Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report to
GULF CANADA RESOURCES INC.
on
BEAUFORT SEA GEOTECHNICAL INVESTIGATION - 1981

WEST TINGMIARK

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812-2102

November, 1982

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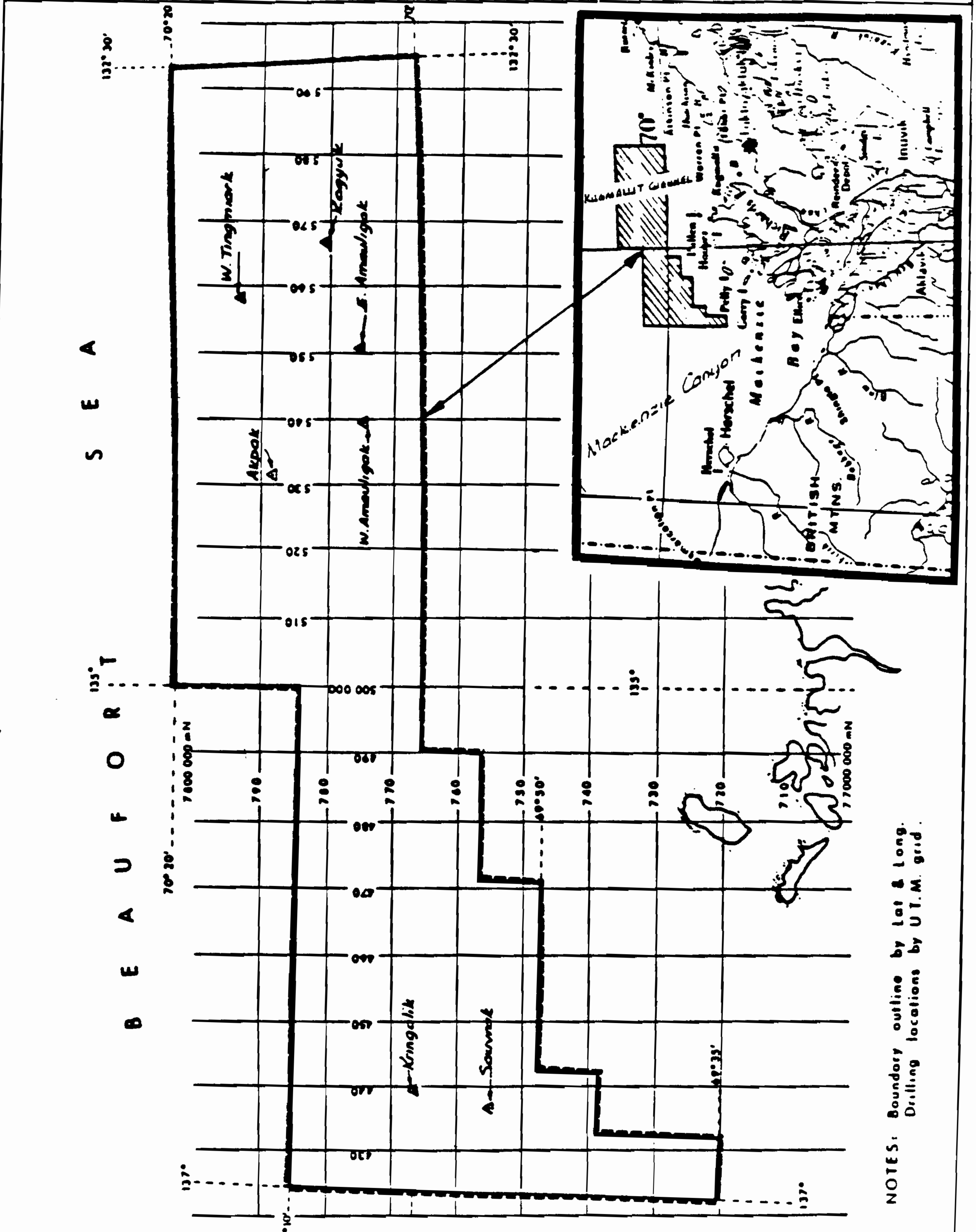

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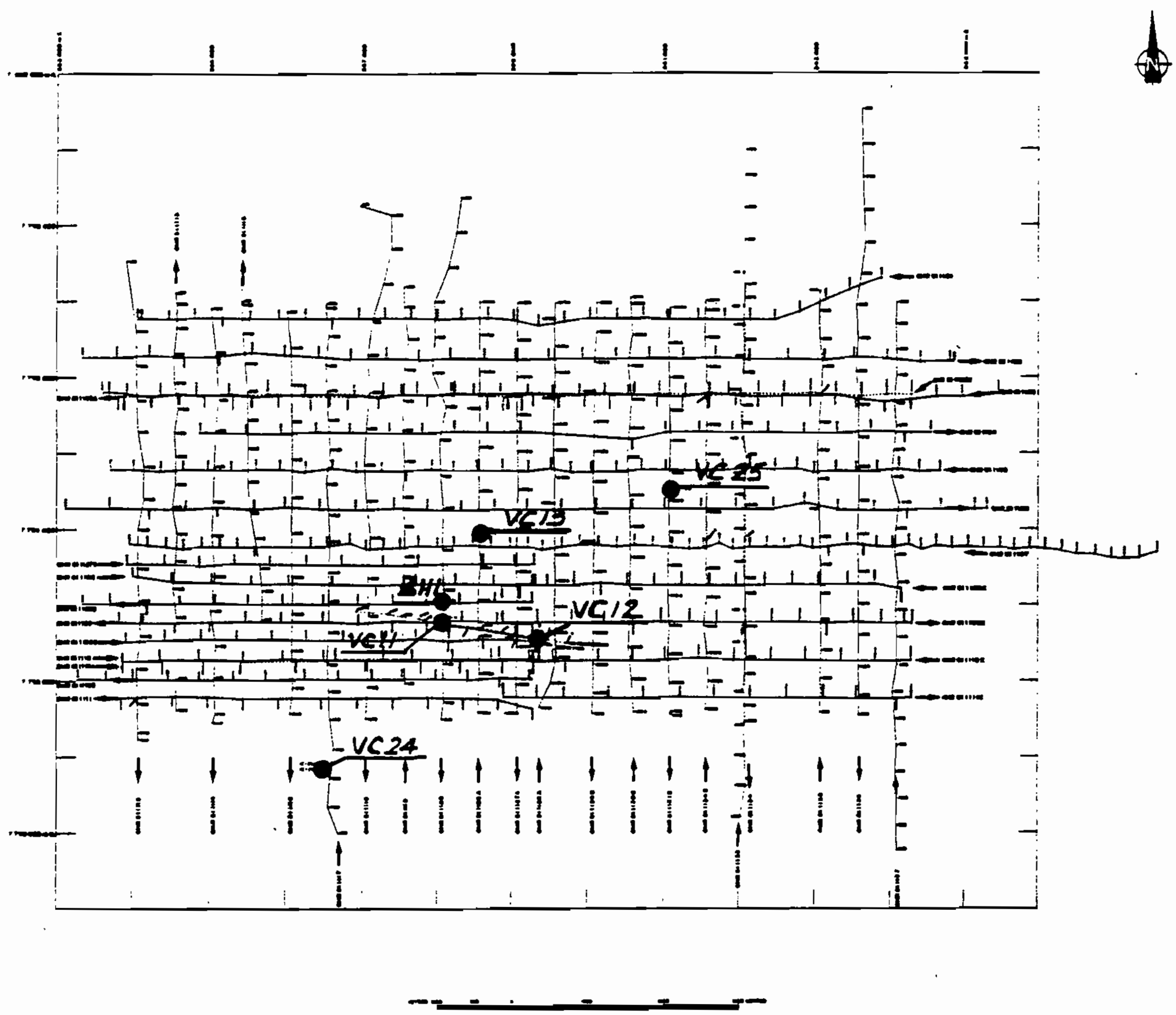
GEOPHYSICAL SURVEY LINES AND BOREHOLE LOCATIONS

