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Golder Associates

REPORT

FOUNDATION INVESTIGATION
HIGHWAY 11
FROM 0.8 km SOUTH OF LAKESHORE DRIVE
TO HIGHWAY 11/17 INTERCHANGE
DISTRESS AREA REMEDIATION
BETWEEN STATIONS 14+800 AND 15+500
AGREEMENT NUMBER PO-5005A000006
G.W. P. 184-92-00

Submitted to:

Cole, Sherman & Associates
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Thornhill, Ontario
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PART A –FOUNDATION INVESTIGATION

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1.0 INTRODUCTION

Golder Associates Ltd. has been retained by Cole, Sherman & Associates (Cole, Sherman) on behalf of the Ministry of Transportation, Ontario (MTO) to carry out a foundation investigation to assess the pavement distress of the existing Highway 11 between Stations 14+800 and 15+500. The current foundation investigation was carried out as part of the Highway 11 four-lane resurfacing project from 0.8 km south of Lakeshore Drive Interchange northerly 6.7 km to Highway 11/17 Interchange, District 54, Sudbury.

This report addresses the area of distress between Stations 14+800 and 15+500 where settlement and cracking of the pavement structure is evident and it is known that remedial measures have been required in this area in the past. It is considered that this distress is potentially related to a deep-seated (foundation) problem.

In the preparation of this report, we have reviewed the existing foundation information as provided in the vicinity of the existing CNR Overhead structure titled " MTO Foundation Investigation & Design Report, W.P. 71-74-02, District 13, Highway 11, Site 43-105B, CNR Overhead Southbound, 2.8 Miles South of Highways 17 and 11", dated March 04, 1977, GEOCRES 31L-39.

The purpose of the foundation investigation is to determine the subsurface conditions at the site of the distress area by drilling boreholes and carrying out in-situ tests and laboratory tests on selected samples. Recommendations on the remediation of the embankment are also provided. The terms of reference for the scope of work are outlined in our proposal letter P91-8005, dated August 3, 1999.

2.0 SITE DESCRIPTION

The site is located on the west side of the highway embankment carrying the Southbound Lanes (SBL) of Highway 11, between Stations 14+800 and 15+500. The site extends from immediately to the south and to about 400 m to the north of the existing CNR overhead structure. Highway 11 is a four-lane divided highway with the embankment approximately 9 m to 11 m in height. Within this area, there is evidence of distress in the form of settlement and cracking of the pavement structure (Plates 1 and 2).

The original ground surface within the site slopes down toward the west. A large swamp area extends to the west of the existing SBL Highway 11 from about 60 m to the north of the CNR bridge and about 30 m to the west of the toe of the SBL Highway. There is bedrock outcropping at the north end and to the east of the distress section. The existing vegetation cover on both sides of the existing highway consists of trees, shrubs and grass.

3.0 INVESTIGATION PROCEDURES

The field work for this investigation was carried out on September 2 and 3, 1999. At this time four (4) boreholes were put down on the west side of the highway in the vicinity of the toe of the existing embankment at the following locations:

Borehole 99-1	-	Station 15+260
Borehole 99-2	-	Station 15+075
Borehole 99-3	-	Station 14+975
Borehole 99-4	-	Station 14+772.

The boreholes were drilled using a bombardier mounted CME 55 drill rig supplied and operated by Marathon Drilling Co. Ltd. of Ottawa. In the boreholes, samples of the soils were obtained at regular intervals of depth using 50 mm outside diameter split-spoon samplers in accordance with the Standard Penetration Test (SPT) procedures. In-situ vane testing were carried out in the soft silty clay deposit encountered at some borehole locations. A Shelby tube sample was collected from the silty clay deposit encountered in Borehole 99-2. Groundwater conditions in the open boreholes were observed throughout the drilling operations and upon completion of drilling. Piezometers were installed in selected boreholes to permit monitoring of the groundwater levels at the site.

The field work was supervised on a full-time basis by members of our technical staff who located the boreholes in the field, cleared the locations of the boreholes for buried services, directed the drilling, sampling and in-situ testing operations, and logged the boreholes. The soil samples were identified in the field, placed in labeled containers and transported back to our laboratory in Mississauga for further examination. Index and classification tests were carried out on selected samples. The results of the testing are shown on the Record of Borehole sheets, on Figures 1 and 2 and in Appendix A.

The locations of the boreholes were established in the field by our personnel with reference to the staked out alignment of Highway 11 and to the site features. Ground surface elevations at the borehole locations were inferred from the profile drawing provided by Cole, Sherman and are referenced to Geodetic Datum. The borehole locations (stations and off sets) and ground surface elevations are indicated on the Record of Borehole sheets; the locations of the boreholes are shown on Drawing C1168001, "Highway 11, Stations 14+775 to 15+500, Borehole Locations", attached.

4.0 GENERAL SITE GEOLOGY AND STRATIGRAPHY

4.1 Site Geology

From published geologic information, the site is located in the physiographic region known as the Canadian Precambrian Shield (Geology of Ontario; OGS Special Volume 4). The Canadian Shield comprises a southeast-trending, slightly elevated region underlain by Precambrian bedrock which was eroded to form an undulating surface with frequent rounded knobs and ridges. The terrain comprises large expanses of intrusive and metamorphic rocks such as gneisses and gneissic or massive granitic rocks. The local physiography is characterized by shallow overburden consisting mainly of outwash sand and gravel and glaciolacustrine silty clay and irregular, variable bedrock surface with frequent rock outcrops. Since irregular bedrock surface is typical in the area, terrain with organic deposits is widespread.

4.2 Site Stratigraphy

The detailed subsurface soil and groundwater conditions encountered in the boreholes, together with the results of the laboratory tests carried out on selected soil 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 geological change. Subsoil conditions will vary between and beyond the borehole locations.

In summary the soils encountered within the site consist of a sand deposit which contains interlayers of silty clay up to 4.4 m in thickness. Silty clay interlayers were not encountered in the borehole located in the northern portion of the site, where sand extends to the bedrock surface.

A detailed description of the subsurface conditions along the west side of the Highway 11 alignment as encountered at the boreholes is provided below.

Borehole 99-1 was put down at Station 15+260 in the vicinity of the toe of the highway embankment. Approximately 210 mm of topsoil overlies very loose fine sand extending to about 0.8 m depth. The sand grades with depth to gravelly sand containing trace silt. The gravelly sand is compact with Standard Penetration Test (SPT) 'N' values ranging from 15 blows for 0.3 m of penetration to 25 blows per 0.3 m penetration. The measured natural water content for samples of this deposit varies from 12 percent to 18 percent. Grain size distribution test results for one sample of the gravelly sand are shown on Figure 1. The gravelly sand extends to the base of the borehole at a depth of about 8.5 m, where refusal to further auger penetration on probable bedrock was encountered.

