SECTION 4 GROUND CONDITIONS OF KAMPONG PANDAN AND SENTUL

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As explained in Section 1 (Introduction), two typical ex-mining lands were first selected for the present study; i.e. Kampong Pandan and Sentul. Fig. 4-1 shows the locations of the sites. Detailed investigations were performed in these 2 sites in order to explore subsurface ground conditions of ex-mining land during both Phase I and Phase II.

The field works for Phase I were carried out during the period from December 1979, to February 1980, and those for Phase II were performed during the period from September 1980, to July 1981.

The ground investigations carried out at the Kampong Pandan and Sentul sites are classified into 2 categories, i.e. field subsurface ground investigations and laboratory soil/rock tests.

To study the sub-soil condition in detail, a pilot test area was established at the Sentul site. Very detailed and extensive subsurface investigations were performed at the pilot test area.

In addition to the various types of subsurface investigations, a test embankment was constructed at the pilot test area, and the behaviour of the ground under the load of the embankment was also monitored. Details and results of the test embankment are presented in Section 6.

SECTION 4

GROUND CONDITIONS

OF KAMPONG PANDAN AND SENTUL

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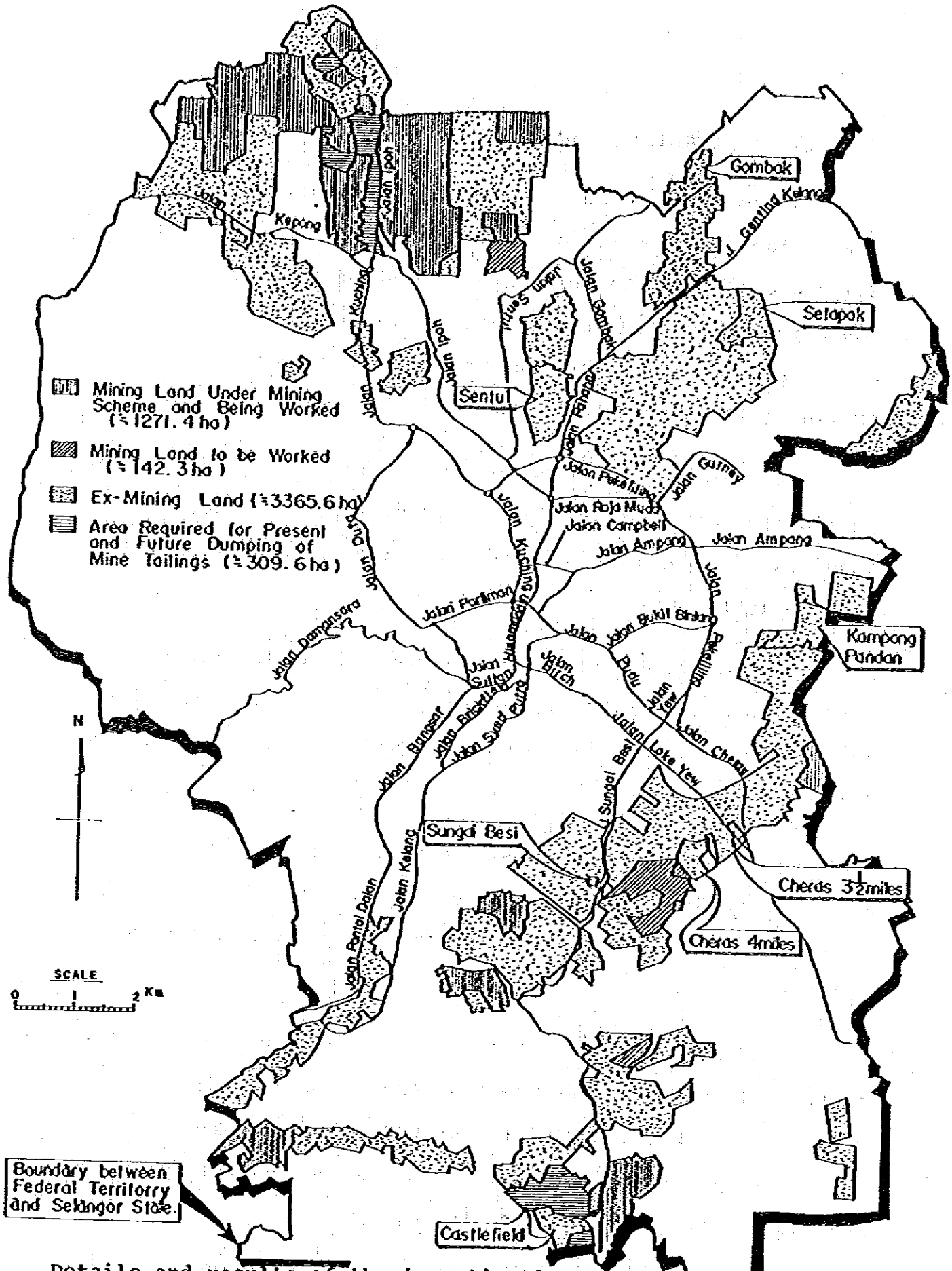


Details and results of the investigation at Kampong Pandan and Sentul are presented in Section 4, those for the other 6 sites are presented in Section 5.

Fig. 4-1 Location of Sites Investigated

In the present section, the first part describes the contents and results of the subsurface ground investigations performed at the Kampong Pandan site with a description of the subsurface ground condition following. The latter part describes those of the Sentul site.

4.1 Kampong Pandan

The Kampong Pandan site is situated 5 km away from the city centre, next to the edge of the Federal Territory and adjacent to the Royal Serangor Golf Course. The acreage of the site is about 43 ha. There are many ponds at the site and an abundance of water grass is also present. Most of the dry areas are occupied by squatters.

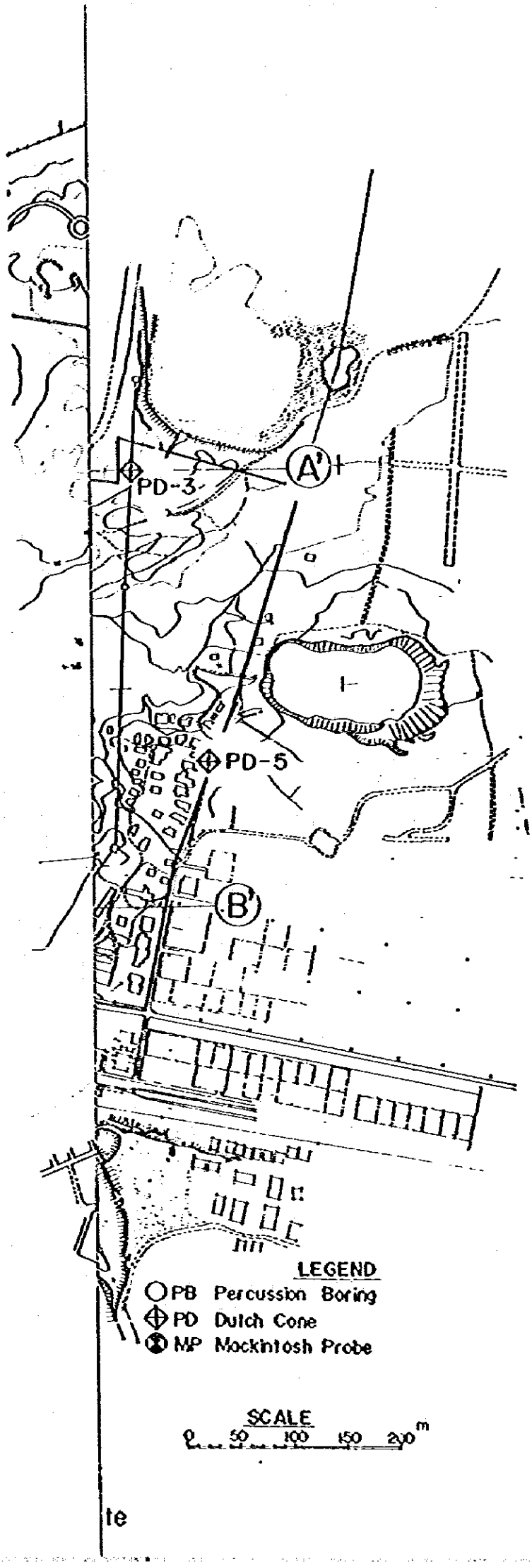
4.1.1 Details of Subsurface Ground Investigations Performed at Kampong Pandan

As already mentioned, field investigations and laboratory soil tests were carried out at the Kampong Pandan site. Fig. 4-2 shows the site plan and locations of the filed investigations performed at the site.

Percussion borings were carried out at 5 locations and were accompanied by Standard Penetration Tests (SPT) at each 1m in depth. Dutch cone penetrometer tests were also carried out at 9 locations. To investigate the sub-bottom soil conditions of ponds, Mackintosh probe tests and soil samplings were carried out. The samplings were performed using a peat

sampler and obtained disturbed soil samples. Details of these field works are summarized in Table 4-1.

Laboratory soil tests were performed on the soil samples obtained by standard penetration tests. Types of tests and quantities performed are summarized in Table 4-2. These tests were carried out at the soil mechanics laboratory of Kiso-Jiban Consultants, Singapore Branch.


PD-3
A'
PD-5
B'
LEGEND
PB Percussion Boring
PD Dutch Cone
MP Mockintosh Probe
SCALE
50 100 150 200 m
te

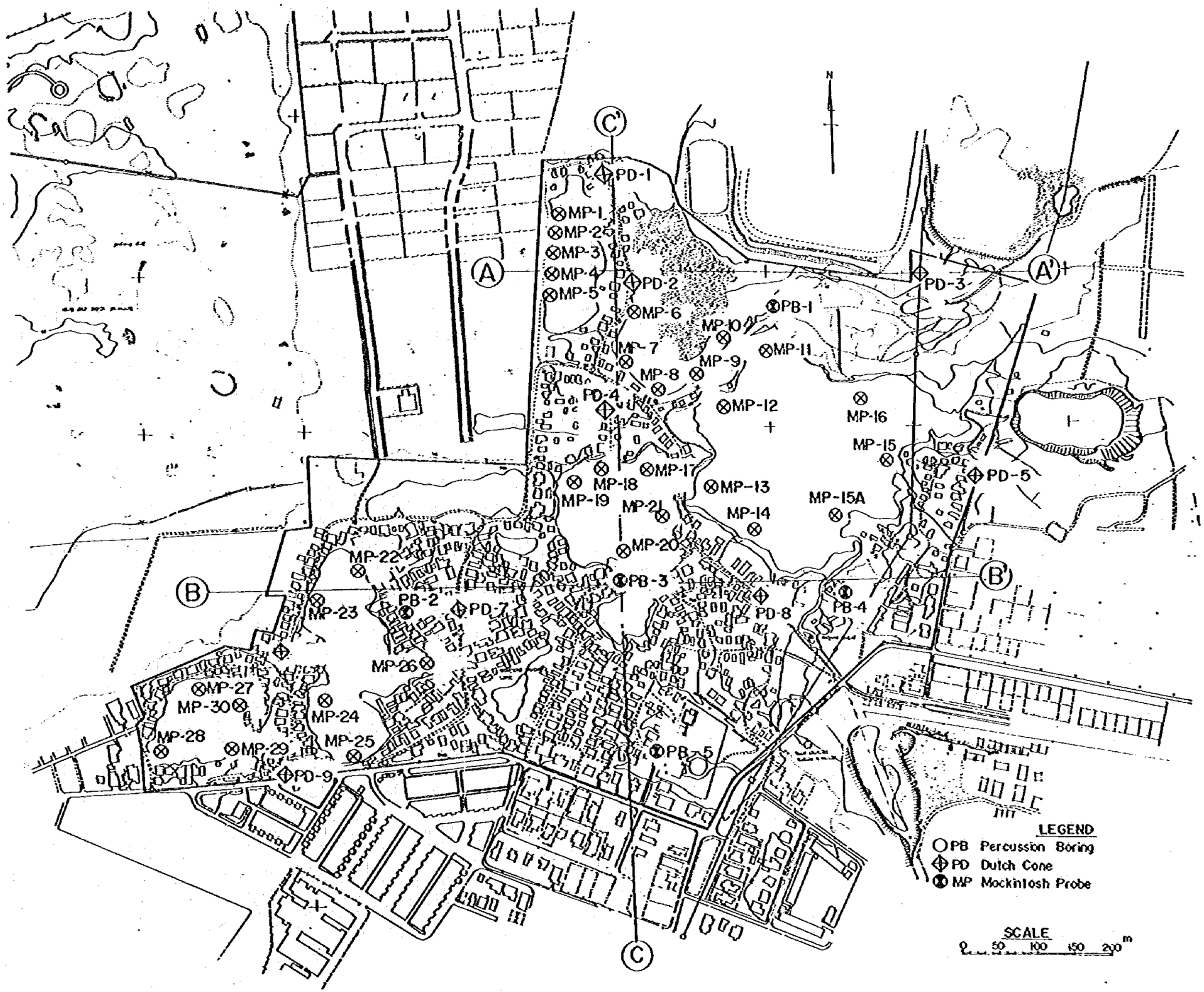


Fig. 4-2 Boring and Sounding Locations at Kampong Pandan Site

Table 4-1 Details of Field Ground Investigations Performed at Kampong Pandan

On Land					In Pond			
Percussion Boring			Dutch Cone Penetrometer Test		Mackintosh Probe Sounding			Disturbed Soil Sampling*
Boring No.	Boring Depth (m)	Standard Penetration Test (Nos.)	Test No.	Sounding Depth (m)	Pond No.	Location No.	Sounding Depth (m)	(Nos.)
PB-1	21.80	22	PD-1	22.6		MP-1	7.6	3
PB-2	7.25	7	PD-2	18.4		MP-2	9.1	3
PB-3	14.75	15	PD-3	20.8	P-1	MP-3	9.4	3
PB-4	11.55	11	PD-4	13.8		MP-4	10.0	3
PB-5	15.10	15	PD-5	6.0		MP-5	10.6	2
			PD-6	16.8		MP-6	7.5	5
			PD-7	16.6		MP-7	9.7	5
			PD-8	6.0	P-2	MP-8	10.9	6
			PD-9	18.2		MP-9	10.1	5
						MP-10	10.0	4
						MP-11	7.9	5
						MP-12	9.4	3
						MP-13	8.5	6
					P-3	MP-14	8.8	4
						MP-15A	11.5	5
						MP-15	8.5	6
						MP-16	7.9	4
						MP-17	9.3	4
						MP-18	8.1	3
					P-4	MP-19	9.4	3
						MP-20	7.5	2
						MP-21	9.4	3
						MP-22	4.8	4
						MP-23	6.6	3
					P-5	MP-24	4.9	3
						MP-25	6.6	3
						MP-26	5.4	3
						MP-27	11.6	2
					P-6	MP-28	8.2	2
						MP-29	9.1	4
						MP-30	11.9	3
Total 5 ** loc.	70.45m	70 Nos.	9 ** loc.	139.2 m	6 ponds	31 locations	320.8 m	138 Nos.