Figure 2



WEST TINGMIARK

Project No. 812-2102 Drawn DS Reviewed Date NOV-82

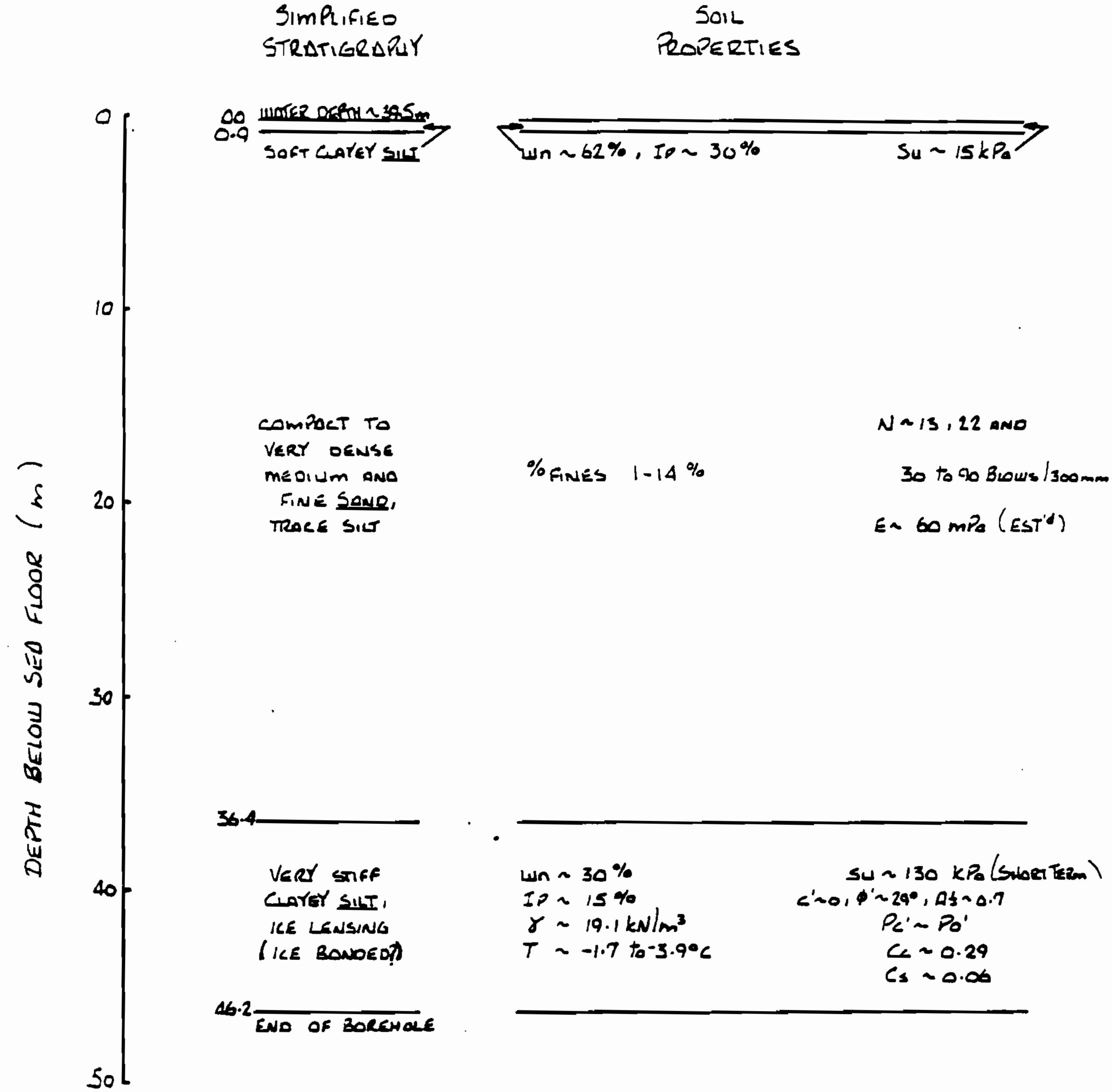
TABLE 1

Locations and Depths for West Tingmiark VC Boreholes
(Locations in UTM Zone 8, WAD 72)

Borehole		VC11	VC12	VC24	VC25
Location	N	7 792 747	7 792 548	7 790 927	7 794 509
	E	558 087	559 348	566 489	561 094
Depth(m)		12.2	15.2	8.2	10.4

SUMMARIZED STRATIGRAPHY AND ENGINEERING PROPERTIES FOR PRELIMINARY DESIGN
WEST TINGMIARK SITE

Figure 3



NOTE: STRATIGRAPHY AND ENGINEERING PROPERTIES GIVEN ON THIS FIGURE ARE FOR PRELIMINARY DESIGN PURPOSES ONLY.

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TABLE 2 LABORATORY TEST RESULTS, BOREHOLE #1 - WEST TINGMIARK

Unit #	Description	Sample #	Depth (m)	Wn %	W_L %	W_P %	Plastic Index	Unit Wt. (kN/m³)	Grain Size Distribution: Sand C	Sand M	Sand F	Fines* -	Silt C	Silt M	Silt F	Clay -	Fall Cone	Undrained Shear Strength (kPa): Pocket Penetrometer	Lab Vane Undist.	Lab Vane Rem.	Triaxial Tests	Consolidation Tests
1	Soft Clay	No Samples Taken																				
2	Compact to	1	0.9 - 1.5							46	50	4										
	very dense,	2	2.6 - 3.1						1	19	66	14										
	brown medium	3	4.1 - 4.6						2	86	10	2										
	and fine sand	4	5.6 - 6.1						2	82	14	2										
	trace of silt	5	7.0 - 7.5						7	86	5	2										
		6	8.5 - 9.0						2	87	9	2										
		7	10.2 - 10.6																			
		8	11.7 - 12.2						2	83	13	2										
		9	13.1 - 13.7						4	78	16	2										
		10	14.8 - 15.2						2	89	7	2										
		11	16.3 - 16.9						3	91	5	1										
		12	17.7 - 18.1																			
		13	19.4 - 19.8						1	79	18	2										
		14	20.9 - 21.3																			
		15	22.3 - 22.9						2	90	7	1										
		16	22.9 - 23.5						2	88	8	2										
		17	23.8 - 24.2						2	84	12	2										
		18	25.3 - 25.8						1	88	9	2										
		19	26.8 - 27.3							90	8	2										
		20	28.4 - 28.8							82	15	3										
		21	29.9 - 30.3							65	28	7										
		22	31.4 - 31.9							66	27	7										
		23	32.9 - 33.4							78	18	2										
		24	36.1 - 36.6	31.4																		
3	Very stiff	25	37.6 - 38.3	32.3	39	23	16	19.4		1	1		2	30	30	36	250	180			CIU, Unconfined	
	dark gray,	26	39.0 - 39.6	33.2	49	30	19	18.9									110	126			UU	OED
	clayey silt	27	40.5 - 41.2	29.2	44	30	14										150	172				
		28	42.1 - 42.7	33.6	38	25	13										134	126/203				
		29	43.6 - 44.2	28.6				19.0		1	2		10	37	25	25	82	76	94	26	CIU	
		30	45.1 - 45.7	30.2													191	203	100	6		

*All material passing #200 Sieve

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TABLE 3 - WEST TINGMIARK TRIAXIAL TESTS

Borehole No.	Sample No.	Depth (m)	Type of Test	Vert. Overbur. Pressure P_o' (kPa)	Cell Pressure (kPa)	Back Pressure (kPa)	Effective Consolid. Pressure (kPa)	Rate of Strain %/Hr	Failure: Deviator Stress (kPa)	Failure: % Strain	Failure: Change in Pore Press. (kPa)	Failure: A_f	Comments
1	25	37.6-38.3	CU*	360	655	255	400	3.2	383	7.7	275	0.70	Some ice lensing in sample
1	25	37.6-38.3	unconfined*	360	0	-	-	3.6	84	2.8	-	-	
1	26	39.0-39.6	UU*	375	760	-	-	3.5	97	4.2	-	-	Some ice lensing
1	29	43.6-44.2	CU	420	368	52	316	1.0	304	6.4	165	0.54	

* Denotes tests performed on Frank Broderick

APPENDIX 1

BOREHOLE, VIBRACORE LOGS and GRAIN SIZE CURVES

LIST OF ABBREVIATIONS

The abbreviations commonly employed on each "Record of Borehole," on the figures and in the text of the report, are as follows:

I. SAMPLE TYPES

AS	auger sample
CS	chunk sample
DO	drive open
DS	Denison type sample
FS	foil sample
RC	rock core
ST	slotted tube
TO	thin-walled, open
TP	thin-walled, piston
WS	wash sample

II. PENETRATION RESISTANCES

Dynamic Penetration Resistance: The number of blows by a 63.5 kg hammer dropped 760mm required to drive a 50mm diameter, 60 degree cone 0.3 m , where the cone is attached to 'A' size drill rods and casing is not used.