At the locations of Boreholes 99-2 to 99-4, the topsoil thickness varies from 90 mm to 150 mm. The topsoil is underlain by a very loose to compact sand deposit about 0.2 m to 0.3 m thick in Boreholes 99-2 and 99-3 and 1.8 m thick in Borehole 99-4. The surficial sand deposit is underlain by a silty clay layer ranging in thickness from 2.1 m to 4.4 m. The measured natural water content for samples of the silty clay varies from 29 percent to 57 percent. The Atterberg Limits testing carried out on six samples of the silty clay indicate liquid limits ranging from 21 percent to 55 percent and plasticity indices ranging from 9 percent to 35 percent. Grain size distribution test results for two samples of the silty clay are shown on Figure 2.

In-situ vane testing was carried out within the silty clay deposit. In-situ undrained shear strengths ranging typically from 23 kPa to 50 kPa were measured within this deposit. The silty clay layer encountered in Borehole 99-3 was stiffer, where the measured undrained shear strength ranges from about 50 kPa to in excess of 100 kPa.

The base of the silty clay extends to depths ranging from 2.6 m to 4.7 m. The thickest silty clay layer of 4.4 m was encountered in Borehole 99-2. Consolidation testing carried out on a sample of silty clay collected from Borehole 99-2 indicates a compression index Cc of about 0.15. The results of the consolidation testing are included into Appendix A, following text of this report.

Underlying the silty clay in Boreholes 99-2 to 99-4 is a deposit which grades from silty sand to sand. This deposit is very loose to compact with Standard Penetration Test (SPT) 'N' values ranging from weight of hammer for 0.3 m of penetration to 13 blows per 0.3 m penetration. The measured natural water content for samples of this deposit varies from 16 percent to 45 percent. The sand deposit extends to the base of the boreholes at depth ranging from 8.5 m to about 9.8 m. In Borehole 99-2, refusal to further auger penetration was encountered, possibly on bedrock, at about 8.5 m depth.

It should be noted that the existing geotechnical / foundation information in the vicinity of the existing CNR Overhead structure as documented in the report titled "MTO Foundation Investigation & Design Report, W.P. 71-74-02, District 13, Highway 11, Site 43-105B, CNR Overhead Southbound, 2.8 Miles South of Highways 17 and 11", dated March 04, 1977, GEOCRES 31L-39, indicate that the subsoils in the vicinity of the CN Rail structure consist of about 12 m to 15 m of compact to dense sand directly overlying bedrock. There are no silty clay interlayers noted on the borehole logs.

The water levels in the open boreholes varied from being at ground surface to about 0.7 m depth on completion of drilling operations. Piezometers were installed in Boreholes 99-1 and 99-4 to monitor the groundwater conditions. Details of the piezometer installations and water level measurements are shown on the attached Record of Borehole sheets.

The following table summarizes the groundwater conditions at the locations of the boreholes.

Borehole	***Station***	***Water Level in Open Borehole at Completion of Drilling***		***Water Level in Piezometer on October 3, 1999***	
		Depth (m)	***Elevation (m)***	***Depth (m)***	***Elevation (m)***
99-1	15+260	0.7	204.8	0.4	205.1
99-2	15+075	0.5	204.1	-	-
99-3	14+975	0.0	204.9	-	-
99-4	14+772	0.5	208.4	3.5	205.4

The groundwater level is expected to fluctuate seasonally and is expected to be higher during wet periods of the year.

PART B – FOUNDATION DESIGN

HIGHWAY 11
FROM 0.8 KM SOUTH OF LAKESHORE DRIVE
TO HIGHWAY 11/17 INTERCHANGE
DISTRESS AREA REMEDIATION
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5.0 ENGINEERING RECOMMENDATIONS AND CONCLUSIONS

5.1 General

This section of the report provides our recommendations on the remediation works along the Highway 11, between Stations 14+800 and 15+500. Within this area, there is evidence of distress in the form of cracking of the pavement structure and it is understood that remedial measures have been implemented in the past in this area.

The road cross-sections and existing highway alignment were shown on the drawing provided to us by Cole, Sherman. Also, the construction contract drawings (Contract 79-53, W.P. 71-74-01) were provided to us for review.

Based on the results of the boreholes, it is considered that the distress of the highway pavement is due to the presence of the silty clay layer. The silty clay deposit as encountered in the boreholes is typically soft to firm and extends to depths ranging from 2.6 m to 4.7 m below the existing ground surface at the toe of the embankment. A review of the construction drawings for the existing highway does not indicate that any subexcavation was carried out for embankment construction in this area. There were no organic deposits encountered in the boreholes, therefore this lack of subexcavation could be expected given the presence of the surficial sand layer. The embankment is about 9 m to 11 m in height and there would have been consolidation settlement of the silty clay layer occurring due to embankment loading. Based on the original ground surface contours and the bedrock outcrop locations, it is probable that the silty clay layer is variable in thickness to the north of the CN Rail. The settlement would, therefore, have to be differential across the width of the embankment to the north of the CN Rail structure due to variable thickness of the compressible layer. Distress is also evident to the south of the CN Rail structure where, based on the previous ground surface profile, there is not likely to be significant variation in the thickness of the silty clay layer. It is considered, therefore, that the distress is not related solely to the variable thickness of the silty clay layer.

Given the height of the embankment in comparison to the in-situ shear strength of the silty clay layer, it is considered that the stability was only marginal during construction and that there would have been potential for instability of the embankment. The curved nature of the pavement cracking and differential movement evident across the cracks at some locations is indicative of deep seated movement which could be on-going (Plates 1 and 2). It is also considered that, due to the compressible nature of the silty clay deposit, there will still be future settlement of the embankment in addition to on-going instability. The following sections present the results of the stability analyses completed for the highway embankment and the range of the future settlement due to secondary consolidation of the silty clay deposit.

5.2 Slope Stability Analyses

Slope stability analyses for two sections located at Chainages 14+770 and 15+070 have been carried out using the commercially available program Slope/W. The analyses were carried out using a limiting equilibrium method of analyses as described by Morgenstern Price (1965). The program utilizes numerous trial "failure" circular and non-circular surfaces in order to compute minimum factor of Safety for a plane strain condition. The factor of safety is defined as the ratio of the forces tending to resist failure to the driving forces tending to cause the failure.

The slope stability analysis for section at Chainage 15+070 was carried out using the undrained shear strength of the silty clay as measured by the in-situ vane testing carried out at the toe of the embankment. For the upper 3.5 m of silty clay, a value of undrained shear strength of 26 kPa and unit weight of 21 kN/ m^3 has been used in analysis. For the lower 1 m of silty clay, an undrained shear strength of 40 kPa was used in analysis. The results of the analysis indicate that the computed factor of safety is about 1 for the existing conditions (Figure 3). This factor of safety was based on the thickness and strength parameters as established at the borehole locations and does not reflect any potential increased strength of the silty clay under the embankment. For an estimated 50 percent increase in the silty clay strength due to consolidation of the deposit, the calculated factor of safety improves to about 1.15.

Given the low factor of safety for the existing embankment, we carried out a further assessment assuming that a berm was placed on the west side of the embankment. The calculated overall factor of safety of the highway embankment improves to 1.3 for the condition where a berm of at least 8 m in length and at least 4 m in height is placed on the west side of the embankment (Figure 4).