* Disturbed soil samplings were performed at Mackintosh probe test locations using a peat sampler

** loc.: locations

Table 4-2 Laboratory Soil Tests Performed on Samples from Kampong Pandan

Area			On Land				
Type of Boring			Percussion				Total
Boring No.			PB-1	PB-2	PB-3	PB-5	
Physical Property Tests	Water Content (Nos.)		10	5	9	7	31
	Specific Gravity (Nos.)		10	5	9	7	31
	Unit Weight (Nos.)		-	-	-	-	-
	Atterberg Limits (Set)		4	4	3	-	11
	Grain Size Analysis	By Sieve Only (Nos.)	4	1	3	7	15
		By Sieve and Sedimentation (Nos.)	6	4	6	-	16
Study Phase			I				

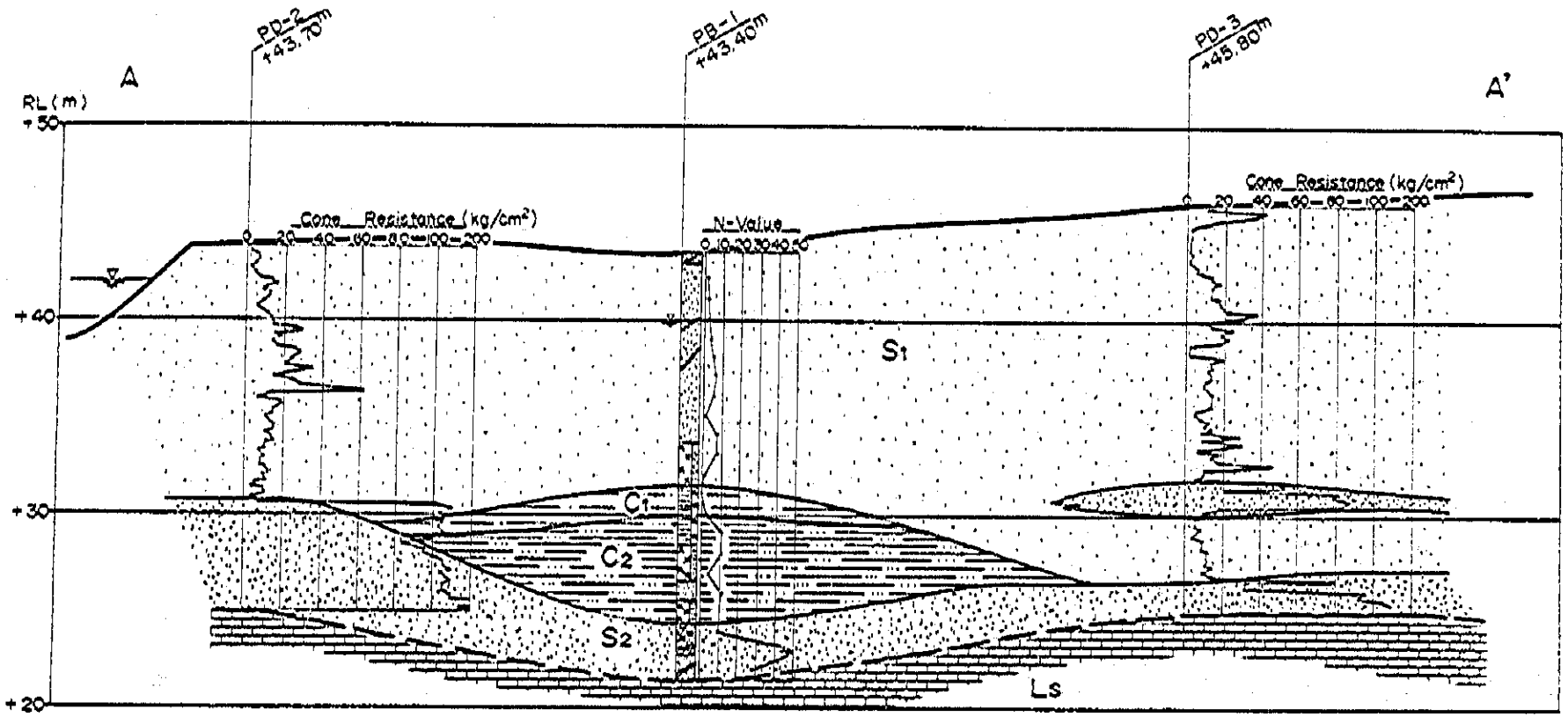
4.1.2 Subsurface Ground Conditions at Kampong Pandan

According to the mining record of the Kampong Pandan site, the proposed area may be classified into sandy and clayey areas. However, as the indicated clayey areas were filled with water, most of the percussion borings and Dutch cone penetrometer tests were performed at the indicated sandy areas. The locations of the borings and the cone penetrometer tests are shown in Fig. 4-2. Figs. 4-3a to 4-3c show cross sections of the subsurface ground at the Kampong Pandan site. The results of laboratory soil tests performed on samples from the Kampong Pandan site are summarized in Table 4-3.

As will be explained in detail in Section 5, ground conditions of ex-mining land has been classified for the purpose of clarification into 5 types in this report (Table 4-4). At the Kampong Pandan site, all 5 types of ground were found. However, Type A ground is more predominant at Kampong Pandan. Hard layers with N-values of more than 50 were encountered at a depth of 7 to 20m with an average of 13.5m. Ground water tables were found at depths of 2 to 4m. A description of the layers encountered at Kampong Pandan follows:

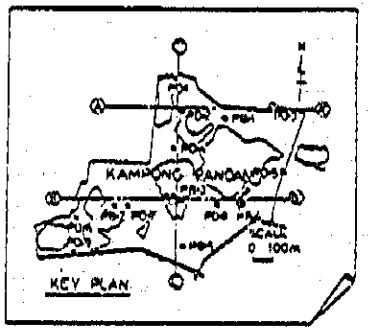
1) Clayey Layers

The clayey layers at Kampong Pandan site generally contain some amount of sand and gravel particles.



Horizontal Scale

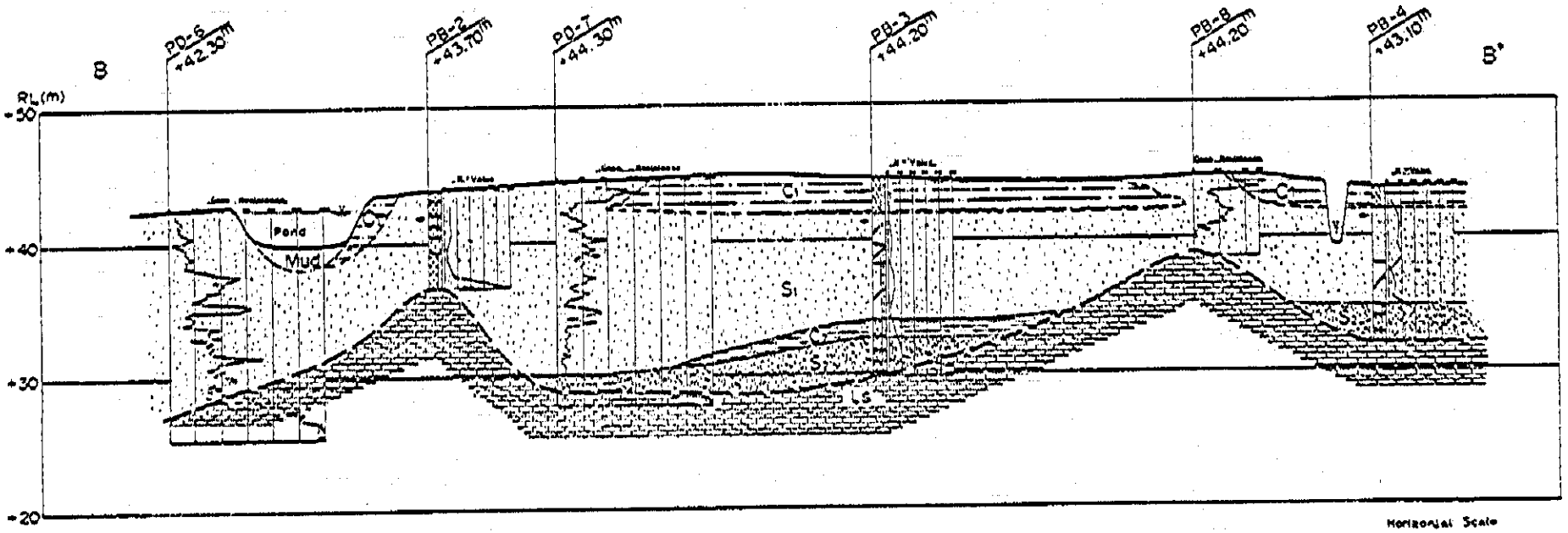
0 50 100 (m)

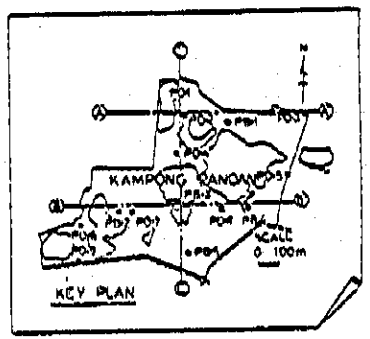


LEGEND

LAYER	LEGEND	COLOUR	N-Value	qc (kg/cm²)
Mud	Mud	Dark Grey	k0	k0
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White~Greyish-Brown	0~1	k0
Lower Clayey Layer (Soft to Medium Clay)	C2	Greyish-Brown~Dark-Grey	3~6	2~10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Light-Grey	1~10	<40
Lower Sandy Layer (Medium-Dense Sand)	S2	Light-Grey, Dark-Brown	1~20	40~120
Limestone Bedrock	Ls	Grey, Whitish-Grey	>30	>120

Fig. 4-3a Soil Profile at Kampong Pandan, Cross Section A-A'

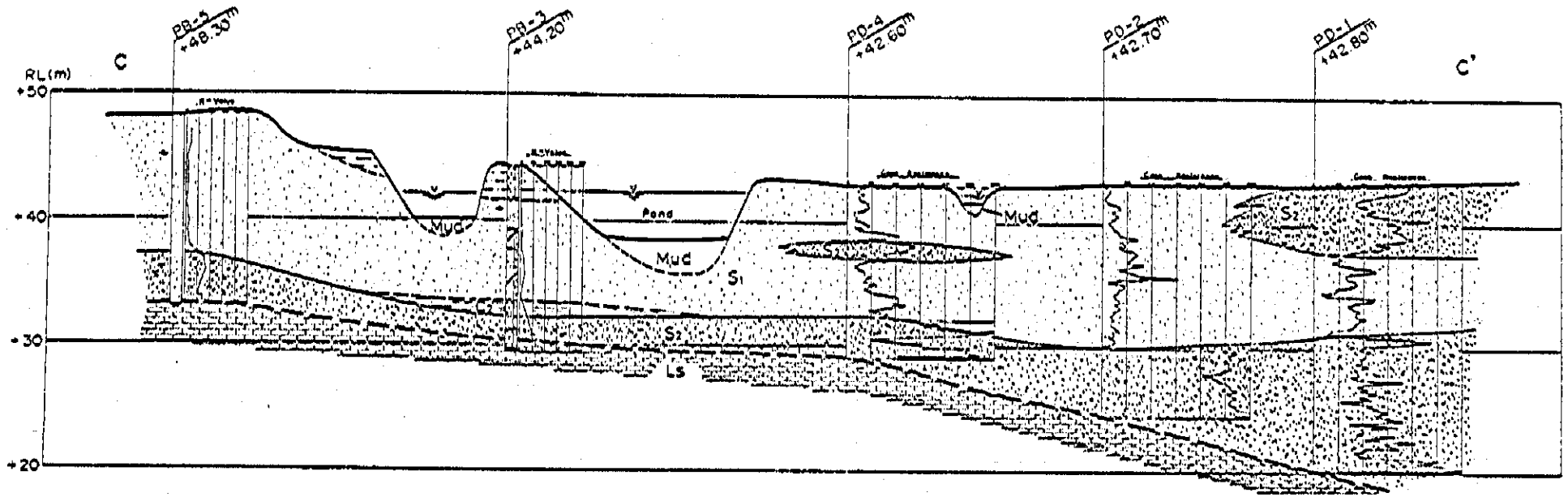


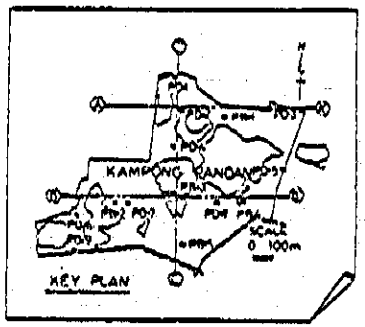


LEGEND

LAYER	LEGEND	COLOUR	N-Value	qc (kg/cm²)
Mud	Mud	Dark Grey	<0	<0
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White~ Greyish-Brown	0 ~ 1	<0
Lower Clayey Layer (Soft to Medium Clay)	C2	Greyish-Brown~ Dark-Grey	3 ~ 6	2 ~ 10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Light-Grey	1 ~ 10	<40
Lower Sandy Layer (Medium-Dense Sand)	S2	Light-Grey, Dark-Brown	1 ~ 20	40~120
Limestone Bedrock	LS	Grey, Whitish-Grey	>30	>120

Fig. 4-3b Soil Profile at Kampong Pandan, Cross Section B-B'





LEGEND

LAYER	LEGEND	COLOUR	N-value	qc (kg/cm²)
Mud	Mud	Dark Grey	<0	<0
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White~ Greyish-Brown	0~1	<0
Lower Clayey Layer (Soft to Medium Clay)	C2	Greyish-Brown~ Dark-Grey	3~6	2~10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Light-Grey	1~10	<40
Lower Sandy Layer (Medium-Dense Sand)	S2	Light-Grey, Dark-Brown	1~20	40~120
Limestone Bedrock	Ls	Grey, Whitish-Grey	>30	>120

Fig. 4-3c Soil Profil at Kampong Pandan, Cross Section C-C'

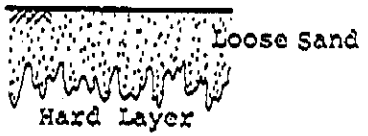
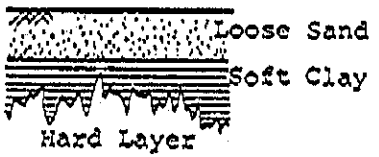
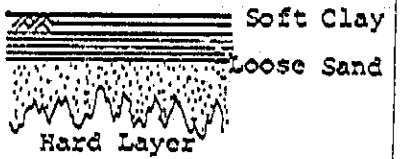
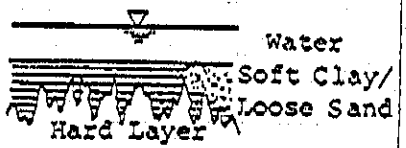
Table 4-3 Summary of Soil Tests on Samples from Kampong Pandan

Boring No.		PB-1										PB-2				
Sample No.*		P-1	P-4	P-7	P-9	P-11	P-13	P-15	P-17	P-19	P-20	P1/D2	P2/D3	P3/D4	P4/D5	P5/D6
Sample depth		1.15~1.45m	4.15~4.45m	7.15~7.45m	9.15~9.45m	11.15~11.45m	13.15~13.45m	15.15~15.45m	17.15~17.45m	19.15~19.45m	21.15~21.45m	1.00~1.45m	2.00~2.45m	3.00~3.45m	4.00~4.45m	5.00~5.45m
Natural water content, %		13.8	12.5	9.3	8.5	33.1	39.7	20.5	42.8	20.7	18.1	23.2	17.3	32.7	23.2	19.9
Specific gravity		2.648	2.633	2.644	2.651	2.605	2.612	2.726	2.608	2.655	2.722	2.599	2.611	2.575	2.617	2.622
Atterberg limits	Liquid limit , %	-	-	-	-	35.0	51.1	34.0	61.3	-	-	61.9	-	59.8	41.8	33.6
	Plastic limit , %	-	-	-	-	21.4	27.0	19.5	33.8	-	-	22.0	-	24.9	18.2	15.4
	Plasticity index	-	-	-	-	13.6	24.1	14.5	27.5	-	-	39.9	-	34.9	23.6	18.2
Grain size analysis	Gravel , %	21	6	22	22	14	0	24	0	5	15	8	18	5	4	8
	Sand , %	76	93	75	74	24	14	39	0	48	48	58	71	35	44	50
	Silt , %	3	1	3	4	37	37	21	47	18	18	7	11	10	15	15
	Clay & colloid, %					25	49	16	53	29	9	27		50	37	27
	Max. diameter , mm	9.52	9.52	9.52	9.52	9.52	2.00	9.52	0.074	9.52	9.52	9.52	9.52	4.76	4.76	9.52
	Diam. at 60%	1.1	0.60	1.0	1.1	0.062	0.016	0.75	0.012	0.16	0.83	0.50	1.2	0.085	0.17	0.31
	Diam. at 10%	0.18	0.17	0.21	0.24	-	-	-	-	-	0.0077	-	-	-	-	-
Visual soil description		Gravel Sand	Sand	Gravel Sand	Gravel Sand	Sandy Clay	Silty Clay with Sand	Clayey Sand with Gravel	Silty Clay	Clayey Sand	Silty Sand	Clayey Sand	Sand	Sandy Clay	Sandy Clay	Clayey Sand
Unified soil classification		SW	SP	SP	SP	CL	CH	SC	MH	-	-	SC	-	CH	CL	SC

Boring No.		PB-3									PB-5						
Sample No.*		P-1	P-3	P-5	P-7	P-9	P-11	P-12	P-13	P-14	P-1	P-4	P-7	P-10	P-12	P-14	P-15
Sample depth		1.15~1.45m	3.15~3.45m	5.15~5.45m	7.15~7.45m	9.15~9.45m	11.15~11.45m	12.15~12.45m	13.15~13.45m	14.00~14.18m	1.15~1.45m	4.15~4.45m	7.15~7.45m	10.15~10.45m	12.15~12.45m	14.15~14.45m	15.00~15.10m
Natural water content, %		17.1	14.7	14.5	16.9	17.7	73.5	38.9	37.7	13.2	8.8	15.9	21.6	19.8	16.4	21.2	9.5
Specific gravity		2.642	2.649	2.639	2.637	2.621	2.499	2.474	2.623	2.712	2.643	2.632	2.637	2.647	2.656	2.651	2.638
Atterberg limits	Liquid limit , %	-	-	-	-	-	82.2	50.6	48.8	-	-	-	-	-	-	-	-
	Plastic limit , %	-	-	-	-	-	42.7	32.3	26.0	-	-	-	-	-	-	-	-
	Plasticity index	-	-	-	-	-	39.5	18.3	22.8	-	-	-	-	-	-	-	-
Grain size analysis	Gravel , %	18	37	3	11	27	0	16	4	2	7	6	2	2	7	6	46
	Sand , %	64	55	86	79	48	0	36	29	58	80	86	96	91	86	88	48
	Silt , %	10	8	11	10	14	18	24	38	32	13	8	2	7	7	6	6
	Clay & colloid, %	8				11	82	24	29	8							
	Max. diameter , mm	9.52	19.1	4.76	9.52	9.52	0.022	9.52	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76	25.4
	Diam. at 60%	0.95	2.1	0.35	0.68	1.1	-	0.25	0.044	0.18	0.47	0.49	0.67	0.53	0.46	0.46	5.0
	Diam. at 10%	0.0092	0.10	-	0.074	0.0030	-	-	-	0.0075	-	0.087	0.21	0.15	0.11	0.12	0.10
Visual soil description		Sand w/Silt	Gravel Sand	Sand	Sand	Gravel Sand with Clay	Silty Clay	Sandy Clay	Sandy Clay	Silty Sand	Sand	Sand	Sand	Sand	Sand	Sand	Gravel Sand
Unified soil classification		-	(SW-SM)	(SP-SM)	(SW-SM)	-	MH	MH	CL	-	-	(SP-SM)	SP	(SP-SM)	(SP-SM)	(SP-SM)	(SP-SM)

* Note: All samples are disturbed.