Standard Penetration Resistance, *N*: The number of blows by a 63.5 kg hammer dropped 760 mm required to drive a 50mm drive open sampler

WH sampler advanced by static weight—weight, hammer

PH sampler advanced by pressure—pressure, hydraulic

PM sampler advanced by pressure—pressure, manual

III. SOIL DESCRIPTION

(a) *Cohesionless Soils*

Relative Density	*N*, *blows*/0.3 m
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, kPa
Very soft	Less than 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	over 200

IV. SOIL TESTS

C	consolidation test
H	hydrometer analysis
M	sieve analysis
MH	combined analysis, sieve and hydrometer[1]
Q	undrained triaxial[2]
R	consolidated undrained triaxial[2]
S	drained triaxial
U	unconfined compression
V	field vane test
F	fall cone
L	lab vane
P	pocket penetrometer

NOTES:

[1]Combined analyses when 5 to 95 per cent of the material passes the No. 200 sieve.

[2]Undrained triaxial tests in which pore pressures are measured are shown as $\bar{Q}$ or $\bar{R}$.

LIST OF SYMBOLS

I. GENERAL

$\pi = 3.1416$

e = base of natural logarithms 2.7183

$\log_e a$ or $\ln a$, natural logarithm of a

$\log_{10} a$ or $\log a$, logarithm of a to base 10

- t time
- g acceleration due to gravity
- V volume
- W weight
- M moment
- F factor of safety

II. STRESS AND STRAIN

- u pore pressure
- σ normal stress
- σ' normal effective stress ($\bar{\sigma}$ is also used)
- τ shear stress
- ϵ linear strain
- ϵ_{xy} shear strain
- ν Poisson's ratio (μ is also used)
- E modulus of linear deformation (Young's modulus)
- G modulus of shear deformation
- K modulus of compressibility
- η coefficient of viscosity

III. SOIL PROPERTIES

(a) *Unit weight*

- γ unit weight of soil (bulk density)
- γ_s unit weight of solid particles
- γ_w unit weight of water
- γ_d unit dry weight of soil (dry density)
- γ' unit weight of submerged soil
- G_s specific gravity of solid particles $G_s = \gamma_s/\gamma_w$
- e void ratio
- n porosity
- w water content
- S_r degree of saturation

(b) *Consistency*

- w_L liquid limit
- w_P plastic limit
- I_P plasticity index
- 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
- D_r relative density $= (e_{max} - e)/(e_{max} - e_{min})$

(c) *Permeability*

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

(d) *Consolidation (one-dimensional)*

- m_v coefficient of volume change $= -\Delta e/(1+e)\Delta\sigma'$
- C_c compression index $= -\Delta e/\Delta \log_{10} \sigma'$
- c_v coefficient of consolidation
- T_v time factor $= c_v t/d^2$ (d, drainage path)
- U degree of consolidation

(e) *Shear strength*

- τ_f shear strength
- c' effective cohesion intercept; ϕ' effective angle of shearing resistance, or friction — in terms of effective stress $\tau_f = c' + \sigma' \tan \phi'$
- c_u apparent cohesion*; ϕ_u apparent angle of shearing resistance, or friction — in terms of total stress $\tau_f = c_u + \sigma \tan \phi_u$
- μ coefficient of friction
- S_t sensitivity

*For the case of a saturated cohesive soil, $\phi_u = 0$ and the undrained shear strength $\tau_f = c_u$ is taken as half the undrained compressive strength.

SOIL CLASSIFICATION SYSTEM

GRAIN SIZE SCALE: M.I.T. STANDARD

BOULDERS	Large than 200 mm
COBBLES	60 mm to 200 mm
GRAVEL	2 mm to 60 mm
SAND	0.06 mm to 2 mm
SILT	0.002 to 0.06 mm
CLAY	Smaller than 0.002 mm

COMPOSITION:

"and"	36 to 50%
"y" or "ey"	21 to 35%
"some"	11 to 20%
"trace"	0 to 10%

EXAMPLE:

Gravel 70% Sand 22%

Pass #200 Sieve 8%

Sandy Gravel, Trace of Silt

EXCEPTION:

Silt 70% Clay 30%

And plots above 'A' line

Silty clay not clayey silt

Summary of Ground Ice Descriptive System
(After Pihlainen and Johnston 1963, Linell and Kaplar 1966)

A. ICE NOT VISIBLE[a]

Group Symbol	Subgroup Description	Subgroup Symbol	Field Identification
N	Poorly bonded or friable	Nf	To determine presence of excess ice, use procedure under note[b] and hand magnifying lens as necessary. For soils not fully saturated, estimate degree of ice saturation: medium, low. Note presence of crystals or of ice coatings around larger particles.
	Well-bonded: No excess ice	Nb: Nbn	
	Well-bonded: Excess ice	Nb: Nbe	

B. VISIBLE ICE—LESS THAN 1 INCH THICK[a]

Group Symbol	Subgroup Description	Subgroup Symbol	Field Identification
V	Individual ice crystals or inclusions	Vx	For ice phase, record the following when applicable: Location; Size Orientation; Shape Thickness; Pattern of arrangement Length Spacing Hardness, Structure, Colour } per Group C Estimate volume of visible segregated ice present as percentage of total sample volume.
	Ice coatings on particles	Vc	
	Random or irregularly oriented ice formations	Vr	
	Stratified or distinctly oriented ice formations	Vs	

C. VISIBLE ICE—GREATER THAN 1 INCH THICK

Group Symbol	Subgroup Description	Subgroup Symbol	Field Identification
ICE	Ice with soil inclusions	ICE + soil type	Designate material as ICE[c] and use descriptive terms as follows, usually one item from each group, when applicable: *Hardness*: HARD, SOFT (of mass, not individual crystals) *Structure*[d]: CLEAR, CLOUDY, POROUS, CANDLED, GRANULAR, STRATIFIED *Colour* (Examples): COLOURLESS, GRAY, BLUE *Admixtures* (Examples): CONTAINS FEW THIN SILT INCLUSIONS
	Ice without soil inclusions	ICE	

(a) Frozen soils in the N group may, on close examination, indicate presence of ice within the voids of the material by crystalline reflections or by a sheen on fractured or trimmed surfaces. The impression received by the unaided eye, however, is that none of the frozen water occupies space in excess of the original voids in the soil. The opposite is true of frozen soils in the V group.

(b) When visual methods are inadequate, a simple field test to aid evaluation of volume of excess ice can be made by placing some frozen soil in a small jar, allowing it to melt, and observing the quantity of supernatant water as a percentage of total volume.

(c) Where special forms of ice such as hoarfrost can be distinguished, more explicit description should be given.

(d) Observer should be careful to avoid being misled by surface scratches or frost coating on the ice.

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RECORD OF BOREHOLE BH1

LOCATION (See Figure 1.2) N. 7 793 048 E. 588 066 WEST TINGMIARK   BORING DATE SEPTEMBER 13-15/1982   BOREHOLE DIAMETER 10.2 cm

SAMPLE HAMMER WEIGHT 63.5 Kg   DROP 0.76 METERS   DATUM SEA FLOOR

Boring Method: BQ SAMPLING RODS, AW RODS FOR IN SITU VANE TEST; 4 5/8 in. O.D. (117.5 mm) DRILL PIPE WITH CASING SHOE DRILL BIT. MUD SUPPORTED HOLE **

