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**FOUNDATION INVESTIGATION
AND DESIGN REPORT
HIGHWAY 17 – FROM 10.1 KM EAST OF
HIGHWAY 108 – EASTERLY 12.3 KM
DISTRICT 54, SUDBURY
WP 445-98-00**

Submitted to:

The Greer Galloway Group Inc.
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PART A

**FOUNDATION INVESTIGATION REPORT
HIGHWAY 17 – FROM 10.1 KM EAST OF
HIGHWAY 108 – EASTERLY 12.3 KM
DISTRICT 54, SUDBURY
WP 445-98-00**

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List of Abbreviations and Symbols

Record of Borehole Sheets (1 to 18, inclusive)

1.0 INTRODUCTION

Golder Associates Ltd. has been retained by the Greer Galloway Group Inc. (Greer Galloway) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation for the proposed embankment raising and widening on Highway 17. The full study addresses 12.3 km of Highway 17, extending easterly from 10.1 km east of Highway 108. This report addresses a section within the study where the highway crosses a swamp approximately 910 m in length.

The purpose of the foundation investigation is to determine the subsurface conditions along the proposed widening by drilling boreholes, and carrying out in-situ tests and laboratory tests on selected samples. The Terms of Reference for the Scope of Work are outlined in our Proposal Letter P01-1129, dated April 14, 2000. The work was carried out in accordance with our Quality Control Plan for Foundation Engineering Services.

2.0 SITE DESCRIPTION

2.1 Site Location

The study area encompasses about 1 km of the existing Highway 17 extending between Stations 13+300 and 14+210. The site is located within MTO District 54, Sudbury and is about 10 km east of Highway 108.

The topography at the site consists of a generally level swampy area that is bounded at the east and west limits by steep rock outcropping. The flat swampy area is covered by grass and bush. The existing ground surface adjacent to the highway at the site varies locally from about Elevations 184.6 m to 185.4 m. The existing Highway 17 is a two-lane, undivided roadway which runs east-west within the project limits. Based on available information, the approximate existing grade of Highway 17 is at about Elevation 185.8 m in the central area of the swamp at about Elevation 186.6 m at the east and west ends of the swamp. The existing road embankment is about 1 m to 2 m high above the ditch level on the north side of the road. This portion of the highway has past history of flooding in spring.

2.2 Site Geology

The site is located in the physiographic region known as the Elliot Lake Group, which is part of the Huronian Supergroup (OGS Map 2543). The Elliot Lake Group is comprised of conglomerate, wacke, arkose, quartz, arenite, argillite, limestone and dolostone rock types. For the project area, the surficial geology maps indicate that subsurface conditions generally consist of bedrock at shallow depth and overburden soils comprising lacustrine sands and clays and glacial till. The bedrock knolls and generally hilly terrain results in low lying areas between the rock outcrops where organic deposits are typically encountered.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out between July 31 and August 4, 2000. At this time eighteen boreholes were put down at the site. All the boreholes were located relative to the staked alignment with chainages and offsets. Boreholes 2 to 18 were put down at 50 m intervals, starting at Station 13+350 and Borehole 1 was put down at Station 14+192.

The investigation was carried out using a bombardier mounted CME-55 drill rig supplied and operated by Marathon Drilling Co. Ltd. of Ottawa, Ontario. The boreholes were advanced to depths of between 5.2 m and 10.4 m, using 108 mm inside diameter hollow-stem augers. In each boring, samples were obtained at regular intervals of depth of 0.75 m to 1.5 m using 50 mm outside diameter split-spoon samplers in accordance with Standard Penetration Test (SPT) procedure. In-situ vane testing was carried out in all the boreholes within the silty clay deposit. Open thin-walled (Shelby tube) samples were collected from the silty clay deposits in Boreholes 2, 3, 6, 12 and 18. Groundwater conditions in the open holes were observed throughout the drilling the drilling operation and on completion of drilling. Piezometers were installed and sealed in four boreholes to permit monitoring of the groundwater levels at the site. The piezometers consisted of a 200 mm long slotted tip threaded into 12 mm diameter polyvinyl chloride (PVC) rigid tubing. The open boreholes were backfilled with bentonite mixed with the auger cuttings.

The field work was supervised on a full-time basis by a member of our technical staff who located the boreholes in the field, directed the drilling, sampling and in-situ testing operations, and logged the borings. The soil samples were identified in the field, placed in labelled water-proof containers and transported to our laboratory in Mississauga for further examination. Index and classification tests consisting of grain size analyses, Atterberg Limits and water content determinations were carried out on selected samples. The results of these tests are shown on the Record of Borehole Sheets and on Figures 2 and 3 and in Appendix A.

The borehole locations and elevations were provided by Greer Galloway. Based on the information provided, the northing and easting co-ordinates of the borehole locations are given in UTM, and the borehole elevations are referenced to the Geodetic Datum. The co-ordinates of boreholes are indicated on the Record of Borehole Sheets and the locations of the boreholes are shown in Drawing 1.

4.0 SUBSURFACE CONDITIONS

4.1 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on the selected samples, are given on the attached Record of Borehole Sheets following the text of this report. The stratigraphic boundaries shown on the borehole sheets are inferred from non-continuous sampling and, therefore, represent transitions between soil types rather than exact planes of the geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary, the subsoils at the site generally consist of a surficial layer of topsoil or sand and gravel fill underlain by silty clay with occasional silty sand and / or sand interlayers. The silty clay can be separated into three distinct layers; a soft to firm upper layer which contains variable amounts of organic material, a very soft to firm middle layer, and a soft to firm irregularly layered lower deposit. The upper layer is distinctive with the organic content; the lower layer is distinctive by the red-brown layering within the typically grey deposit.

A layer of fibrous peat was encountered below the topsoil in two boreholes. In the boreholes at the east and west limits of the swamp, a very loose to loose deposit of silty sand and / or sand was encountered within the middle silty clay layer.

4.1.1 Topsoil and Fibrous Peat

A surficial layer of topsoil between 200 mm to 400 mm thick was encountered in all the boreholes, except in Borehole 13.

In Boreholes 8 and 18, a layer of fibrous peat was encountered immediately below the topsoil. The thickness of this layer was found to be 0.6 m and 0.7 m in Boreholes 8 and 18, respectively. A relatively extensive interlayer of fibrous peat with thickness ranging from 0.15 m to 0.3 m was encountered within the upper silty clay in Boreholes 10 to 14, inclusive. The top of this fibrous peat interlayer is at about Elevations 184.2 m to 183.4 m.

4.1.2 Sand and Gravel Fill

A surficial layer of sand and gravel fill with a thickness of about 0.5 m was encountered at the location of Boreholes 13 and 16.

4.1.3 Silty Clay

4.1.3.1 Upper Silty Clay

Below the topsoil and / or sand and gravel fill exists an upper deposit about 0.9 m to 2 m thick of silty clay, with trace organics and sand. The high organic content was generally noted up to 1.4 m depth. The upper silty clay was encountered in all the boreholes except Borehole 2. Standard Penetration Testing (SPT) carried out within this deposit measured 'N' values ranging from 0 blows per 0.3 m penetration (i.e. penetration under weight of hammer) to 4 blows per 0.3 m. The upper silty clay deposit has a very soft to soft consistency, but is generally soft. Laboratory vane testing was carried out on the Shelby tube samples of this deposit. The results of the testing gave undrained shear strengths varying from 5 kPa to 13 kPa with an average of 10 kPa.

Atterberg limits testing was carried out on four selected samples of the upper silty clay. The limit test results are summarized in the following table.

	<i>Depth (m)</i>	<i>Liquid Limit (%)</i>	<i>Plastic Limit (%)</i>	<i>Plasticity Index (%)</i>
Borehole 5	1.5 – 2.1	64	24	40
Borehole 11	0.8 – 1.4	72	24	48
Borehole 17	1.5 – 2.1	57	22	35
Borehole 18	1.5 – 2.1	54	22	32
Average		62	23	39

Based on these results and as shown on the plasticity chart on Figure 4, the upper silty clay has a high plasticity. The natural water content measured for selected samples of the upper silty clay ranged from 37 percent to 144 percent, with an average of 73 percent. A laboratory oedometer (consolidation) test was carried out on a sample of the upper silty clay obtained at Borehole 18. A pre-consolidation pressure of approximately 55 kPa is deduced from the void ratio versus logarithmic pressure plot. Details of the test results are shown on Figure 1 and also included in Appendix A. Organic content testing carried out on three samples of the upper silty clay obtained from 0.76 m to 1.4 m depth, measured organic contents ranging from 8 percent to 16 percent. A summary of these test results are shown in Table 1 in Appendix A.

4.1.3.2 Middle Silty Clay

A deposit of silty clay with trace sand and occasional light grey clayey silt to silt seams, was encountered in all the boreholes. Occasional silty sand to sand interlayers up to 30 mm thick were noted in Boreholes 3 and 5 at a depth of about 1.8 m and 3.3 m, respectively. In the boreholes where the middle silty clay deposit was fully penetrated, the deposit was found to be 1.7 m to 4.1 m thick.

Standard Penetration Testing (SPT) carried out in Boreholes 1, 2, 4 and 15, within this deposit, measured 'N' values ranging from 1 blow per 0.3 m to 5 blows per 0.3 m of penetration. The results of the in-situ vane testing carried out within the middle silty clay deposit are summarized in the following table.

	<i>Maximum Undrained Shear Strength (kPa)</i>	<i>Minimum Undrained Shear Strength (kPa)</i>	<i>Average Undrained Shear Strength (kPa)</i>
Undisturbed Strength	54	8	16
Remoulded Strength	13	1.4	4

The maximum undrained shear strength of 54 kPa was measured in Borehole 3 and could be affected by the presence of the sand deposit immediately below the middle silty clay deposit. Based on the results of in-situ vane testing, the middle silty clay has a very soft to firm consistency.

Atterberg limits testing was carried out on two selected samples of the middle silty clay. The limit test results are summarized in the following table.

	<i>Depth (m)</i>	<i>Liquid Limit (%)</i>	<i>Plastic Limit (%)</i>	<i>Plasticity Index (%)</i>
Borehole 11	4.6 – 5.2	38	21	17
Borehole 17	3.0 – 3.6	38	21	17
Average		38	21	17

Based on these results and as shown on the plasticity chart on Figure 5, the middle silty clay has intermediate plasticity. The natural water content measured for selected samples of the middle silty clay ranged from 28 percent to 71 percent, with an average of 51 percent.

4.1.3.3 Lower Silty Clay

The middle silty clay deposit in Boreholes 1, 5, 8, 11, 12, 14, 17 and 18 and the silty sand deposit in Borehole 2 are underlain by an irregularly layered silty clay deposit with trace sand. This deposit was not fully penetrated but it was proved to a depth of 10.4 m in Boreholes 5, 8, 11, 14 and 17. Standard Penetration testing was carried out; in all cases the spoon sampler was advanced 0.3 m by either the weight of the hammer or the weight of the rods. The results of in-situ vane testing carried out within the deposit are summarized in the following table.

	<i>Maximum Undrained Shear Strength (kPa)</i>	<i>Minimum Undrained Shear Strength (kPa)</i>	<i>Average Undrained Shear Strength (kPa)</i>
Undisturbed Strength	44	13	22
Remoulded Strength	12	2	5

Based on the in-situ vane test results, the lower silty clay has a soft to firm consistency. Atterberg limits testing was carried out on three selected samples of the middle silty clay. The limit test results are summarized in the following table.

	<i>Depth (m)</i>	<i>Liquid Limit (%)</i>	<i>Plastic Limit (%)</i>	<i>Plasticity Index (%)</i>
Borehole 5	7.6 – 8.3	25	17	8
Borehole 11	6.0 – 6.7	30	18	12
Borehole 11	9.1 – 9.8	35	20	15
Average		30	18	12

Based on these results and as shown on the plasticity chart on Figure 6, the lower silty clay has low plasticity. The natural water content measured for selected samples of the lower silty clay ranged from 32 percent to 44 percent, with an average of about 38 percent.

4.1.4 Silty Sand / Sand

A non-cohesive deposit of silty sand and / or sand was encountered below the middle silty clay deposit in Boreholes 1 to 4. The silty sand / sand deposit was fully penetrated in all the boreholes, except Borehole 3, and was found to be 0.7 m to 2 m thick. Standard Penetration testing (SPT) carried out in the sand measured 'N' values ranging from 1 blow per 0.3 m to 5 blows per 0.3 m of penetration corresponding to a very loose to loose state of packing. A grain

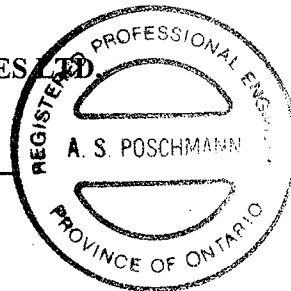
size distribution curve for a selected sample of the sand is shown on Figure 2. The natural water content measured for selected samples of the sand ranged from 20 percent to 24 percent, with an average of 22 percent. Figure 3, indicates grain size distribution curve for a selected sample of the silty sand. The natural water content measured for selected samples of the silty sand ranged from 21 percent to 25 percent, with an average of 23 percent.


4.2 Groundwater Conditions


The water levels in the open Boreholes 1 to 6 were at depths ranging from 0.2 m to 2.4 m below ground surface upon completion of drilling operation. All of the remaining boreholes were dry upon completion of drilling operation. Piezometers were installed and sealed in Boreholes 2, 6, 12 and 18. Details of the piezometer installations and water level measurements are shown on the attached Record of Borehole Sheets. The water level measured in the piezometers varies from 0.4 m to 2.7 m below ground surface (corresponding to Elevations 182.5 m to 184.3 m).

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PART B

**FOUNDATION DESIGN REPORT
HIGHWAY 17 – FROM 10.1 KM EAST OF
HIGHWAY 108 – EASTERLY 12.3 KM
DISTRICT 54, SUDBURY
WP 445-98-00**

5.0 ENGINEERING RECOMMENDATIONS

5.1 General

This section of the report provides our recommendations on the geotechnical aspects of design of the proposed embankment widening and grade raise of Highway 17 swamp crossing about 10 km east of Highway 108 between Stations 13+300 and 14+210 based on our interpretation of the factual information obtained during the investigation. It should be noted that the interpretation and recommendations are intended for use by the design engineers only. Where comments are made on construction they are provided only in order to highlight those aspects which could affect the design of the project. Those requiring information on aspects of construction should make their own interpretation of the factual information provided as it may affect equipment selection, proposed construction method and scheduling.

