR		72	+ S=31 + S=21						
	Soft to firm Grey		7	SS	WR			+ S=11 + S=17						
70.4														
16.2	Sandy silt, some gravel, trace clay (glacial till)						70	+ S=15						
85.2	Compact Grey		8	SS	11									
17.4	End of hole													
	*Split spoon sank under weight of rods						68							

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 422; E 373 743 ORIGINATED BY DM
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
DATUM Geodetic DATE December 21, 1990 CHECKED BY AFC

[illegible]

METRIC

W P 373-89-02/03

LOCATION Co ords N 4 992 401; E 373 782

ORIGINATED BY DM

DIST 9 HWY. 416

BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic

DATE December 20, 1990

CHECKED BY AFC

[illegible]

+³, x⁵ : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 14

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 335; E 373 760 ORIGINATED BY DM
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
DATUM Geodetic DATE December 19, 1990 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa							WATER CONTENT (%)
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE x LAB VANE						
86.6	Ground Surface							20 40 60 80 100	20 40 60						
0.0	Topsoil														
86.0	Silty sand	Brown													
0.6	Silty clay, some sandy silt seams (weathered crust)		1	SS	3										
	Stiff	Grey brown													
83.5															
3.1	Silty clay, some sandy silt seams														
			2	TW	PM										
	Soft to firm	Grey													
79.8			3	SS	WR*										
6.8	Sandy silt, some gravel trace clay (glacial till)														
78.4	Loose	Grey	4	SS	6										
8.2	End of hole														
	*Split spoon sank under weight of rods														

METRIC

W P 373-89-02/03

LOCATION Co ords N 4 992 193; E 373 886

ORIGINATED BY DM

DIST 9 HWY 416

BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic

DATE January 14, 1991

CHECKED BY AFC

[illegible]

+3, x5: Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 136; E 373 873 ORIGINATED BY DM
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
DATUM Geodetic DATE January 18, 1991 CHECKED BY AFC

[illegible]

+³, x⁵: Numbers refer to Sensitivity

RECORD OF BOREHOLE No 17

METRIC

W P 373-89-02/03 LOCATION Co ords 4 992 094; E 373 911 ORIGINATED BY DM
 DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
 DATUM Geodetic DATE January 18, 1991 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV. DEPTH	DESCRIPTION	STRAT. PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100	20 40 60 80 100	W _p	W	W _L		
86.3	Water Level													
0.0	Ice													
0.2	Peat		1	AS*	-									
	Dark brown					**								
85.1			2	SS	PM									
1.2	Sandy silt													
1.4	Grey brown													
	Silty clay, some sandy silt seams													
			3	SS	3									
	Stiff to very stiff Grey													
81.4														
4.9	Silty clay, some sandy silt seams													
80.4	Soft to firm Grey													
5.9	Sandy silt, some gravel, trace clay (glacial till)													
79.6	Loose Grey		4	SS	4									
6.7	End of hole													
	*Auger sample													
	**Water level not established													

RECORD OF BOREHOLE No 18

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 992 073; E 373 947 ORIGINATED BY DM
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
DATUM Geodetic DATE January 14, 1991 CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT Y	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			20 40 60 80 100							WATER CONTENT (%)
								SHEAR STRENGTH kPa							
								○ UNCONFINED	+ FIELD VANE						
								● QUICK TRIAXIAL	x LAB VANE						
								20 40 60 80 100		20 40 60					
86.4	Ground Surface														
0.0	Peat														
0.1	Silty sand														
0.3	Grey brown														
	Silty clay, some sandy silt seams (weathered crust)		1	SS	4		86								
			2	SS	5										
			3	SS	4		84								
83.3	Stiff Grey brown														
3.1	Silty clay, some sandy silt seams		4	TW	PM										
82.1	Firm Grey														
4.3	Sandy silt, some gravel trace clay (glacial till)		5	SS	3		82								
81.1	Very loose Grey														
5.3	End of hole														

+3, x5: Numbers refer to
Sensitivity

20
15 \div 5 (%) STRAIN AT FAILURE
10

METRIC

W P 373-89-02/03

LOCATION Co ords N 4 992 009; E 373 925

ORIGINATED BY DM

DIST 9 HWY 416

BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic

DATE January 18, 1991

CHECKED BY AFC

[illegible]

+³, x⁵ : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 991 974; E 373 968

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic DATE January 2, 1991

CHECKED BY AFC

[illegible]

+³, x⁵ : Numbers refer to Sensitivity

20
15 ϕ 5 (%) STRAIN AT FAILURE
10

RECORD OF BOREHOLE No 21

METRIC

W P 373-89-02/03 LOCATION Co ords N 4 991 941; E 373 996

ORIGINATED BY DM

DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger

COMPILED BY AFC

DATUM Geodetic DATE January 23, 1991

CHECKED BY AFC

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ (kN/m ³)	REMARKS & GRAIN SIZE DISTRIBUTION (%)	
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa									WATER CONTENT (%)
								20	40	60	80						
86.4	Ground Surface																
0.1	Ice																
86.0	Peat Dark Brown																
0.4	Silty sand																
85.5	Grey Brown																
0.9	Silty clay, some sandy silt seams (weathered crust)		1	SS	5												
			2	SS	2												
			3	SS	2												
83.5																	
2.9	Silty clay, some sandy silt seams, trace black mottling		4	SS	PM												
			5	SS	WR*												
			6	TW	WR												
			7	TW	WR												
			8	SS	WH**												
75.7																	
10.7	Sandy silt, trace gravel & clay (glacial till)		9	SS	7												
75.1	Loose Grey																
11.3	End of hole																
	*Sank under weight of rods																
	**Soil under weight of hammer																

+³, x⁵: Numbers refer to
Sensitivity

20
15 5 (%) STRAIN AT FAILURE
10



RECORD OF BOREHOLE No 22

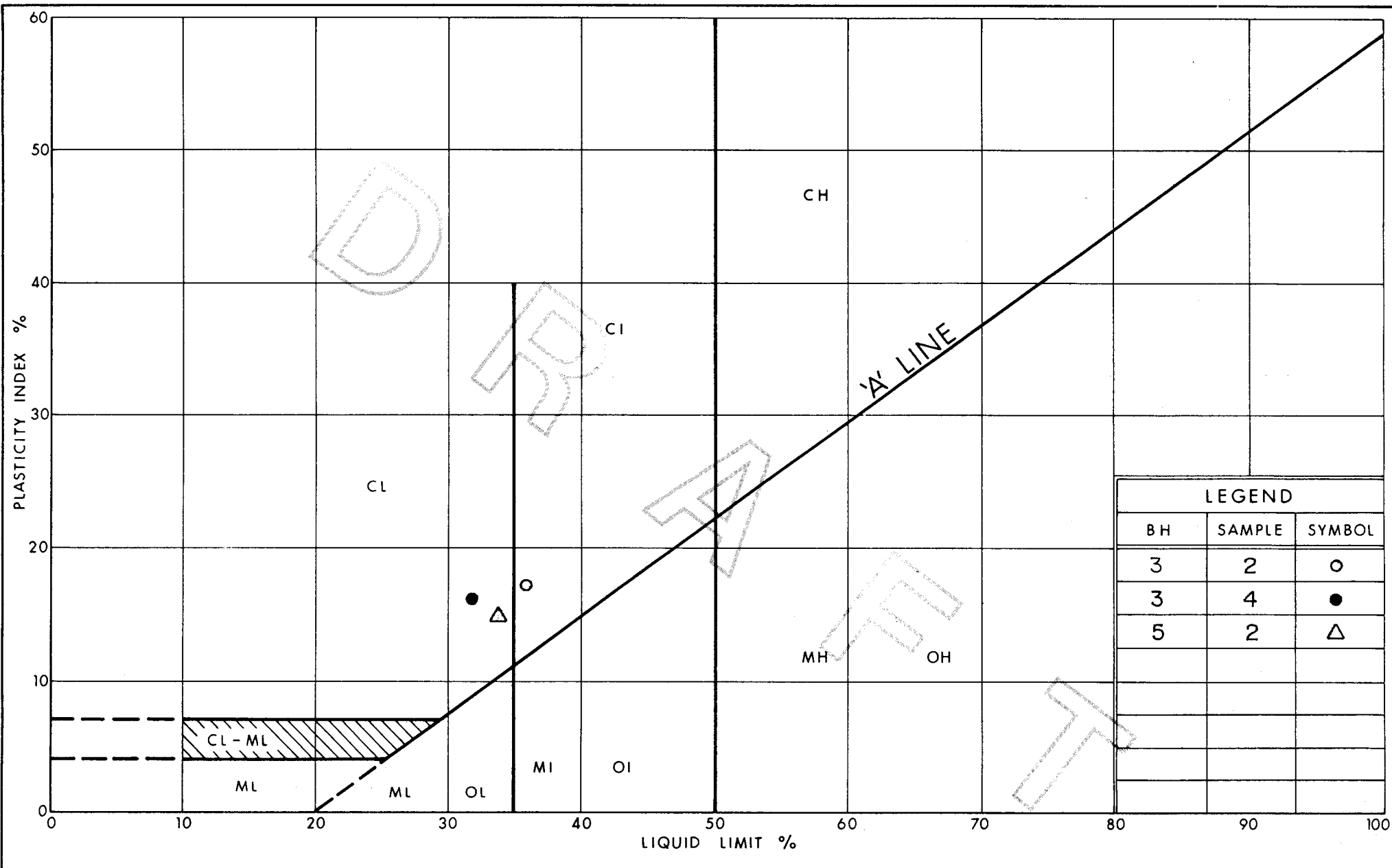
METRIC

W P 373-89-02/03 LOCATION Co ords N 4 991 881; E 373 971 ORIGINATED BY DM
DIST 9 HWY 416 BOREHOLE TYPE Hollow Stem Auger COMPILED BY AFC
DATUM Geodetic DATE January 23, 1991 CHECKED BY AFC