Table 4-4 Types of Ground in Ex-mining Land
Classified from Engineering Viewpoint

Type of Deposit on Bedrock or Other Bearing Layer	Relation to Mining Operation	Examples of Ex-Mining Land
Type A 	Tailing Area near Tailing Point	Kampong Pandan Cheras 3-1/2 miles Cheras 4 miles Sungai Besi
Type B 	Tailing Area and/or Slime Pond Covered Later with Sandy Tailing or Sandy Dumping	Gombak, Kampong Pandan, Cheras 3-1/2 miles, Cheras 4 miles Sungai Besi, Castlefield
Type C 	Tailing Area far from Tailing Point, or Slime Pond	Sentul, Gombak Kampong Pandan, Cheras 3-1/2 miles, Cheras 4 miles
Type D 	Slime Pond, Tailing Area far from Tailing Point	Sentul, Setapak Castlefield
Type E 	Old Mining Hole	Pond of Kampong Pandan Setapak

N-values of the layer were higher than those of the very soft clay at the Sentul site. However, there are also extremely soft clay layers at the Kampong Pandan site as can be seen in Table 4-5. Other than the above-mentioned extremely soft clay layers, the clayey layers found at the Kampong Pandan site have the following properties:

N-Values	:	1 to 11 with average of 6
Natural Water Content	:	25 to 75% with average of 40%
Sand and Gravel Content	:	0 to 50% with average of 30%

2) Sandy Layers

Sandy layers are generally very loose to loose (N-values of less than 10). About 10 to 40% of the layer is composed of gravel-size particles.

3) Hard Layers

Hard layers with N-values greater than 50 were encountered at a depth of 7 to 20m with an average of 13.5m. Dutch cone penetrometer tests were terminated at a depth of 6.0 to 22.6m with an average of 15.5m.

4) Sub-Bottom Conditions of Ponds

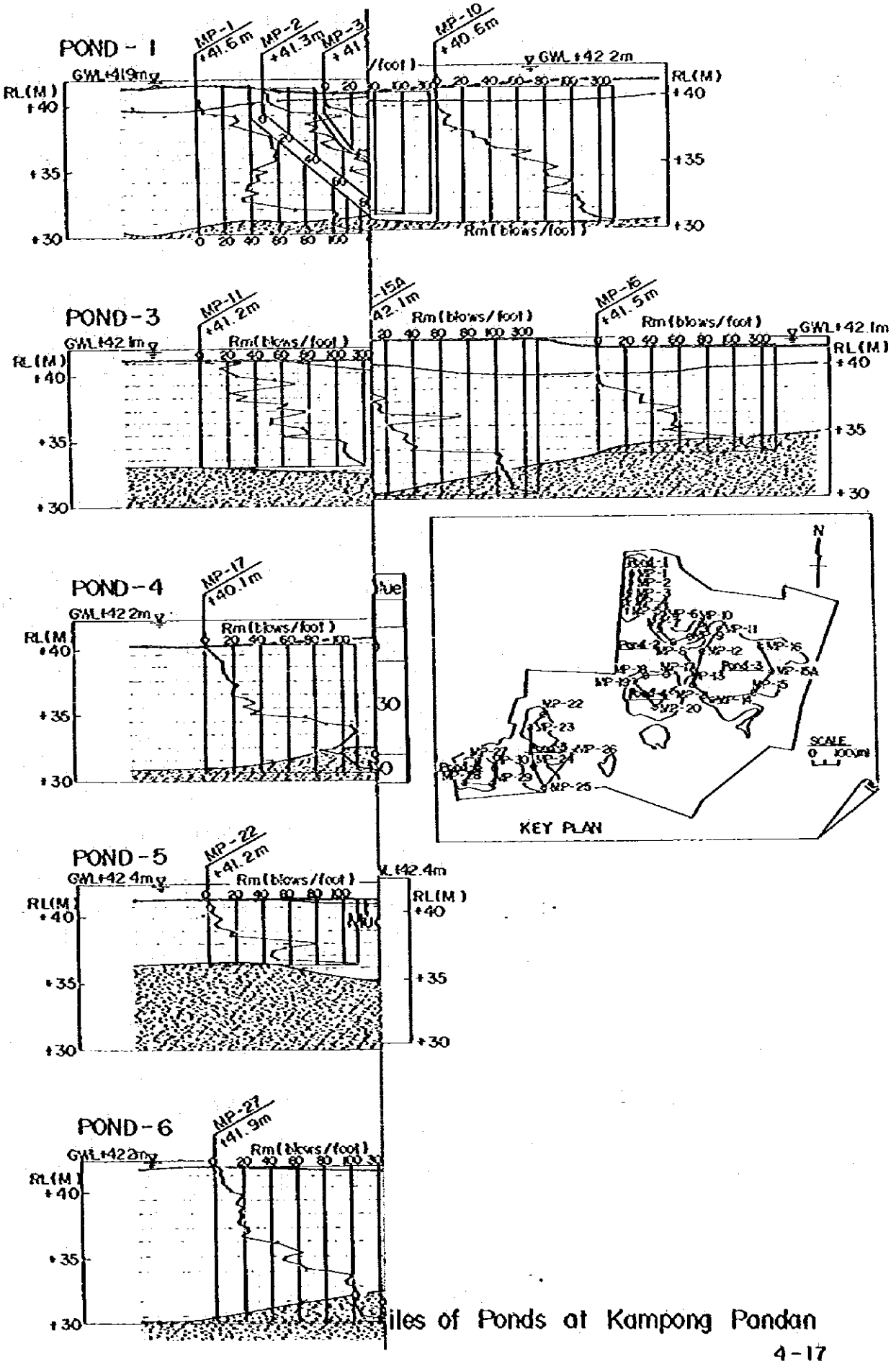
Sub-bottom conditions of the ponds were investigated by Mackintosh probe tests and special samplings. Fig. 4-4 shows cross sections of the sub-bottom conditions of the ponds at the Kampong Pandan site. The water depth and the thickness of the floating mud or very soft clay are summarized in Table 4-6.

Table 4-5 Extremely Soft Clay Layers Found at Kampong Pandan

Location	Depth of the Layer	Cone Resistance
PD-3	1.0 to 3.0 m	0 kg/cm^2
PD-5	0.5 to 5.0 m	0 kg/cm^2
PD-8	4.2 to 5.6 m	0 kg/cm^2

Table 4-6 Water Depth, Thickness of Floating Mud or Very Soft Clay at Bottom of Ponds at Kampong Pandan

Site	Pond No.	Water Depth at Sounding Point	Thickness of Floating Mud or Very Soft Clay at Bottom of Pond
Kampong Pandan	P-1	1.5 m	0 ∿ 3.0 m
	P-2	2.0 m	0 ∿ 1.5 m
	P-3	1.5 m	0 ∿ 2.0 m
	P-4	2.0 m	0 ∿ 2.0 m
	P-5	2.5 m	0 ∿ 2.5 m
	P-6	1.5 m	0 ∿ 2.5 m



Profiles of Ponds at Kampong Pandan

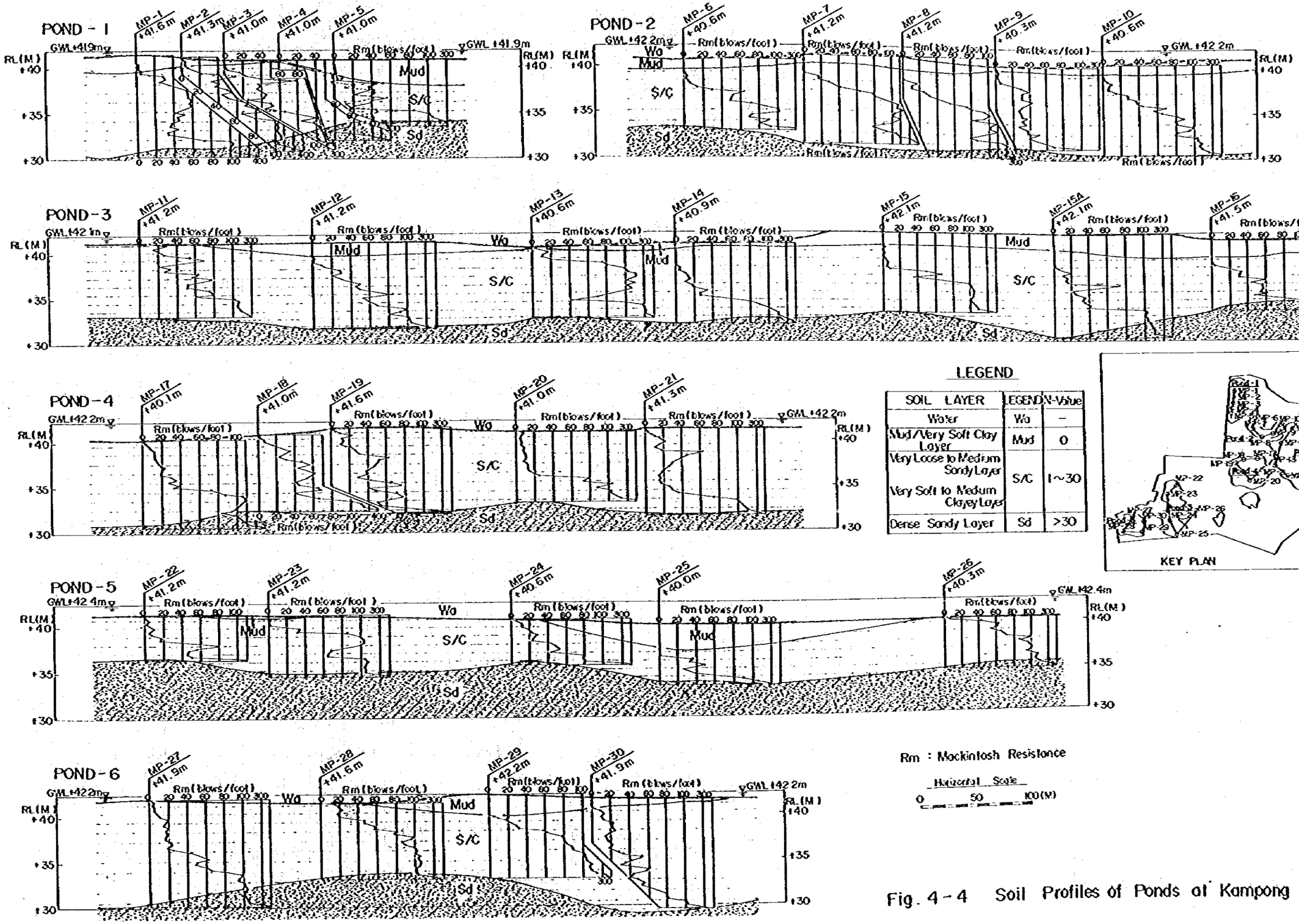


Fig. 4-4 Soil Profiles of Ponds at Kampong Pandan

4.2 Sentul

The Sentul site is situated 3 km north of the city centre. However most of all the area is un-ocupied because ground conditions are too bad to construct structures without counter measures. The City Hall has begun a low-cost housing scheme at the site using pile foundations.

4.2.1 Details of Subsurface Ground Investigations Performed at Sentul

Subsurface ground investigations performed at the Sentul site consisted of field investigations and laboratory soil/rock tests. Details of those investigations are described below.

(1) Field Ground Investigations

Types and quantity of the field works performed in the present study are summarized in Tables 4-7 and 4-8. Types of field ground investigations performed at the Sentul site together with the locations and main objects of the investigations are listed in Table 4-9.

(a) Entire Area

For the investigation on land for the entire area of the site, percussion borings and Dutch cone penetrometer tests were performed. The locations of borings and soundings carried out at the site

Table 4-7 Details of Field Ground Investigation Performed at Sentul

		Geophysical Survey		Soundings												Boring	
		Electrical Sounding	Micro-gravity Measurement	Dutch Cone Penetrometer Test		Dynamic Cone Test		Pore Pressure Sounding			Swedish Sounding	Mackintosh Probe Sounding			Disturbed Soil Sampling (Nos.)	Percussion Boring	Rotary Boring
				Test No./ Location	Sounding Depth (m)	Test No./ Location	Sounding Depth (m)	Location	Test No.	Sounding Depth (m)	Refer Detail in Table 4-11 & 4-12	Test No./ Location		Sounding Depth (m)			
Pilot Test Area		25 Locations	121 Locations	A'	7.8	-	-	A"	1	2.69						Refer Detail in Table 4-8	
				A"	12.8	A"	19.2		2	2.68							
				B	16.0	B	14.2	B	1	11.50							
									2	11.60							
	Sub-Total	25 Locations	121 Locations	3 Locations	36.0m	2 Locations	33.4m	2 Locations	4 Tests	28.47m	96 Locations					4 Locations 66.0 m	10 Locations 227.1 m
Entire Area	On Land	5 Locations	9 Locations	SD-1	28.8											Refer detail in Table 4-8	
				SD-2	17.2												
				SD-3	18.6												
				SD-4	17.4												
				SD-5	20.2												
				SD-6	27.4												
				SD-8	12.6												
				SD-9	15.4												
				SD-10	22.0												
				SD-11	20.2												
				SD-12	19.4												
				SD-13	19.6												
				SD-15	13.8												
				SD-16	17.8												
				SD-17	15.0												
				SD-18	7.4												
	In Pond											Pond No.1	MS-1	10.9	5		
													MS-2	8.8	5		
													MS-3	10.6	5		
													MS-4	10.6	9		
													MS-5	9.7	9		
	Sub-Total	5 Locations	9 Locations	16 Locations	292.8m	0 Location	0 m	0 Location	0 Tests	0 m	0 Location 0 m	5 Locations		50.6m	33 Nos.	9 Locations 144.3 m	0 Location 0 m
Total		30 Locations	130 Locations	19 Locations	328.8m	2 Locations	33.4m	2 Locations	4 Tests	28.47m	96 Locations 1179 m	5 Locations		50.6m	33 Nos.	13 Locations 210.3 m	10 Locations 227.1 m

Table 4-8 Exploratory Boring Performed at Sentul

Type of Boring	Area	Sub-Section	Boring No.	Boring Length: Soil Boring (m)	Boring Length: Rock Boring (m)	Boring Length: Total (m)	Undisturbed Sampling (Nos)	In-Situ Tests in Boreholes: Standard Penetration Test (Nos)	In-Situ Tests in Boreholes: Vane Test (Nos)	In-Situ Tests in Boreholes: Pressuremeter Test (Nos)	In-Situ Tests in Boreholes: In-Situ Permeability Test (Nos)
Percussion Boring	Pilot Test Area	A		10.80	0	10.80	0	11	0	0	1
		A'		10.03	0	10.03	0	10	0	0	1
		A"		19.20	0	19.20	0	19	0	0	4
		B		26.00	0	26.00	0	26	0	0	0
		Sub-Total		66.03	0	66.03	0	66	0	0	6
	Entire Area on Land		SB-1	13.05	0	13.05	0	13	0	0	0
			SB-2	8.70	0	8.70	0	9	0	0	0
			SB-3	10.52	0	10.52	0	11	0	0	0
			SB-4	20.01	0	20.01	0	20	0	0	0
			SB-5	17.02	0	17.02	0	17	0	0	0
			SB-6	36.10	0	36.10	0	36	0	0	0
			SB-7	10.10	0	10.10	0	10	0	0	0
			SB-8	12.03	0	12.03	0	12	0	0	0
			SB-9	16.80	0	16.80	0	17	0	0	0
		Sub-Total		144.33	0	144.33	0	145	0	0	0
	Total			210.36	0	210.36	0	211	0	0	9
Rotary Drilling	Pilot Test Area	A"	A	21.25	8.20	29.45	3	7	0	1	0
			B	14.15	5.55	19.70	0	0	2	5	0
		B	A	29.00	7.00	36.00	9	14	0	5	0
			B	26.00	7.50	33.50	0	1	11	0	3
		Sub-Total		90.40	28.25	118.65	12	22	13	11	3
		Test Embankment	SBH-1*1	18.11	0	18.11	8	10	27	0	0
			SBH-2*1	20.15	0	20.15	8	12	23	0	0
			SBH-3*2	25.00	0.50	24.50	17	9	36	0	0
			SBH-4*2	23.06	0	23.06	9	7	17	0	0
			SBH-5*3	24.20	0	24.20	11	7	11	0	0
			SBH-6*3	26.17	0	26.17	10	11	12	0	0
		Sub-Total		136.69	0.50	136.19	63	56	126	0	0
	Total			227.09	28.75	254.84	75	78	139	11	3
Grand Total				437.45	28.75	465.20	75	289	139	11	12