The slope stability analyses were also carried out for the section of the embankment at Chainage 14+770, located on the south side of the CN Rail structure. At this location, the thickness of the silty clay as encountered in Borehole 99-4 is 2.1 m and in-situ vane test values of undrained shear strength ranging from 31 kPa to 46 kPa were measured in this deposit. For these conditions, a computed overall factor of safety greater than 1.5 was obtained for this cross-section. This factor of safety is considered sufficient from the embankment stability point of view.

5.3 Settlement of the Highway Embankment

A layer of silty clay underlies the surficial sand deposit in three of the four boreholes drilled within the distress area. The silty clay is typically soft to firm and ranges in thickness from 2.1 m to 4.4 m. The thickness of the clay is unknown underneath the highway embankment and probably varies across the width of the embankment increasing toward the west.

Consolidation testing was carried out on a sample of silty clay collected from Borehole 99-2. The results of the test indicate a compression index Cc of about 0.15. Based on the laboratory testing carried out on the silty clay sample, it is estimated that approximately 350 mm and 650 mm of settlement for a 2 m thick and 4 m thick, respectively, layer of silty clay has occurred due to primary consolidation of the silty clay deposit induced by the 10 m high embankment loading. For this estimate, we have assumed the cross-section of the embankments as shown at Chainage 15+070 and 14+770. It is considered that the process of primary consolidation of the silty clay deposit underlying the embankment has been completed since the time of construction 20 years ago and the current settlement of the embankment is due to the secondary consolidation settlement of the silty clay.

The secondary consolidation settlement is expected to be nominal for the next 30 years provided there is no increase in loading of the silty clay layer.

5.4 Conclusion

Based on the results of the stability analyses, the stability of the existing highway embankment is marginal at the locations where the silty clay layer is of relatively low strength and is as thick as about 4.5 m. To enhance the stability of the embankment, we recommend that a berm of at least

8 m in length and at least 4 m in height be placed on the west side of the SBL Highway 11 embankment. The berm should commence at Chainage 14+850, immediately to the north of the CN Rail structure and extend to approximately Chainage 15+150.

We understand that consideration is being given to place excess rockfill materials generated within the project area within the median of Highway 11. We would suggest that these fill materials be used to construct the berm within the area as indicated above.

Additional settlement of the highway embankment due to secondary consolidation should be anticipated, however, this settlement will be nominal. The majority of the settlement will be due to long-term consolidation of the rockfill itself.

GOLDER ASSOCIATES LTD.

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AMP/ASP/FJH/amp/clg
WORD S/FINALDAT/1100/991-1168/91168KR1

LIST OF SYMBOLS

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

I. General

π	3.1416
in 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 stress (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 (continued)

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)

(b) 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

(c) Consolidation (one-dimensional)

C_c	compression index (normally consolidated range)
C_r	recompression index (over-consolidated range)
C_s	swelling index
C_a	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	over-consolidation ratio $= \sigma'_p/\sigma'_{vo}$

(d) 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 δ
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

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

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.)

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 cm^2 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.

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

(b) Cohesive Soils

Consistency	c_u,s_u kPa	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

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.

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RECORD OF BOREHOLE No 99-1

METRIC

PROJECT 991-1168
W.P. 184-92-00
DIST 52 HWY 11
DATUM Geodetic
LOCATION Sta. 15+260, 18m Lt of centerline
BOREHOLE TYPE Hollow Stem Augers
DATE Sept.2/99
ORIGINATED BY MSB
COMPILED BY AP
CHECKED BY ASP

ELEV / DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	WATER CONTENT (%)	GR	SA	SI	CL
205.50										
205.29 / 0.21	TOPSOIL									
	Sand, trace silt, trace gravel, trace organics, Very loose, Moist to wet, Grey brown	1	50 DO	2	205					
204.74 / 0.76	Gravelly Sand, trace silt, Compact, Wet, Brown	2	50 DO	17		o	20	75	5	
		3	50 DO	21	204					
		4	50 DO	15	203	o				
		5	50 DO	25	202					
		6	50 DO	21		o				
		7	50 DO	24	201					
200.47 / 5.03	END OF BOREHOLE									

END OF BOREHOLE
REFUSAL TO FURTHER AUGER PENETRATION, PROBABLY BEDROCK

Note:
1. Water level in open hole at 0.7m depth on completion of drilling.
2. Water level in piezometer at 0.43m depth on Oct.3,99.

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE; DYNAMIC CONE PENETRATION RESISTANCE PLOT (20 40 60 80 100); SHEAR STRENGTH kPa (O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, X REMOULDED; 20 40 60 80 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

$+^3, \times^3$: Numbers refer to Sensitivity $O^{3\%}$ STRAIN AT FAILURE

Ministry of Transportation Ontario

Foundation Design

RECORD OF BOREHOLE No 99-2

METRIC

PROJECT 991-1168			
W.P. 184-92-00	LOCATION Sta. 15+075, 29m Lt of centerline	ORIGINATED BY MSB	
DIST 52	HWY 11	BOREHOLE TYPE Hollow Stem Augers	COMPILED BY AP
DATUM Geodetic	DATE Sept.2/99	CHECKED BY ASP	

ELEV / DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES	ELEVATION SCALE	UNIT WEIGHT γ kN/m³	GR	SA	SI	CL
204.60										
0.00	TOPSOIL									
0.30	Sand, trace silt, Loose, Wet, Grey	1	50 DO	4	204					
	Silty Clay, trace sand, trace organics, irregularly layered, Soft to firm, Moist, Grey to brown	2	50 DO	3	203					
		3	50 DO	PH	202	19.3	1	28	48	23
		4	50 TO	1	201		0	5	40	55
199.94 / 4.66	Sand, some silt, some gravel, Very loose to compact, Wet, Grey	5	50 DO	13	200 / 199					
		6	50 DO	WH	198					
	Cobbles and boulder inferred from resistance to augering below 8.2m.	7	50 DO	WR	197					
196.07 / 8.53	END OF BOREHOLE. REFUSAL TO FURTHER AUGER PENETRATION, PROBABLY BEDROCK									

Note:
Water level in open hole at 0.5m depth on completion of drilling.

Legend: DYNAMIC CONE PENETRATION RESISTANCE PLOT (20, 40, 60, 80, 100); SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED (20, 40, 60, 80, 100); PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) (20, 40, 60); REMARKS & GRAIN SIZE DISTRIBUTION (%)

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

RECORD OF BOREHOLE No 99-3

METRIC

PROJECT 991-1168
W.P. 184-92-00
LOCATION Sta. 14+975, 27m Lt of centerline
ORIGINATED BY MSB
DIST 52 HWY 11
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AP
DATUM Geodetic
DATE Sept.2/99
CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	SAMPLE NUMBER	TYPE	"N" VALUES
204.90 / 0.00	TOPSOIL			
204.45 / 0.45	Sand, trace silt, Very loose, Wet, Grey to brown	1	50 DO	2
202.30 / 2.60	Silty Clay, trace sand, Soft to very soft, Moist to wet, Brown to grey	2	50 DO	N/A
201.25 / 3.65	Silty Sand, trace clay and gravel, occasional layers of coarse sand, occ. cobble, Compact, Wet, Grey	3	50 DO	18
195.76 / 9.14	Sand trace to some gravel, trace silt, occ. cobble and boulder, Very loose to compact, Wet, Brown to grey	4	50 DO	3
		5	50 DO	6
		6	50 DO	11
		7	50 DO	13
	Cobbles and boulders inferred from resistance to augering below 5.4m depth.			
	END OF BOREHOLE			

Note:
Water level in open hole at ground surface on completion of drilling.