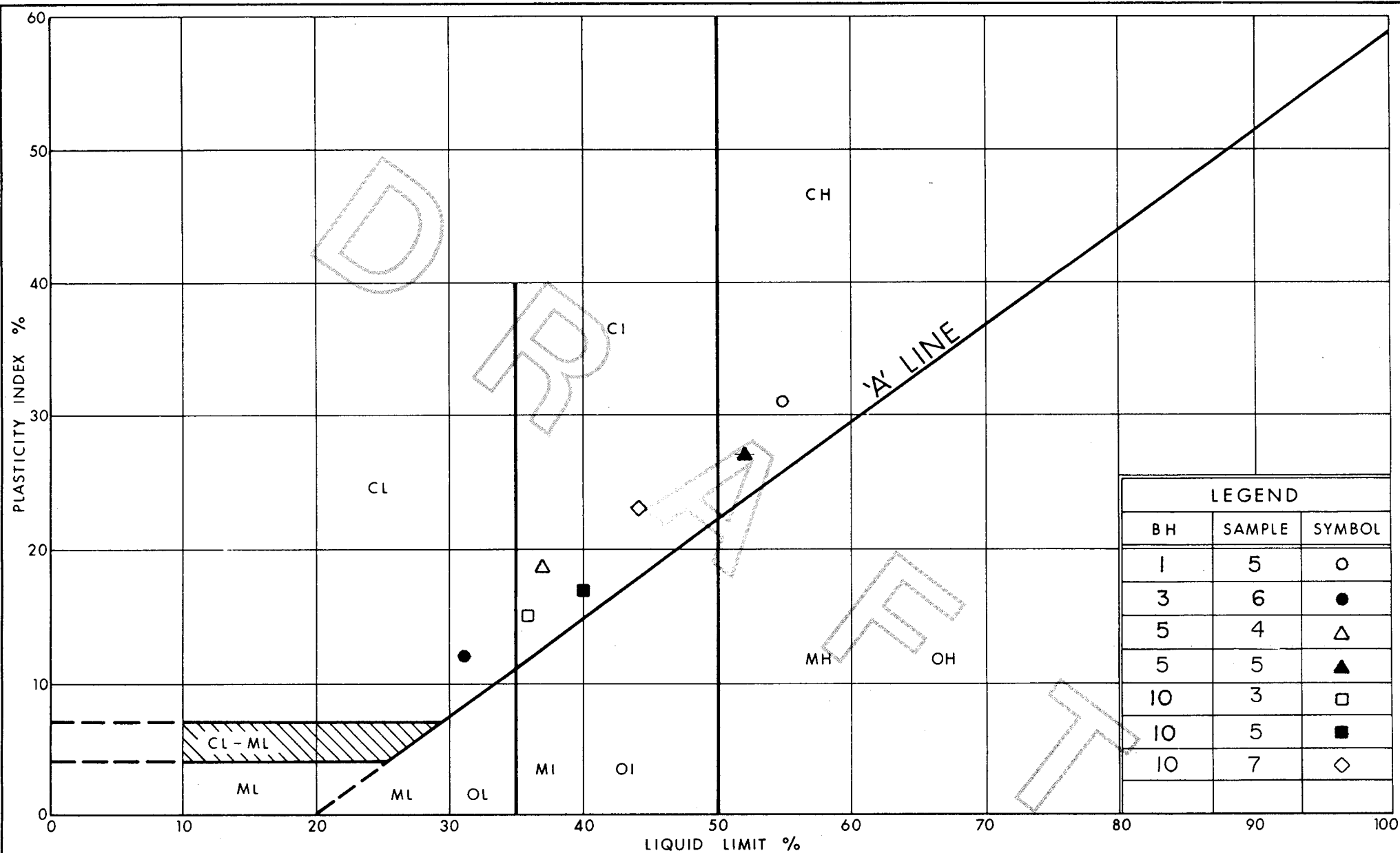
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT W _p	NATURAL MOISTURE CONTENT W	LIQUID LIMIT W _L	UNIT WEIGHT γ	REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	'N' VALUES			SHEAR STRENGTH kPa								
								20	40	60	80	100	WATER CONTENT (%)			
86.4	Ground Surface															
86.2	Topsoil															
0.2 85.9	Silty sand Grey brown															
0.5	Silty clay, some sandy silt seams (weathered crust)		1	SS	6											
	Stiff Grey brown		2	SS	2	Bentonite										
83.3																
3.1	Silty clay, occasional sandy silt seam, trace black mottling		3	SS	PM											
			4	SS	PM	Native backfill										
			5	SS	WH*											
			6	SS	WR*											
			7	TW	WR	Bentonite										
	Soft to firm Grey		8	SS	WH	Standpipe										
			9	SS	WR											
72.7						Bentonite										
13.7	Sandy silt, trace gravel and clay		10	SS	6											
72.1	(glacial till) Grey															
14.3	End of hole															