Elev. Depth (m)	Description	Number	Type	Blows/300mm	Temperature °C	Additional Lab. Testing
0.0	SEA FLOOR (WATER DEPTH ≈ 39.5 m)					
0.9	(1) SOFT GREY CLAYEY SILT					
1.5	COMPACT, GREY, FINE-MED, SAND	1	To		0	M
	(2) DENSE TO VERY DENSE BUT, OCCASIONALLY COMPACT, BROWN MEDIUM AND FINE SAND, TRACE OF COARSE SAND AND SILT	2	Do	42	0.6	M
4		3	Do	44	0.6	M
6	MINOR GREY FINE SANDY SILT TO SILTY SAND LAYERS BETWEEN 5.5 AND 10 m.	4	Do	55	0.6	M
8		5	Do	61	0.6	M
		6	Do	62		M
10		7	To		0.6	
12	THREE, THIN HORIZONTAL LAYERS OF BLACK MATERIAL AT 13 m.	8	Do	50	0.6	M
14		9	Do	40	0.6	M
16		10	Do	58		M
		11	Do	13		M
18		12	Do	45		
20		13	Do	31	0.6	M
22		14	Do	22	0.6	
		15	Do	89	0	M
24		16	Do	79	0.6	M
		17	Do	55	0.6	M
26		18	Do	33	0.6	M
27.5		19	Do	52	0.6	M
28	EXTREMELY HARD, POSSIBLY ICE BONDED LAYER	20	Do	51	1.1	M
30		21	Do	91	0.6	M
32	DENSE, MEDIUM AND FINE SAND	22	Do	47	0	M
		23	Do	38	0	M
34						
35.5	DENSE GREY FINE TO MEDIUM GRAINED SAND, TRACE OF SILT AND COARSE SAND.	24	Do	35	0.6	
36.4	(3) VERY STIFF, DARK GREY CLAYEY SILT, THINLY BEDDED SILT AND CLAY LAYERS, TRACE GRAVEL, OCCASIONAL THIN CLEAR RANDOMLY ORIENTED ICE LENSES (Vr). SOME MOTTLING AND RANDOMLY ORIENTED LAMINATIONS.					
38		25	To		-1.7	H, U, R̄ γ=19.4 kN/m³
		26	To		-1.7	qc γ=18.9 kN/m³
40		27	To		-2.2	
42		28	To		-2.2	
44		29	To		-2.2	MH, R̄ γ=19.0 kN/m³
46		30	To		-3.9	
46.5	END OF BOREHOLE					

Undrained shear strength (kPa), field vane: + Natural, ⊕ Remoulded (50, 100, 150, 200). Water content percent: W_p, W, W_L (20, 40, 60, 80).

VANE CAPACITY EXCEEDED IN ALL TESTS, REMOULDED TEST NOT CARRIED OUT.

NOTE: ALL T.O. SAMPLES WERE 75 mm DIA. ALL D.O. SAMPLES WERE 50 mm DIA.

Piezometer or standpipe installation: —

** CONDUCTOR STRING

a) 6 5/8 in (168 mm) OD RISER CASING FROM 1 m BELOW SEA FLOOR TO MOON POOL

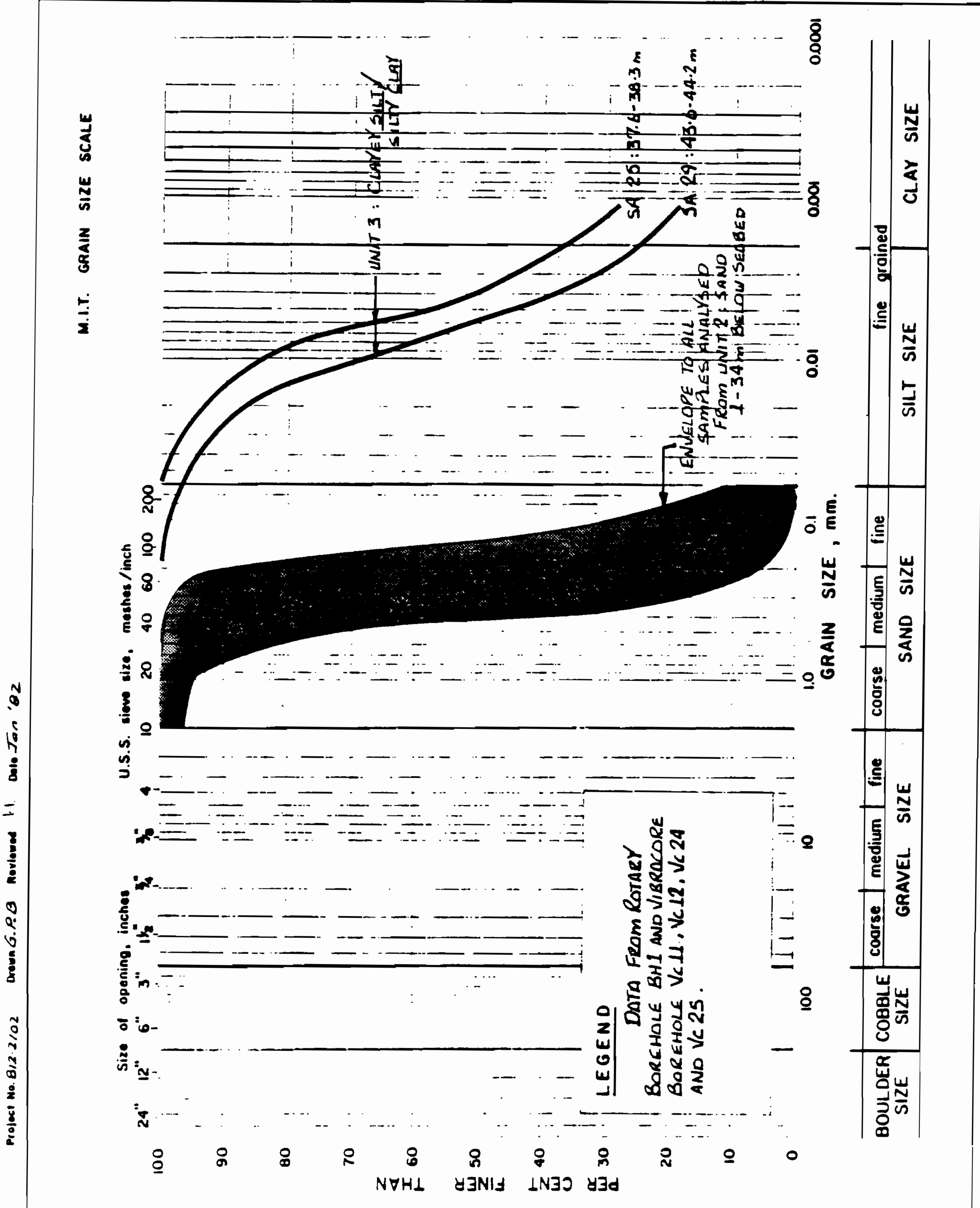
b) 8 5/8 in (219 mm) OD OUTER CASING TO 26.8 m BELOW MOON POOL DECK.

c) DRILLING MUD DISCHARGE ONTO SEABED THROUGH SLOTS IN 6 5/8 in. CASING

SCALE 1:200

GRAIN SIZE DISTRIBUTION

Figure 3



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RECORD OF BOREHOLE VC 11

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 792 747 E 558 087 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 3, 1981 WATER DEPTH: 39.9 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_p W W_L (20 40 60 80)	ADDITIONAL LAB. TESTING
	Sea Floor				
0.0	Very soft, dark grey clayey SILT				W=128%
0.8	Dark grey laminated clayey SILT				
1.1	Dense brown, medium grained SAND occasional organics fine to medium graded bedding occasional clay filled burrows		2		M
2.0			3		M
			4		M
4.0			5		M
6.0			6		M
8.0			7		M
			8		M
9.7	no recovery				

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RECORD OF BOREHOLE VC 11

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 792 747 E 558 087 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 3, 1981 WATER DEPTH: 39.9 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_P — W — W_L (20 40 60 80)	ADDITIONAL LAB. TESTING
10.0	no recovery				
12.0					
12.2	End of Borehole				

PROJECT No. 812-2102 **Golder Associates** BORE HOLE No. VC 11 SHEET 2 OF 2

RECORD OF BOREHOLE VC 12

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 792 548 E 599 348 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 3, 1981 WATER DEPTH: 37.5 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_p W W_L (20 40 60 80)	ADDITIONAL LAB. TESTING
	Sea Floor				
0.0	Very soft dark grey laminated clayey SILT				
1.8 / 2.0	as above with numerous layers of laminated, fine to medium grained sand				
3.3 / 4.0	Compact grey fine to medium grained SAND, very wet & highly saturated		3		M
5.2 / 6.0	Compact brownish grey fine to medium grained SAND, very wet		4		M
7.6 / 8.0	Dense greyish brown fine to medium grained SAND		5		M
9.3 / 10.0	Dense brownish grey, fine grained SAND, and SILT (silt layers)		6		M

PROJECT No 812-2102 **Golder Associates** BORE HOLE No. VC 12 SHEET 1 OF 2

RECORD OF BOREHOLE VC 12

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 792 548 E 599 348 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: September 3, 1981 WATER DEPTH: 37.5 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_p — W — W_L (20 40 60 80)	ADDITIONAL LAB. TESTING
10.0	as above				
10.8	Dense, brown medium grained SAND		7		M
12.1	no recovery				
14.0					
15.2	End of Borehole				

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RECORD OF BOREHOLE VC 24

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 790 927 E 566 489 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: October 8, 1981 WATER DEPTH: 29.6 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT W_P — W — W_L (20 40 60 80)	ADDITIONAL LAB. TESTING
	Sea Floor				
0.0	Grey medium to fine grained SAND, some silt and clay, some coarse sand		1		M
0.9	Brownish grey, medium to fine grained SAND, occasional shell fragments. some silt		2		M
2.0					
4.0			3		M
6.0			4		M
7.3	core lost				
3.0					
3.2	End of Borehole				

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RECORD OF BOREHOLE VC 25

UTM GRID ZONE 8 WAD 72

SITE NAME: West Tingmiark LOCATION CO-ORDS: N 7 794 509 E 561 094 DATUM: Sea floor

BOREHOLE TYPE: Sonic. DIAMETER: 10·16cm BORING DATE: October 8, 1981 WATER DEPTH: 36.9 m.