Column headings: SOIL PROFILE (ELEV DEPTH, DESCRIPTION, STRAT PLOT); SAMPLES (NUMBER, TYPE, "N" VALUES); GROUND WATER CONDITIONS; ELEVATION SCALE (204 to 196); DYNAMIC CONE PENETRATION RESISTANCE PLOT 20 40 60 80 100; SHEAR STRENGTH kPa: O UNCONFINED, + FIELD VANE, ● QUICK TRIAXIAL, × REMOULDED, 20 40 60 80 100; PLASTIC LIMIT W_P, NATURAL MOISTURE CONTENT W, LIQUID LIMIT W_L; WATER CONTENT (%) 20 40 60; UNIT WEIGHT γ kN/m³; REMARKS & GRAIN SIZE DISTRIBUTION (%) GR SA SI CL

+³, ×³: Numbers refer to Sensitivity   O³% STRAIN AT FAILURE

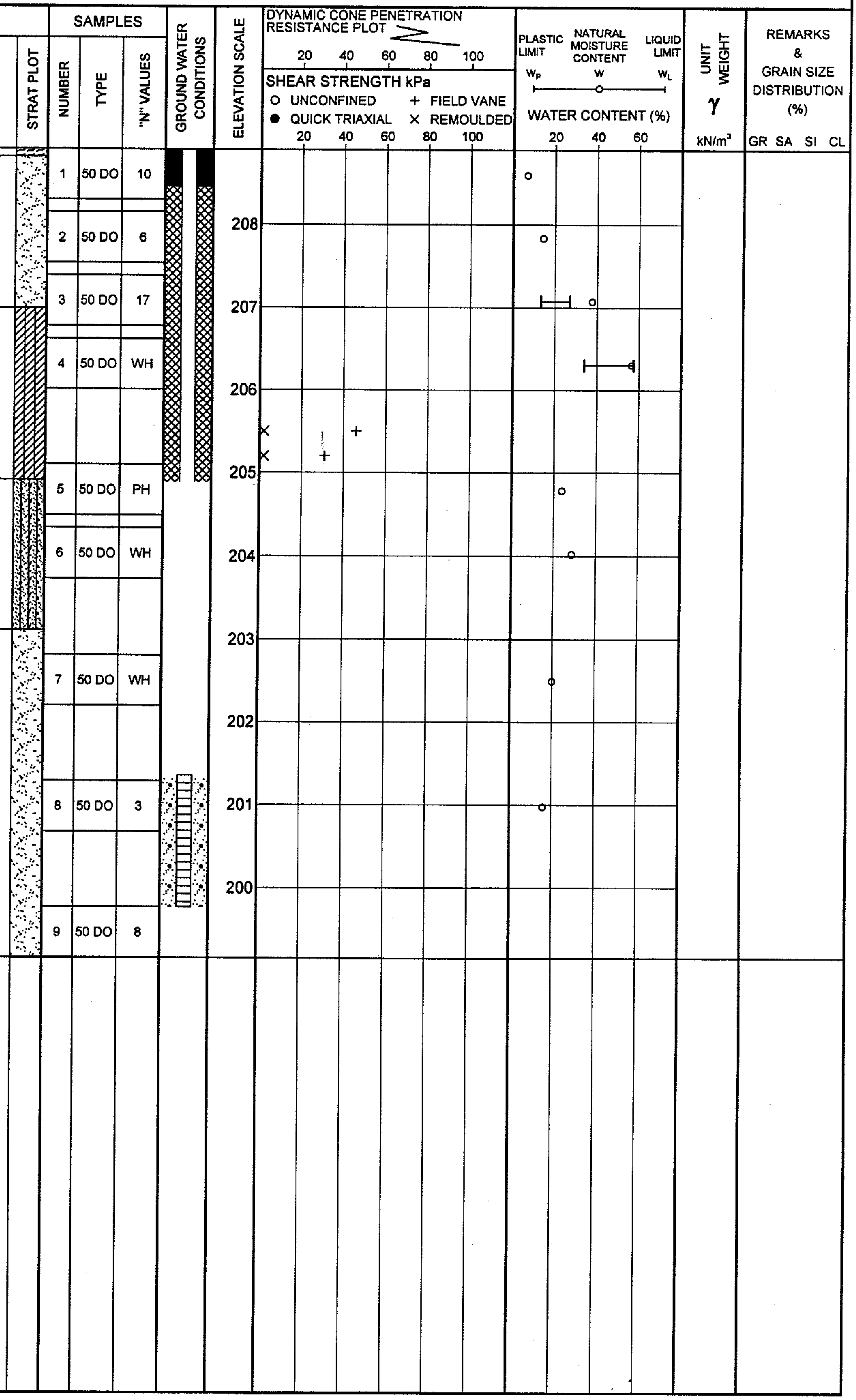
Ministry of Transportation Ontario

RECORD OF BOREHOLE No 99-4

METRIC

PROJECT 991-1168
W.P. 184-92-00
LOCATION Sta. 14+772, 32m Lt of centerline
ORIGINATED BY MSB
DIST 52 HWY 11
BOREHOLE TYPE Hollow Stem Augers
COMPILED BY AP
DATUM Geodetic
DATE Sept.3/99
CHECKED BY ASP

ELEV DEPTH	DESCRIPTION	NUMBER	TYPE	"N" VALUES
208.90				
0.09	TOPSOIL			
	Sand, trace silt, trace gravel Loose to compact Moist to wet Brown to grey	1	50 DO	10
		2	50 DO	6
206.98		3	50 DO	17
1.92	Silty Clay, trace sand Soft to firm Brown to grey	4	50 DO	WH
204.90 4.00	Sandy Silt, trace silt Very loose Wet Grey	5	50 DO	PH
		6	50 DO	WH
203.10 5.80	Sand, trace to some gravel, trace silt Very loose to loose Wet Brown	7	50 DO	WH
		8	50 DO	3
		9	50 DO	8
199.15 9.75	END OF BOREHOLE			



Note:
1. Water level in open hole at 0.5m depth on completion of drilling.
2. Water level in piezometer at 3.5m depth on Oct.3,99.