+³, x⁵: Numbers refer to
Sensitivity

20
15
10
5
0
(%) STRAIN AT FAILURE



LEGEND		
BH	SAMPLE	SYMBOL
3	2	○
3	4	●
5	2	△

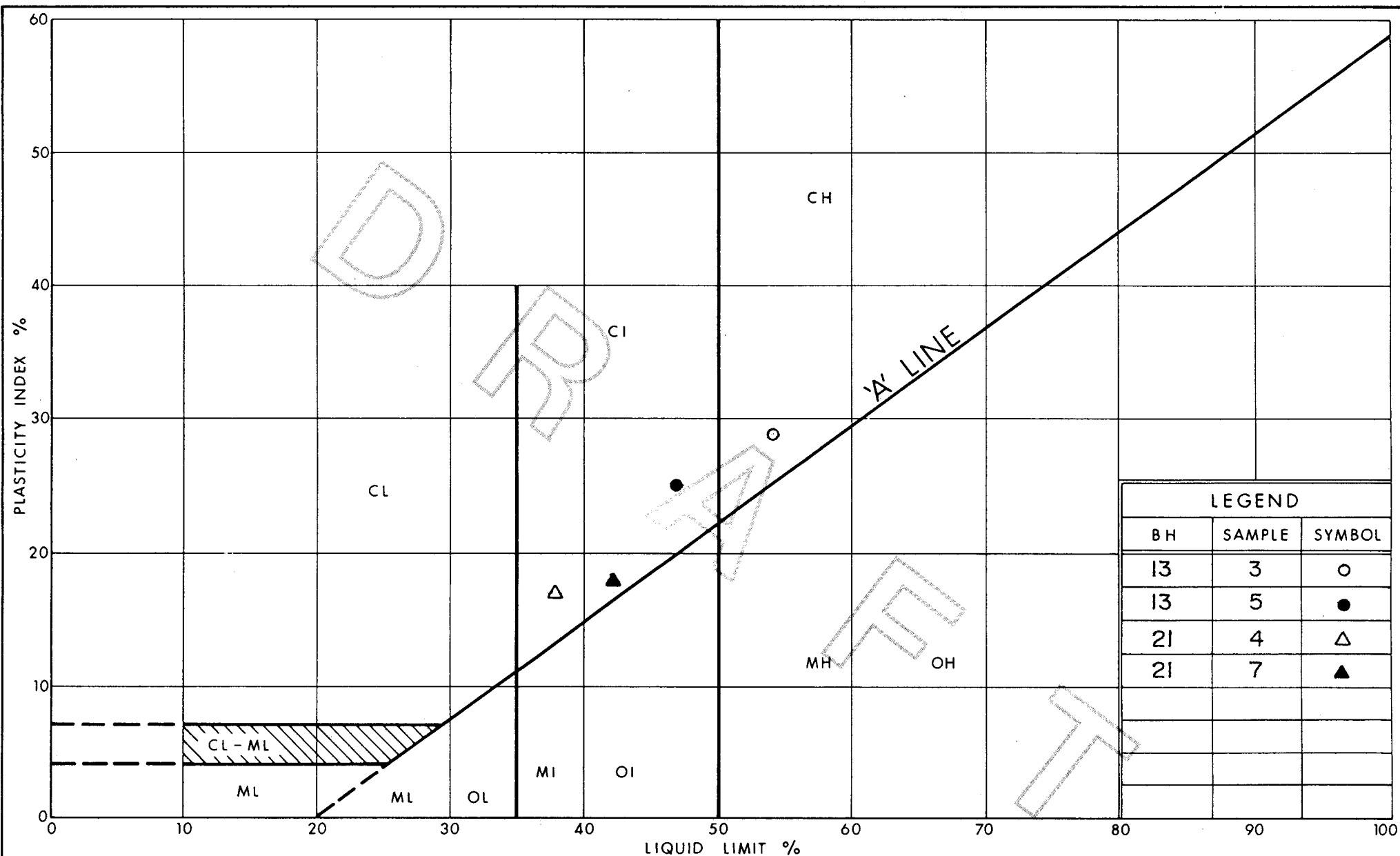


Ministry of
Transportation

PLASTICITY CHART SILTY CLAY

FIG No. 2

W P 373-89-02/03



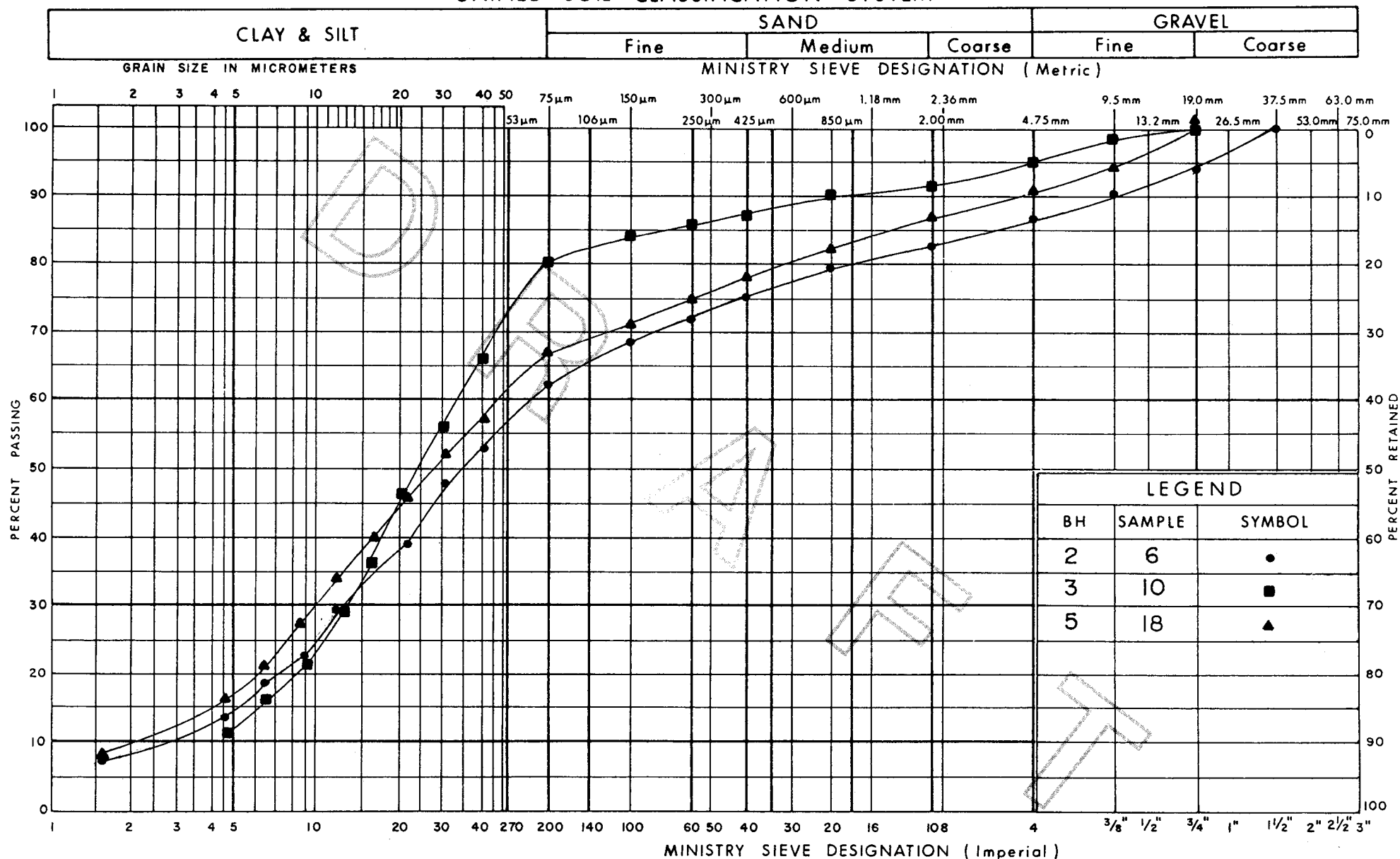
Ministry of
Transportation

PLASTICITY CHART SILTY CLAY

FIG No. 3

W P 373-89-02/03

UNIFIED SOIL CLASSIFICATION SYSTEM



Ontario

Ministry of
Transportation

GRAIN SIZE DISTRIBUTION

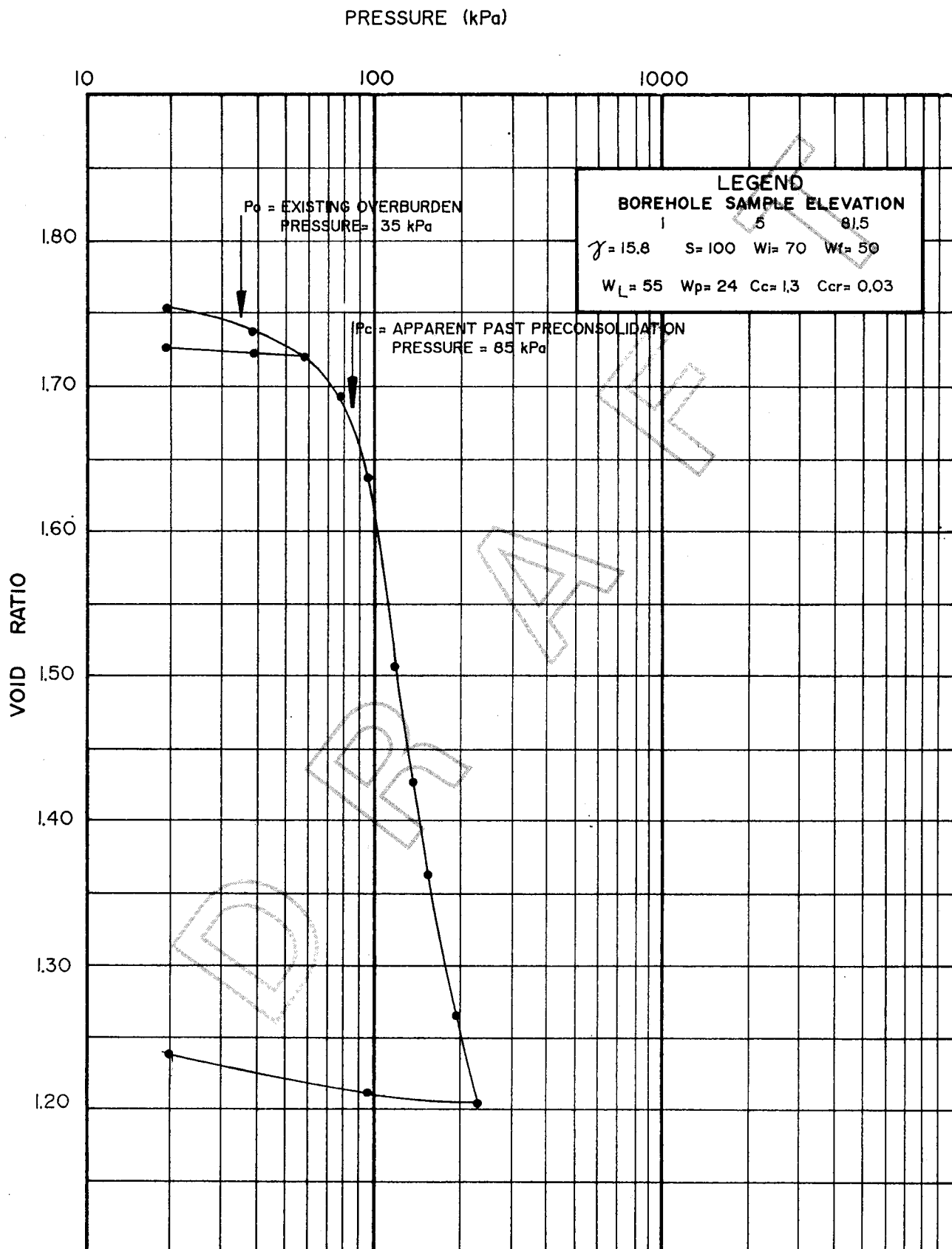
SANDY SILT with gravel, clay, cobbles,
and boulders (GLACIAL TILL)