It is understood that the centreline of the existing Highway 17 from Stations 13+300 to 14+210 will be shifted to the north and that a passing lane will be provided on the north side of the highway. This realignment will also involve raising the existing grade by up to about 2 m for a final proposed road grade at Elevation 187.5 m. Foundation investigation carried out along the north side of the Highway 17 within this area of swamp crossing revealed shallow organic deposits over a silty clay deposit. Organic materials are also present at ground surface on the south side of Highway 17. Based on the in-situ shear strength profile of the silty clay, embankment stability is a major concern between Stations 13+500 and 14+000. Embankment settlement is also a consideration for the full length of the swamp crossing. Recommendations are made regarding embankment stability and settlement in the following sections of this report.

5.2 Embankment Stability

The variation in undrained shear strength at this site is shown on Figures 7 and 8 where the in-situ vane test results are compiled for the full length of the site and then compiled in groupings for specific sections along the highway. As shown, the zone of minimum undrained shear strength appears to vary along the length of swamp both in magnitude and in depth below ground surface. The undrained shear strengths above the minimum zone (above Elevation 182 m) are highly variable. The laboratory vane testing has shown that the upper silty clay has lower strength than the middle clay. In the area between Stations 13+700 and 13+900, the base of the upper clay is at about Elevation 182.3 m. For the purpose of the stability analyses, a range in undrained shear strength for this upper clay of 15 kPa to 20 kPa was assumed.

Based on the in-situ shear strength data and the proposed embankment cross-sections, it is considered that the most critical area for embankment stability is between Stations

13+500 to 14+000. A total of six sections were chosen at 100 m intervals to investigate the embankment stability within this portion of highway. Embankment side slopes of 3 horizontal to 1 vertical (3H:1V) and earthfill with a friction angle of 32 degrees were used in the stability analysis to model the embankment. Embankment side slopes of 2H:1V were also analysed.

At this site, a small change in shear strength has a large impact on the stability of the embankment. A minimum factor of safety of 1.4 was therefore initially chosen as the appropriate value using the average undrained shear strength profile. The berm configuration requirements were then checked for a Factor of Safety of 1.3 using the minimum measured undrained shear strength profile.

The results of the stability analyses carried out for the proposed embankment, using the expected range of undrained shear strength are shown on Figures 9 to 12. As shown on Figures 9 to 12, the minimum factors of safety obtained range from about 1.1 to 1.3 for the proposed embankment height (based on a final grade at Elevation 187.5 m) and for side slopes at 2H:1V and 3H:1V.

For the case with the minimum undrained shear strength profile, a berm length of 5 m is required to achieve a Factor of Safety of 1.3. For the higher shear strength profile as shown on Figure 9, a berm length of 4 m is required for a Factor of Safety of 1.4. A berm length of 2 m is required for this higher shear strength profile for a Factor of Safety of 1.3. Based on these stability analysis results, construction of a berm is considered necessary between Stations 13+500 and 14+000 as shown in the following table. The top of the berm should be taken at mid-height of the embankment or at Elevation 186 m. Corresponding berms are required on both the north and south sides of the highway.

Table 1

Berm Configuration

<i>Station</i>	<i>Berm Length (m)</i>
13+300 to 13+500	0
13+600 to 13+700	2
13+800	5
13+900 to 14+000	2
14+000 to 14+210	0

— see draft for
report for
transitioning

For design purposes, where the berm length changes, straight-line interpolation between the sections can be made (i.e. the length of berm would change linearly between the stations). It should be noted that the berm is to be constructed of the same material as the final embankment and with the same side slope of 3H:1V raised to mid-height of embankment. On the north side

where the highway is to be widened, the berm and the lower portion of the embankment should be raised together, after which the embankment can be raised to the final height. On the south side, the berm should be constructed initially up to level of the existing road and the existing roadway may then be raised when scheduled.

5.3 Settlement

From the geotechnical investigation it appears that the shallow organic cover was removed from below existing embankment. To minimize settlement below the new embankment areas, the organic materials should be removed up to a depth of about 1.4 m. The excavation should be carried out in strips of 5 m or less and backfilled to the original ground surface with acceptable earth borrow. The subsoils under the embankment consist of firm to very soft silty clay deposits which change with depth from a slightly over consolidated to a normally consolidated state. Therefore a minor increase in the effective stress could result in large settlements in the silty clay.

Based on the results of the oedometer test carried out on the silty clay, we estimate that the settlement of the new embankment areas where the earthfill is directly placed on the subgrade will be about 600 mm (based on an assumed estimated clay depth of 20 m). We further estimate that the settlement will be 450 mm under the existing highway after the grade raise. If the majority of this grade difference is due to consolidation settlement under the existing embankment loading, these settlement calculations are considered to be appropriate.

Based on the oedometer test results, 50 percent of the settlement will take place in the first year and a half. These clay deposits, particularly where varved or interlayered, generally have a higher horizontal permeability than vertical permeability and this tends to result in the settlement taking place quicker than that calculated. Long-term settlement would however be on-going at the site over a period of several years. We recommend that consideration be given to raising the new embankment first and delaying raising the old embankment for three to six months to minimize differential settlement between the old and new embankment areas. We recommend that final paving be delayed for a period of 1 year to allow the differential movement between the old and new embankments to take place. The rate of settlement could be increased considerably by the use of wick drains.

Traffic could be maintained on the existing Highway 17 (and the south berm if required). Subsequently the traffic could be directed to the new embankment and passing lane while the fill is placed over the existing Highway 17.

If these settlements are considered excessive, alternative materials could be used for the embankment to lessen the load and decrease the settlement. The substitution of rockfill (above a

blanket of earthfill on the clay subgrade) would provide an inexpensive alternative and slight decrease in load (15 percent). More effective alternatives, but at a substantial cost, would be the use of light weight slag fill or extruded Polystyrene in the embankment.


5.4 Embankment Construction


Topsoil and organic deposits should be stripped from below the fill embankment areas. Construction of the embankment and berm above the prepared subgrade may be carried out using clean earthfill meeting the specifications of OPSS 212 or Select Subgrade Material meeting the specifications of OPSS 1010, depending on material availability. All embankment and berm fill should be placed in regular lifts with loose thickness not exceeding 300 mm, and be compacted to at least 95 percent of the material's Standard Proctor maximum dry density. The final lift prior to placement of the granular subbase or base course should be compacted to 100 percent of the Standard Proctor maximum dry density. Inspection and field density testing should be carried out by qualified geotechnical personnel during all fill placement operations to ensure that appropriate materials are used and that adequate levels of compaction have been achieved. The permanent soil slopes of the embankment should be maintained not steeper than 3 horizontal to 1 vertical (3H:1V). Vegetation cover should be established on all soil slopes to protect embankment fill against surficial erosion, as per OPSS 572.

It is important that the embankment be raised only to the mid-height with the berm being placed simultaneously along the entire route. The raising of the embankment to the full height may then follow. The embankment and berm subgrade soils consist of a very soft to firm silty clay with occasional silty sand and / or sand interlayers. The embankment subgrade should be properly prepared for the embankment and berm with side slopes maintained at 3 horizontal to 1 vertical.

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LIST OF ABBREVIATIONS

The abbreviations commonly employed on Records of Boreholes, on figures and in the text of the report are as follows:

I. SAMPLE TYPE

AS	Auger sample
BS	Block sample
CS	Chunk sample
SS	Split-spoon
DS	Denison type sample
FS	Foil sample
RC	Rock core
SC	Soil core
ST	Slotted tube
TO	Thin-walled, open
TP	Thin-walled, piston
WS	Wash sample

III. SOIL DESCRIPTION

(a) Cohesionless Soils

Density Index (Relative Density)	N Blows/300 mm or Blows/ft.
Very loose	0 to 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	over 50

II. PENETRATION RESISTANCE

Standard Penetration Resistance (SPT), N:

The number of blows by a 63.5 kg. (140 lb.) hammer dropped 760 mm (30 in.) required to drive a 50 mm (2 in.) drive open sampler for a distance of 300 mm (12 in.)

(b) Cohesive Soils

Consistency	c_u, s_u	psf
Very soft	0 to 12	0 to 250
Soft	12 to 25	250 to 500
Firm	25 to 50	500 to 1,000
Stiff	50 to 100	1,000 to 2,000
Very stiff	100 to 200	2,000 to 4,000
Hard	over 200	over 4,000

Dynamic Cone Penetration Resistance; N_d :

The number of blows by a 63.5 kg (140 lb.) hammer dropped 760 mm (30 in.) to drive uncased a 50 mm (2 in.) diameter, 60° cone attached to "A" size drill rods for a distance of 300 mm (12 in.).

PH: Sampler advanced by hydraulic pressure

PM: Sampler advanced by manual pressure

WH: Sampler advanced by static weight of hammer

WR: Sampler advanced by weight of sampler and rod

Piezo-Cone Penetration Test (CPT)

A electronic cone penetrometer with a 60° conical tip and a project end area of 10 cm² pushed through ground at a penetration rate of 2 cm/s. Measurements of tip resistance (Q_t), porewater pressure (PWP) and friction along a sleeve are recorded electronically at 25 mm penetration intervals.

IV. SOIL TESTS

w	water content
w _p	plastic limit
w _l	liquid limit
C	consolidation (oedometer) test
CHEM	chemical analysis (refer to text)
CID	consolidated isotropically drained triaxial test ¹
CIU	consolidated isotropically undrained triaxial test with porewater pressure measurement ¹
D _R	relative density (specific gravity, G _s)
DS	direct shear test
M	sieve analysis for particle size
MH	combined sieve and hydrometer (H) analysis
MPC	Modified Proctor compaction test
SPC	Standard Proctor compaction test
OC	organic content test
SO ₄	concentration of water-soluble sulphates
UC	unconfined compression test
UU	unconsolidated undrained triaxial test
V	field vane (LV-laboratory vane test)
γ	unit weight

Note: 1 Tests which are anisotropically consolidated prior to shear are shown as CAD, CAU.

LIST OF SYMBOLS

Unless otherwise stated, the symbols employed in the report are as follows:

I GENERAL

π	= 3.1416
$\ln x$	natural logarithm of x
$\log_{10} x$ or $\log x$	logarithm of x to base 10
g	acceleration due to gravity
t	time
F	factor of safety
V	volume
W	weight

II STRESS AND STRAIN

γ	shear strain
Δ	change in, e.g. in stress: $\Delta \sigma$
ϵ	linear strain
ϵ_v	volumetric strain
η	coefficient of viscosity
ν	Poisson's ratio
σ	total stress
σ'	effective stress ($\sigma' = \sigma - u$)
σ'_{vo}	initial effective overburden stress
$\sigma_1, \sigma_2, \sigma_3$	principal stresses (major, intermediate, minor)
σ_{oct}	mean stress or octahedral stress = $(\sigma_1 + \sigma_2 + \sigma_3)/3$
τ	shear stress
u	porewater pressure
E	modulus of deformation
G	shear modulus of deformation
K	bulk modulus of compressibility

III SOIL PROPERTIES

(a) Index Properties

$\rho(\gamma)$	bulk density (bulk unit weight*)
$\rho_d(\gamma_d)$	dry density (dry unit weight)
$\rho_w(\gamma_w)$	density (unit weight) of water
$\rho_s(\gamma_s)$	density (unit weight) of solid particles
γ'	unit weight of submerged soil ($\gamma' = \gamma - \gamma_w$)
D_R	relative density (specific gravity) of solid particles ($D_R = \rho_s / \rho_w$) (formerly G_s)
e	void ratio
n	porosity
S	degree of saturation
*	Density symbol is ρ . Unit weight symbol is γ where $\gamma = \rho g$ (i.e. mass density x acceleration due to gravity)

(a) Index Properties (con't.)

w	water content
w_l	liquid limit
w_p	plastic limit
I_p	plasticity Index = $(w_l - w_p)$
w_s	shrinkage limit
I_L	liquidity index = $(w - w_p) / I_p$
I_C	consistency index = $(w_l - w) / I_p$
e_{max}	void ratio in loosest state
e_{min}	void ratio in densest state
I_D	density index = $(e_{max} - e) / (e_{max} - e_{min})$ (formerly relative density)

(c) Hydraulic Properties

h	hydraulic head or potential
q	rate of flow
v	velocity of flow
i	hydraulic gradient
k	hydraulic conductivity (coefficient of permeability)
j	seepage force per unit volume

(d) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (overconsolidated range)
C_s	swelling index
C_α	coefficient of secondary consolidation
m_v	coefficient of volume change
c_v	coefficient of consolidation
T_v	time factor (vertical direction)
U	degree of consolidation
σ'_p	pre-consolidation pressure
OCR	Overconsolidation ratio = σ'_p / σ'_{vo}

(e) Shear Strength

τ_p, τ_r	peak and residual shear strength
ϕ'	effective angle of internal friction
δ	angle of interface friction
μ	coefficient of friction = $\tan \delta$
c'	effective cohesion
c_u, s_u	undrained shear strength ($\phi = 0$ analysis)
p	mean total stress $(\sigma_1 + \sigma_3) / 2$
p'	mean effective stress $(\sigma'_1 + \sigma'_3) / 2$
q	$(\sigma_1 - \sigma_3) / 2$ or $(\sigma'_1 - \sigma'_3) / 2$
q_u	compressive strength $(\sigma_1 - \sigma_3)$
S_t	sensitivity

Notes: 1. $\tau = c' + \sigma' \tan \phi'$
2. Shear strength = (Compressive strength)/2

PROJECT 001-1136			RECORD OF BOREHOLE No 1			1 OF 1			METRIC							
W.P. 445-98-00			LOCATION N 5118795.2581; E 200016.4011			ORIGINATED BY SB										
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ										
DATUM Geodetic			DATE Aug. 4/00			CHECKED BY SMM										
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED								
185.37	GROUND SURFACE															
0.00	Topsoil															
184.97																
0.40	Silty Clay with organics and rootlets, trace sand															
184.57	Dark grey															
0.80	Moist		1	SS	5											
	Silty Clay, trace sand, trace organics up to 1.2m depth, occ. light grey clayey silt/silt seams															
	Firm		2	SS	5											
	Grey															
	Moist															
183.07																
2.30	Sand, some silt, trace clay and gravel															
	Loose		3	SS	5											
182.40	Grey															
2.97	Wet															
	Silty Clay, trace sand, occ. light grey clayey silt/silt seams		4	SS	1											
181.64	Very soft															
	Grey															
3.73	Wet															
	Silty Clay (irregularly layered), trace sand		5	SS	WH											
	Very soft															
	Reddish brown and grey															
	Wet		6	SS	WH											
180.19																
5.18	END OF BOREHOLE															
	Note: 1. Water level in open borehole measured at 2.4m depth (El.183.0m) upon completion of drilling.															