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

$O^{3\%}$ STRAIN AT FAILURE

ON_MOT 991-1168.GPJ ON_MOT.GDT 2/11/99

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

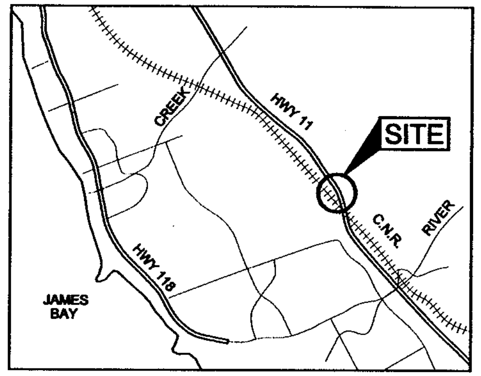
DIST	HWY 11
CONT. No.	
WP No.	292-97-00

HIGHWAY 11
Sta. 14+775 to Sta. 15+500
BOREHOLE LOCATIONS

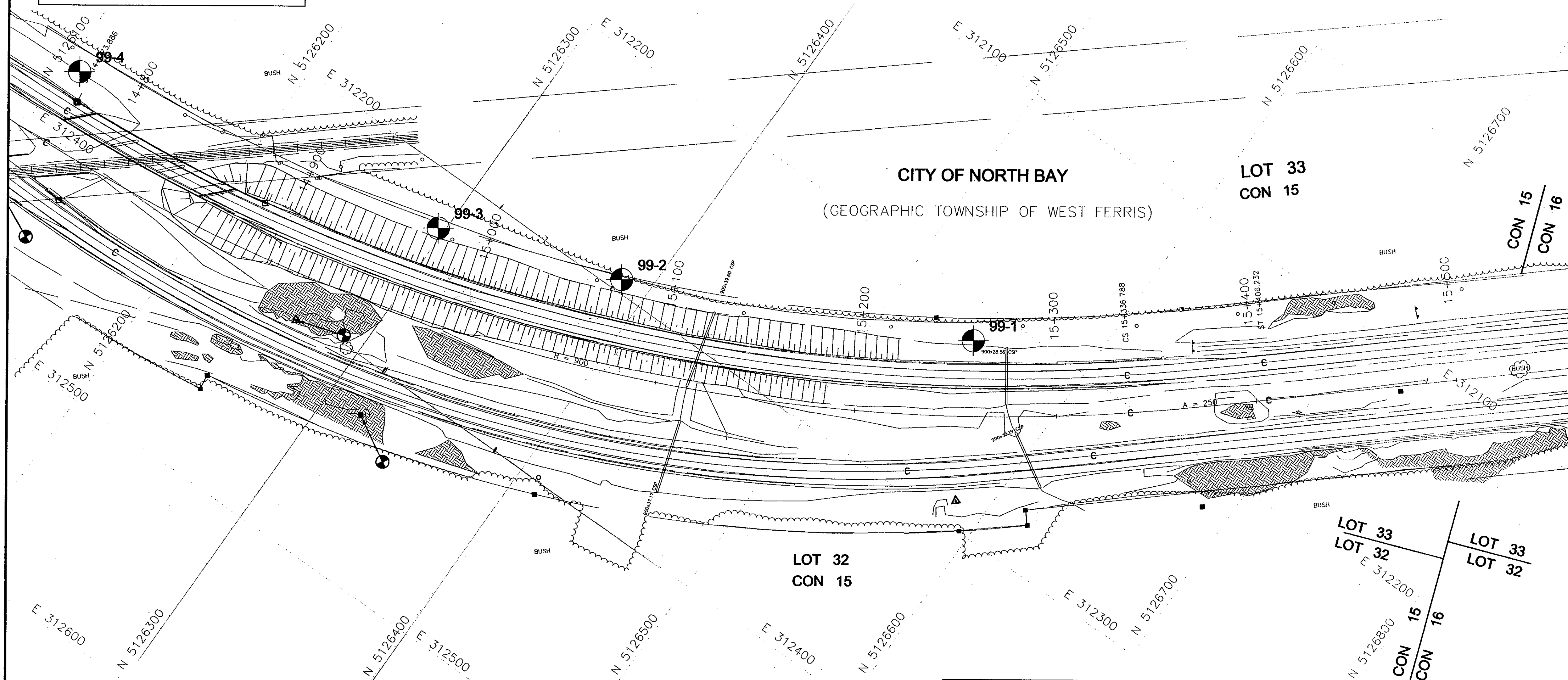
SHEET

Golder Associates

Golder Associates Ltd.
MISSISSAUGA, ONTARIO, CANADA



KEY PLAN



PLAN

0 50 100 150 200m

SCALE 1:2,000

LEGEND				
⊕ Borehole				
No.	ELEVATION	COORDINATES		
		STATION	OFFSET	
99-1	205.5	15+158	38m LT. ℄ MEDIAN	
99-2	204.6	15+072	46m LT. ℄ MEDIAN	
99-3	204.9	14+973	47m LT. ℄ MEDIAN	
99-4	208.9	14+770	39m LT. ℄ MEDIAN	

NO.	DATE	BY	REVISION

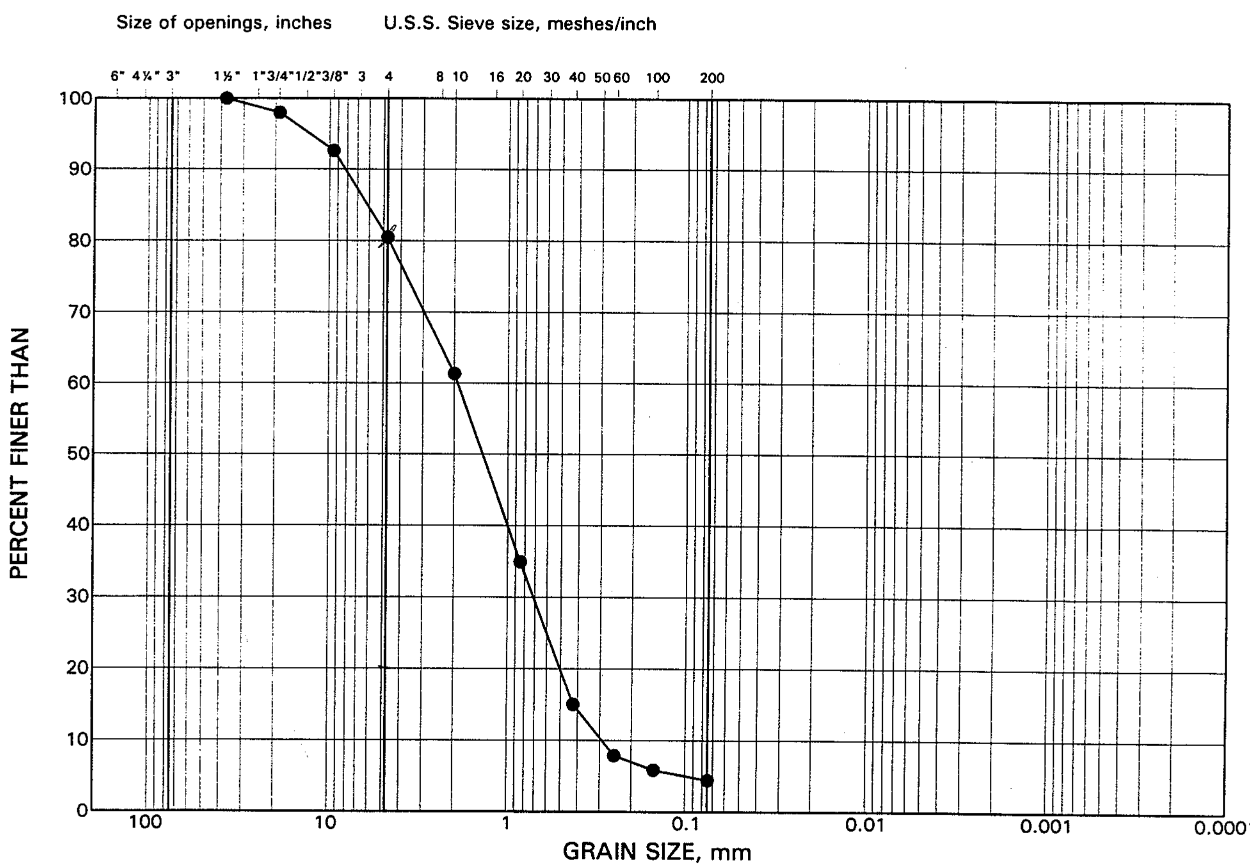
Geocres No.