FIG No. 4

W P 373-89-02/03

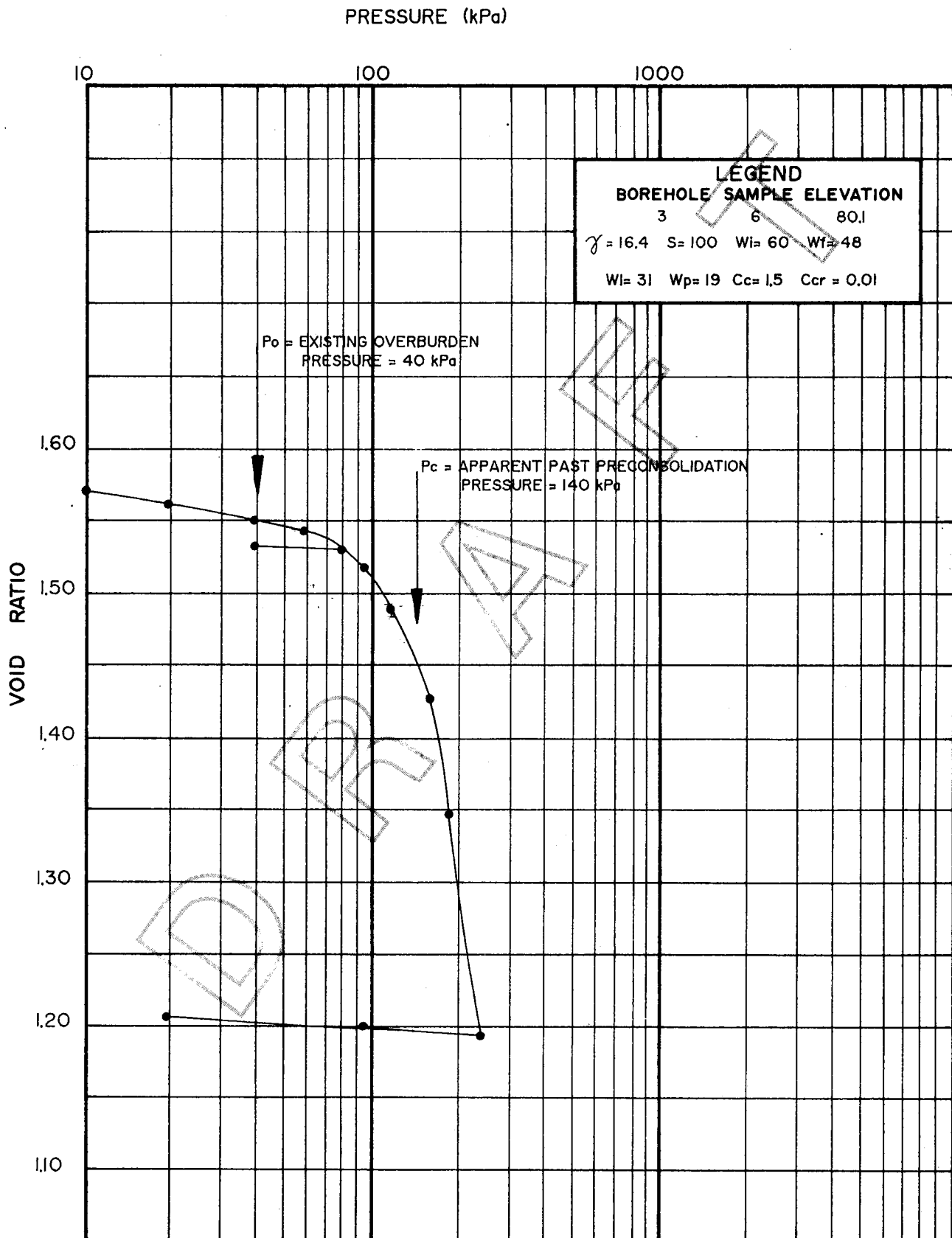
VOID RATIO - PRESSURE CURVES CONSOLIDATION TEST

FIGURE 5
WP 373-89-02/03



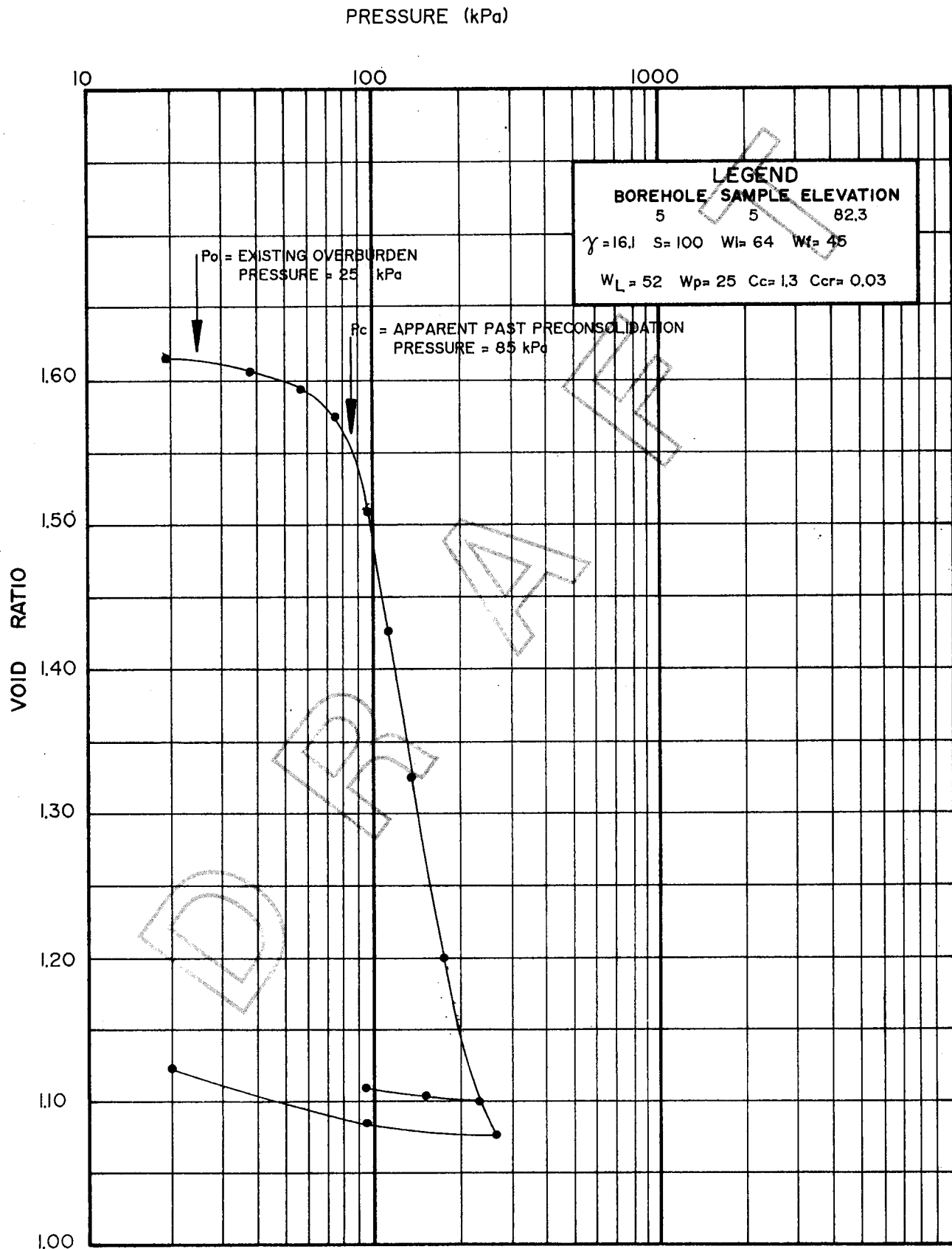
VOID RATIO - PRESSURE CURVES CONSOLIDATION TEST

FIGURE 6
WP 373-89-02/03



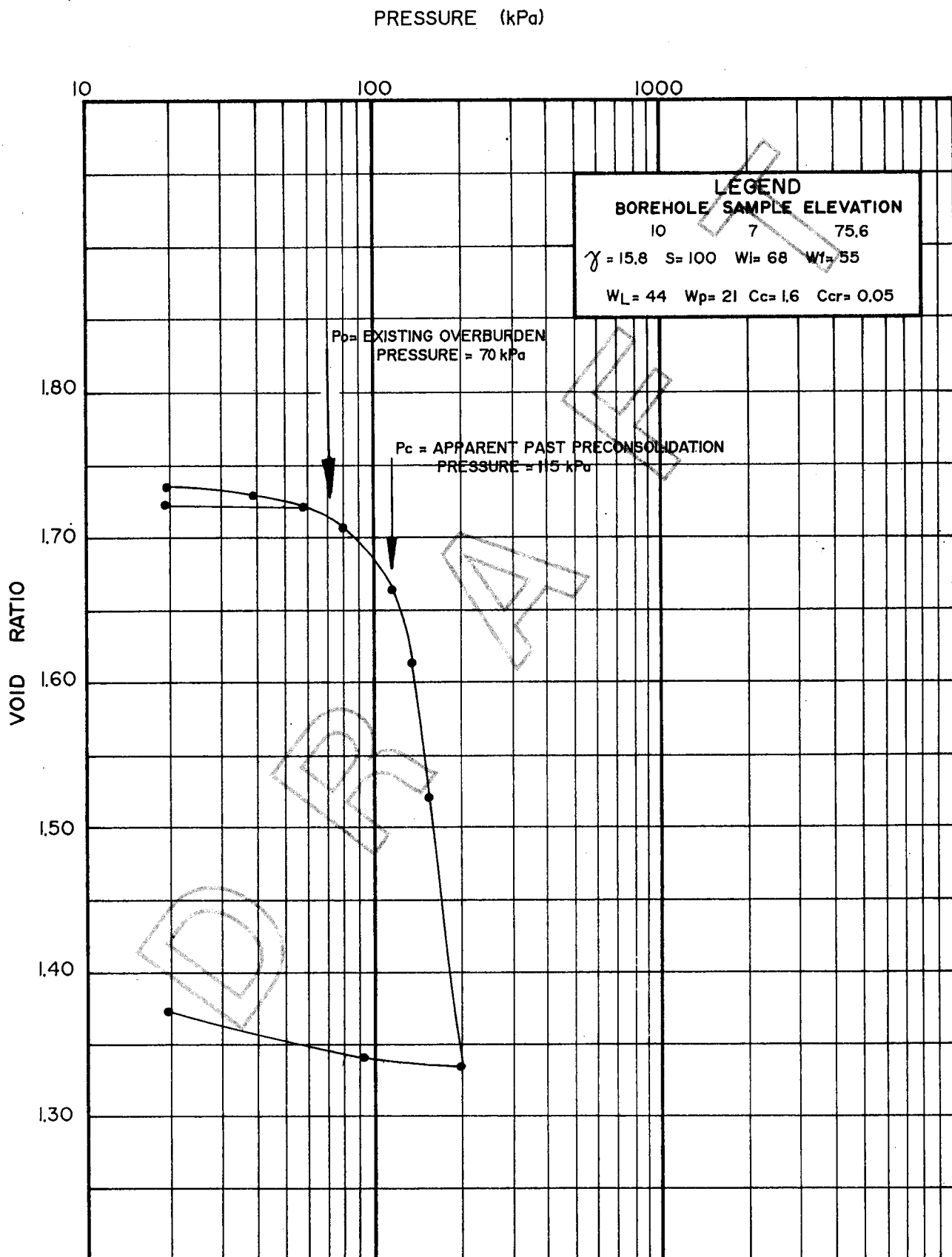
VOID RATIO - PRESSURE CURVES CONSOLIDATION TEST

FIGURE 7
WP 373-89-02/03



VOID RATIO - PRESSURE CURVES CONSOLIDATION TEST

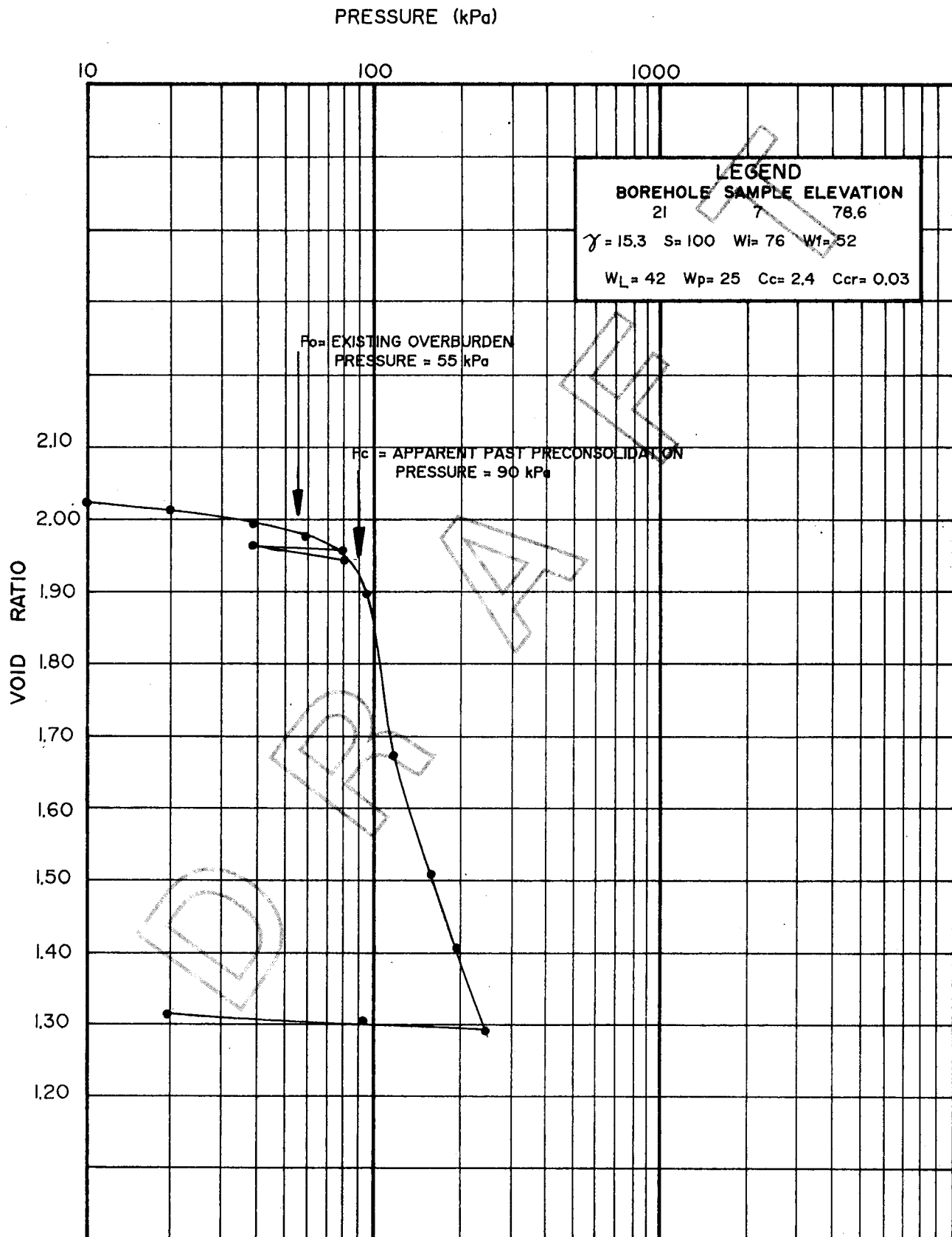
FIGURE 8
WP 373-89-02/03



Golder Associates

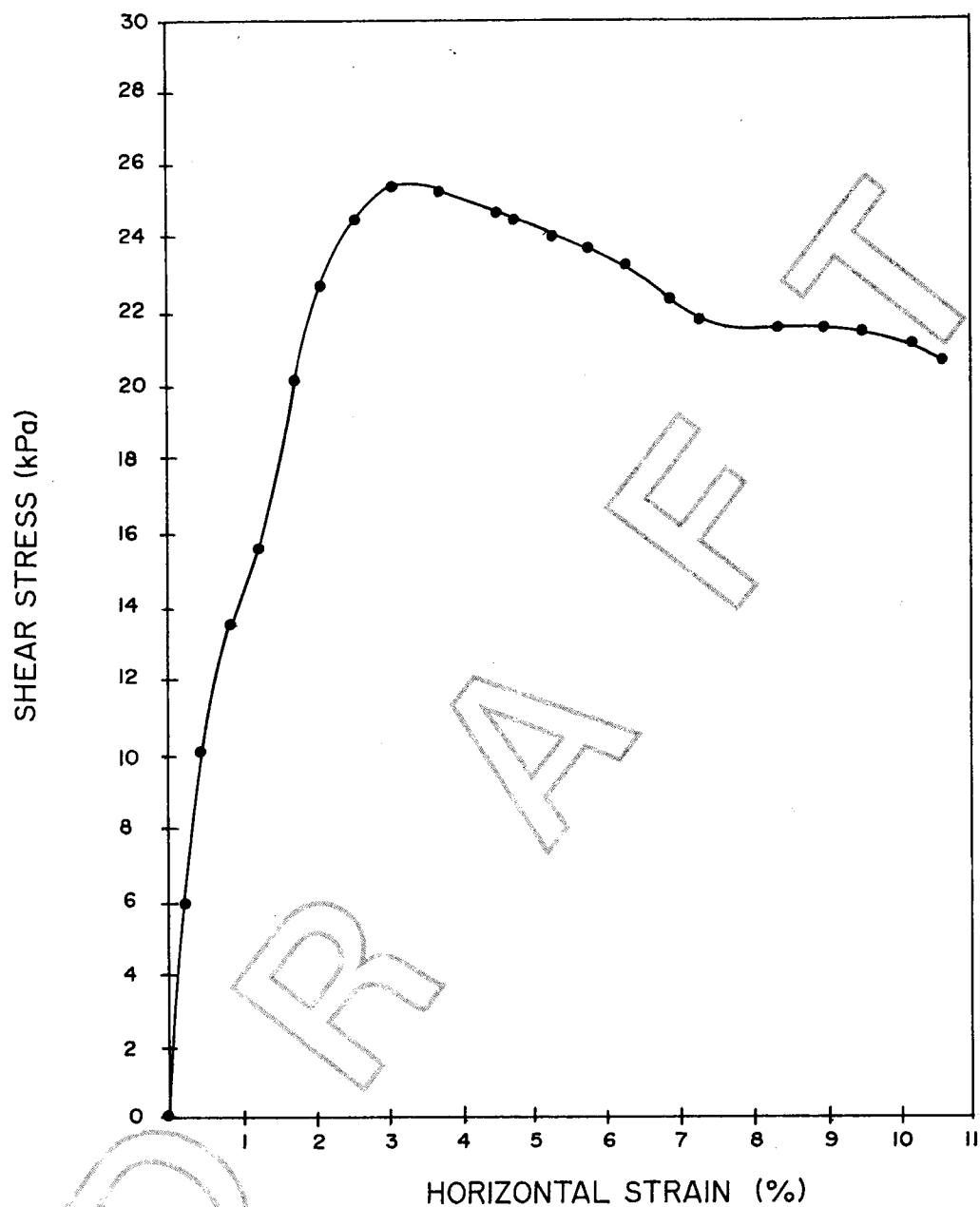