Notes: *1 SBH-1 and SBH-2 were performed before trial embankment.
*2 SBH-3 and SBH-4 were performed after 1st stage of embankment
*3 SBH-5 and SBH-6 were performed after 2nd stage of embankment
* SBH-1 to SBH-6 were performed in Phase II, others in Phase I

Table 4-9 Types, Location, and Main Objects of Field Ground Investigations at Sentul

Type of Field Ground Investigation	Location	Main Object
Electrical Sounding	° Pilot Test Area	Average Depth to Bedrock
Microgravity Measurement	° Pilot Test Area	Undulation of Bedrock Surface and Existence of Cavities in Bedrock
Rotary Boring	° Sub-Sections A" and B	Depth to Sound Bedrock and Obtainment of Rock Core Samples
Percussion Boring	° Entire Area ° Sub-Sections A, A', A" and B	Depth to Hard Layer
Undisturbed Sampling	° Sub-Sections A" and B ° Test Embankment Area	Obtainment of Samples for Mechanical Property Tests
In-Situ Vane Test	° Sub-Sections A" and B ° Test Embankment Area	Undrained Shear Strengths of Soft Materials
Standard Penetration Test	° Entire Area ° Test Embankment Area ° Sub-Sections A, A', A" and B	Relative Density of Sand or Consistency of Clay
In-Situ Permeability Test	° Sub-Sections A" and B	Permeability of Sandy Layer
Pressuremeter Test	° Sub-Sections A, A' and A"	Deformation Properties of Hard Materials
Dutch Cone Penetrometer Test	° Sub-Sections A, A" and B ° Entire Area	Cone Resistance of Ground and Depth to Hard Layer
Dynamic Cone Test	° Sub-Sections A" and B	Penetration Resistance of Ground and Depth to Hard Layer
Pore-Pressure Sounding	° Sub-Sections A" and B	Detection of Thin Embedded Layers of Sand or Clay
Swedish Sounding	° Test Embankment Area	Sounding of Soil Type Depth to Hard Layer
Mackintosh Probe Test	° Pond	Depth to Hard Layer

are shown in Fig. 4-5. Electrical soundings and micro-gravity measurements were also performed. At the percussion boring locations, standard penetration tests (SPT) were performed every 1 m in depth. A Dutch cone penetrometer with the capacity of 10 tons was used to obtain the cone resistance of the ground and testing was carried out at locations selected between borings.

The results of borings with SPT and Dutch cone penetrometer tests are summarized and compiled into soil profile cross sections and shown in Figs. 4-6a to 4-6g. Locations of the cross sections are indicated in Fig. 4-5.

(b) Pond at Sentul

Sub-bottom conditions of the pond at this site were investigated using Mackintosh probe tests and special samplings. Locations of the tests are shown in Fig. 4-5. Fig. 4-7 shows a cross section of the sub-bottom condition in the pond. The water depth and the thickness of the floating mud or very soft clay are summarized in Table 4-10.

(c) Pilot Test Area

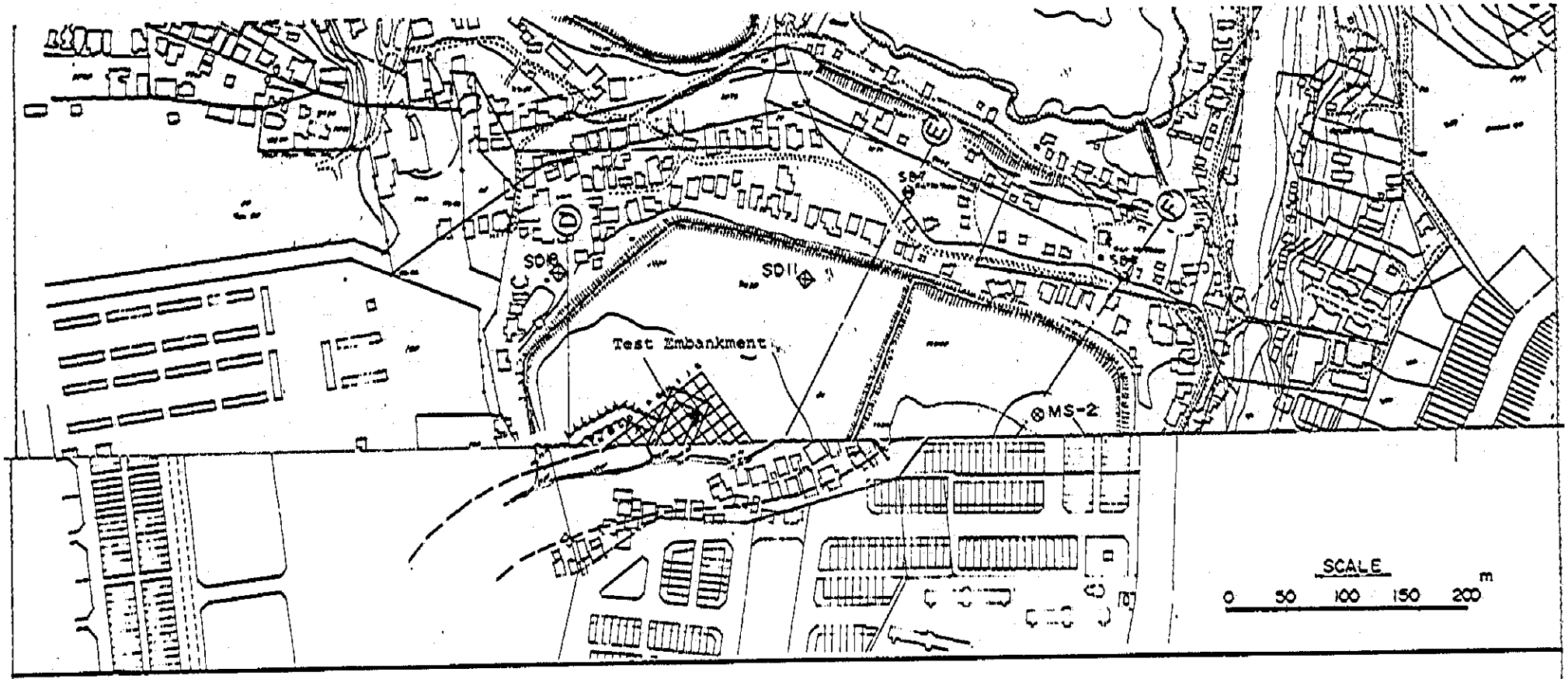
To study the soil characteristics of ex-mining land in detail, a pilot test area was established at

the Sentul site and comprehensive investigations were carried out. The pilot test area was 100 m by 100 m divided into sub-sections of 10 m by 10 m. Concentrated subsurface investigations were performed at Sub-Sections A, A', A" and B. The location and layout of the pilot test area together with the configuration of the test embankment are shown in Fig. 4-8. Details of the sub-sections are illustrated in Fig. 4-9.

The subsurface ground investigations performed at the Sentul pilot test area were comprised of the following:

o <u>During Phase I</u>

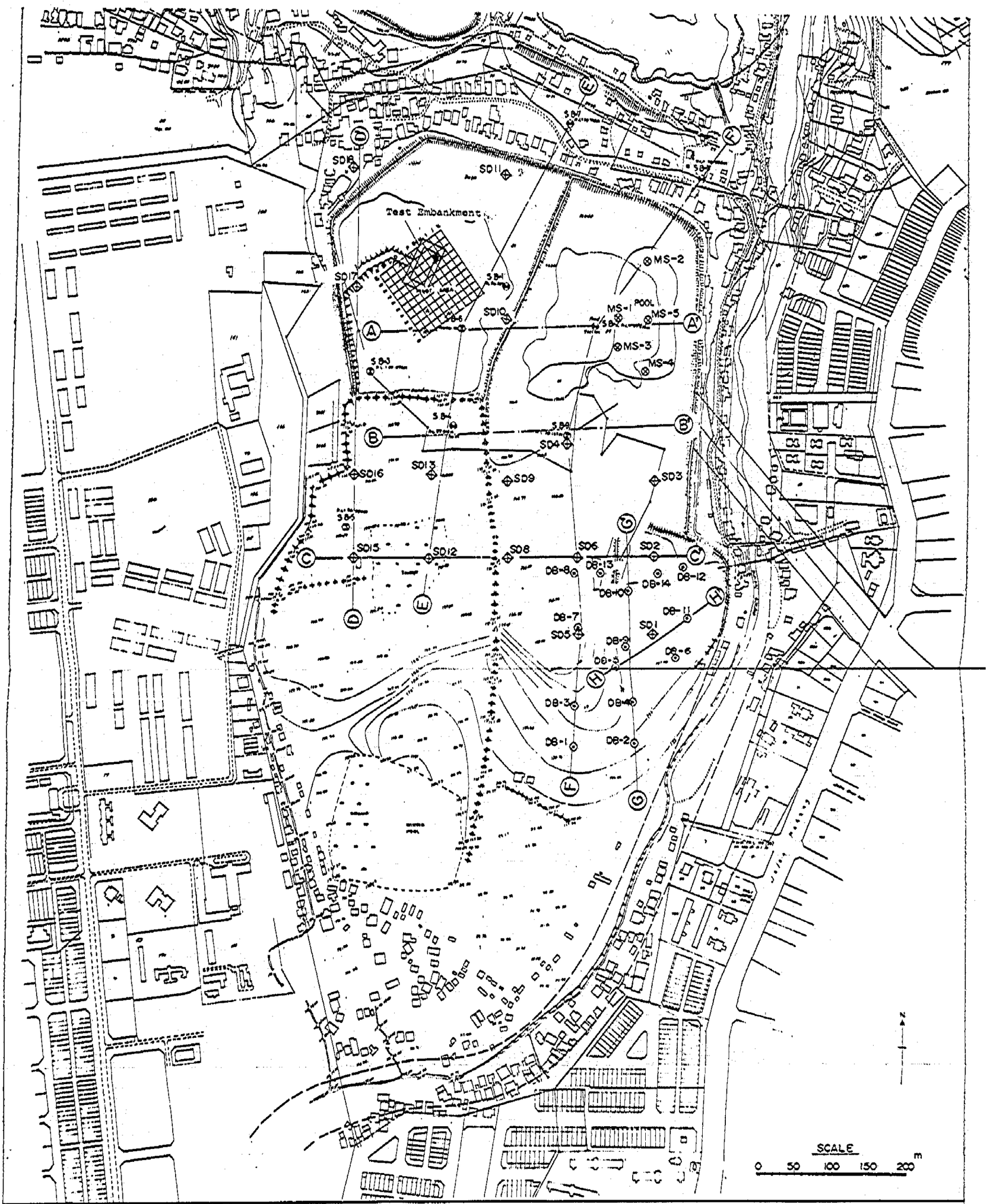
1) Electrical Soundings
2) Micro-Gravity Measurements
3) Dutch Cone Penetrometer Tests
4) Dynamic Cone Tests
5) Pore-Pressure Soundings
6) Percussion Borings
7) Rotary Drillings including Rock Coring
8) Undisturbed Samplings
9) Standard Penetration Tests
10) In-Situ Vane Shear Tests
11) Pressuremeter Tests
12) In-Situ Permeability Tests



LEGEND

- Boring (Performed by Malaysian Government)
- Percussion Boring
- Dutch Cone
- Mackintosh Probe and Special Sampling

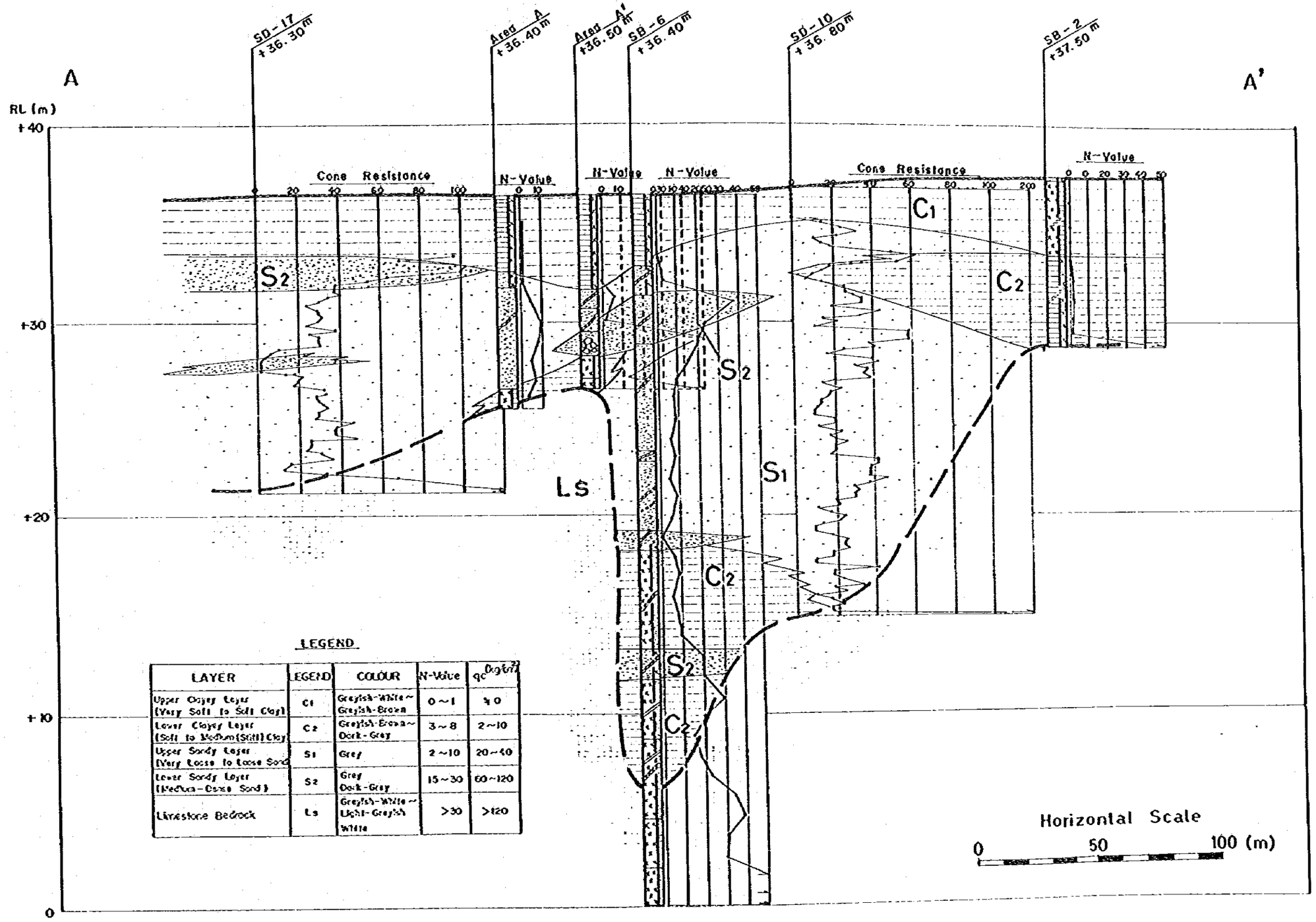
Fig. 4-5 Sentul Site with Pilot Test Area and Test Embankment