HWY 11		PROJECT NO.: 991-1168	DIST.
SUBM'D. ASP	CHKD:	DATE: 1999 10 07	SITE
DRAWN: JFC	CHKD. ASP	APPD.	DWG C1168001

01168001.DWG

GRAIN SIZE DISTRIBUTION
Gravelly Sand

FIGURE 1



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

LEGEND

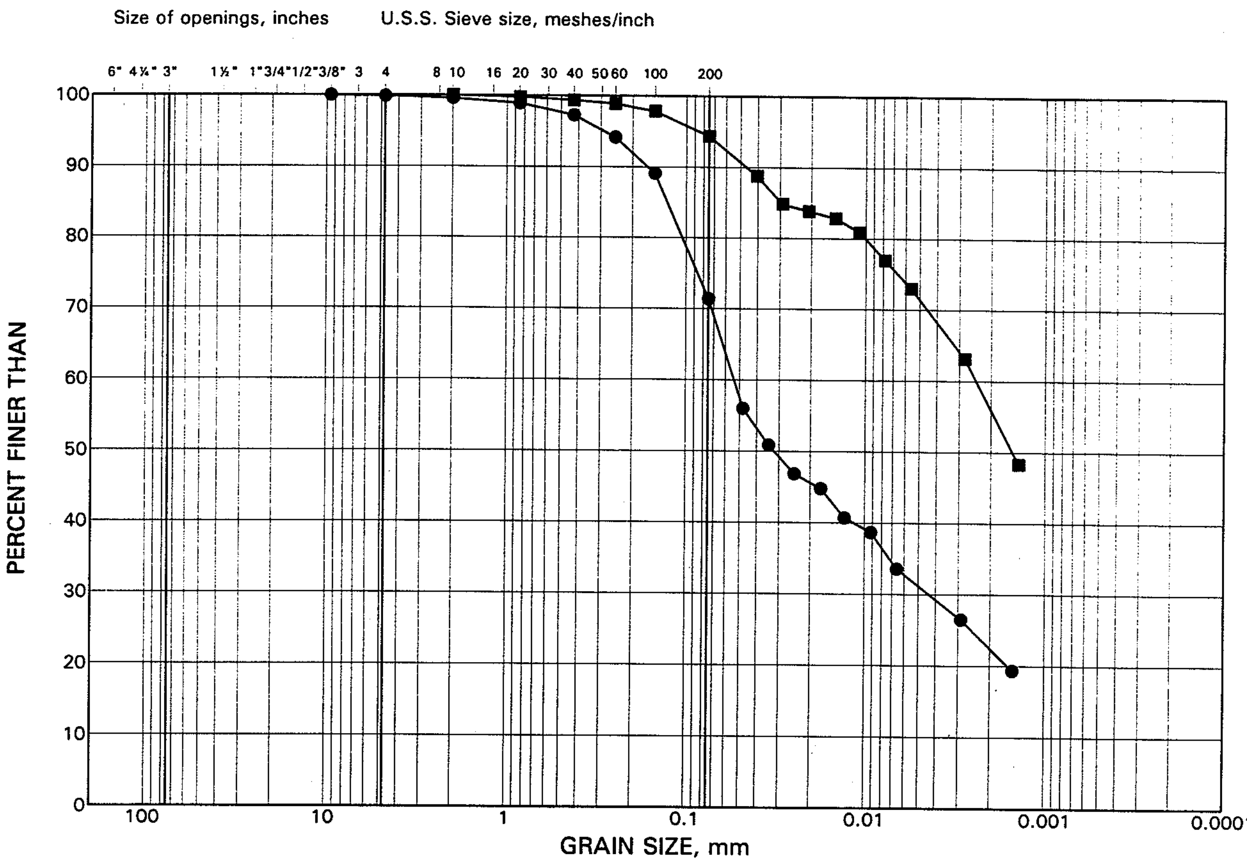
SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	99-1	2	1.4