DEPTH. 1:50 (m)	SOIL DESCRIPTION	STRAT PLOT	SAMPLE NUMBER	WATER CONTENT PERCENT (W_p W W_L) 20 40 60 80	ADDITIONAL LAB. TESTING
	Sea Floor				
0.0	Very soft, grey silty CLAY, some sandy organics				
0.6	Brown to greyish brown medium to fine grained SAND, some silt		1		M
2.0			2		M
4.0			3		M
6.0			4		M
7.9	Greyish brown silty SAND, some clay				
8.2	Brown to greenish brown, medium to fine grained SAND, some silt		5		M
9.7	core lost				
10.0	End of Borehole 10.4 m				

PROJECT No. 812-2102 **Golder Associates** BORE HOLE No. VC 25 SHEET 1 OF 1

TABLE 2

GRAIN SIZE DISTRIBUTION

BOREHOLE VC - 11,12,24,25 BOREHOLE TYPE: Sonic SITE NAME: West Tingmiark

	Depth		Sample No.	Gravel	Sand			Fines	Silt			Clay
	From	To	—	—	C	M	F	—	C	M	F	—
VC 11	1.1	1.5	2	0	2	72	24	2				
	1.5	2.3	3	0	4	73	21	2				
	3.1	3.8	4	0	4	73	20	3				
	4.6	5.3	5	0	5	76	17	2				
	6.1	6.9	6	0	4	83	9	4				
	7.6	8.4	7	0	5	81	12	2				
	9.1	9.8	8	0	1	52	46	1				
VC 12	3.3	4.3	3	0	2	51	43	4				
	5.2	6.1	4	0	2	35	53	10				
	8.1	8.7	5	0	2	75	21	2				
	9.3	9.9	6	0	0	8	57	35				
	10.8	11.4	7	0	2	74	22	2				
VC 24	0.3	0.9	1	0	3	64	15	18				
	2.4	3.1	2	0	4	79	15	2				
	4.6	5.2	3	0	0	55	43	2				
	6.7	7.3	4	0	1	60	37	2				
VC 25	0.6	1.2	1	0	3	71	24	2				
	2.7	3.4	2	0	1	47	42	10				
	4.9	5.5	3	0	2	40	48	10				
	7.0	7.6	4	0	1	56	30	13				
	9.1	9.8	5	0	0	30	66	4				

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APPENDIX 2

SHEAR STRENGTH and CONSOLIDATION TEST RESULTS

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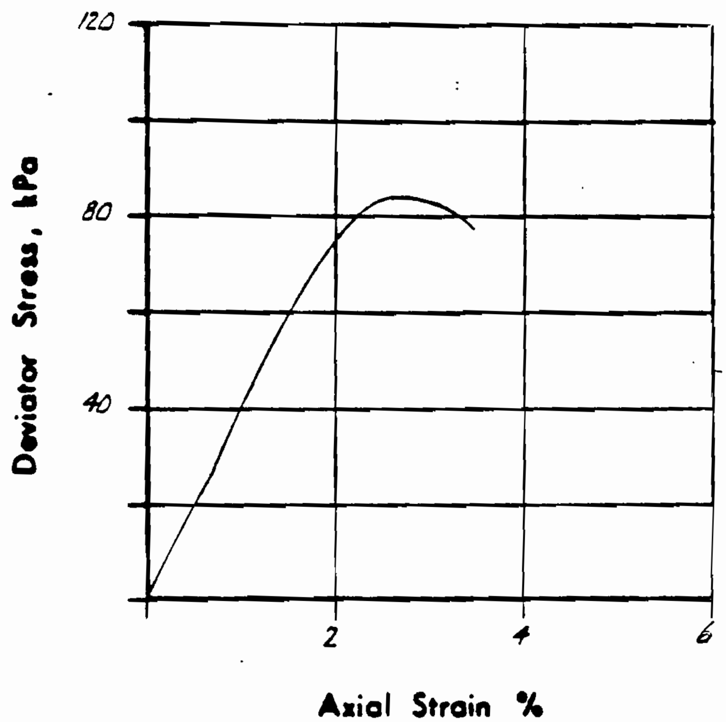
UNCONFINED COMPRESSION TEST

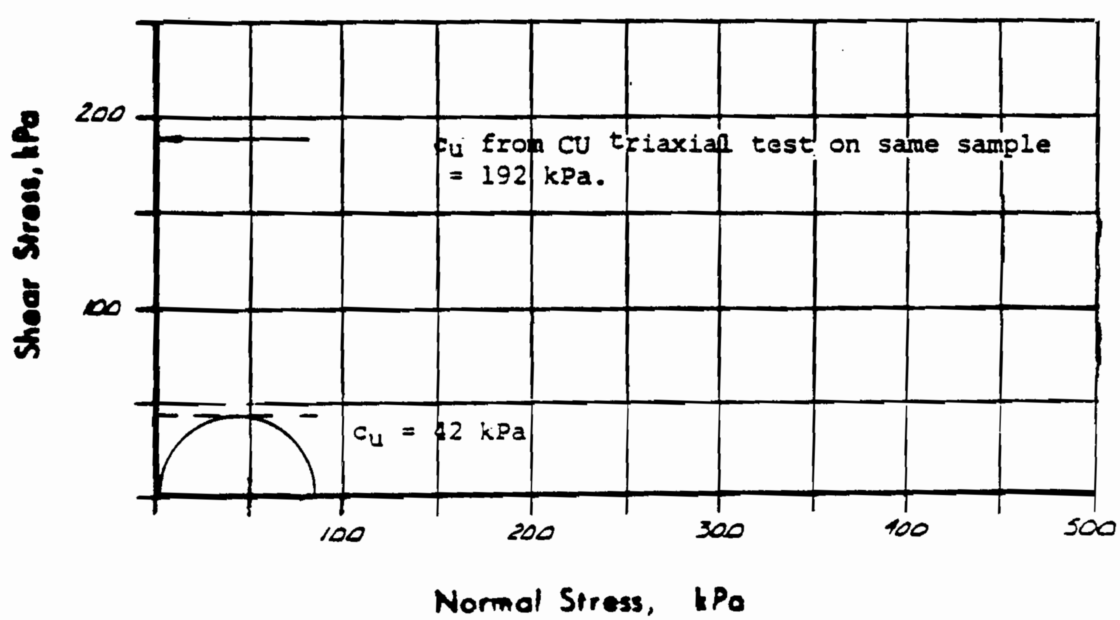
Figure. 5

Site. WEST TINGMIARK   Borehole No. 1

Sample No. 25   Depth 37.6 - 38.3 m

SUMMARY	
Cell Pressure kPa	unconfined
Rate of Strain % per hour	3.6
Deviator stress at failure: kPa	84
% Strain at failure	2.8