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PROJECT 001-1136			RECORD OF BOREHOLE No 2			1 OF 1			METRIC										
W.P. 445-98-00			LOCATION N 5119147.4230; E 199250.5405			ORIGINATED BY SB													
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ													
DATUM Geodetic			DATE July 31/00			CHECKED BY SMM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa					WATER CONTENT (%)			γ			
184.68	GROUND SURFACE							20 40 60 80 100	○ UNCONFINED	+	FIELD VANE	W _p	W	W _L					
184.38	Topsoil		1	SS	5		184												
0.30	Silty Clay, trace sand and organics, occ. light grey clayey silt/silt seams Very soft to firm Grey Moist		2	SS	1		183												
182.68			3	75 TO	PH		182												
2.00	Silty Sand, trace clay, gravel and organics Very loose Grey Wet		4	SS	1		181												
181.71			5	SS	1		180												
2.97	Sand, some silt, trace to some gravel, trace clay Very loose Grey Wet		6	SS	1		179												
180.95			7	SS	WH		178												
3.73	Silty Sand, trace clay Very loose Grey Wet		8	SS	WH		177												
179.05			9	75 TO	PH		176												
5.63	Silty Clay (irregularly layered), trace sand Firm Reddish brown and grey Wet		10	75 TO	PH														
175.08																			
9.60	END OF BOREHOLE																		
Note: 1. Water level in open borehole measured at 0.8m depth (El.183.9m) upon completion of drilling. 2. Water level in piezometer measured at 0.8m depth (El.183.9m) on Aug.10, 2000.																			

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PROJECT 001-1136			RECORD OF BOREHOLE No 3			1 OF 1			METRIC							
W.P. 445-98-00			LOCATION N 5119140.9871; E 199301.1262			ORIGINATED BY SB										
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ										
DATUM Geodetic			DATE Aug. 1/00			CHECKED BY SMM										
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED								
184.73	GROUND SURFACE															
184.09	Topsoil															
0.20	Silty Clay with organics, trace sand Soft Dark grey															
183.83	Moist															
0.90	Silty Clay, trace sand and gravel, occ. silty sand/sand interlayers up to 30mm thick above 1.8m depth (El. 182.9m), occ. light grey clayey silt/silt seams Soft Grey Moist		1	SS	3											
			2	75 TO	PH											
182.13																
2.60	Sand, trace to some gravel, trace silt Very loose Grey Wet		3	SS	2											
			4	SS	1											
180.23																
4.50	Silty Sand, trace clay Very loose Grey Wet		5	SS	2											
179.55																
5.18	END OF BOREHOLE															
	Note: 1. Water level in open borehole measured at 1.1m depth (El. 183.6m) upon completion of drilling.															

PROJECT 001-1136			RECORD OF BOREHOLE No 4			1 OF 1			METRIC								
W.P. 445-98-00			LOCATION N 5119131.9095; E 199351.8676			ORIGINATED BY SB											
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ											
DATUM Geodetic			DATE Aug. 1/00			CHECKED BY SMM											
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 kPa 20 40 60 80 100 ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED									
184.75	GROUND SURFACE																
0.00	Topsoil																
184.45																	
0.30	Silty Clay with organics, trace sand																
184.05	Dark grey																
0.70	Moist Silty Clay, trace sand and organics, occ. light grey clayey silt/silt seams, occ. reddish brown sand seams and pockets above 0.9m depth (El. 183.8m). Soft Grey Moist		1	SS	4												
			2	SS	2												
181.70																	
3.05	Sand, some silt, trace to some gravel, trace clay Very loose Grey Wet		3	SS	1												
180.45			4	SS	1												
4.30	Silty Clay, trace to some sand, occ. light grey clayey silt/silt seams Very soft Grey Wet		5	SS	1												
179.57																	
5.18	END OF BOREHOLE Note: 1. Water level in open borehole measured at 1.0m depth (El. 183.7m) upon completion of drilling.																

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PROJECT 001-1136			RECORD OF BOREHOLE No 5			1 OF 1			METRIC					
W.P. 445-98-00			LOCATION N 5119112.8573; E 199399.6181			ORIGINATED BY SB								
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ								
DATUM Geodetic			DATE Aug. 1/00			CHECKED BY SMM								
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED						
184.77	GROUND SURFACE													
0.00 184.77	Topsoil													
0.30	Silty Clay with to some organics, trace sand Very soft to soft Dark grey Moist		1	SS	1									
			2	SS	WH									
182.47														
2.30	Silty Clay, trace sand, occ. light grey clayey silt seams/silt, occ. fine sand seams above 3.3m depth (El. 181.5m) Very soft to soft Grey Moist		3	SS	WH									
			4	SS	WH									
179.47														
5.30	Silty Clay (irregularly layered), trace sand Soft to firm Reddish brown and grey Wet		5	SS	WH									
			6	SS	WH									
			7	SS	PM									
174.41														
10.36	END OF BOREHOLE													
	Note: 1. Water level in open borehole measured at 0.3m depth (El. 184.5m) upon completion of drilling.													

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+³, X³: Numbers refer to Sensitivity **○³%** STRAIN AT FAILURE

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PROJECT 001-1136			RECORD OF BOREHOLE No 7			1 OF 1			METRIC							
W.P. 445-98-00			LOCATION N 5119070.5079; E 199492.1842			ORIGINATED BY SB										
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ										
DATUM Geodetic			DATE Aug. 2/00			CHECKED BY SMM										
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED								
184.74	GROUND SURFACE															
0.00 184.44	Topsoil															
0.30	Silty Clay, trace sand and organics Very soft Dark grey Moist		1	SS	1											
			2	SS	WH											
182.44																
2.30	Silty Clay, trace sand, occ. clayey silt/silt seams, occ. thin fine sand seams at 4.8m depth Very soft to soft Grey Wet		3	SS	WH											
			4	SS	WH											
178.94																
5.80	END OF BOREHOLE															
	Note: 1. Open borehole dry upon completion of drilling.															

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PROJECT 001-1136		RECORD OF BOREHOLE No 8		1 OF 1	METRIC
W.P. 445-98-00		LOCATION N 5119047.7334; E 199536.7025		ORIGINATED BY SB	
DIST 54 HWY 17		BOREHOLE TYPE CME 55 Bombardier		COMPILED BY AZ	
DATUM Geodetic		DATE Aug. 2/00		CHECKED BY SMM	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			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 kPa				WATER CONTENT (%)				
								20 40 60 80 100		20 40 60		w _p w w _L				
							○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL x REMOULDED									
184.76	GROUND SURFACE															
0.00	Topsoil															
184.36																
0.40	Fibrous Peat															
183.76	Soft Blackish grey															
1.00	Moist Silty Clay with to trace organics, trace sand		1	SS	WH											
	Soft Dark grey															
	Moist		2	SS	WH											
182.46																
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams															
	Very soft to soft Grey Wet															
			3	SS	WH											
			4	SS	WH											
179.46																
5.30	Silty Clay (irregularly layered), trace sand															
	Soft Reddish brown and grey Wet															
			5	SS	WH											
			6	SS	WH											
			7	SS	WR											
174.40																
10.36	END OF BOREHOLE															
	Note: 1. Open borehole dry upon completion of drilling.															

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PROJECT 001-1136			RECORD OF BOREHOLE No 9			1 OF 1			METRIC							
W.P. 445-98-00			LOCATION N 5119028.7416; E 199579.7642			ORIGINATED BY SB										
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ										
DATUM Geodetic			DATE Aug.2/00			CHECKED BY SMM										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED				WATER CONTENT (%) W _p W W _L				
184.69	GROUND SURFACE															
0.00	Topsoil															
184.39																
0.30	Silty Clay with to trace organics, trace sand, occ. reddish brown sand seams and pockets above 1.8m depth (El.182.9m) Soft Dark grey Moist		1	SS	WH											
			2	SS	WH											
182.39																
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	WH											
			4	SS	WH											
178.89																
5.80	END OF BOREHOLE Note: Open borehole dry upon completion of drilling.															

PROJECT 001-1136			RECORD OF BOREHOLE No 10			1 OF 1			METRIC								
W.P. 445-98-00			LOCATION N 5119005.6998; E 199627.4992			ORIGINATED BY SB											
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ											
DATUM Geodetic			DATE Aug.2/00			CHECKED BY SMM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED			WATER CONTENT (%) W _p W W _L			γ	GR SA SI CL		
184.64	GROUND SURFACE							20 40 60 80 100									
0.00	Topsoil																
182.34																	
0.30	Silty Clay with to trace organics, trace sand, occ. reddish brown sand seams and pockets at 1.8m depth (El.182.9m) A 0.15m thick layer of fibrous peat at 0.9m depth (El.183.7m) Soft Dark grey Moist		1	SS	2		184										
			2	SS	WH		183										
182.34																	
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	WH		182	X +									
								X +									
							181										
								X +									
							180	X +									
			4	SS	WH												
178.84							179	X +									
5.80	END OF BOREHOLE							X +									
	Note: 1. Open borehole dry upon completion of drilling.																

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PROJECT 001-1136		RECORD OF BOREHOLE No 11		1 OF 1	METRIC
W.P. 445-98-00		LOCATION N 5118984.2825; E 199672.6984		ORIGINATED BY SB	
DIST 54 HWY 17		BOREHOLE TYPE CME 55 Bombardier		COMPILED BY AZ	
DATUM Geodetic		DATE Aug.2/00		CHECKED BY SMM	

SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT		PLASTIC NATURAL LIQUID LIMIT MOISTURE CONTENT			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 kPa							WATER CONTENT (%)		
								○ UNCONFINED		+ FIELD VANE		● QUICK TRIAXIAL			x REMOULDED		w _p
							20	40	60	80	100	20	40	60			
184.74	GROUND SURFACE																
180.00	Topsoil																
0.20	Silty Clay with to trace organics, trace sand A 0.2m thick layer of fibrous peat at 0.9m depth (El.183.8m) Soft Dark grey Moist		1	SS	WH		184										
			2	SS	WH		183										
182.44																	
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	WH		182	x +									
			4	SS	WH		181	x +									
							180										
179.44																	
5.30	Silty Clay (irregularly layered), trace sand Soft Reddish brown and grey Moist		5	SS	WH		179	x +									
							178	x +									
							177										
							176	x +									
				</													

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PROJECT 001-1136			RECORD OF BOREHOLE No 12			1 OF 1		METRIC											
W.P. 445-98-00			LOCATION N 5118962.1588; E 199717.5396			ORIGINATED BY SB													
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ													
DATUM Geodetic			DATE Aug.3/00			CHECKED BY SMM													
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)				
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa			WATER CONTENT (%)			γ			GR SA SI CL		
184.60	GROUND SURFACE							20 40 60 80 100			20 40 60								
0.00	Topsoil							○ UNCONFINED + FIELD VANE											
184.20								● QUICK TRIAXIAL × REMOULDED											
0.40	Silty Clay with to trace organics, trace sand A 0.3m thick layer of fibrous peat at 0.9m depth (El.183.7m) Very soft to soft Dark grey Moist		1	SS	WH		184							143.2					
			2	75 TO	PH		183												
182.30							182	X +											
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Soft Grey Moist		3	SS	WH		181	X +											
			4	SS	WH		180	X +											
179.30							179	X +											
5.30	Silty Clay (irregularly layered), trace sand																		
178.80	Soft																		
5.80	Reddish brown and grey Moist END OF BOREHOLE																		
Note: 1. Open borehole dry upon completion of drilling. 2. Water level in piezometer measured at 0.92m depth (El.183.7m) on Aug.10, 2000.																			

PROJECT 001-1136			RECORD OF BOREHOLE No 13			1 OF 1			METRIC							
W.P. 445-98-00			LOCATION N 5118924.8241; E 199754.4397			ORIGINATED BY SB										
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ										
DATUM Geodetic			DATE Aug.3/00			CHECKED BY SMM										
SOIL PROFILE			SAMPLES			GROUND WATER CONDITIONS	ELEVATION SCALE	DYNAMIC CONE PENETRATION RESISTANCE PLOT				PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED				W _p	W	W _L		
185.12	GROUND SURFACE															
0.00	Sand and Gravel (Fill)															
184.52																
0.60	Silty Clay with to trace organics, trace sand A 0.3m thick layer of fibrous peat at 0.9m depth (El. 184.2m) Very soft Dark grey Moist		1	SS	2											
			2	SS	WH											
182.82																
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	WH											
			4	SS	WH											
179.32																
5.80	END OF BOREHOLE															
	Note: 1. Open borehole dry upon completion of drilling.															

PROJECT 001-1136			RECORD OF BOREHOLE No 14			1 OF 1		METRIC						
W.P. 445-98-00			LOCATION N 5118910.7538; E 199803.6133			ORIGINATED BY SB								
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ								
DATUM Geodetic			DATE Aug. 3/00			CHECKED BY SMM								
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED						
184.70	GROUND SURFACE													
0.00 184.40	Topsoil													
0.30	Silty Clay with to trace organics, trace sand A 0.15m thick layer of fibrous peat at 0.75m depth (El. 183.95m) Very soft Dark grey Moist		1	SS	2									
			2	SS	1									
182.40														
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	WH									
			4	SS	WH									
179.40														
5.30	Silty Clay (irregularly layered), trace sand Soft Reddish brown and grey Moist		5	SS	WH									
			6	SS	WH									
			7	SS	WH									
174.34														
10.36	END OF BOREHOLE													
	Note: 1. Open borehole dry upon completion of drilling.													