VOID RATIO - PRESSURE CURVES CONSOLIDATION TEST

FIGURE 9
WP 373-89-02/03



UNCONSOLIDATED UNDRAINED DIRECT SHEAR TEST RESULTS

FIGURE 10
WP 373-89-02/03



LEGEND		
BOREHOLE	SAMPLE	ELEVATION
3	6	80.1
NORMAL STRESS : 45kPa		
PEAK SHEAR STRESS : 25.2kPa		

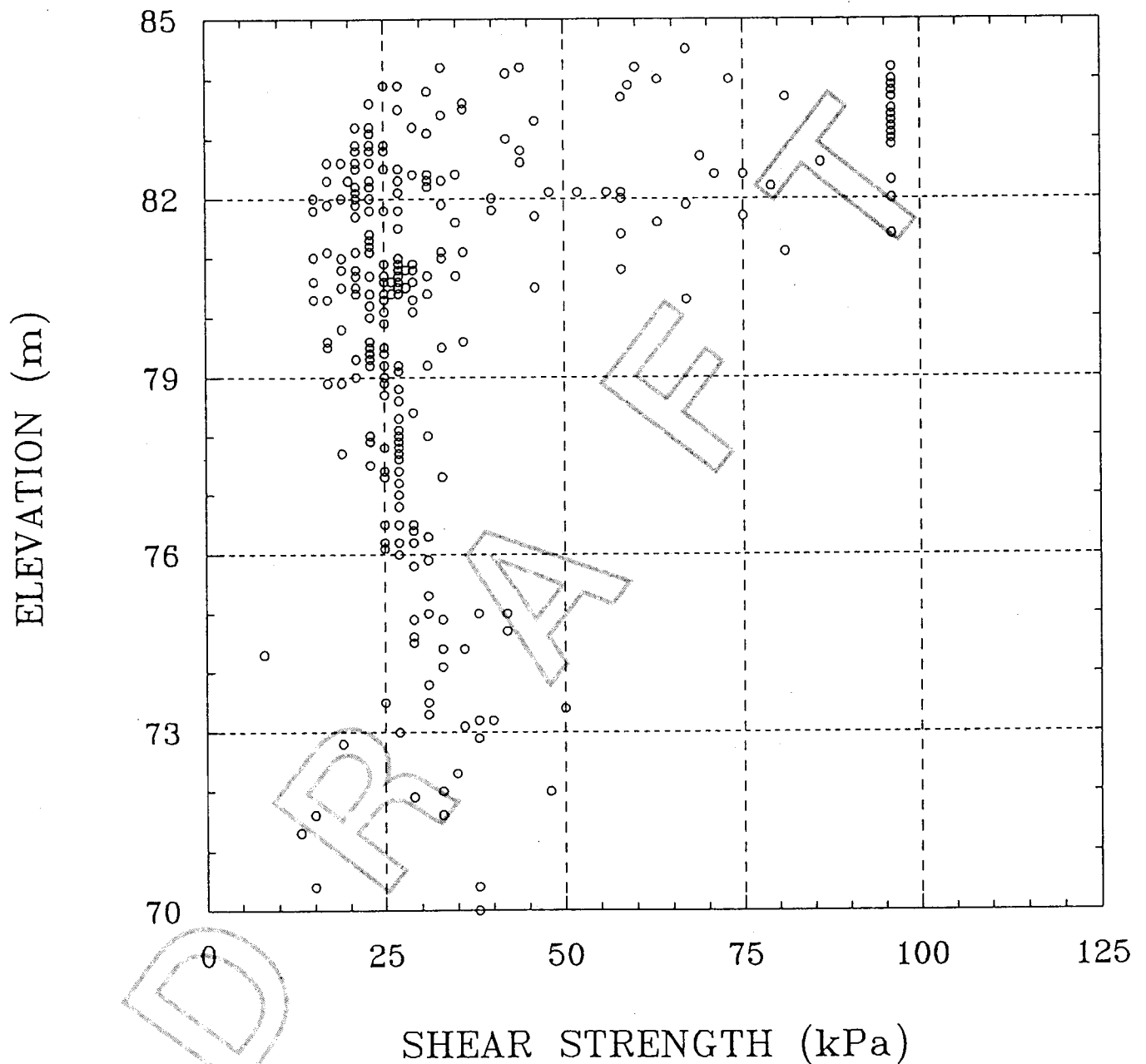
Date MAY 15, 1991
Project 90I-2064B

Golder Associates

Drawn S.L.
Chkd. AC

SUMMARY OF VANE SHEAR STRENGTH VS. ELEVATION

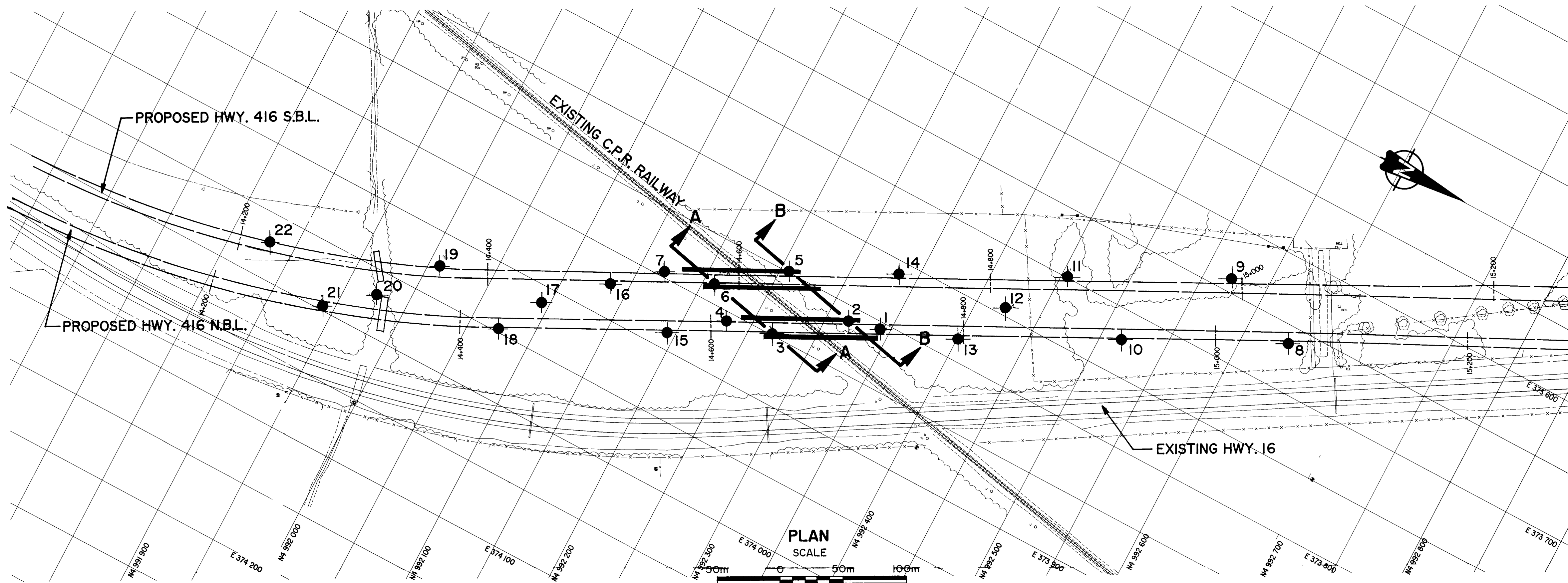
FIGURE II
WP 373-89-02/03



Date MAY 15, 1991
Project 90I-20648

Golder Associates

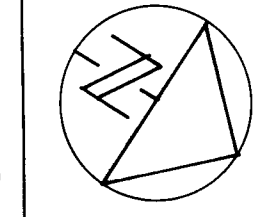