MOHR CIRCLE AT FAILURE

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

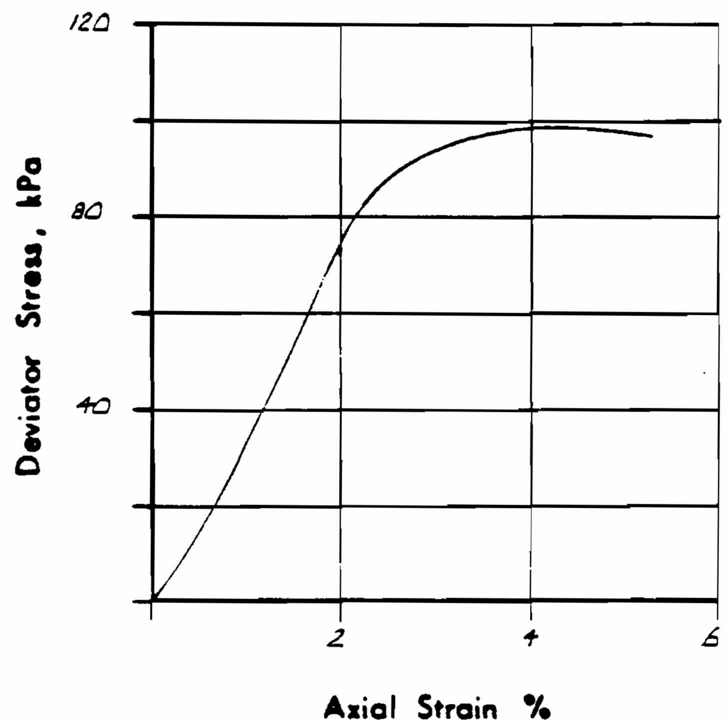
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST

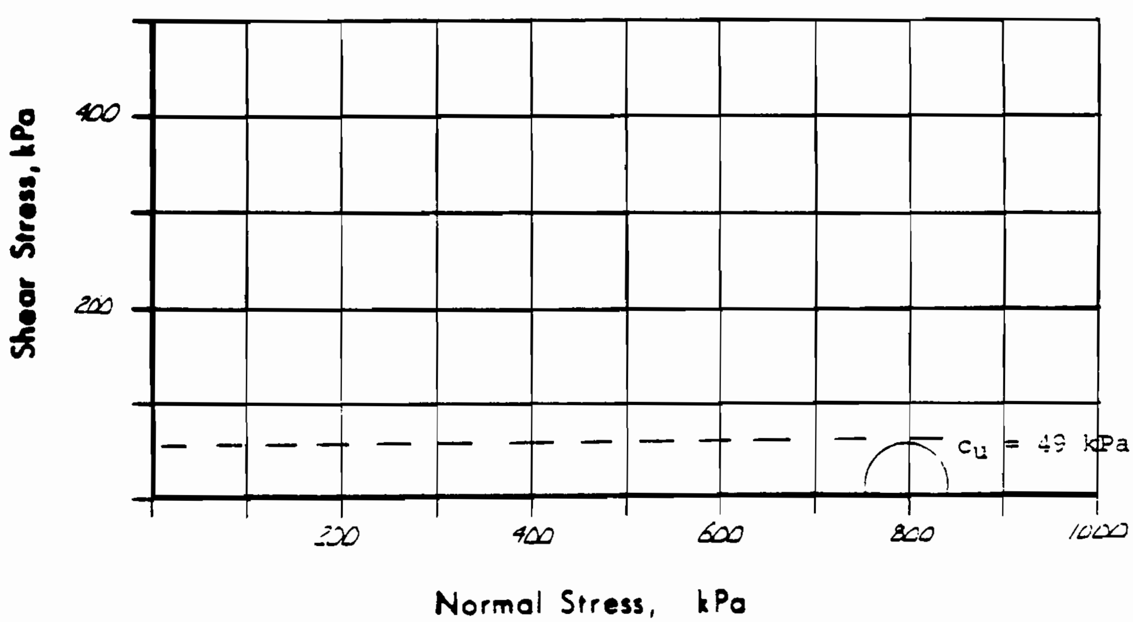
Figure. 6

Site. WEST TINGMIARK **Borehole No.** 1

Sample No. 26 **Depth** 39.0 - 39.6m

SUMMARY	
Cell Pressure kPa	760
Rate of Strain % per hour	3.5
Deviator stress at failure: kPa	97
% Strain at failure	4.2