ON MOT 001-1136.GPJ ON MOT.GDT 11/10/00

PROJECT 001-1136				RECORD OF BOREHOLE No 15				1 OF 1		METRIC						
W.P. 445-98-00		LOCATION N 5118881.4830; E 199844.8515		ORIGINATED BY SB												
DIST 54 HWY 17		BOREHOLE TYPE CME 55 Bombardier		COMPILED BY AZ												
DATUM Geodetic		DATE Aug.3/00		CHECKED BY SMM												
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 kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED								
185.02	GROUND SURFACE															
0.00 184.72	Topsoil															
0.30	Silty Clay with to trace organics, trace sand, occ. reddish brown sand pockets and seams above 1.8m depth (El.183.8m) Soft Dark grey Moist		1	SS	4		184									
			2	SS	2		183									
182.72																
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Very soft to soft Grey Moist		3	SS	2		182	X +								
								X +								
			4	SS	WH		181	X +								
								X +								
179.22							180									
5.80								X +								
								X +								
	END OF BOREHOLE															
	Note: 1. Open borehole dry upon completion of drilling.															

ON MOT 001-1136.GPJ ON MOT.GDT 11/10/00

PROJECT 001-1136			RECORD OF BOREHOLE No 16			1 OF 1			METRIC									
W.P. 445-98-00			LOCATION N 5118857.9279; E 199888.9705			ORIGINATED BY SB												
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ												
DATUM Geodetic			DATE Aug. 3/00			CHECKED BY SMM												
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)			
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED			WATER CONTENT (%) w _p w w _L			γ	GR SA SI CL			
185.16	GROUND SURFACE						185											
0.00	Sand and Gravel (Fill)																	
184.66	Topsoil																	
184.36																		
0.80	Silty Clay with to trace organics and rootlets, trace sand Very soft to soft Dark grey Moist		1	SS	3		184											
			2	SS	1													
182.86							183											
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Soft to firm Grey Moist							X +										
								X +										
			3	SS	WH		182											
							181	X +										
			4	SS	WH			X +										
179.36							180	X +										
5.80	END OF BOREHOLE							X +										
	Note: 1. Open borehole dry upon completion of drilling.																	

PROJECT 001-1136		RECORD OF BOREHOLE No 17		1 OF 1	METRIC
W.P. 445-98-00		LOCATION N 5118836.7724; E 199934.2998		ORIGINATED BY SB	
DIST 54 HWY 17		BOREHOLE TYPE CME 55 Bombardier		COMPILED BY AZ	
DATUM Geodetic		DATE Aug. 3/00		CHECKED BY SMM	

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 kPa							WATER CONTENT (%)	
								○ UNCONFINED ● QUICK TRIAXIAL	+ FIELD VANE × REMOULDED							
184.94	GROUND SURFACE							20 40 60 80 100	20 40 60							
184.00	Topsoil															
0.20	Silty Clay with to trace organics and rootlets, trace sand Soft Dark grey Moist		1	SS	2		184									
			2	SS	2		183									
182.64																
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Soft Grey Moist		3	SS	WH		182	x +								
			4	SS	WH		181	x +								
							180									
179.64																
5.30	Silty Clay (irregularly layered), trace sand Soft to firm Reddish brown and grey Moist		5	SS	WH		179	x +								
			6	SS	WH		178	x +								
							177									
			7	SS	PM		176	x +								
							175	x +								
174.58																
10.36	END OF BOREHOLE															
	Note: 1. Open borehole dry upon completion of drilling.															

ON MOT 001-1136.GPJ ON MOT.GDT 11/10/00

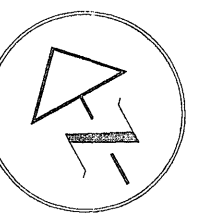
PROJECT 001-1136			RECORD OF BOREHOLE No 18			1 OF 1			METRIC								
W.P. 445-98-00			LOCATION N 5118814.0240; E 199978.8263			ORIGINATED BY SB											
DIST 54 HWY 17			BOREHOLE TYPE CME 55 Bombardier			COMPILED BY AZ											
DATUM Geodetic			DATE Aug. 4/00			CHECKED BY SMM											
SOIL PROFILE			SAMPLES			DYNAMIC CONE PENETRATION RESISTANCE PLOT			PLASTIC LIMIT NATURAL MOISTURE CONTENT LIQUID LIMIT			UNIT WEIGHT			REMARKS & GRAIN SIZE DISTRIBUTION (%)		
ELEV DEPTH	DESCRIPTION	STRAT PLOT	NUMBER	TYPE	"N" VALUES	GROUND WATER CONDITIONS	ELEVATION SCALE	SHEAR STRENGTH kPa ○ UNCONFINED + FIELD VANE ● QUICK TRIAXIAL X REMOULDED			WATER CONTENT (%) W _p W W _L			UNIT WEIGHT γ kN/m ³	GR SA SI CL		
185.19	GROUND SURFACE																
0.00	Topsoil						185										
184.89																	
0.30	Fibrous Peat Soft Blackish grey Moist																
184.19																	
1.00	Silty Clay with to trace organics, trace sand Soft Dark grey Moist		1	SS	2		184										
			2	75 TO	PH												
182.89							183										
2.30	Silty Clay, trace sand, occ. light grey clayey silt/silt seams Soft Grey Moist																
			3	SS	WH		182										
180.69							181										
4.50	Silty Clay (irregularly layered), trace sand Firm Reddish brown and grey Moist		4	SS	WH		180										
179.39																	
5.80	END OF BOREHOLE																
	Note: 1. Open borehole dry upon completion of drilling. 2. Water level in piezometer measured at 2.7m depth (El. 182.5m) on Aug. 10, 2000.																

TABLE 1
SUMMARY OF ORGANIC CONTENT DETERMINATIONS

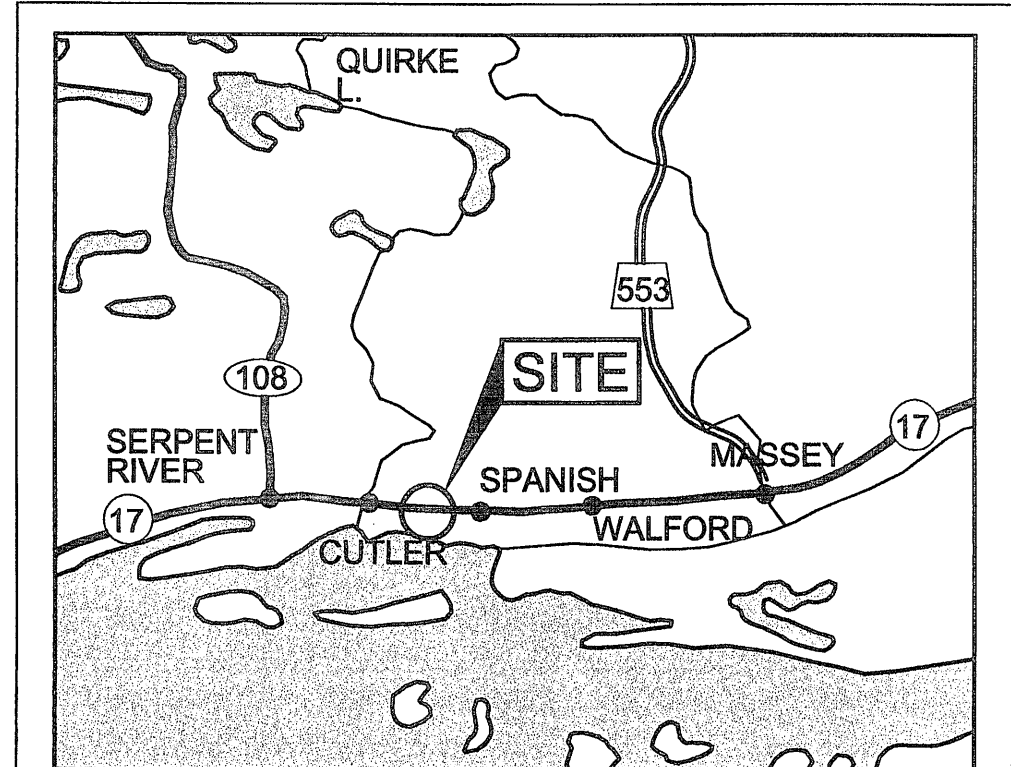
PROJECT NUMBER		001-1136		
PROJECT NAME		Greer / Highway 17 / Sudbury		
DATE TESTED		September, 2000		
Borehole No.	Sample No.	Depth ft	Depth m	Organic Content %
6	1	2.5-4.5	0.76-1.37	8.26
9	1	2.5-4.5	0.76-1.37	16.04
17	1	2.5-4.5	0.76-1.37	13.14

Notes:

1. Samples dried at 110 degree centigrade prior to testing.
2. Test performed according to ASTM D2974-87 Standard, test method C.
3. Organic matter determined by burning the oven dried samples in a muffle furnace at 440 degree centigrade.



Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN

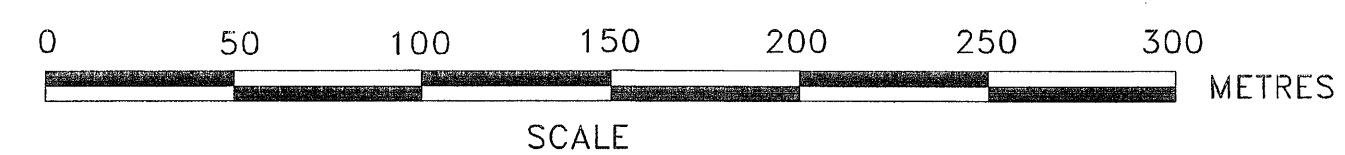
LEGEND



Borehole - Current Golder Associates Ltd.
Investigation

No.	ELEVATION	LOCATION	
		NORTHING	EASTING
BH 1	185.37	5118795.258	200016.401
BH 2	184.68	5119147.423	199250.541
BH 3	184.73	5119140.987	199301.126
BH 4	184.75	5119131.910	199351.868
BH 5	184.77	5119112.857	199399.618
BH 6	184.74	5119091.134	199445.924
BH 7	184.74	5119070.508	199492.184
BH 8	184.76	5119047.733	199536.703
BH 9	184.69	5119028.742	199579.764
BH 10	184.64	5119005.700	199627.499
BH 11	184.74	5118984.283	199672.698
BH 12	184.6	5118962.159	199717.540
BH 13	185.12	5118924.284	199754.440
BH 14	184.7	5118910.754	199803.613
BH 15	185.02	5118881.483	199844.852
BH 16	185.16	5118857.928	199888.971
BH 17	184.94	5118836.772	199934.300
BH 18	185.19	5118814.024	199978.826

PLAN



SCALE

Geocres No.

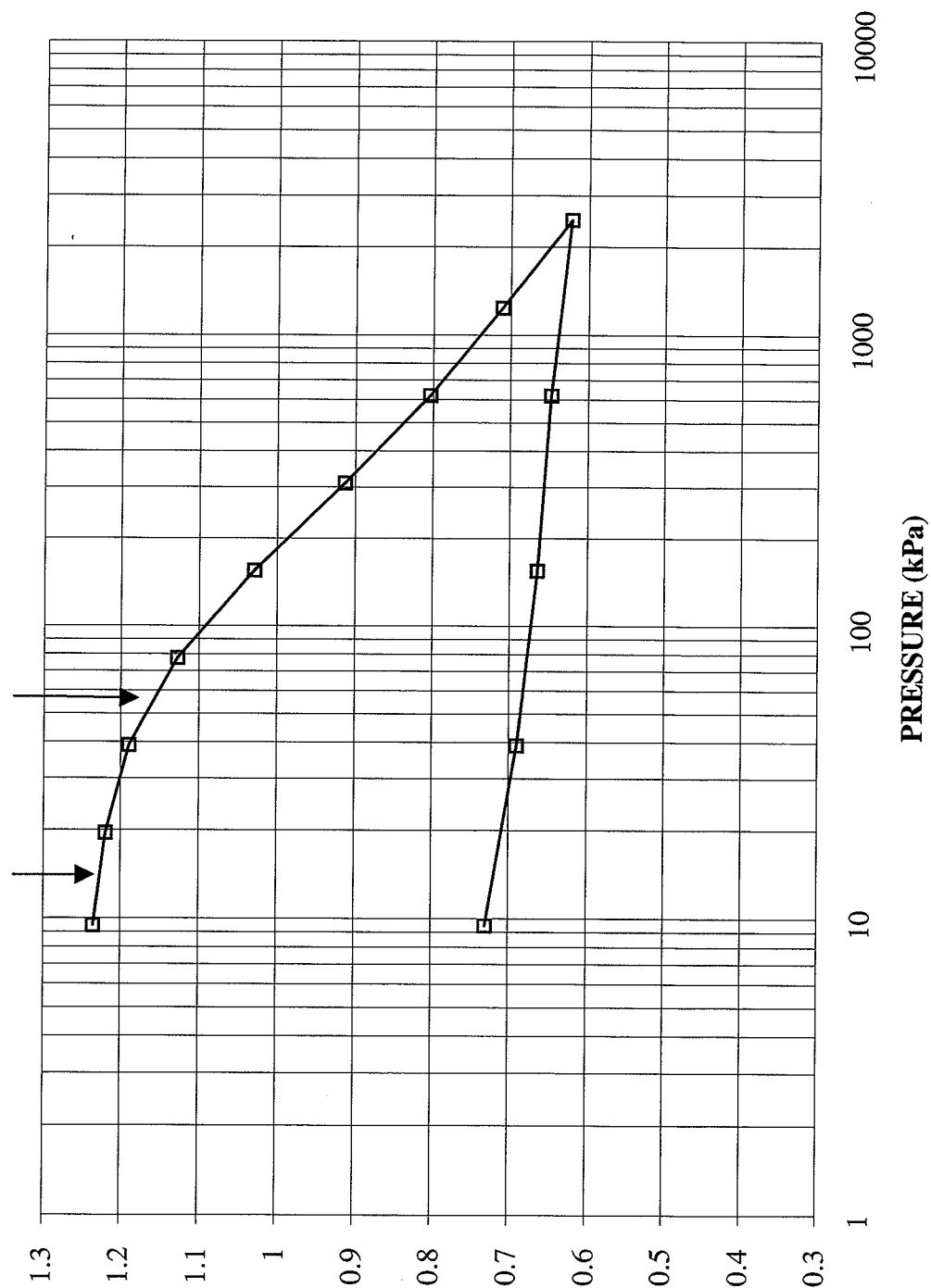
HWY. No.	17	PROJECT NO.:	001-1136	DIST.	54
SUBM'D.	AZ	CHKD:	AMP	DATE:	2000 08 23
DRAWN:	JFC	CHKD.	AZ	APPD.	DWG. 1