LEGEND

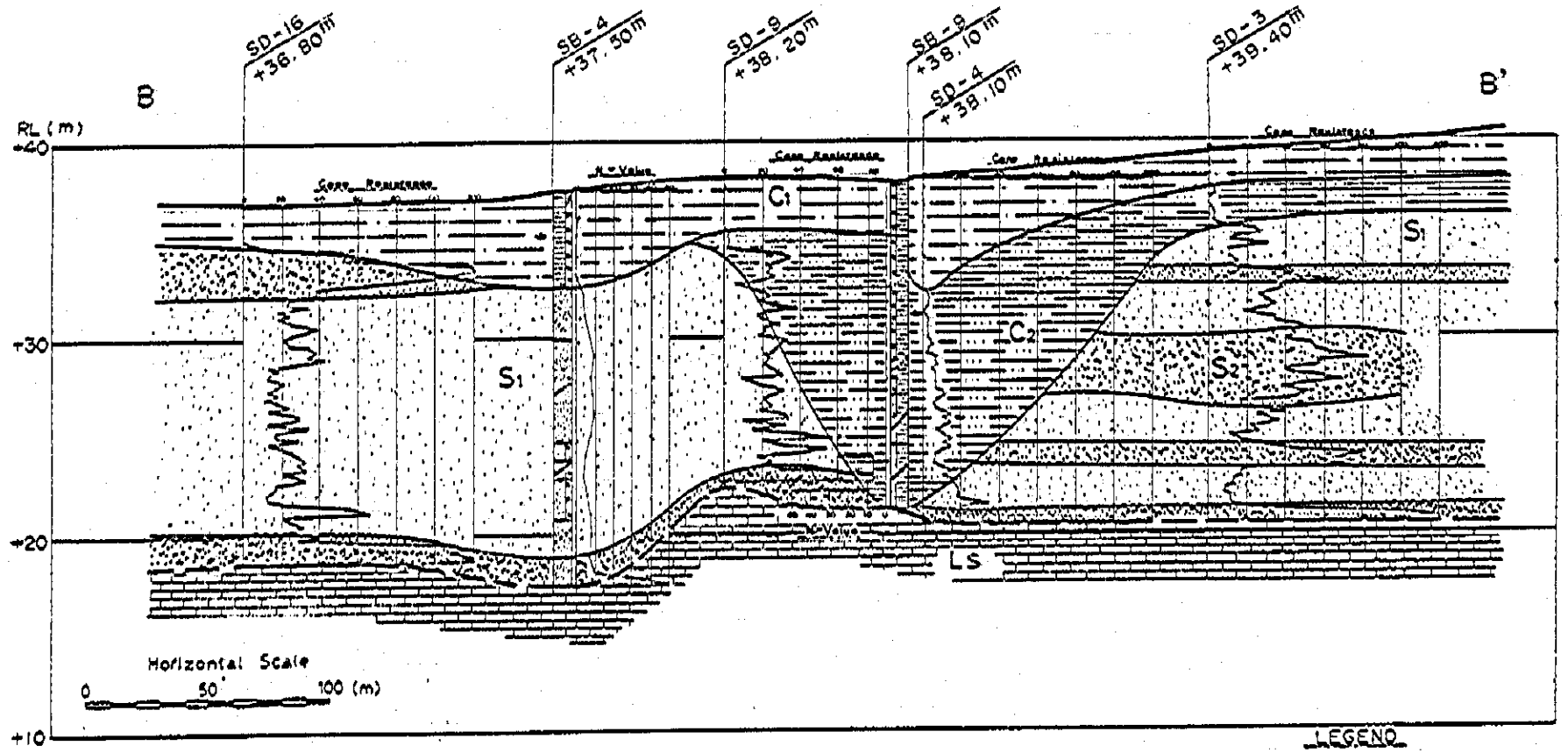
- ⊙ Boring (Performed by Malaysian Government)
- ⊖ Percussion Boring
- ◇ Dutch Cone
- ⊗ Mackintosh Probe and Special Sampling

Fig. 4-5 Sentul Site with Pilot Test Area and Test Embankment



LAYER	LEGEND	COLOUR	N-Value	q_c (kg/cm²)
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White ~ Greyish-Brown	0 ~ 1	≒ 0
Lower Clayey Layer (Soft to Medium (Stiff) Clay)	C2	Greyish-Brown ~ Dark-Grey	3 ~ 8	2 ~ 10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Grey	2 ~ 10	20 ~ 40
Lower Sandy Layer (Medium-Dense Sand)	S2	Grey Dark-Grey	15 ~ 30	60 ~ 120
Limestone Bedrock	Ls	Greyish-White ~ Light-Greyish White	>30	>120

Fig. 4-6a Soil Profile at Sentul, Cross Section A - A'



LEGEND

LAYER	LEGEND	COLOUR	N-Value	qc (kg/cm²)
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White ~ Greyish-Brown	0 ~ 1	≈ 0
Lower Clayey Layer (Soft to Medium (Stiff) Clay)	C2	Greyish-Brown ~ Dark-Grey	3 ~ 8	2 ~ 10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Grey	2 ~ 10	20 ~ 40
Lower Sandy Layer (Medium - Dense Sand)	S2	Grey Dark-Grey	15 ~ 30	60 ~ 120
Limestone Bedrock	Ls	Greyish-White ~ Light-Greyish White	>30	>120

Fig. 4-6b Soil Profile at Sentul, Cross Section B-B'

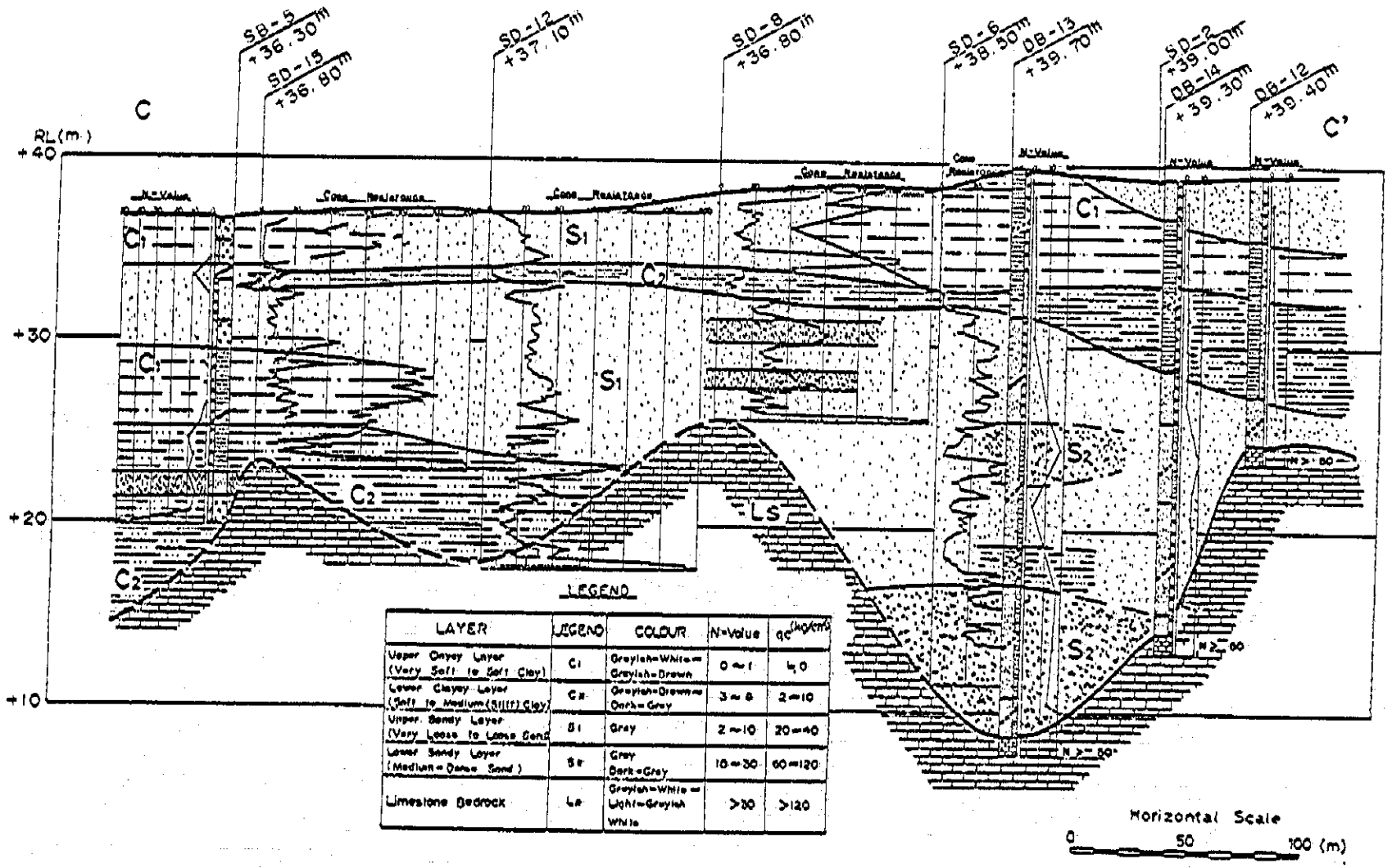
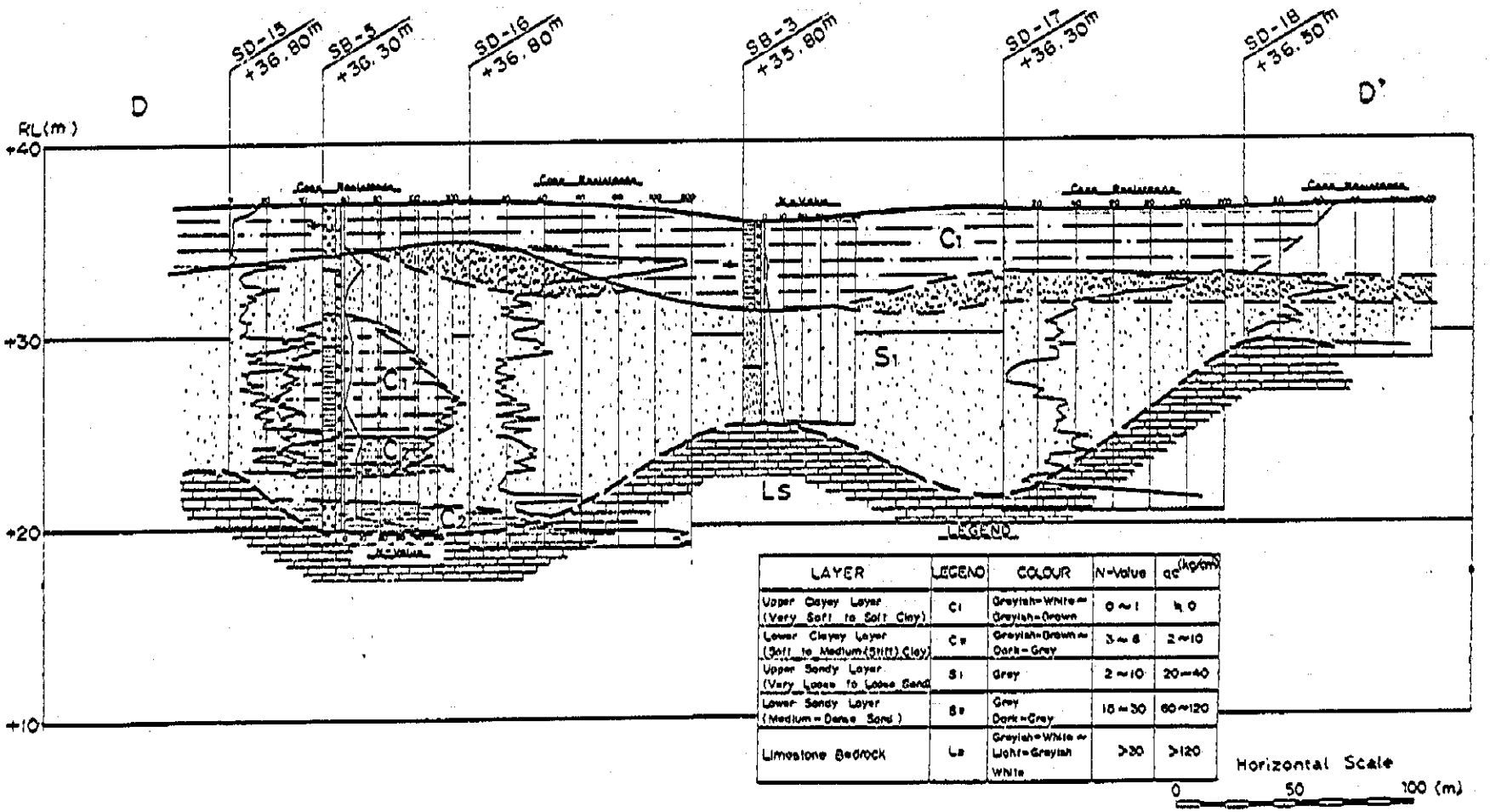


Fig. 4-6c Soil Profile at Sentul, Cross Section C-C'



LAYER	LEGEND	COLOUR	N-Value	qc (kg/cm²)
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White ~ Greyish-Brown	0 ~ 1	4.0
Lower Clayey Layer (Soft to Medium (Stiff) Clay)	C2	Greyish-Brown ~ Dark-Grey	3 ~ 8	2 ~ 10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Grey	2 ~ 10	20 ~ 40
Lower Sandy Layer (Medium-Dense Sand)	S2	Grey Dark-Grey	15 ~ 30	60 ~ 120
Limestone Bedrock	Ls	Greyish-White ~ Light-Greyish White	>30	>120

Fig. 4-6d Soil Profile at Sentul, Cross Section D-D'

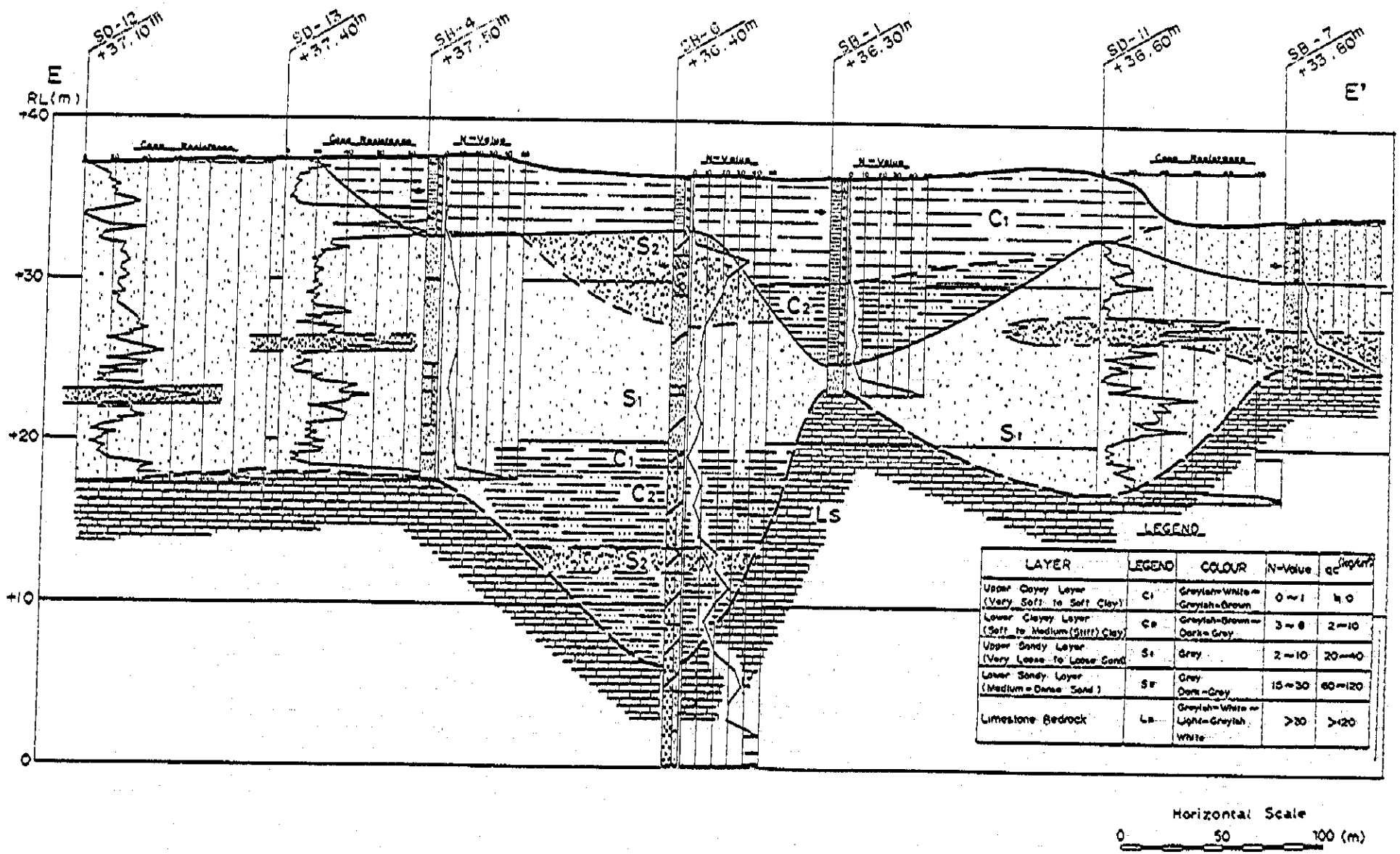
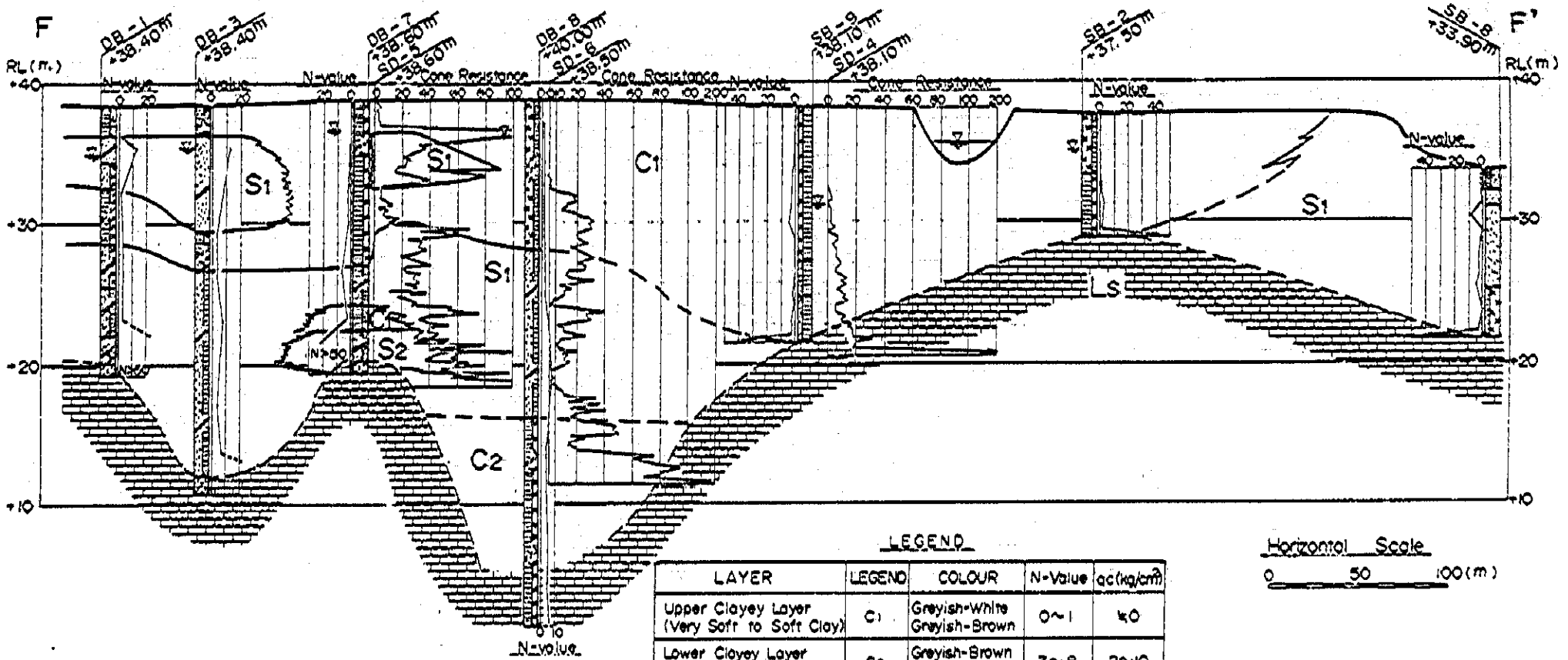