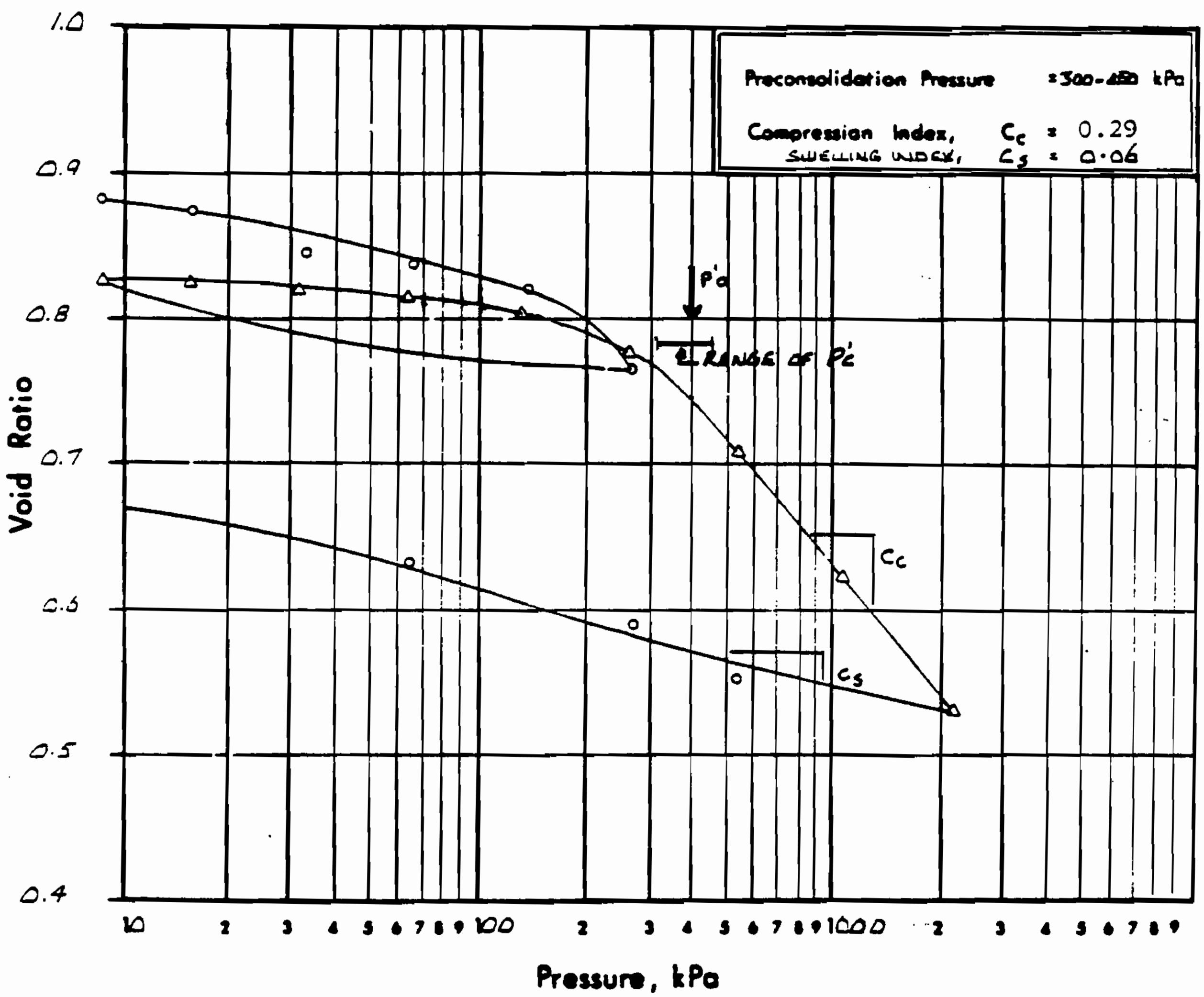
MOHR CIRCLE AT FAILURE

CONSOLIDATION TEST

Figure. 7

Site. West Tingmiark **Borehole No.** 1

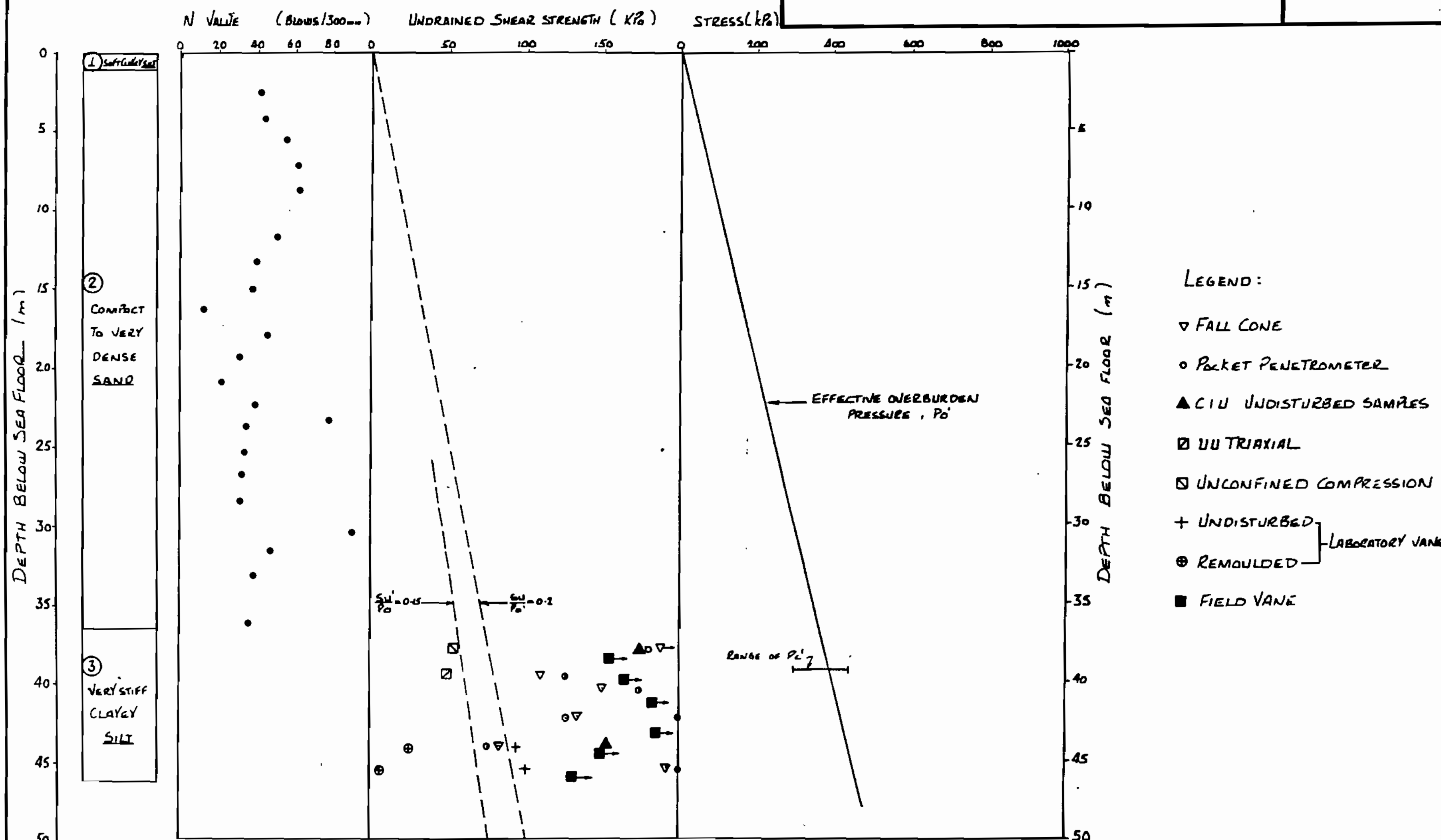
Sample No. 26 **Depth.** 39.0 - 39.6 m (P'_o ≈ 400 kPa)



PRESSURE kPa	VOID RATIO	m_v kPa^{-1}	c_v cm^2/sec	k cm/sec
8.4	0.831			
16.8	0.830	8.27×10^{-5}	9.2×10^{-2}	7.5×10^{-7}
33.7	0.825	1.69×10^{-4}	1.5×10^{-1}	2.4×10^{-6}
67.4	0.816	1.25×10^{-4}	8.2×10^{-2}	1.1×10^{-6}
134.7	0.803	1.11×10^{-4}	8.1×10^{-2}	8.8×10^{-7}
269.4	0.777	1.07×10^{-4}	8.0×10^{-2}	8.3×10^{-7}
538.8	0.711	1.37×10^{-4}	3.4×10^{-2}	4.5×10^{-7}
1078	0.627	9.12×10^{-5}	1.1×10^{-2}	9.9×10^{-8}
2155	0.536	5.21×10^{-5}	9.9×10^{-3}	5.1×10^{-8}

Strength and Preconsolidation Pressure Profiles

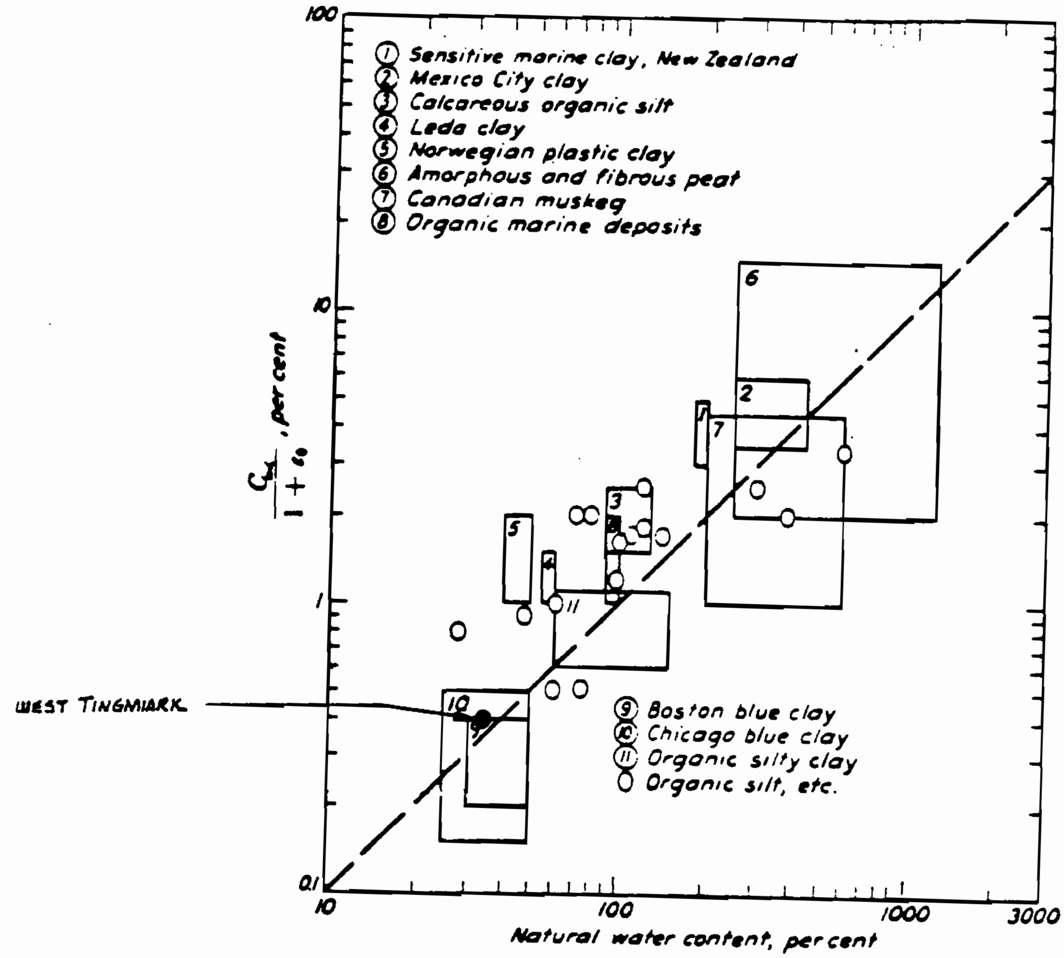
FIGURE 8



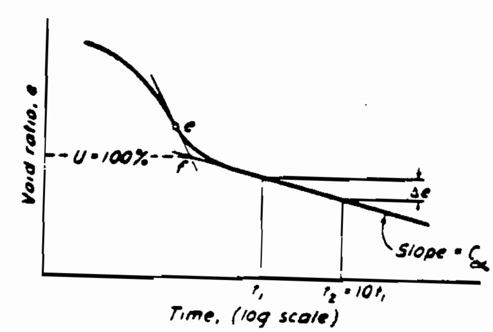
Golder Associates				
DRAWN: D.S.	SCALE	PROJECT: 812-2102	DATE: Nov-82	REVIEWED:

COEFFICIENT OF SECONDARY CONSOLIDATION vs WATER CONTENT

Figure 9



Relation between coefficient of secondary consolidation and natural water content of normally loaded deposits of clays and various compressible organic soils (after Mesri, 1972).