Drawn S.L.
Chkd. AC



CONT No
WP No 373-89-02/03

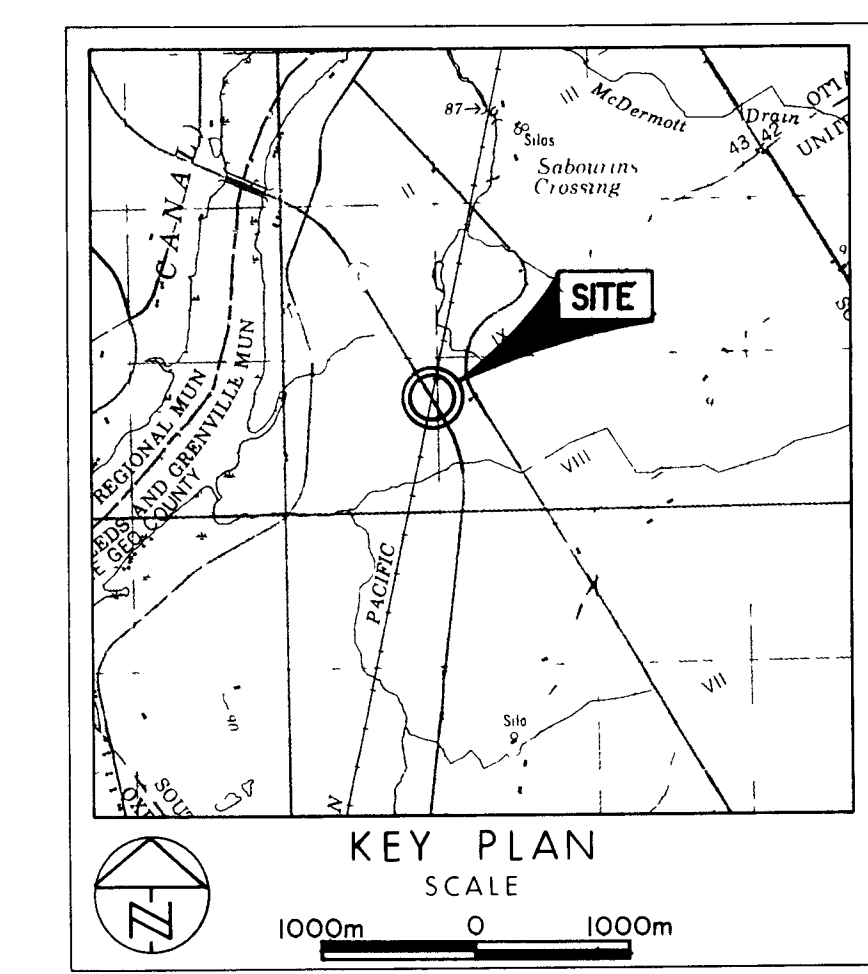
DRAFT COPY
NOT FOR CONSTRUCTION

BORE HOLE LOCATIONS & SOIL STRATA



SHEET

GOLDER ASSOCIATES LTD.



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 (Jan 30, 1991)
- Standpipe

No	ELEVATION	CO-ORDINATES	
		NORTH	EAST
1	86.3	4 992 342	373 805
2	86.2	4 992 317	373 811
3	86.4	4 992 268	373 849
4	86.2	4 992 231	373 857
5	86.2	4 992 257	373 799
6	86.3	4 992 209	373 836
7	86.4	4 992 170	373 844
8	86.9	4 992 635	373 663
9	86.6	4 992 571	373 640
10	86.5	4 992 517	373 723