Fig. 4-6e Soil Profile at Sentul, Cross Section E-E'



LEGEND

LAYER	LEGEND	COLOUR	N-Value	qc(kg/cm²)
Upper Clayey Layer (Very Soft to Soft Clay)	C1	Greyish-White Greyish-Brown	0~1	≤0
Lower Clayey Layer (Soft to Medium(Stiff) Clay)	C2	Greyish-Brown Dark-Grey	3~8	2~10
Upper Sandy Layer (Very Loose to Loose Sand)	S1	Grey	2~10	20~40
Lower Sandy Layer (Medium-Dense Sand)	S2	Grey Dark-Grey	15~30	60~120
Limestone Bedrock	Ls	Greyish-White Light-Greyish White	>30	>120

Horizontal Scale

0 50 100(m)

Fig. 4-6f Soil Profile at Sentul, Cross Section F-F'

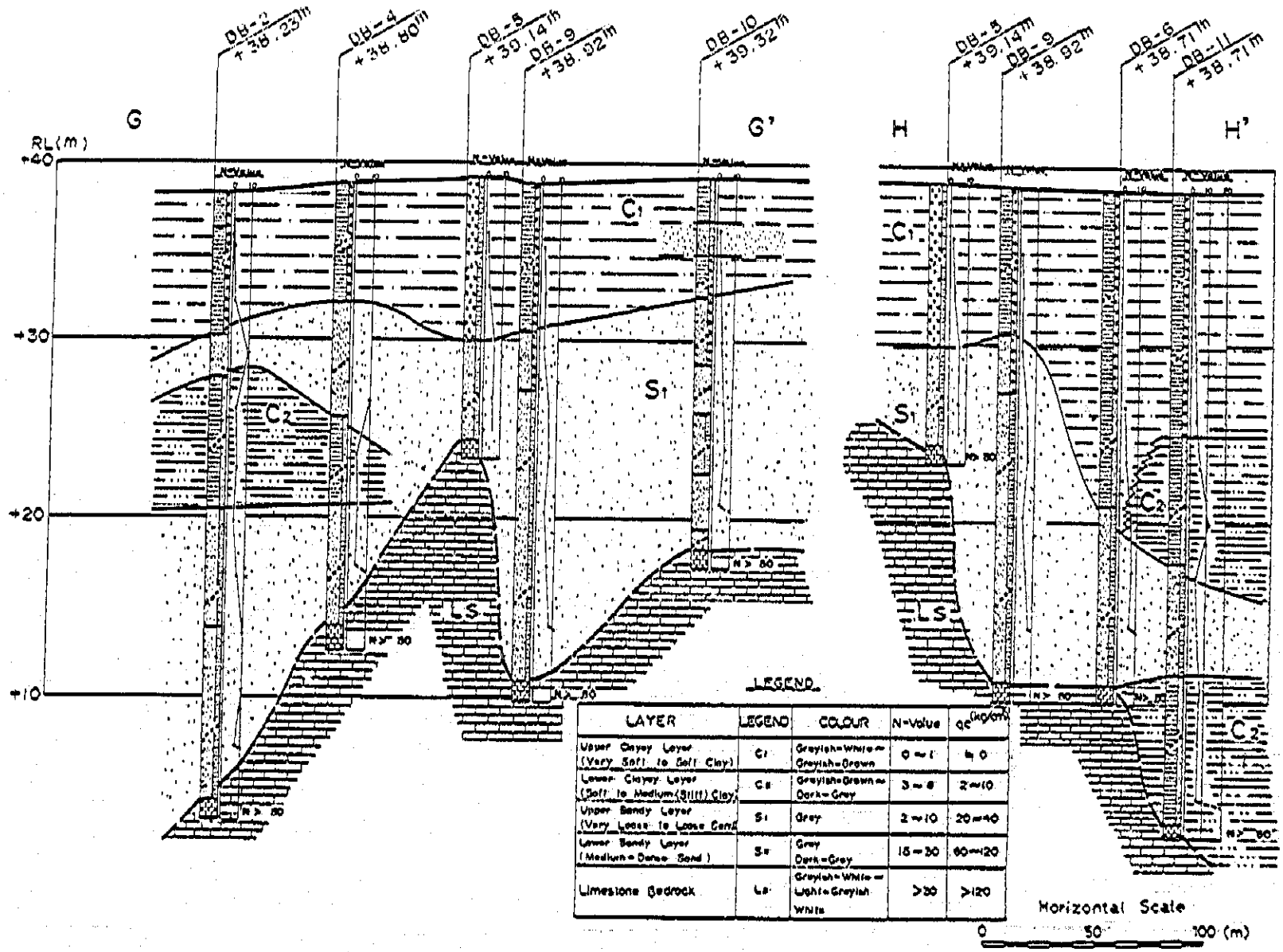
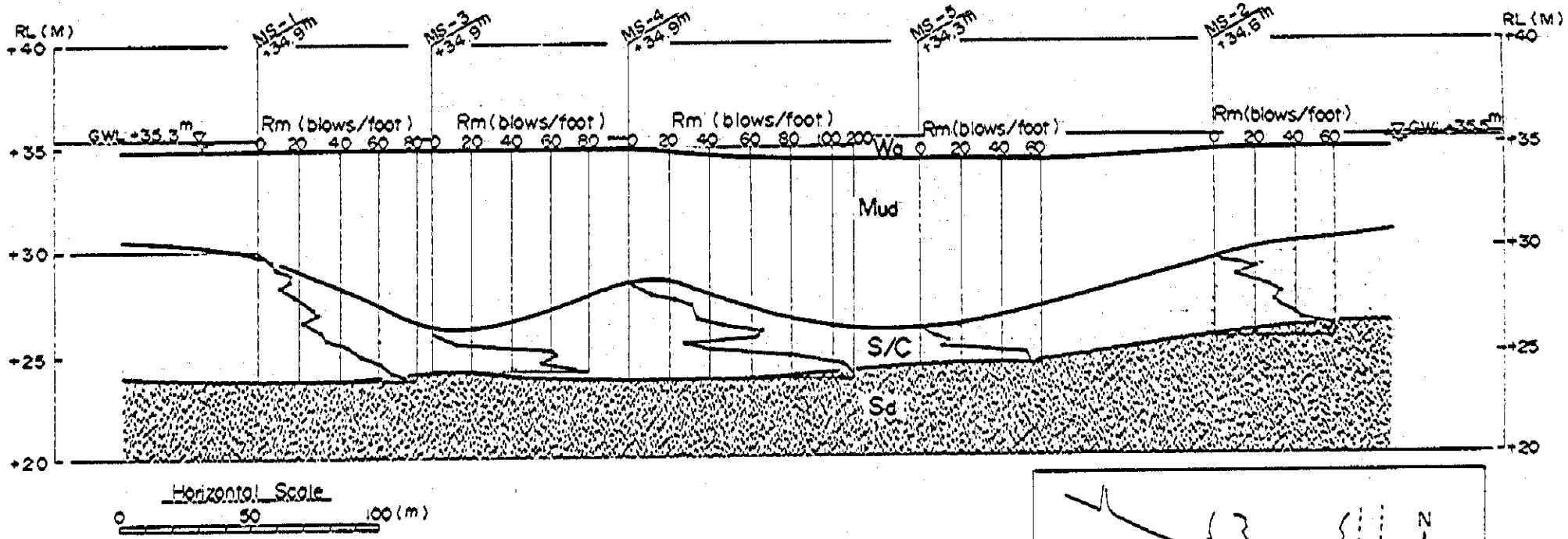


Fig. 4-6g Soil Profile at Sentul, Section G-G' and H-H'



Rm : Mackintosh Resistance.

LEGEND

SOIL LAYER	LEGEND	Sentul N-Value
Water	Wa	----
Mud/Very Soft Clayey Layer	Mud	0
Very Loose to Medium Sandy Layer Very Soft to Medium Clayey Layer	S/C	1 – 30
Dense Sandy Layer	Sd	>30

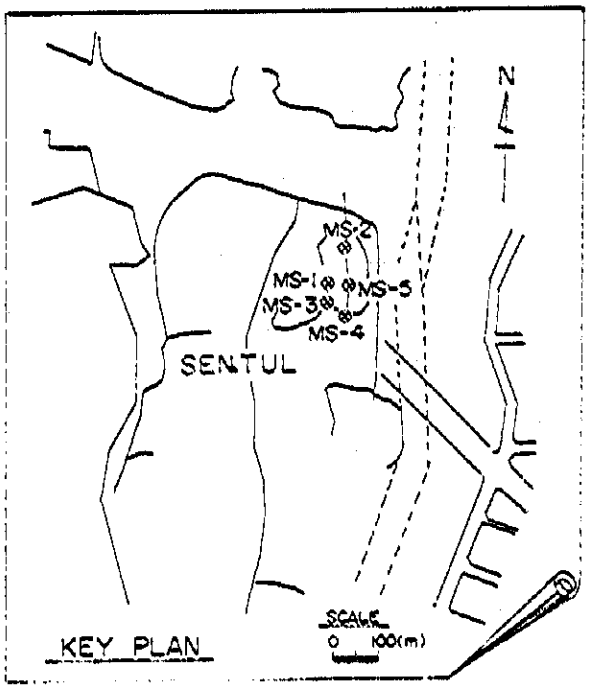


Fig. 4-7 Soil Profile of Pond at Sentul

Table 4-10 Water Depth, Thickness of Floating Mud or Very Soft Clay at Bottom of Pond at Sentul

Site	Pond No.	Water Depth at Sounding Point	Thickness of Floating Mud or Very Soft Clay at Bottom of Pond
Sentul	1	1 m	5 - 8 m