Project No 812 2112 Drawn Reviewed Date Oct '82

APPENDIX 3

FIELD INVESTIGATION PROCEDURES

The initial phase of the 1981 Field Program was to undertake geophysical traverses (by the Arctic Sounder) at the proposed site areas to determine, on a preliminary basis, the general stratigraphy at the sites. For calibration of the geophysical results and for the preliminary borrow search, a number of vibro-cored boreholes (VC series) were carred out from the same vessel. The vibra-coring carried out from the Arctic Sounder was not performed under the direction of Golder Associates, and details of these operations are therefore not included in this report. The geophysical and vibracore data was reviewed on site for selection of a potential MAC (Mobile Arctic Caisson) site within each site area. Potential MAC sites were selected based on water depth, thickness and consistency of surficial deposits, uniformity of stratigraphy and absence of permafrost.

Each selected MAC site was investigated by means of sampling and in situ testing from the Frank Broderick to verify the suitability of the chosen location from a geotechnical standpoint. Detailed sampled borings were put down from the Frank Broderick. This vessel was equipped with a diesel powered all hydraulic combined sonic/rotary top drive drillrig (modified Simco 5000 WS). The rig was mounted on rails to allow moving the rig and thereby to facilitate easier handling of casings and conductor pipes.

The casing system consisted of a conductor pipe and two different size casings. The conductor pipe, 203 mm (8") in diameter, was suspended from the moonpool cover to a maximum depth of approximately 27 m, to give additional lateral support to, and allow free vertical movement of, a 152 mm (6") casing, supported on the seafloor by means of a casing footing. The casing footing was equipped with longitudinal slots to allow discharge of the drilling mud onto the sea floor.

Inside the 152 mm (6") casing, 102 mm (4") casing was used for drilling and advanced by means of a wireline casing advancer. Sampling was carried out below the 102 mm (4") casing using split spoon sampling equipment and/or 76 mm (3") Shelby tubes attached to BQ drillrods.

In addition to conventional split spoon and Shelby tube sampling, the rig was also equipped for wireline Shelby tube sampling and down hole standard penetration testing. However, these options were not used due to time and weather constraints.

For the foundation investigation boreholes, the sampling intervals were generally 1.5 m down to approximately 30 m below sea floor, 3.0 m between 30 m and 60 m and 4.6 m below 60 m. These sampling intervals applied to both split spoon and Shelby tube sampling.

Despite occasional difficulties in performing the standard penetration test in rough weather conditions, the 'N' values obtained are considered to be reliable. This is supported by the comparison between SPT 'N' value profiles where profiles were drilled within 300 m of one another. All tests were performed using a rope and cathead system for raising the drop-hammer, with BQ drill rod used for sampling. Correction of 'N' values for overburden pressure, method of testing, length and type of drill rod was not carried out.

In situ vane tests were performed with a Nilcon vane borer at selected depths in cohesive soils. This instrument has a limited twist slip coupling between the vane and rods, which allows the vane shear resistance to be distinguished from rod friction. In addition a continuous mechanical trace of torque against rotation is obtained. All tests were carried out using a 100 mm vane, with a rated capacity of 220 kPa. Remoulded tests were generally performed after measurement of peak (undisturbed) strengths. To ensure that the vane remained stationary in the soil, the vane and vane rods were suspended from the 152 mm casing resting on the sea bed. Field vane strengths measured during this investigation have not been modified to account for effects such as strain rate or anisotropy.

In addition to the above techniques Static Cone Penetration Testing was attempted, but no results were obtained due to difficulties in handling the equipment on the ship. The equipment was however tried and calibrated by testing in shallow water and under ideal weather conditions.

APPENDIX 4

LABORATORY TESTING PROCEDURES

The geotechnical laboratory on the Frank Broderick was equipped for routine testing of all samples and for preliminary shear strength determination on cohesive soils. The laboratory equipment included the following.

- Hydraulic sample extruder for extrusion of Shelby tube samples.
- Sieves, hydrometers and balances for determination of grain size distribution.
- Oven for water content determination
- Casagrande liquid limit device for determination of liquid limit.
- Pilcon shear vane, pocket penetrometer and Geonor fall cone for determination of undrained shear strength.
- Triaxial apparatus for determination of shear strength by unconfined compression tests, UU (unconsolidated undrained) or CU (consolidated undrained) triaxial tests.
- Thermometers for temperature measurement of samples.
- Microscope for classification of ice bonded soils.

Split spoon samples were classified and a portion of each sample was placed in a sealed container for shipment to Calgary. For most samples, a sieve analysis was carried out on the ship. Hydrometer tests were attempted but were found to give incorrect results due to vibrations and the movements of the ship.

Following extrusion and classification of Shelby tube samples, one portion of each sample was sealed and prepared for shipment to Calgary and another was used for on board testing. On board, laboratory shear strength measurements were made using the fall cone, Pilcon vane and pocket penetrometer. The portions of samples retained onboard were used for determination of moisture content, Atterberg limits and for triaxial testing.

Where temperature measurements indicated the possibility of ice bonding, without visual evidence of ice, the samples were examined under the microscope.

Sample temperatures were taken as soon as the samples arrived in the laboratory by inserting a 1.5 mm diameter probe into the sample. Initially a mechanical dial gauge type reading to the nearest degree Fahrenheit was used. Towards the end of the investigation, an electronic thermometer, accurate to 0.1°C. was used.

Temperatures measured on Shelby tube samples are probably close to the in situ temperature, as ambient temperatures during most of the operation were close to 0°C. Temperatures of split spoon samples should be considered as approximate only as the temperature could be significantly altered when the sampler is driven, particularly as the blowcounts were frequently high.

In general, it appeared that ice or ice bonding was present in samples where the measured temperature was lower than approximately -1.6°C. However, some thawing during the sampling process occurs and this figure may not be representative for the material in situ.

All consolidation tests were performed using a conventional oedometer cell and gravity loading frame. The loading procedure was, however, modified slightly to improve the assessment and interpretation of test results. The vertical stress on the sample was applied in increments up to an effective stress level slightly less than the in situ effective overburden pressure. This load was then removed, allowing the sample to swell back under a nominal load. The purpose of this loading and unloading is to reduce the effects of sample disturbance on the consolidation curve obtained from the subsequent load increments. After the initial loading and rebound, the consolidation tests were performed in the usual manner. Samples were unloaded in increments after the final load increment. Each load was allowed to remain on the sample until primary consolidation was completed, based on Taylors "square root of time" interpretation. Therefore the void ratio - log stress curves have not been corrected for secondary compression effects.

The undrained shear strength of samples was measured using a number of methods. It should be appreciated that rapid methods (i.e. laboratory vane, fall cone and pocket penetrometer tests) provide only approximate values of undrained shear strength since considerable scatter in test results is frequently evident from these various tests on the same sample. This variation is caused by a combination of varying boundary conditions and effective stress paths associated with the various tests. Other factors are also important, such as varying strain rate, and effect of intrinsic anisotropy of the soils being tested together with the small volume of test sample in relation to natural heterogeneity of the soil.

Effective stress strength parameters (c' and Ø') were determined in consolidated undrained triaxial tests with porewater pressure measurement ($\overline{R}$ tests). The triaxial test specimens were about 72 mm in diameter and 156 mm high. To ensure saturation of the test specimens (B>99%), back pressures were applied. Following saturation, the specimens were consolidated. When consolidation was completed, drainage from the test specimen was shut off and undrained shearing carried out at a constant rate of strain. The strain rate of 1 to 3.2%/hr. adopted in these tests allows for equalization of porewater pressure throughout the samples. Water contents, unit weights and Atterberg limits were determined for the majority of triaxial test specimens.

Unconsolidated undrained (UU) tests and unconfined compression tests were also carried out on "undisturbed" samples to determine undrained shear strength. However, it should be noted that since the effective test paths followed in the various tests are quite different, measured undrained strengths may also vary.