CONSOLIDATION TEST VOID RATIO VS. LOG PRESSURE

FIGURE 1

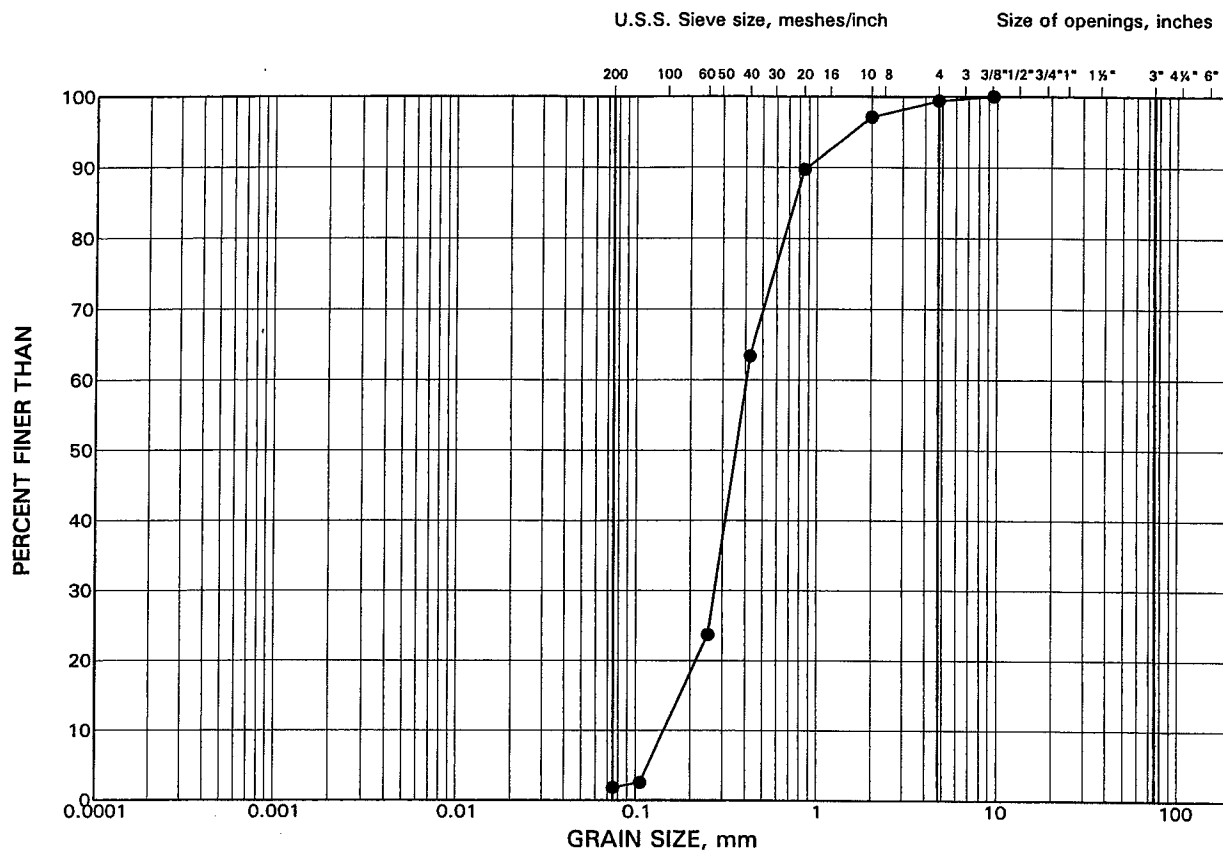
CONSOLIDATION TEST
VOID RATIO vs PRESSURE
BH 18 SA 2

$\sigma'_v = 13.5 \text{ kPa}$ $\sigma'_p = 55 \text{ kPa}$



GRAIN SIZE DISTRIBUTION SAND

FIGURE 2



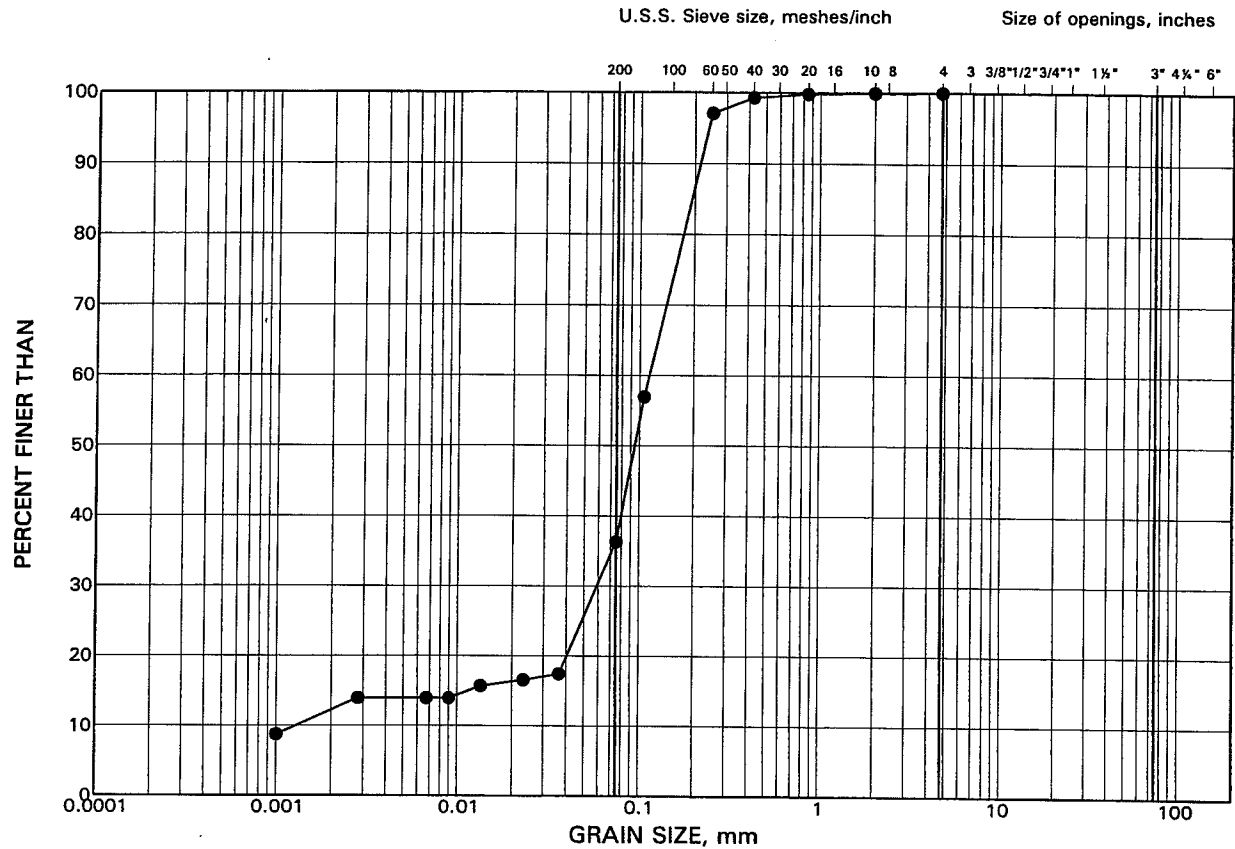
SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
•	3	4	4.4