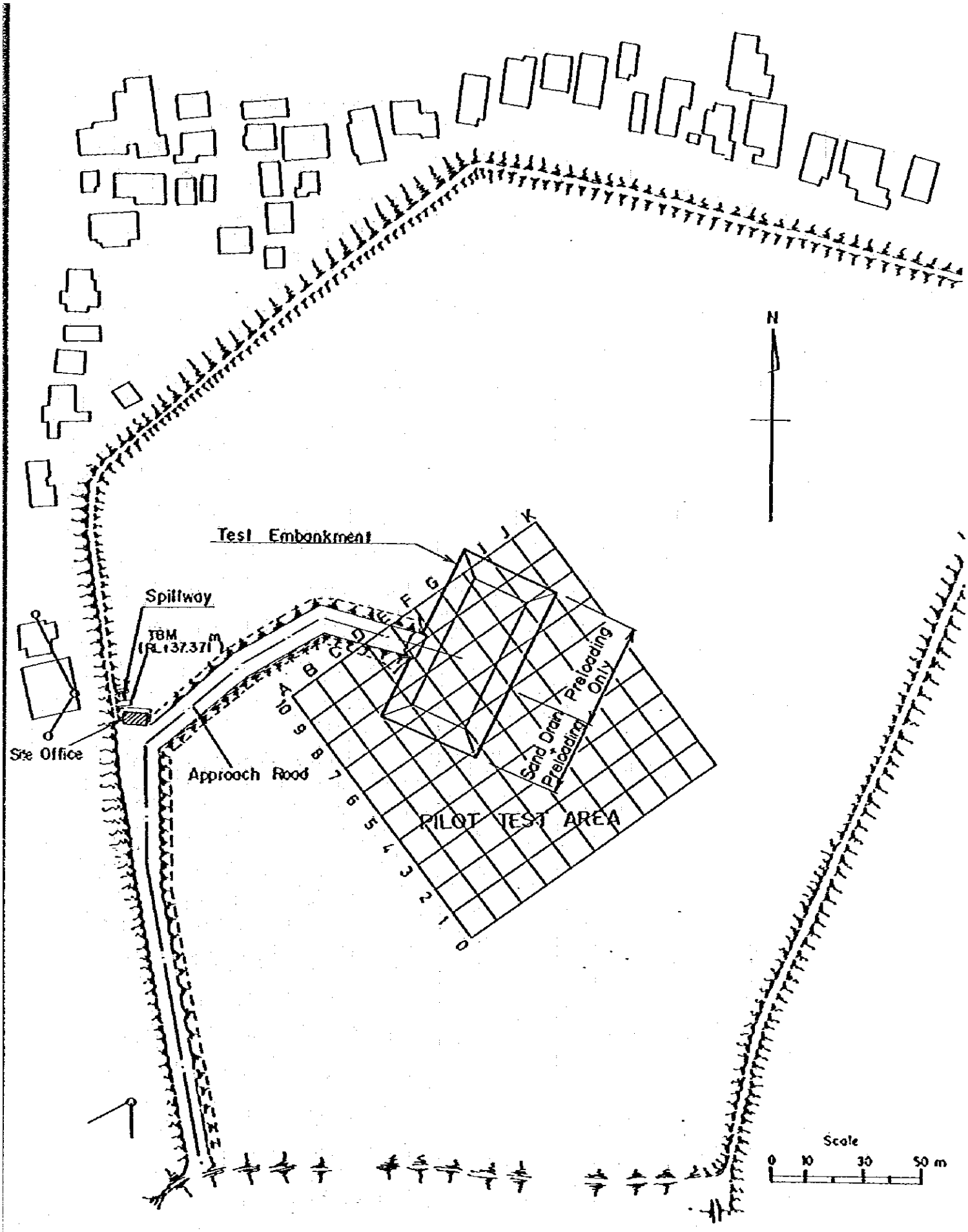
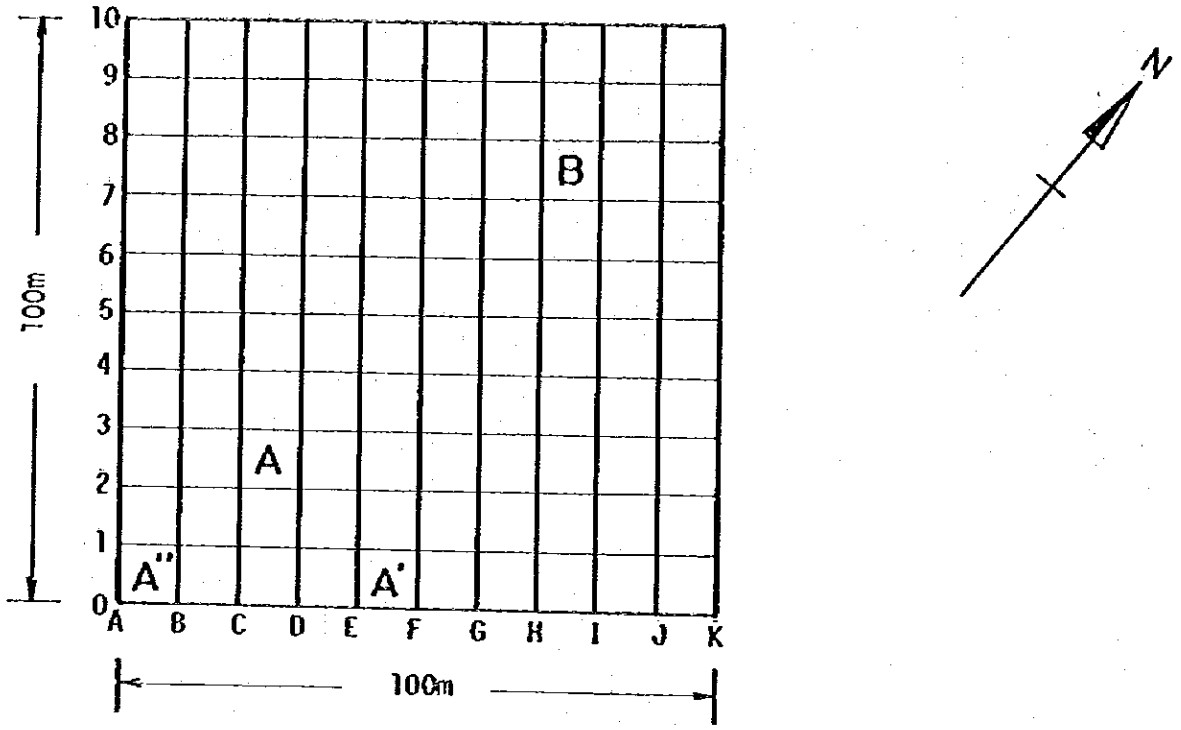
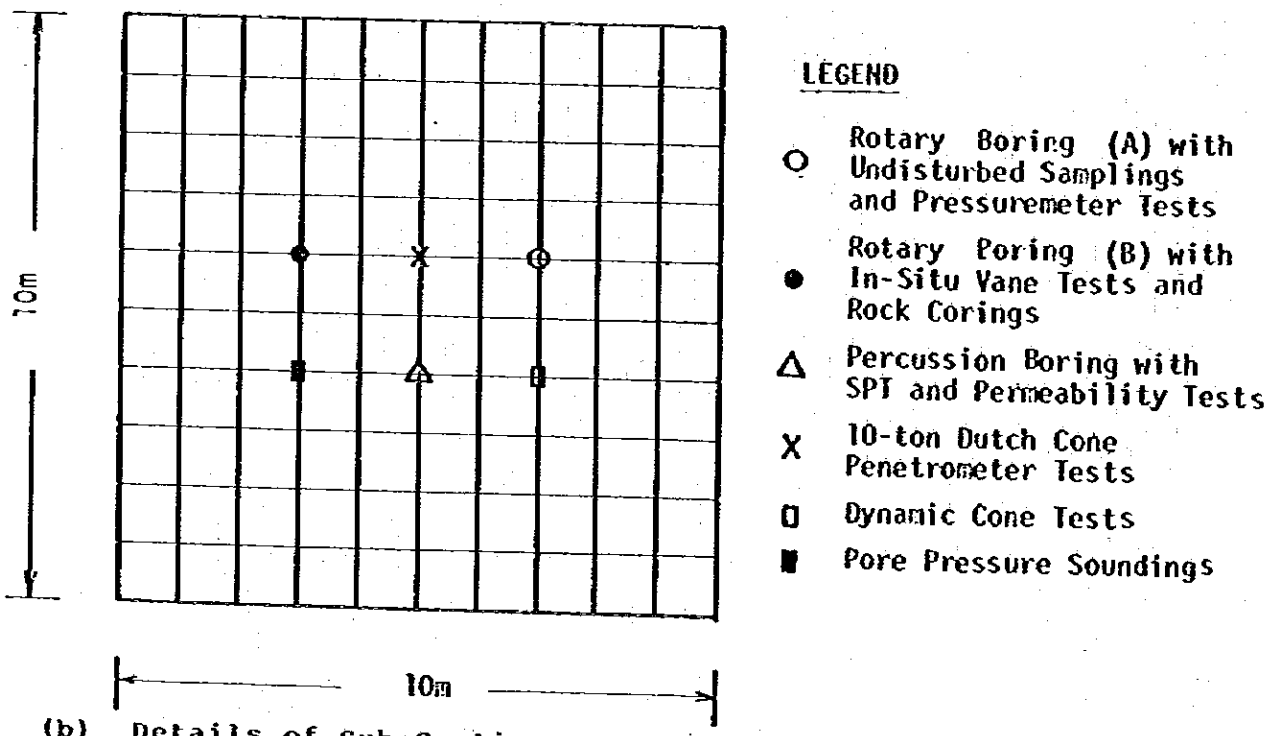


Fig. 4-8 Pilot Test Area and Test Embankment at Sentul



(a) Layout of Sub-Sections



(b) Details of Sub-Section Investigations

Fig. 4-9 Details of Pilot Test Area and Sub-Sections

o <u>During Phase II</u>

1) Swedish Soundings
2) Rotary Drillings
3) Undisturbed Soil Samplings
4) In-Situ Vane Shear Tests

Fig. 4-10 shows the results of electrical soundings and Fig. 4-11 shows the results of micro-gravity measurements. A soil profile of the sub-section is shown in Fig. 4-12. Depth to the lime-stone bedrock as determined by the exploratory bor-ings is compared with the results of micro-gravity measurements in the figure. At Sub-Sections A" and B, ground investigations of several different types were performed. At each sub-section, two rotary borings 4 m apart were performed as shown in Fig. 4-9. Field investigation results at these sub-sections are shown in Figs. 4-13a and 4-13b.

(d) <u>Test Embankment Area</u>

Locations of field investigations performed in conjunction with the test embankment are shown in Fig. 4-14. To confirm the thickness of soft clay layer which had already been investigated by ele-ctrical soundings and microgravity measurements, Swedish soundings were carried out at 96 locations as listed in Tables 4-11 and 4-12. Results of these soundings are shown in Fig. 4-15 as a contour map of

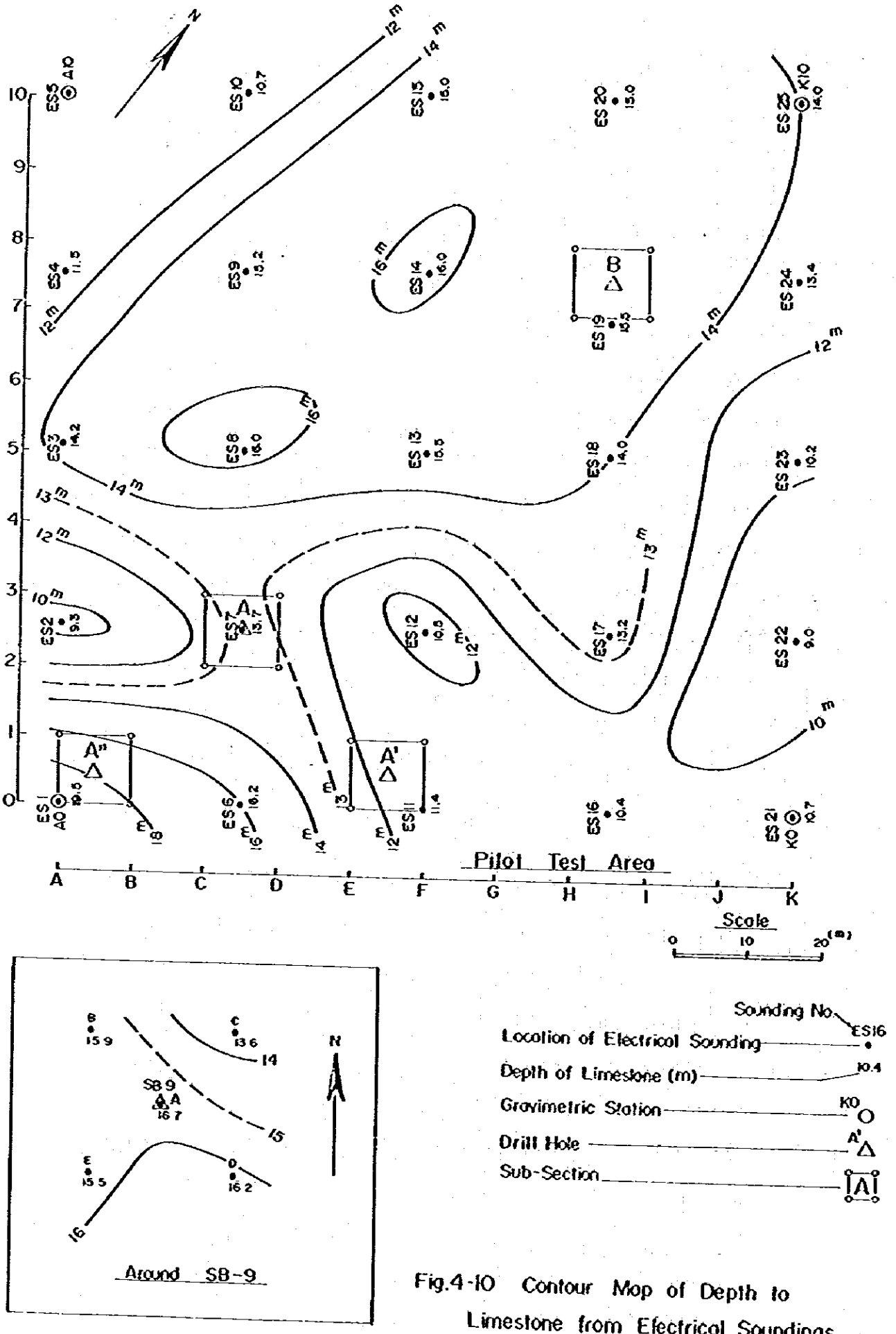
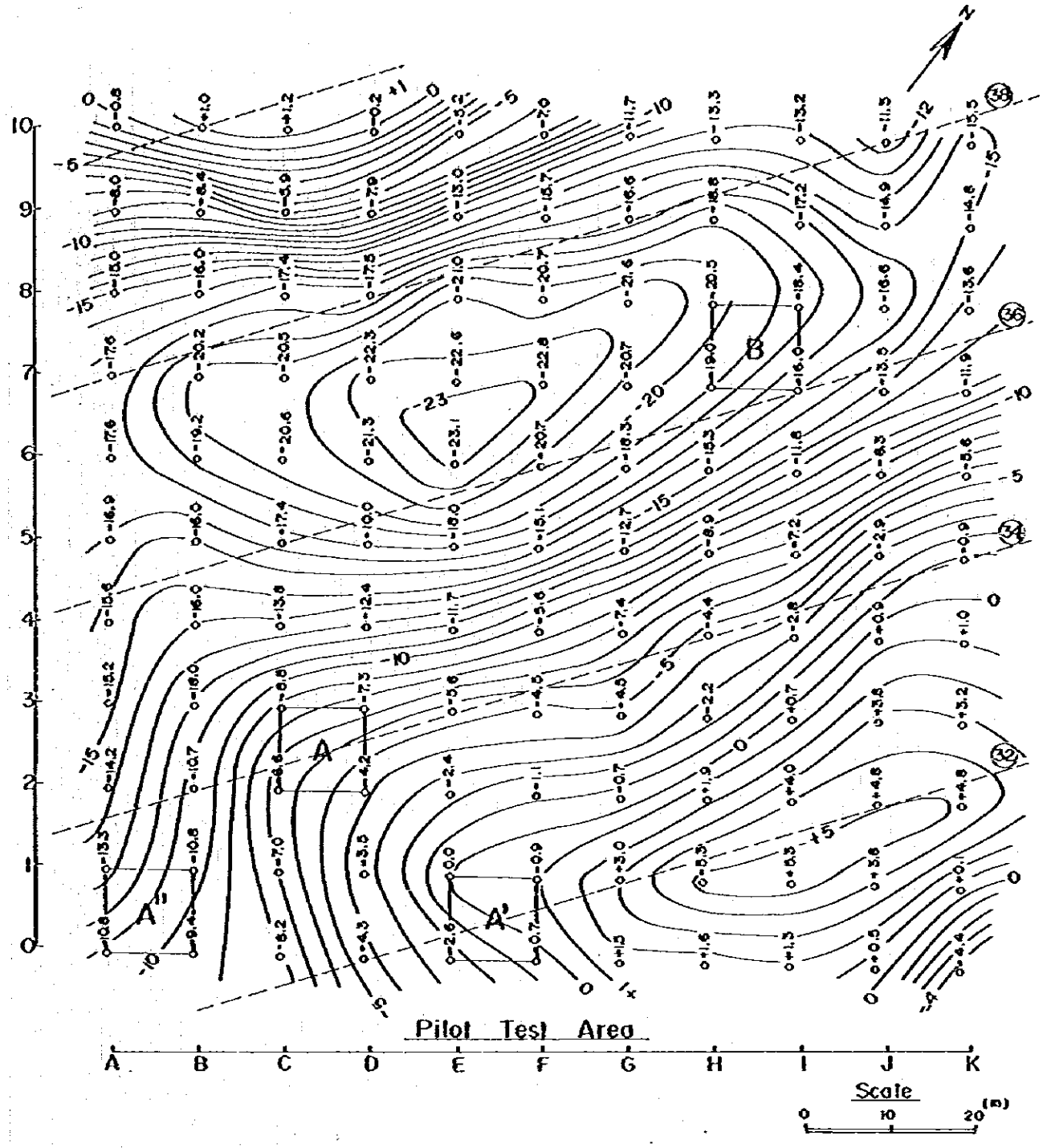


Fig.4-10 Contour Map of Depth to Limestone from Electrical Soundings



Regional Anomaly : ㉞ - - - -

Contour Interval : 0.01m-gal

Sub-Section : [A]