Project 991-1168

Golder Associates

GRAIN SIZE DISTRIBUTION
Silty Clay

FIGURE 2



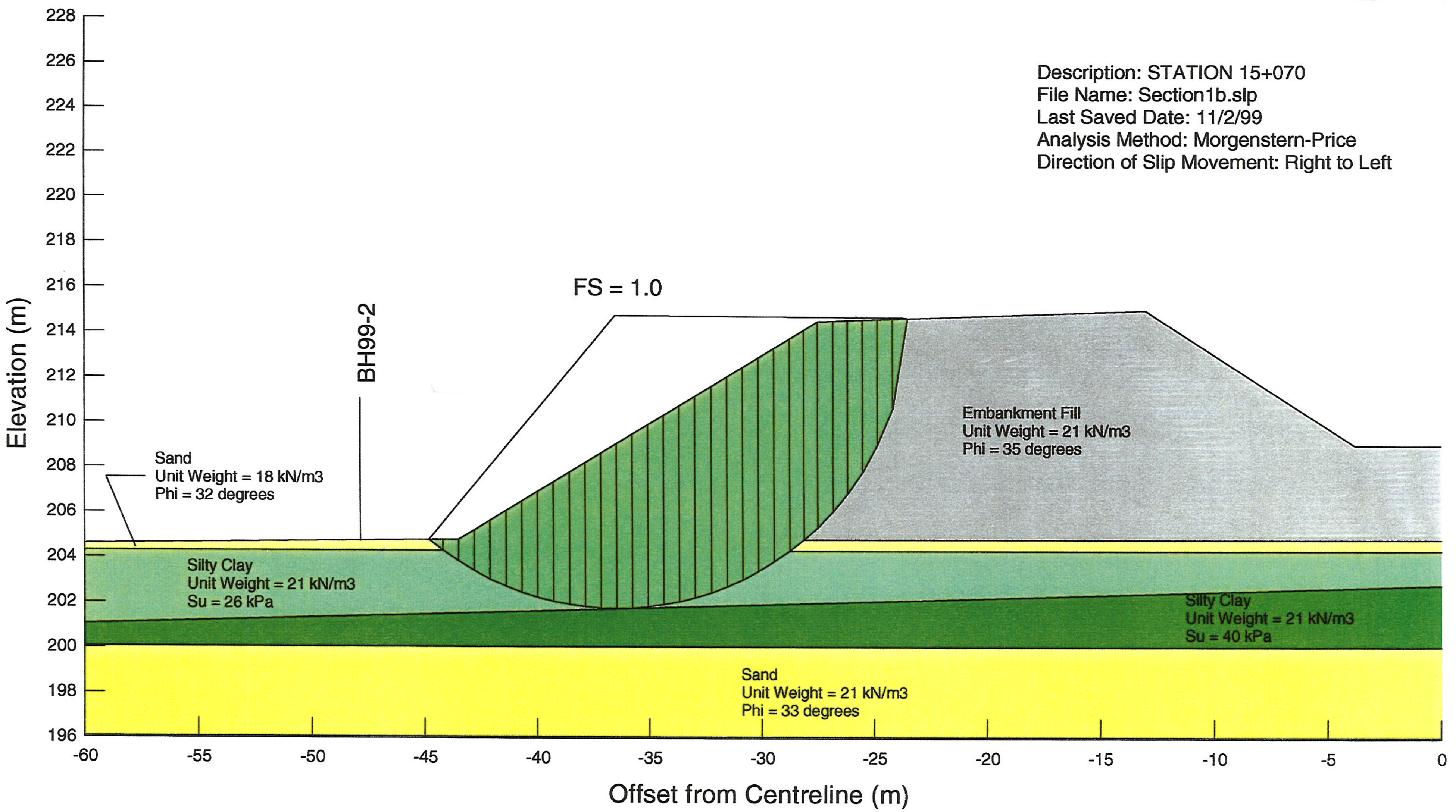
COBBLE	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY SIZES
SIZE	GRAVEL SIZE		SAND SIZE			FINE GRAINED

LEGEND

SYMBOL	BOREHOLE	SAMPLE	DEPTH(m)
●	99-2	3	2.9
■	99-2	4	3.7

SLOPE STABILITY ASSESSMENT
STA. 15+070

FIGURE 3



SCALE 1 : 250

Date NOVEMBER, 1999

Project 991-1168

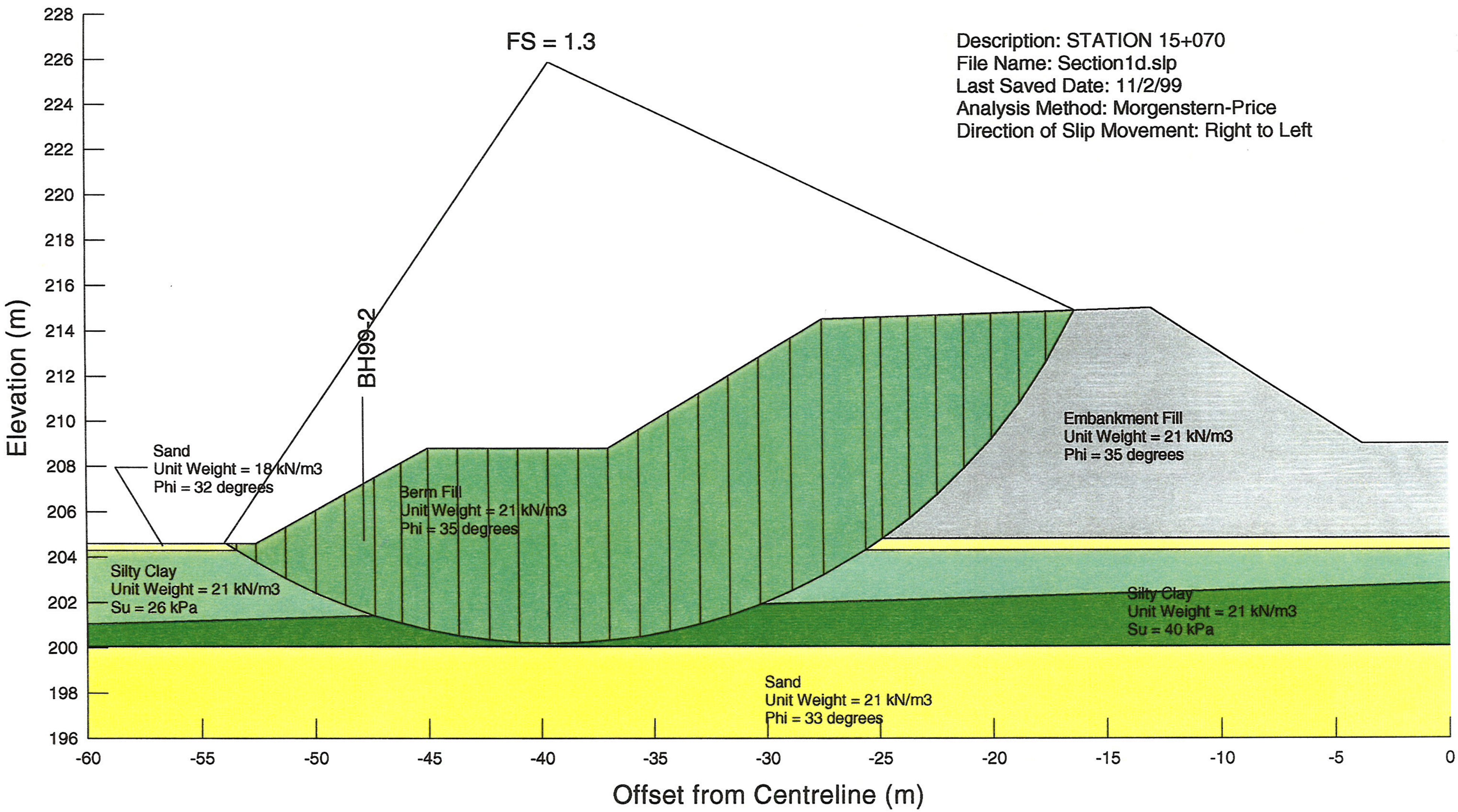
Golder Associates

Drawn R.J.

Chkd. D.K.B.

SLOPE STABILITY ASSESSMENT
STA. 15+070

FIGURE 4



SCALE 1 : 250

Date NOVEMBER, 1999

Project 991-1168

Golder Associates

Drawn R.J.

Chkd. D.K.B

SITE PHOTOGRAPH
HIGHWAY No. 11
NORTH BAY AREA

PLATE 1

DISTRESS CRACKS IN THE VICINITY OF CHAINAGE 15 + 000
(VIEW LOOKING SOUTH)

Project 991-1168 **Golder Associates** Date NOV. , 1999

SITE PHOTOGRAPH
HIGHWAY No. 11
NORTH BAY AREA

PLATE 2

DISTRESS CRACKS IN THE VICINITY OF CHAINAGE 15 + 000
(VIEW LOOKING NORTH)

Project 991-1168

Golder Associates

Date NOV., 1999.