GRAIN SIZE DISTRIBUTION SILTY SAND

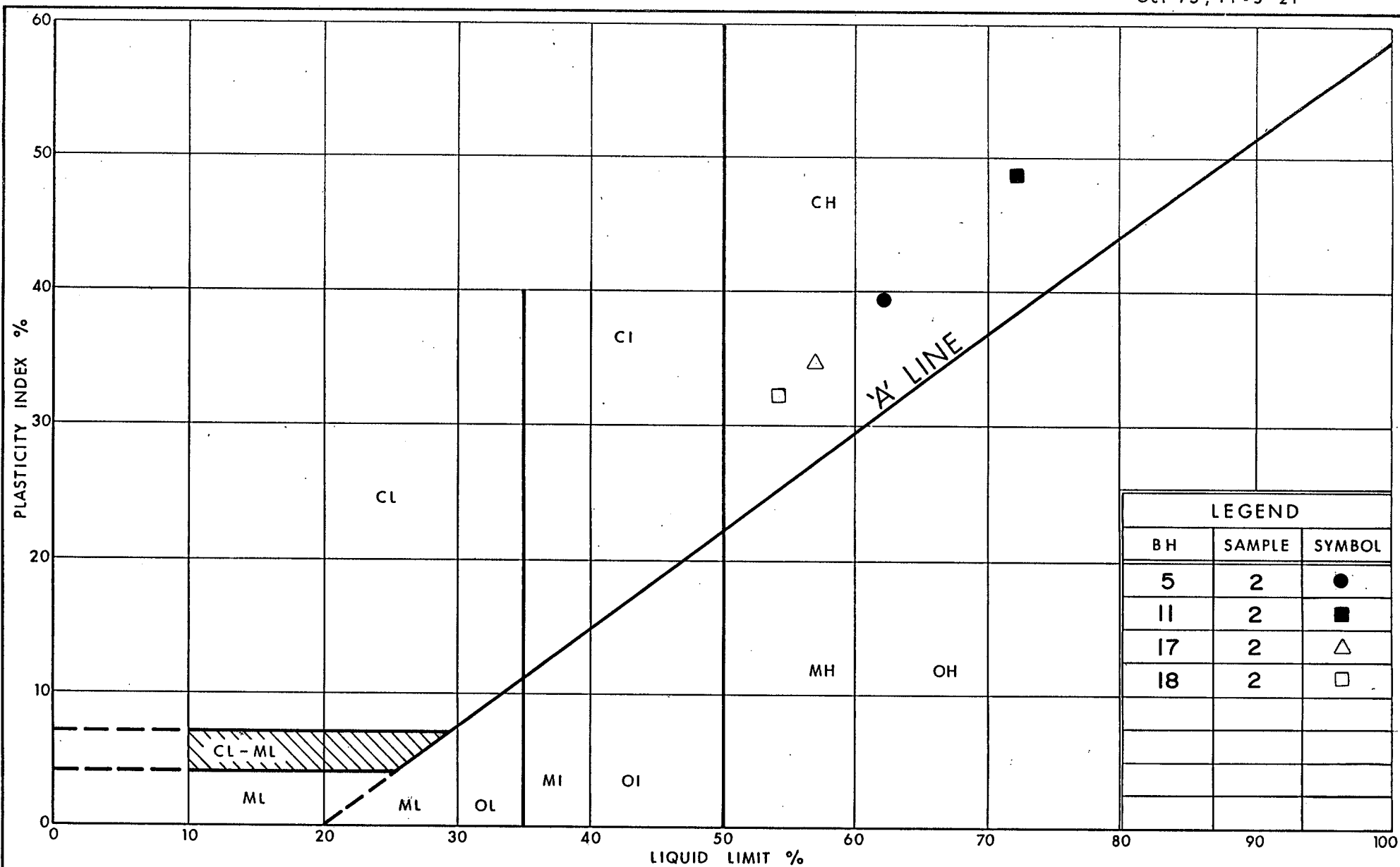
FIGURE 3



SILT AND CLAY SIZES	FINE	MEDIUM	COARSE	FINE	COARSE	COBBLE
FINE GRAINED	SAND SIZE			GRAVEL SIZE		SIZE

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH (m)
•	2	7	5.2



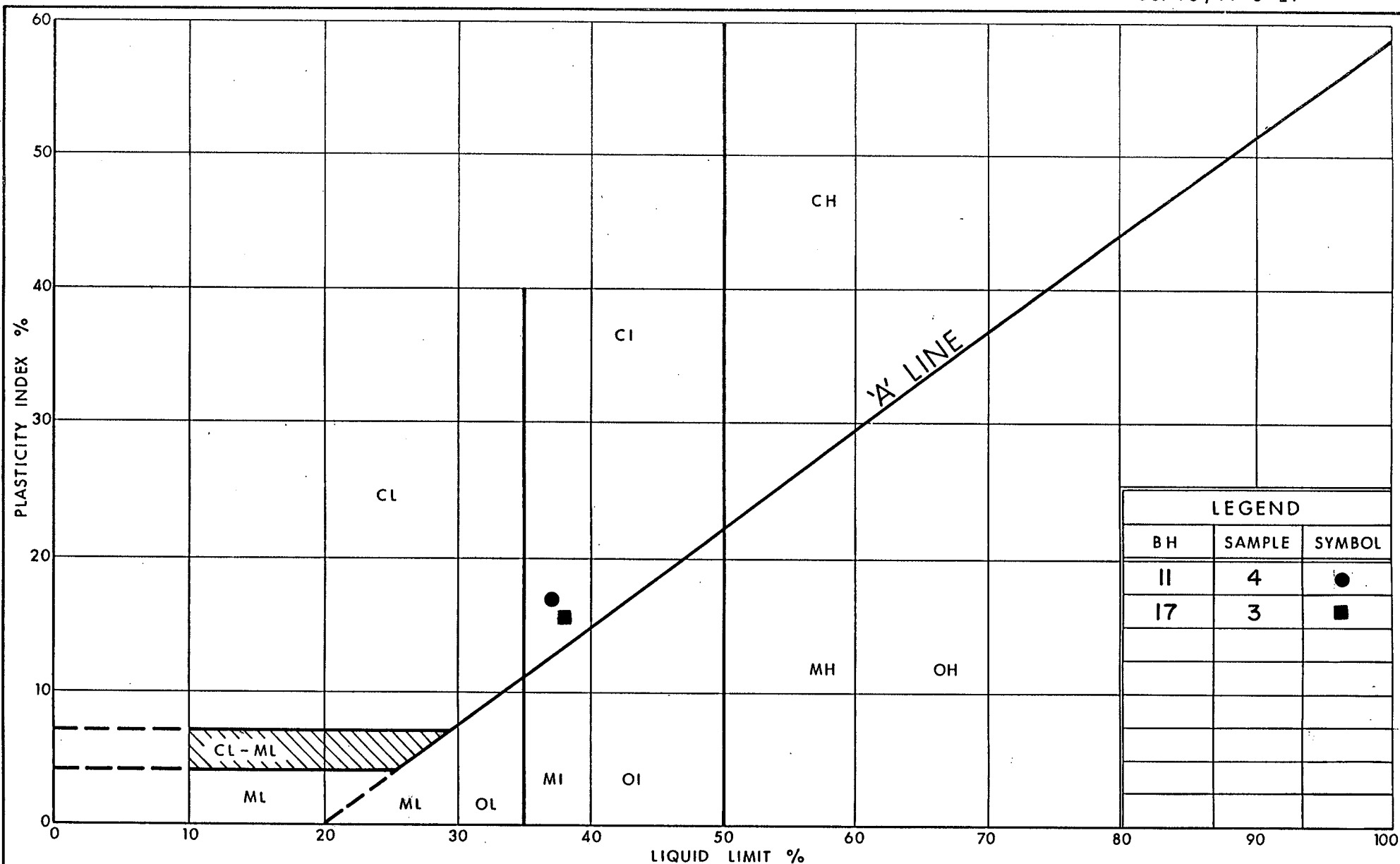
Ontario

Ministry of
Transportation

PLASTICITY CHART UPPER SILTY CLAY

FIG No 4

W P 445-98-00



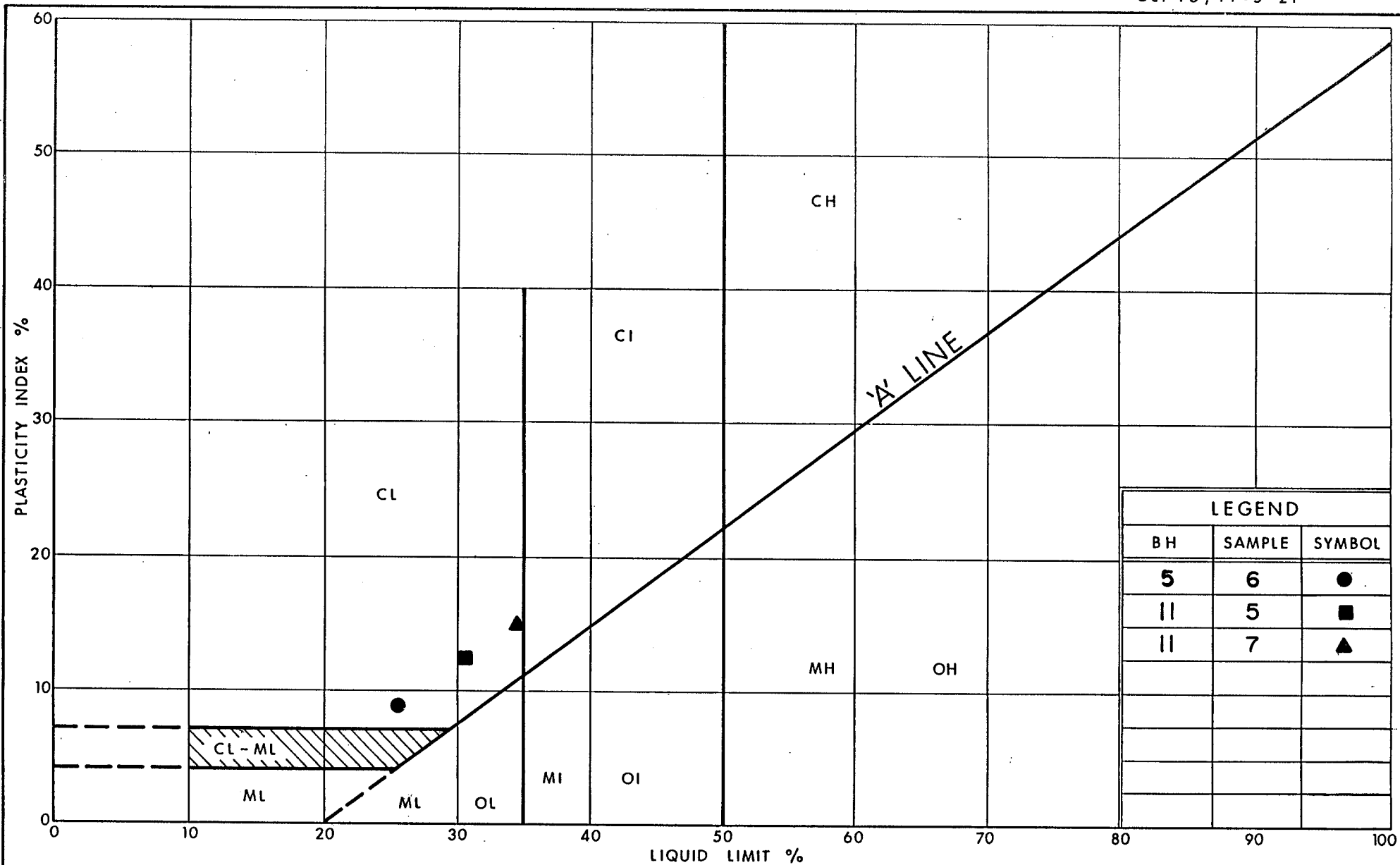
Ontario

Ministry of
Transportation

PLASTICITY CHART MIDDLE SILTY CLAY

FIG-No 5

W P 445-98-00



Ontario

Ministry of
Transportation

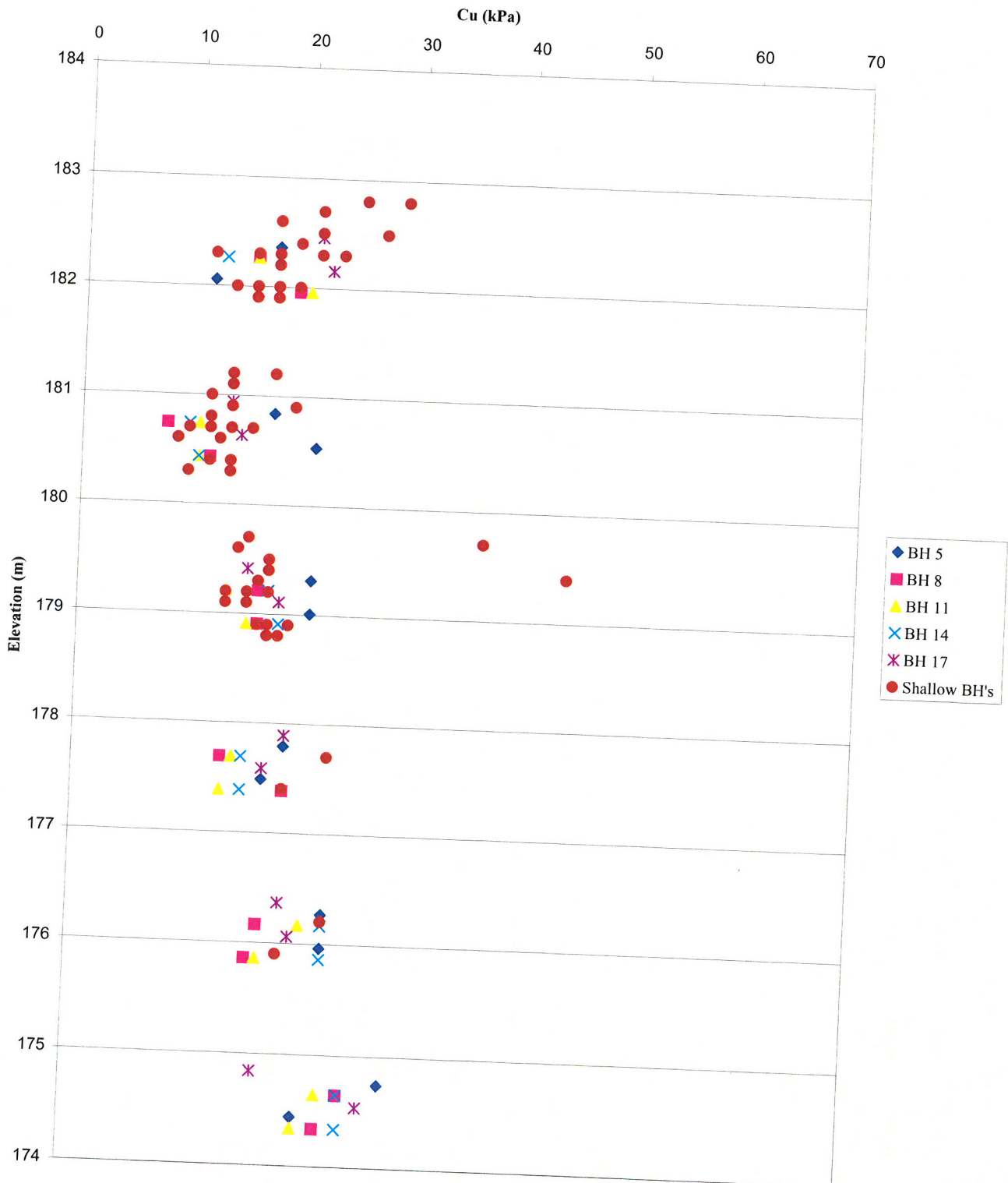
PLASTICITY CHART LOWER SILTY CLAY

FIG No 6

W P 445-98-00

UNDRAINED SHEAR STRENGTH PROFILE ALL BOREHOLES

FIGURE 7



Date FEBRUARY, 2001.

Project 001-1136

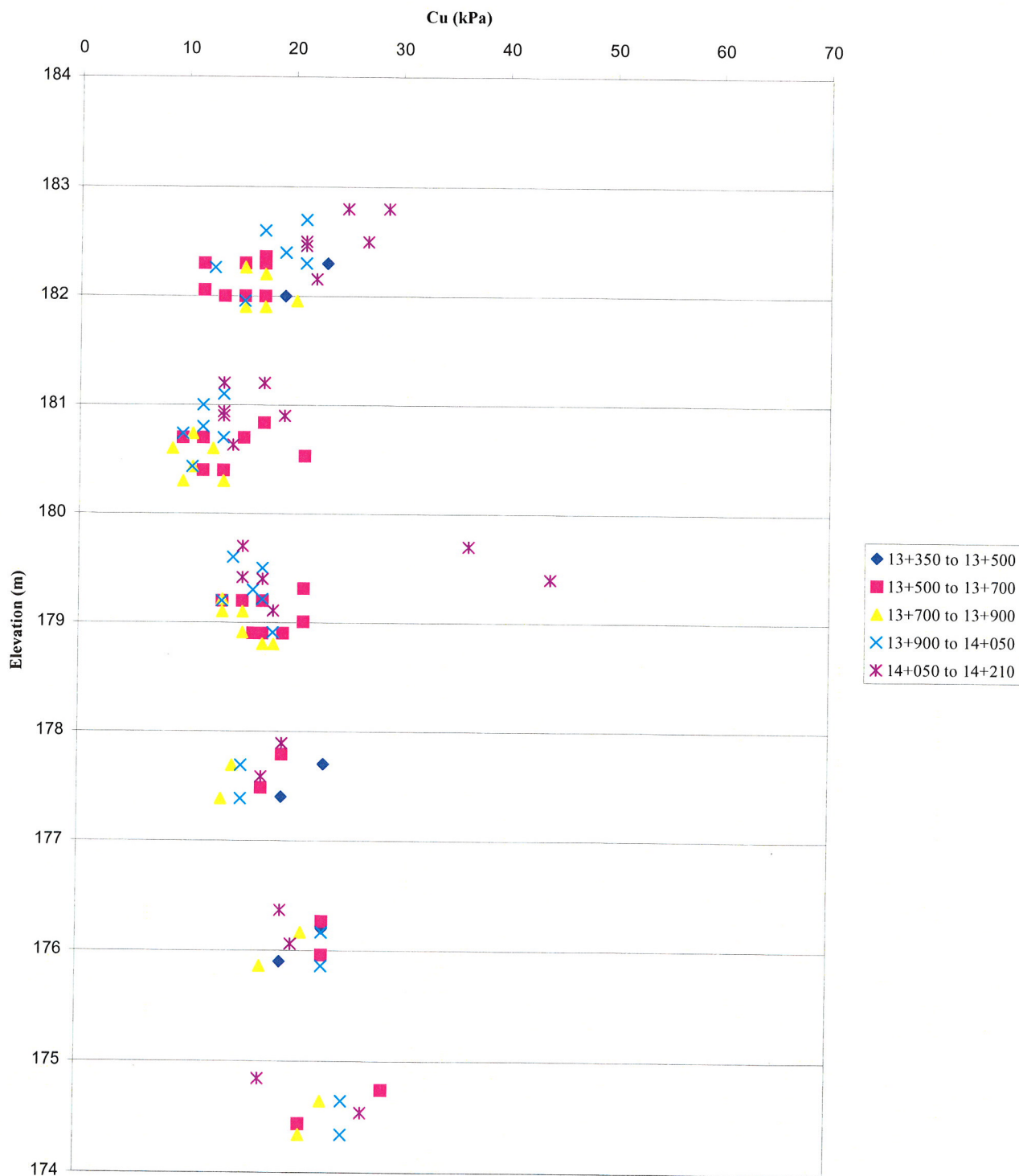
Golder Associates

Drawn R.B.C.