11	86.6	4 992 455	373 699
12	86.5	4 992 422	373 743
13	86.5	4 992 401	373 782
14	86.6	4 992 335	373 760
15	86.4	4 992 193	373 886
16	86.0	4 992 136	373 873
17	86.3	4 992 094	373 911
18	86.4	4 992 073	373 947
19	86.4	4 992 009	373 925
20	87.1	4 991 974	373 968
21	86.4	4 991 941	373 996
22	86.4	4 991 681	373 971

NOTE

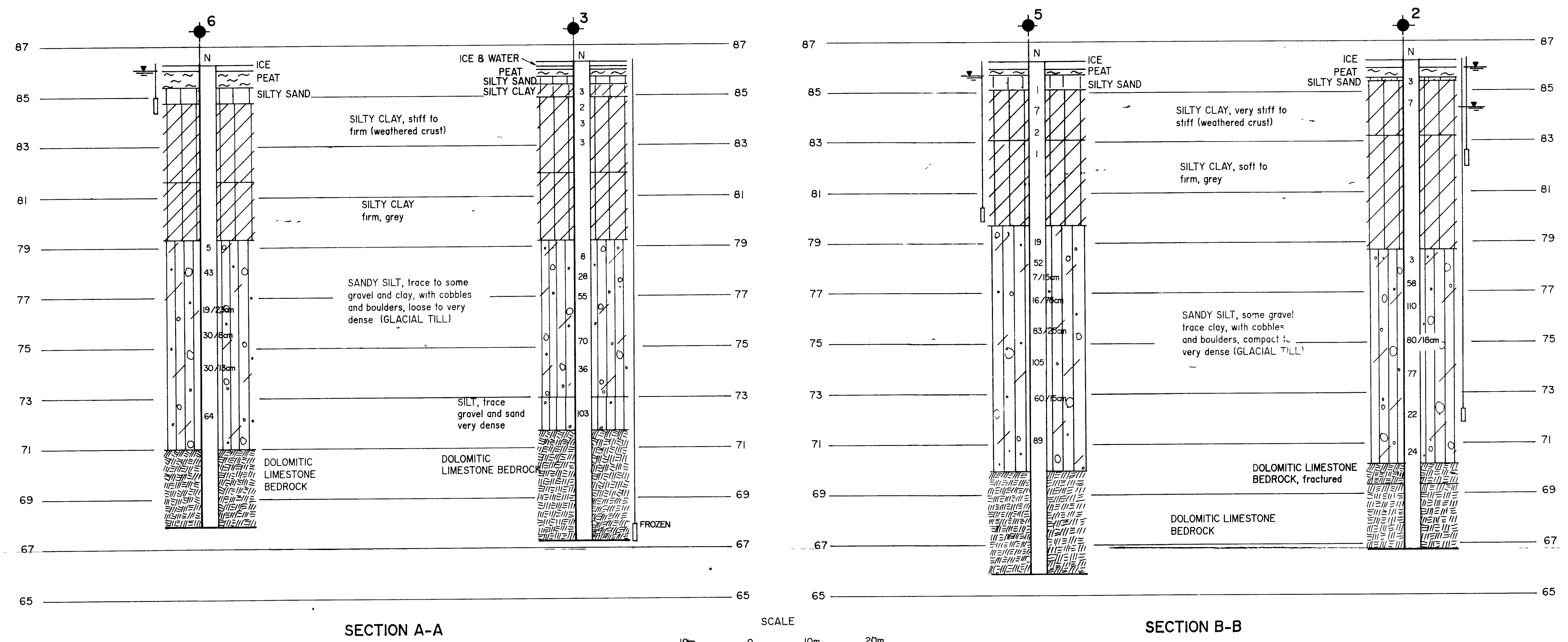
The boundaries between soil strata have been established only at Bore Hole locations. Between Bore Holes the boundaries are assumed from geological evidence.

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.