APPENDIX A

CONSOLIDATION TEST RESULTS

OEDOMETER CONSOLIDATION SUMMARY

SAMPLE IDENTIFICATION

Project Number	991-1168	Sample Number	3
Borehole Number	99-2	Sample Depth, m	2.3-2.9

TEST CONDITIONS

Test Type	Quick	Load Duration, hr	(0.12 -0.42)
Oedometer Number	7		
Date Started	99-07-16		
Date Completed	99-07-16		

SAMPLE DIMENSIONS AND PROPERTIES - INITIAL

Sample Height, cm	1.91	Unit Weight, kN/m^3	19.33
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	15.13
Area, cm^2	31.55	Specific Gravity, measured	2.54
Volume, cm^3	60.10	Solids Height, cm	1.157
Water Content, %	27.77	Volume of Solids, cm^3	36.51
Wet Mass, g	118.49	Volume of Voids, cm^3	23.59
Dry Mass, g	92.74	Degree of Saturation, %	109.2

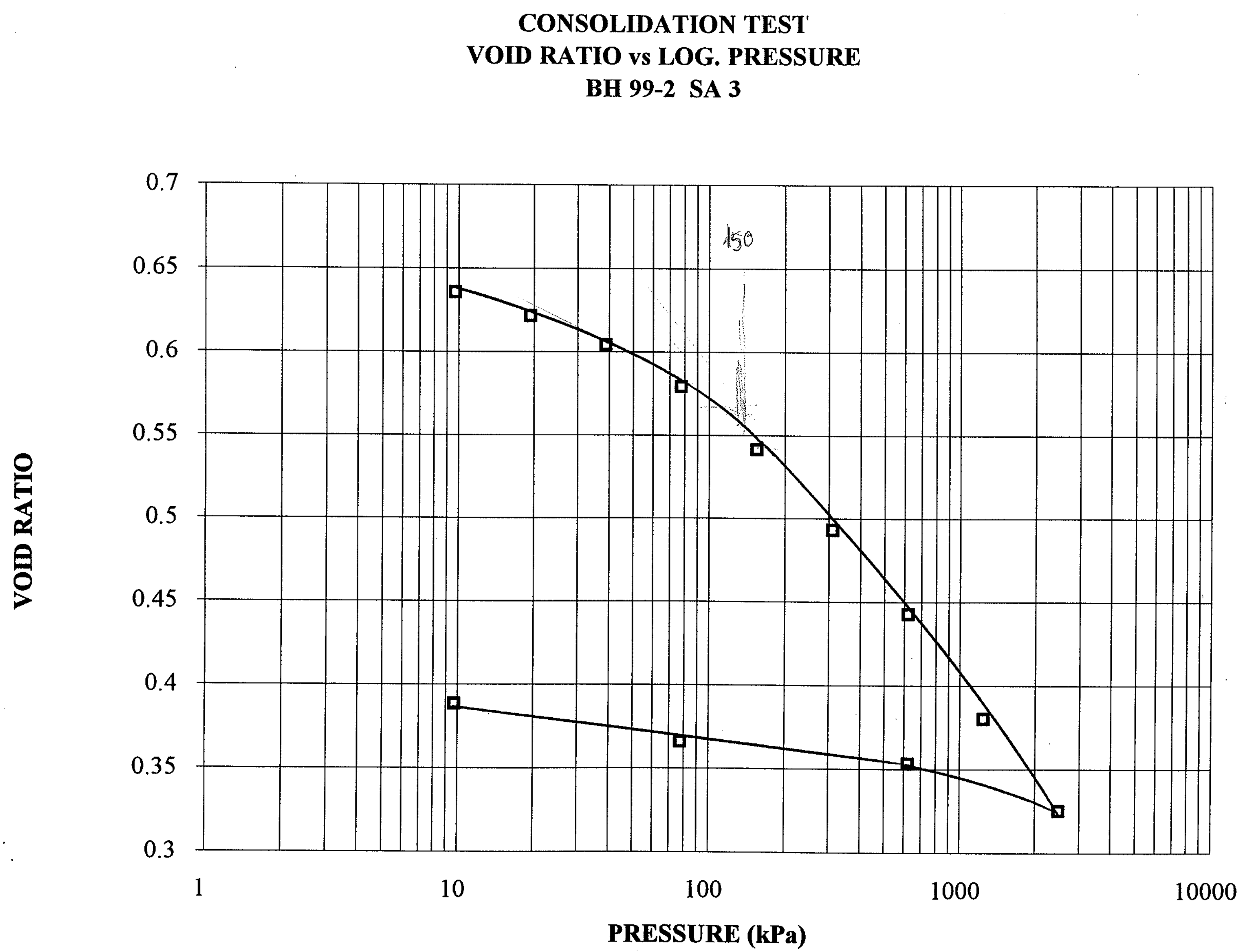
TEST COMPUTATIONS

Pressure kPa	Corr. Height cm	Void Ratio	Average Height cm	t_{90} sec	cv. cm^2/s	mv m^2/kN	k cm/s
0.00	1.905	0.646	1.905				
9.69	1.893	0.636	1.899	7	1.09E-01	6.61E-04	7.07E-06
19.39	1.876	0.621	1.884	42	1.79E-02	9.04E-04	1.59E-06
38.77	1.856	0.604	1.866	72	1.03E-02	5.36E-04	5.39E-07
77.54	1.827	0.579	1.842	16	4.49E-02	3.91E-04	1.72E-06
155.09	1.784	0.541	1.806	20	3.46E-02	2.95E-04	1.00E-06
310.17	1.728	0.493	1.756	24	2.72E-02	1.90E-04	5.06E-07
620.34	1.670	0.443	1.699	12	5.10E-02	9.83E-05	4.91E-07
1240.68	1.597	0.380	1.633	35	1.62E-02	6.13E-05	9.72E-08
2481.36	1.534	0.325	1.565	47	1.11E-02	2.70E-05	2.92E-08
620.34	1.566	0.353	1.550				
77.54	1.581	0.366	1.573				
9.69	1.607	0.388	1.594				

Notes:
k calculated using cv based on t_{90} values.

SAMPLE DIMENSIONS AND PROPERTIES - FINAL

Sample Height, cm	1.61	Unit Weight, kN/m^3	21.42
Sample Diameter, cm	6.34	Dry Unit Weight, kN/m^3	17.94
Area, cm^2	31.55	Specific Gravity, measured	2.54
Volume, cm^3	50.69	Solids Height, cm	1.157
Water Content, %	19.39	Volume of Solids, cm^3	36.51
Wet Mass, g	110.72	Volume of Voids, cm^3	14.18
Dry Mass, g	92.74		



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CONSOLIDATION TEST
VOID RATIO VS. LOG PRESSURE

FIGURE

OEDOMETER CONSOLIDATION SUMMARY