Chkd. *AB*

UNDRAINED SHEAR STRENGTH PROFILE GROUPED BY STATIONS ALONG HWY 17

FIGURE 8



Date **FEBRUARY, 2001.**

Project **001-1136**

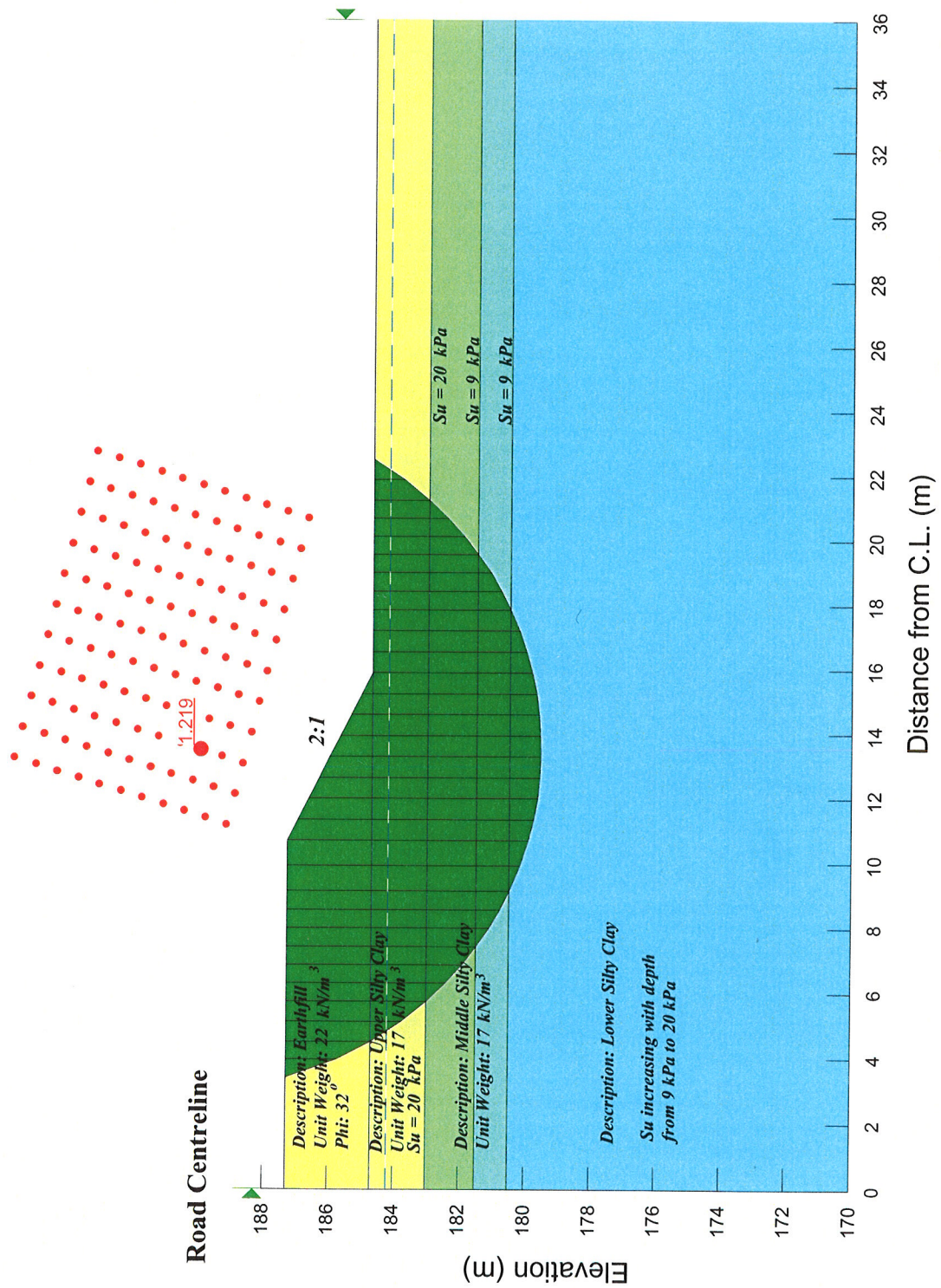
Golder Associates

Drawn **R.B.C.**

Chkd. *[Signature]*

SLOPE STABILITY ASSESSMENT 2 H TO 1 V SIDE SLOPE

FIGURE 9



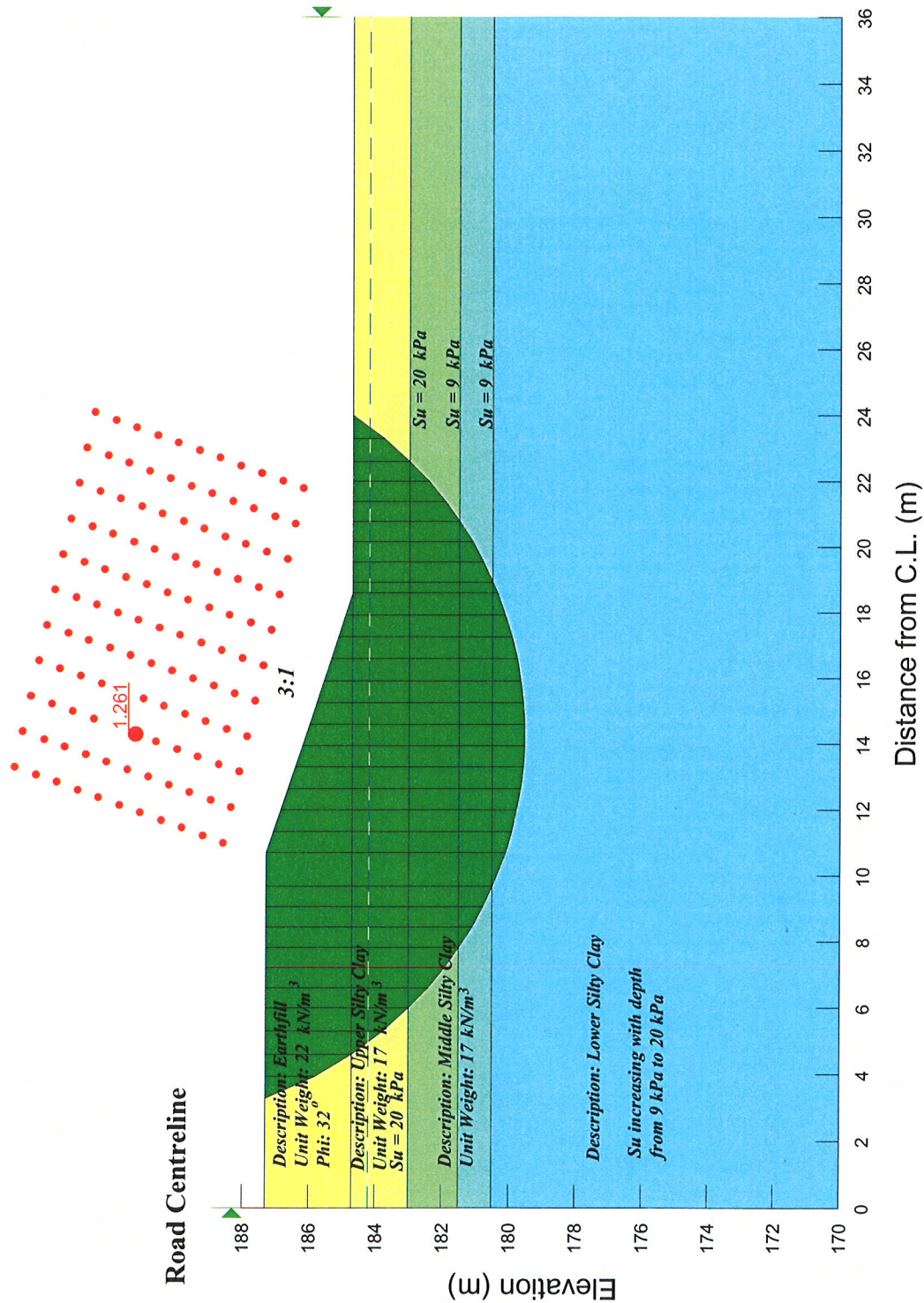
Date FEBRUARY, 2001.
Project 001-1136

Golder Associates

Drawn R.B.C.
Chkd. [Signature]

SLOPE STABILITY ASSESSMENT 3 H TO 1 V SIDE SLOPE

FIGURE 10



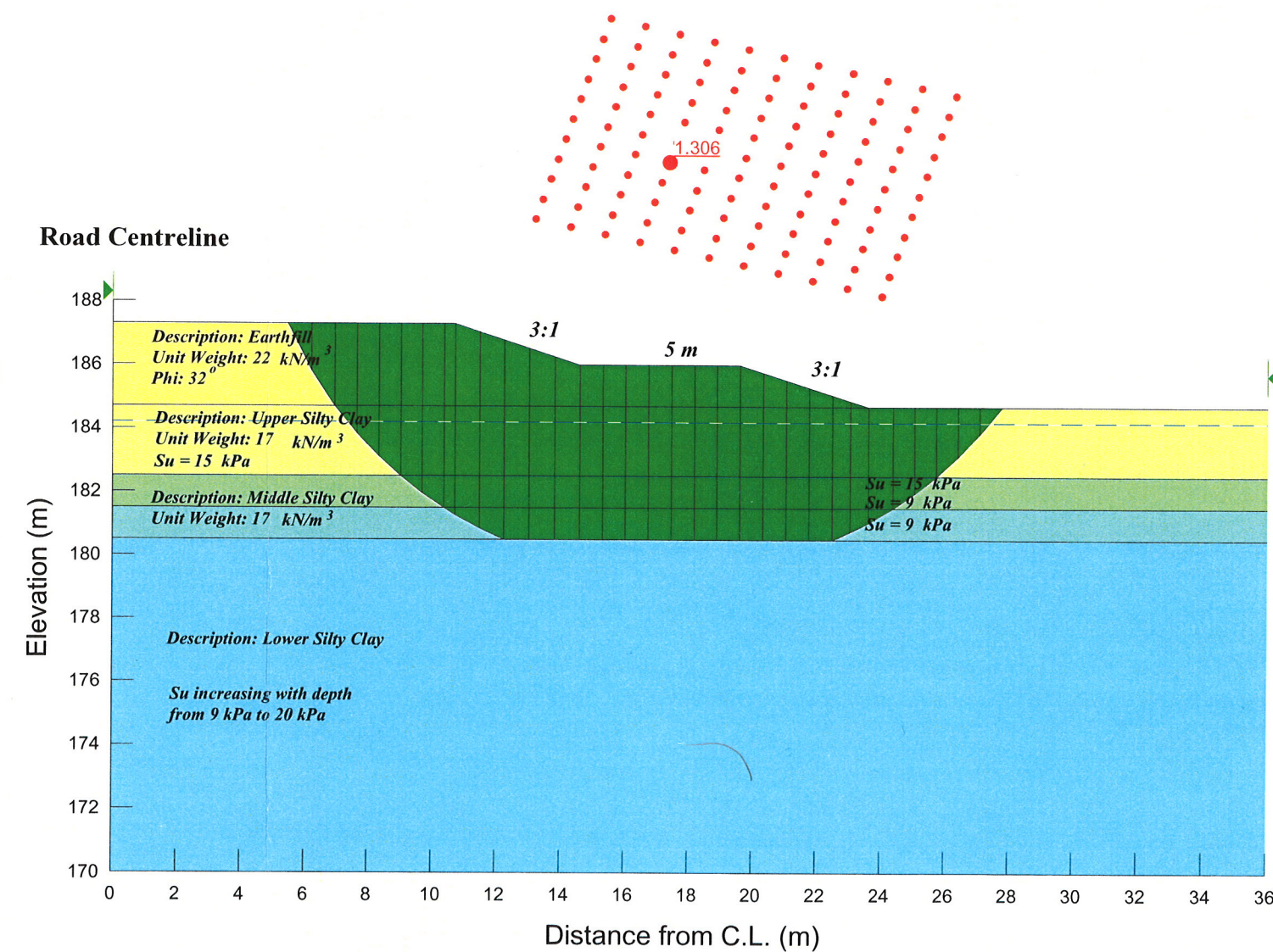
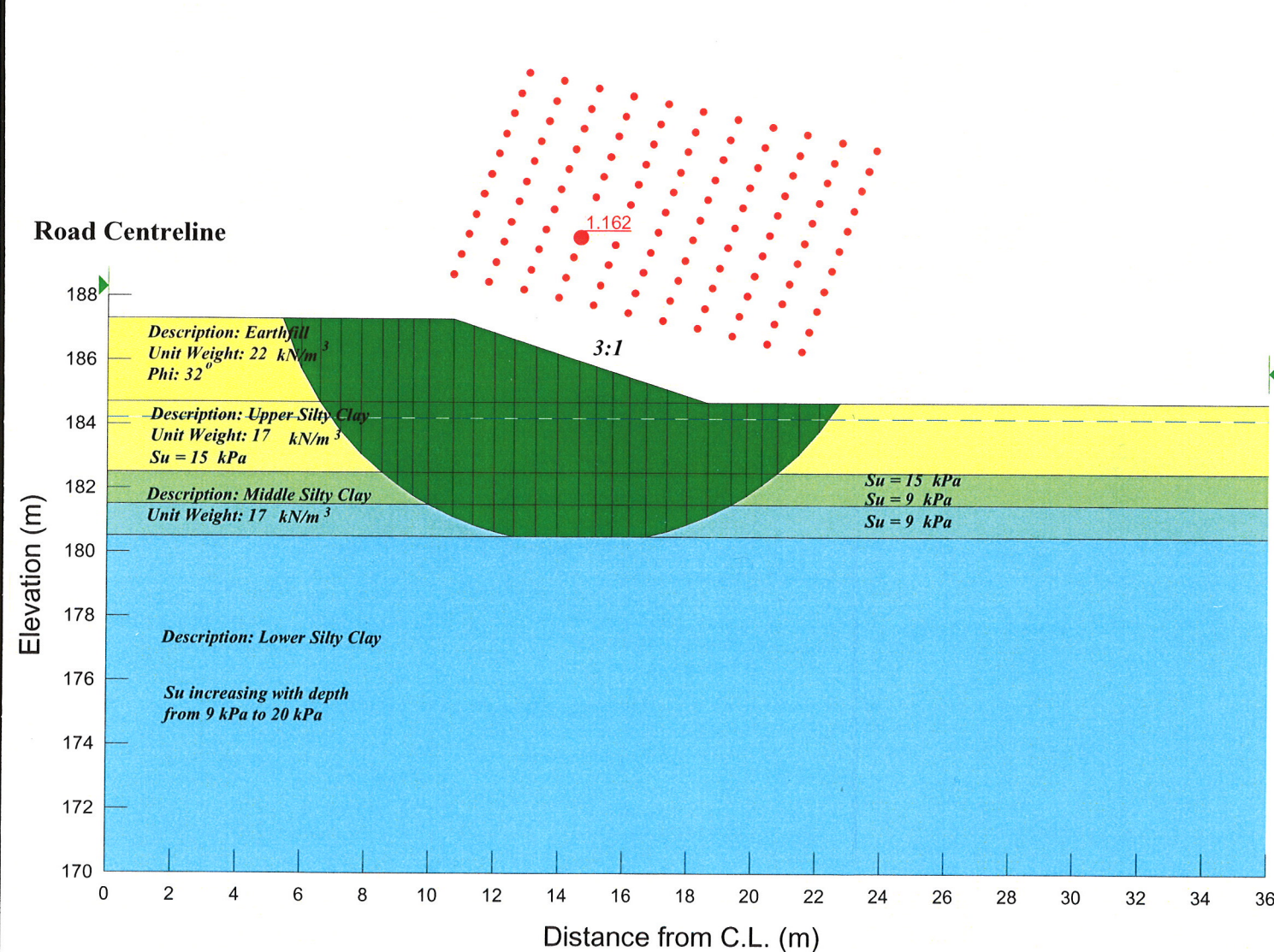
Date FEBRUARY, 2001.
Project 001-1136