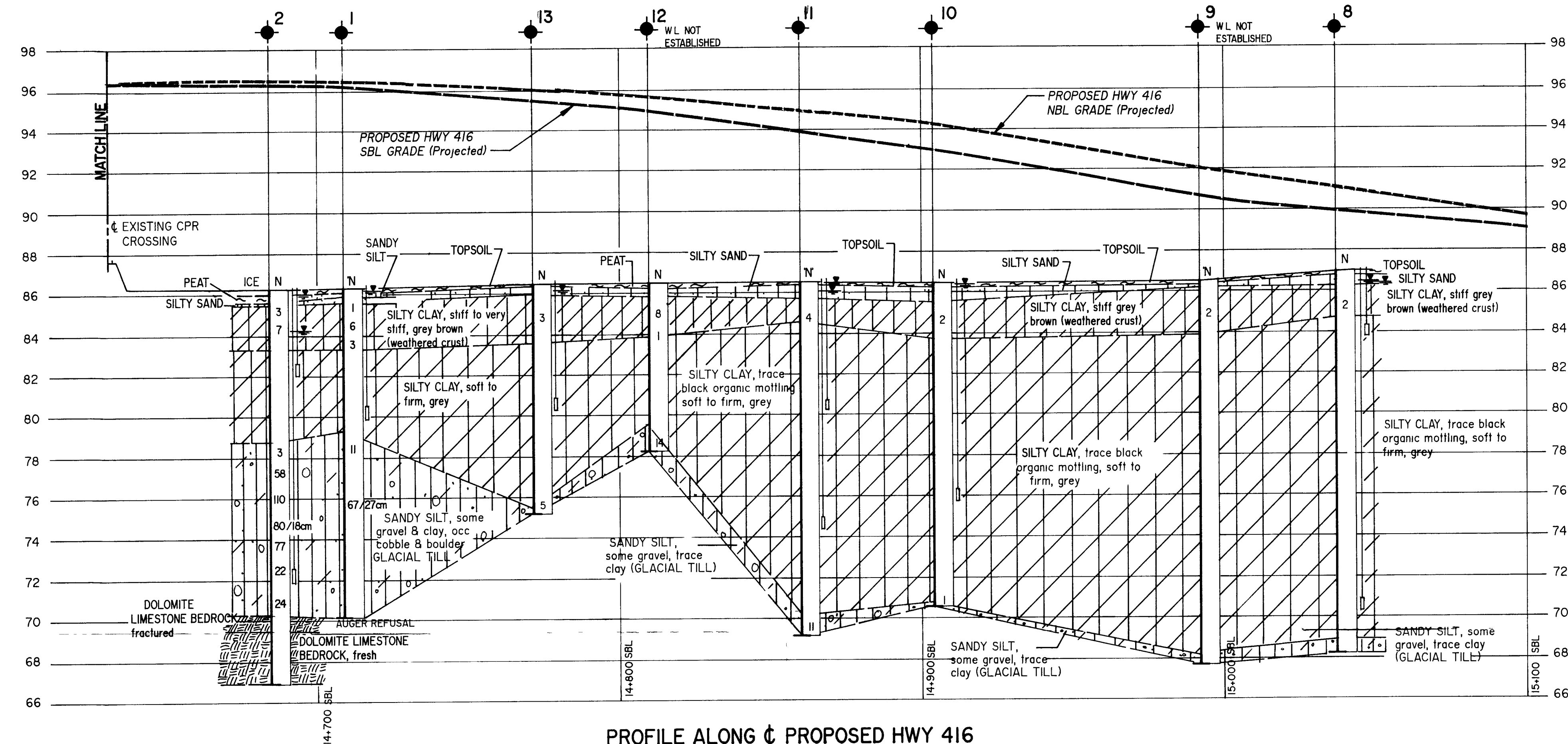
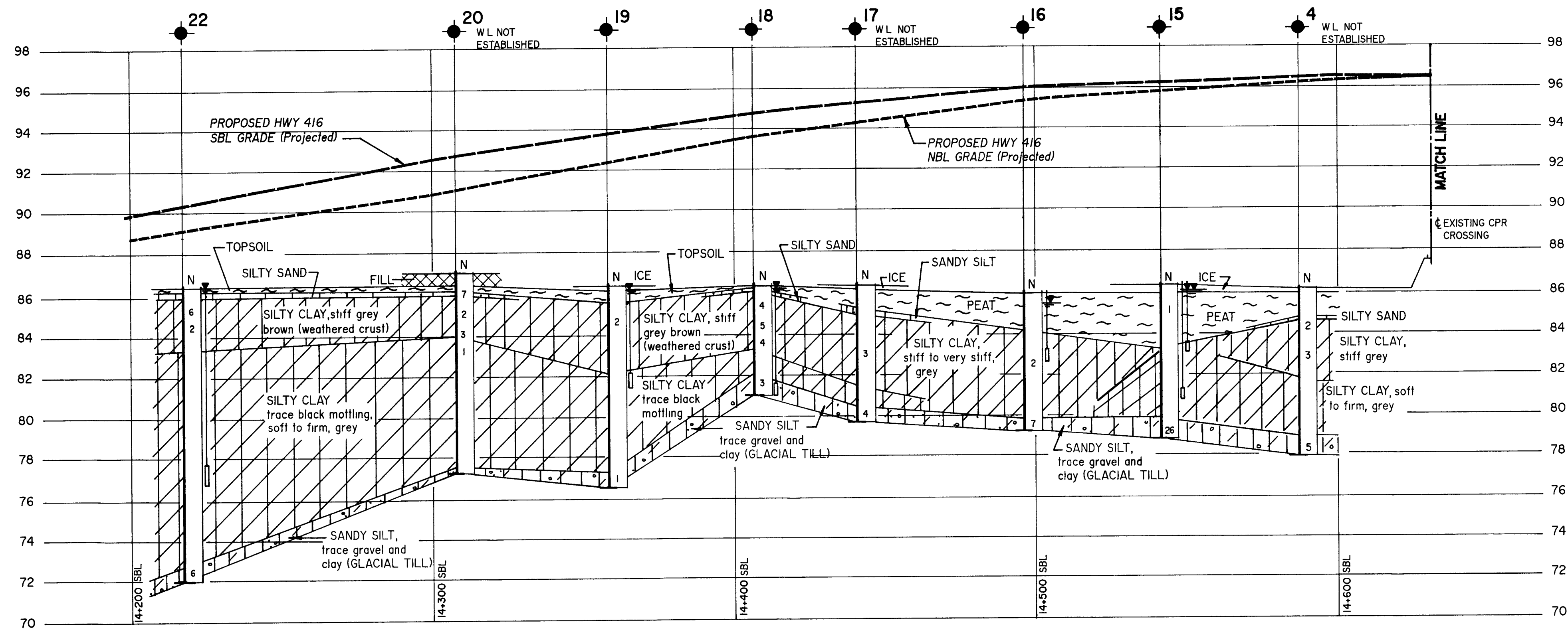
DATE	BY	DESCRIPTION

Geocres No 316-210

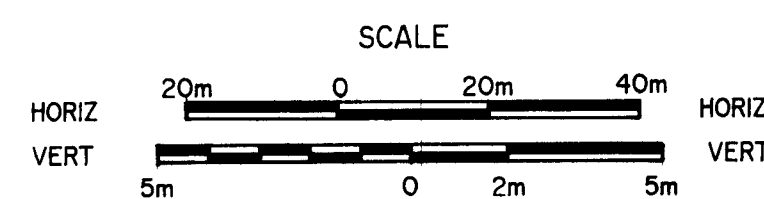
HWY No 416	DIST 9
SUBM'D DM	CHECKED AC
DATE 91/04/09	SITE 16-319-1/2
DRAWN JC	CHECKED
APPROVED	DWG 3738902/03-A



NOTE Refer to drawing no 3738902/03-B for profile along HWY 416



PROFILE ALONG ϕ PROPOSED HWY 416



NOTE Refer to drawing no 3738902/03-A for borehole location in plan

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

CONT No
WP No 3738902/03-A
DRAFT COPY
CPR CROSSING
BORE HOLE LOCATIONS & SOIL STRATA

SHEET

GOLDER ASSOCIATES LTD.

SEE DRAWING No 3738902/03-A

KEY PLAN
SCALE

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 (JANUARY 1990)

No	ELEVATION (m)		
1	86.3		
2	86.2		
4	86.2		
8	86.9		
9	86.6		
10	86.5		
11	86.6		
12	86.5		
13	86.5		
15	86.4		
16	86.0		
17	86.3		
18	86.4		
19	86.4		
20	87.1		
22	86.4		

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 316-210

HWY No 416	SUBM'D AC	CHECKED	DATE 91/04/09	SITE 16-319-1/2	DIST
DRAWN JC	CHECKED	APPROVED		DWG 3738902/03-B	