Golder Associates

Drawn R.B.C.
Chkd. AP

SLOPE STABILITY ASSESSMENT **SOFTER UPPER CLAY & MINIMUM STRENGTH PROFILE**

FIGURE 11



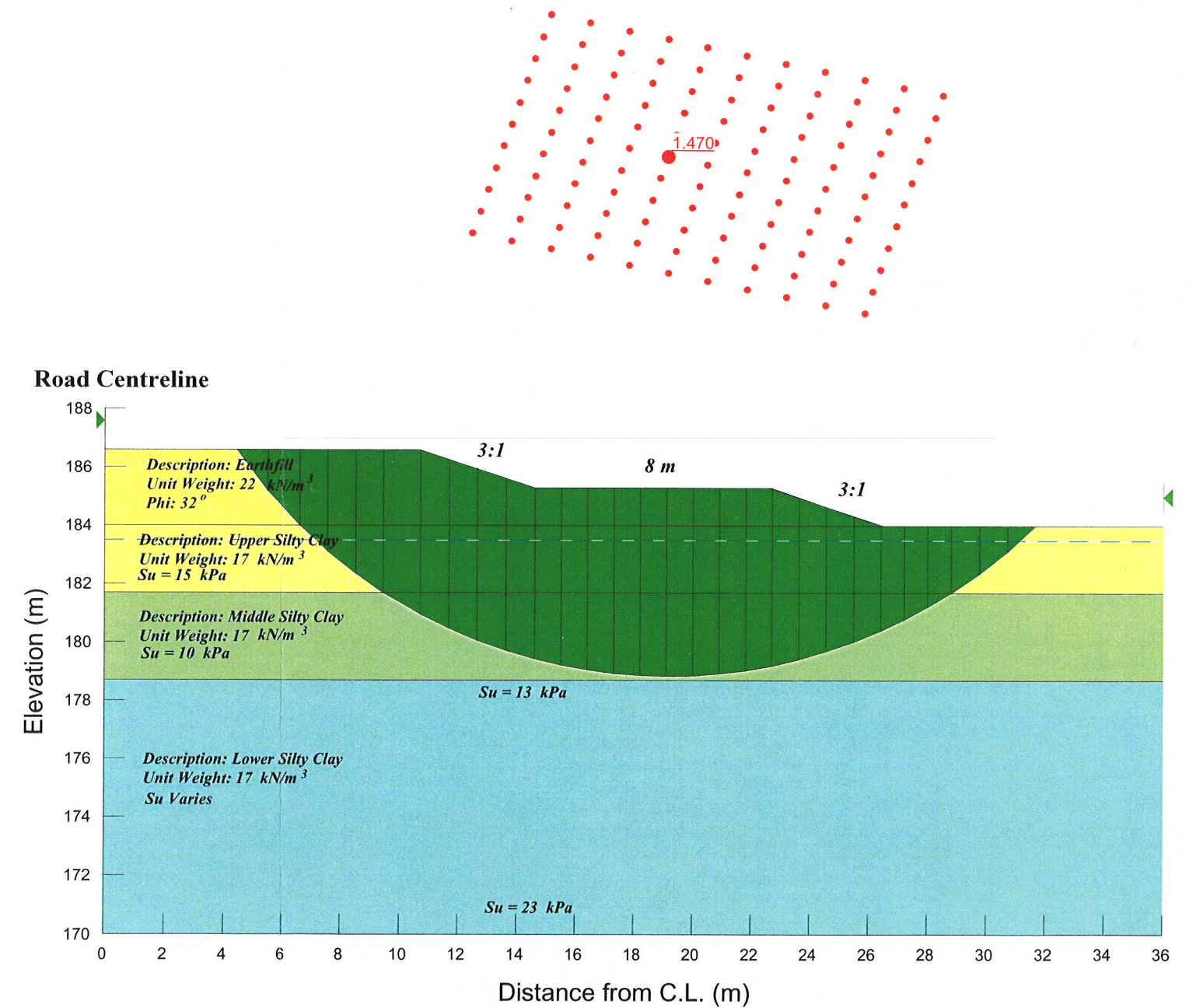
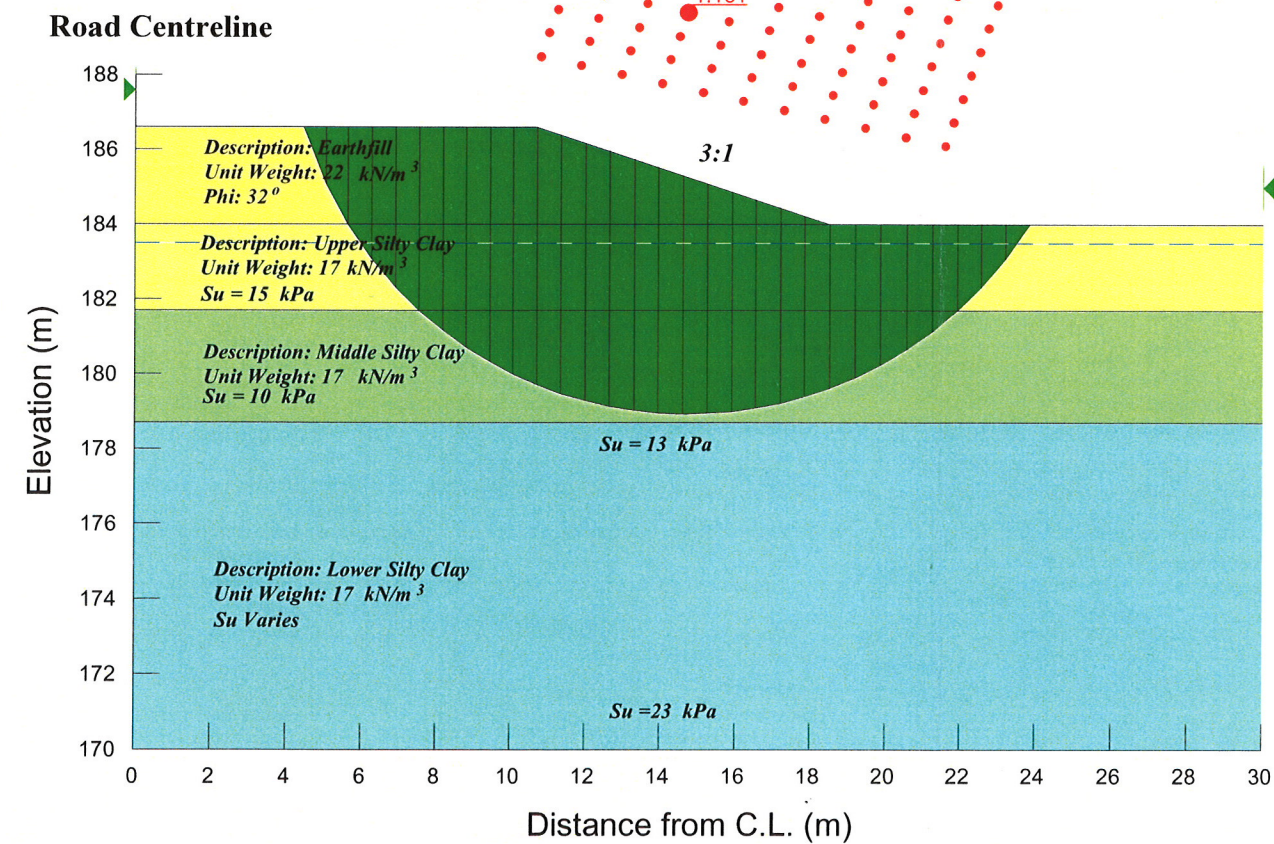
Date..... FEBRUARY , 2001.
 Project..... 001-1136

Golder Associates

Drawn..... R.B.C.
 Chkd *AST*

SLOPE STABILITY ASSESSMENT SOFTER UPPER CLAY AND AVERAGE SHEAR STRENGTH PROFILE

FIGURE 12



Date..... FEBRUARY, 2001.
Project..... 001-1136

Golder Associates

Drawn..... A.Z.
Chkd

APPENDIX A
LABORATORY TEST RESULTS

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER	001-1136
PROJECT NAME	Greer / Highway 17 / Sudbury
DATE TESTED	August, 2000

Borehole No.	Sample No.	Depth (ft)	Depth (m)	Water Content (%)	Atterberg Limits LL, PL, PI
2	2	2.5-4.5	0.76-1.37	28.2%	
2	4	7.5-9.5	2.29-2.90	21.5%	
2	6	12.5-14.5	3.81-4.42	25.3%	
2	7	15.0-17.0	4.57-5.18	24.7%	
2	8	20.0-22.0	6.10-6.71	36.5%	
3	1	2.5-4.5	0.76-1.37	32.2%	
3	3	10.0-12.0	3.05-3.66	22.6%	
3	4	12.5-14.5	3.81-4.42	23.4%	
3	5	15.0-17.0	4.57-5.18	22.6%	
4	2	5.0-7.0	1.52-2.13	38.8%	
4	4	15.0-17.0	4.57-5.18	22.8%	
5	1	2.5-4.5	0.76-1.37	80.6%	
5	2	5.0-7.0	1.52-2.13	65.5%	LL=63.7, PL=24.30, PI=39.4
5	4	15.0-17.0	4.57-5.18	37.6%	
5	5	20.0-22.0	6.10-6.71	35.1%	
5	6	25.0-27.0	7.62-8.23	36.9%	LL=25.40, PL=16.83, PI=8.57
5	7	30.0-32.0	9.14-9.75	36.1%	
6	1	2.5-4.5	0.76-1.37	95.1%	
6	2	5.0-7.0	1.52-2.13	71.3%	
6	4	15.0-17.0	4.57-5.18	38.6%	
7	1	2.5-4.5	0.76-1.37	73.4%	
7	3	10.0-12.0	3.05-3.66	54.7%	
8	2	5.0-7.0	1.52-2.13	70.5%	
8	4	15.0-17.0	4.57-5.18	47.5%	
8	5	20.0-22.0	6.10-6.71	38.2%	
8	7	30.0-32.0	9.14-9.75	40.4%	
9	1	2.5-4.5	0.76-1.37	91.4%	
9	3	10.0-12.0	3.05-3.66	63.2%	

SUMMARY OF WATER CONTENT DETERMINATIONS

PROJECT NUMBER	001-1136
PROJECT NAME	Greer / Highway 17 / Sudbury
DATE TESTED	August, 2000

Borehole No.	Sample No.	Depth (ft)	Depth (m)	Water Content (%)	Atterberg Limits LL, PL, PI
10	2	5.0-7.0	1.52-2.13	66.7%	
10	4	15.0-17.0	4.57-5.18	52.4%	
11	2	2.5-4.5	0.76-1.37	62.6%	LL=71.7, PL=23.09, PI=48.61
11	4	15.0-17.0	4.57-5.18	52.5%	LL=37.8, PL=20.8, PI=17.0
11	5	20.0-22.0	6.10-6.71	42.7%	LL=30.3, PL=18.0, PI=12.3
11	7	30.0-32.0	9.14-9.75	42.7%	LL=34.7, PL=19.7, PI=15.0
12	1	2.5-4.5	0.76-1.37	143.7%	
12	3	10.0-12.0	3.05-3.66	50.3%	
13	2	5.0-7.0	1.52-2.13	68.1%	
13	4	15.0-17.0	4.57-5.18	49.4%	
14	1	2.5-4.5	0.76-1.37	61.8%	
14	3	10.0-12.0	3.05-3.66	59.7%	
14	5	20.0-22.0	6.10-6.71	44.3%	
14	7	30.0-32.0	9.14-9.75	40.8%	
15	2	5.0-7.0	1.52-2.13	49.4%	
15	4	15.0-17.0	4.57-5.18	48.4%	
16	1	2.5-4.5	0.76-1.37	36.9%	
16	3	10.0-12.0	3.05-3.66	48.8%	
17	2	5.0-7.0	1.52-2.13	51.3%	LL=57.0, PL=22.5, PI=34.5 ✓
17	3	10.0-12.0	3.05-3.66	50.6%	LL=37.4, PL=21.5, PI=15.9
17	5	20.0-22.0	6.10-6.71	41.2%	
17	7	30.0-32.0	9.14-9.75	32.1%	
18	2	5.0-7.0	1.52-2.13	43.2%	LL=54.0, PL=22.0, PI=32.0 ✓
18	3	10.0-12.0	3.05-3.66	43.4%	
18	4	15.0-17.0	4.57-5.18	35.6%	
19	1	2.5-4.5	0.76-1.37	38.0%	
19	3	7.5-9.5	2.29-2.90	19.9%	
19	5	12.5-14.5	3.81-4.42	36.2%	

SUMMARY OF LABORATORY VANE TESTING

Project Number		001-1136			Date of Testing				1/2/01
Borehole Number	Sample Number	Sample Depth m	Vane Angular Deflection	Peak	Residual	Vane Blade	Peak	Residual	Water
			Peak / Residual	Torque	Torque	Constant	Shear Strength	Shear Strength	Content
			Degrees	Nm	Nm	m³	kPa	kPa	%
12	2	-	22/0.5	0.02	0	4.24E-06	4.89	0.22	-
12	2	-	51/11	0.05	0.01	4.24E-06	11.33	2.44	-
18	2	-	60/0	0.06	0	4.24E-06	13.32	0.00	-
18	2	-	44/7	0.04	0.01	4.24E-06	9.77	1.55	-