Fig. 4-11 Contour Map of Residual Anomaly from Micro-gravity Measurements

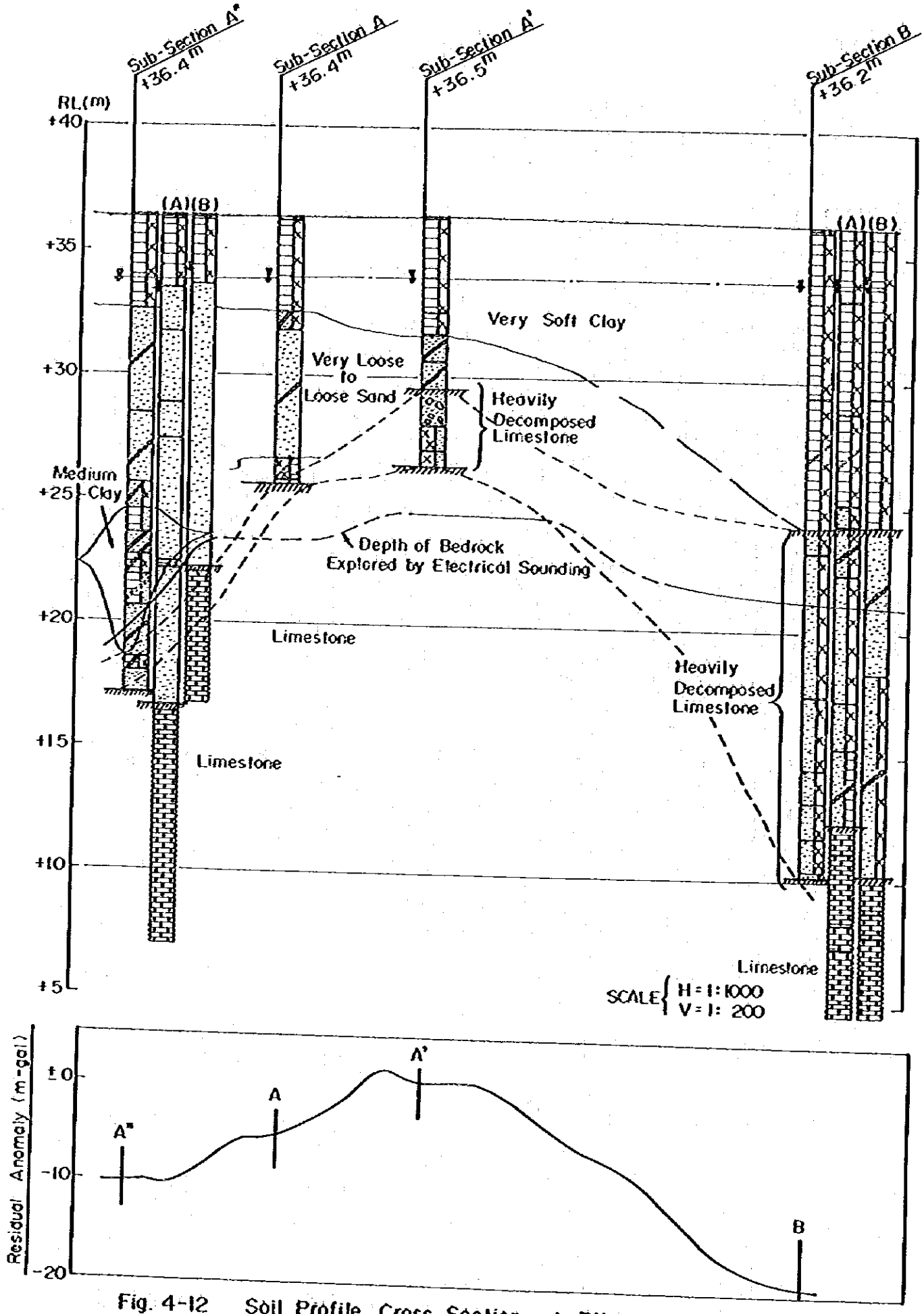


Fig. 4-12 Soil Profile, Cross Section at Pilot Test Area

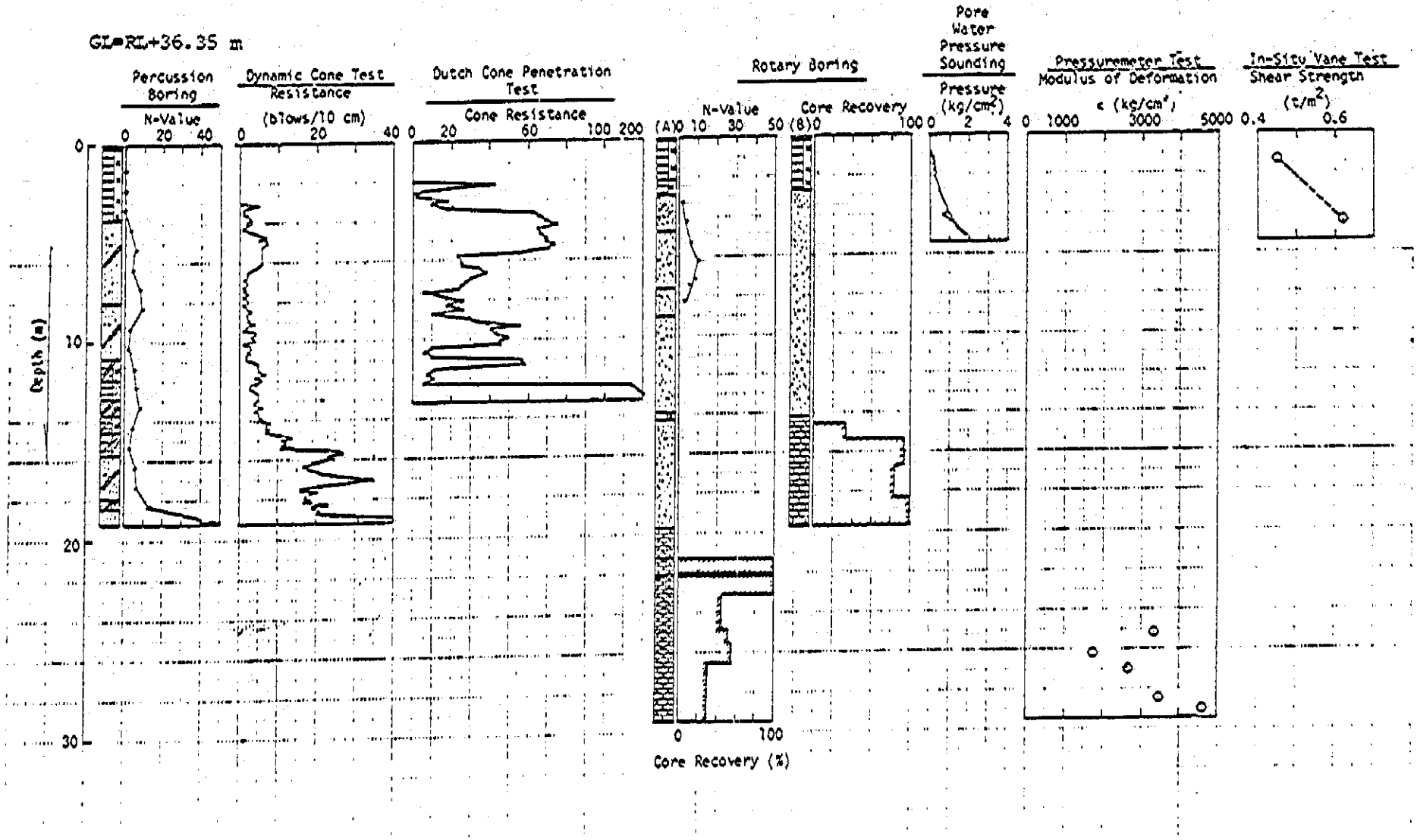


Fig. 4-13a Results of Investigations at Pilot Test Area (Sub-Section A")

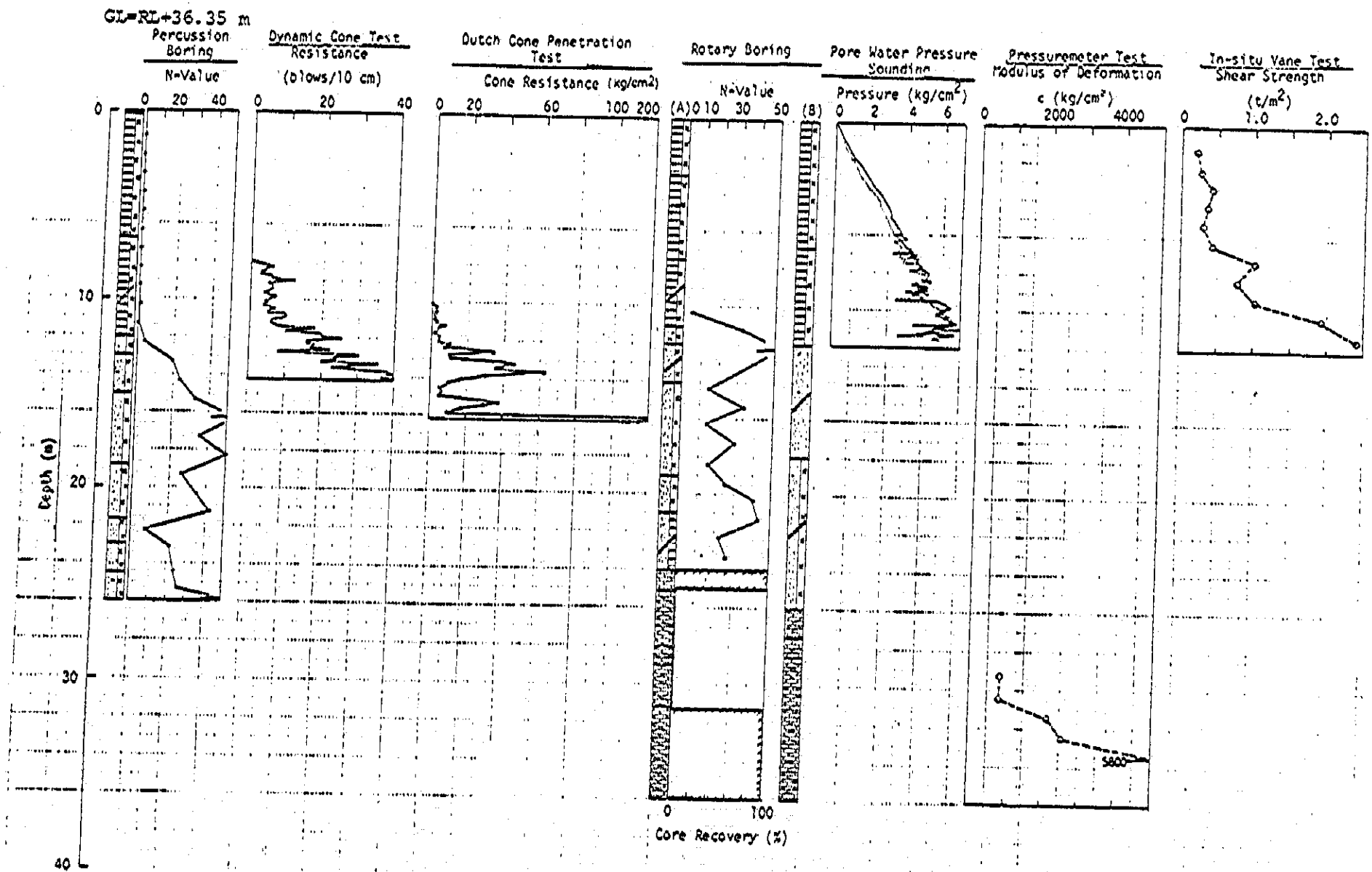


Fig. 4-13b Results of Investigations at Pilot Test Area (Sub-Section B)

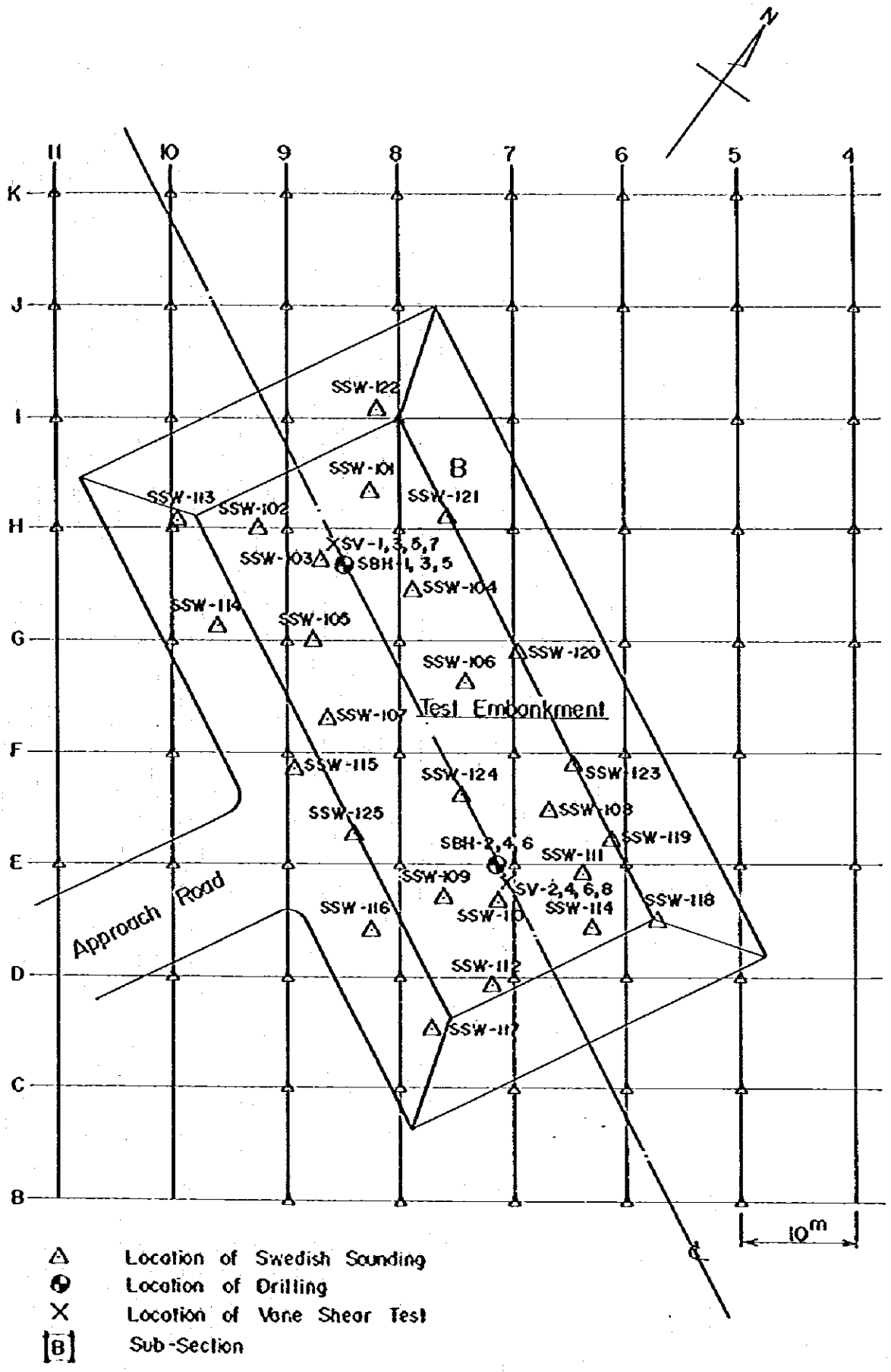


Fig. 4-14 Locations of Various Investigations Performed for Test Embankment

Table 4-11 Summary of Swedish Soundings Carried Out at Pilot Test Area, Sentul

Point No.	Ground Level (RL+m)	Depth of Water (m)	Penetration Depth under 100 kg Weight (m)	Penetration by the Last 10 Nos. of Half Turn (m)	Sounding Depth (m)	Materials at Final Depth
B5	36.469	0.02	5.34	0.08	5.52	Sand
B6	36.387	0.07	5.45	0.46	5.91	Sand
B7	36.317	0.15	9.78	0.08	9.86	Sand
B8	36.347	0.13	8.07	0.32	8.39	Sand
B9	36.299	0.15	8.44	0.31	8.75	Sand
C5	36.430	0.30	5.43	0.28	5.71	Sand
C6	36.338	0.90	11.11	0.12	11.63	
C7	36.338	0.10	12.69	0.32	13.01	Sand
C8	36.317	0.19	12.55	0.13	12.68	Sand
C9	36.366	0.12	8.26	0.05	8.31	
C10	36.347	0.08	7.31	0.02	7.51	Limestone?
D5	36.427	0.08	15.40	0.04	15.44	
D6	36.350	0.13	11.49	0.46	11.95	Sand
D7	36.332	0.19	14.36	0.07	14.43	
D8	36.317	0.15	15.33	0.09	15.42	
D8.5	-	0.17	7.44	0.03	7.47	
D9	36.369	0.07	7.87	0.01	7.88	Limestone?
D10	36.427	0.11	6.88	0.01	6.89	Limestone?
E6	36.378	0.50	15.20	0.19	15.39	
E10	36.457	0.10	10.70	0.01	10.71	Limestone?
K10	36.536	0.10	9.00	0.09	9.09	
K8	36.399	0.10	8.35	0.14	8.49	
K6	36.436	0	8.22	0.20	8.42	
J7	36.427	0.10	9.44	0.08	9.52	
J9	36.384	0.15	11.12	0.17	11.29	
J11	-	0.05	8.72	0.03	8.75	
H10	36.405	0.15	14.09	0.04	14.13	
H8	36.338	0.15	15.34	0.09	15.43	
H6	36.418	0.05	12.09	0.07	12.16	
F7	36.366	0.10	15.44	0.03	15.47	
F9	36.357	0.15	15.49	0.22	15.71	
J5	36.448	0.05	10.32	0.09	10.41	
J10	36.443	0.10	12.73	0.06	12.79	
H12	-	0.10	12.24	0.05	12.29	
F12	-	0.15	9.23	0.10	9.33	
J6	36.460	0.05	8.15	0.16	8.31	
K5	36.521	0.10	7.80	-	7.80	
J4	36.454	0.10	8.89	-	8.89	
I4	36.485	0.10	7.48	-	7.48	
H4	36.457	0.10	8.78	-	8.78	
G4	36.418	0.10	8.61	-	8.61	
F4	36.408	0.10	7.66	-	7.66	
E4	36.393	0.10	9.23	-	9.23	
E5	36.399	0.10	11.97	-	11.97	
F5	36.369	0.10	12.34	-	12.34	
G5	36.396	0.10	11.27	-	11.27	
H5	36.408	0.10	11.38	-	11.38	
I5	36.433	0.10	9.05	-	9.05	
J8	36.360	0.10	11.02	-	11.02	
I11	-	0.10	12.65	-	12.65	
I10	36.424	0.10	11.78	-	11.78	
I9	36.369	0.10	12.23	-	12.23	
I7	36.384	0.10	10.61	-	10.61	
H7	36.332	0.10	10.45	-	10.45	
H9	36.366	0.10	14.58	-	14.58	
H11	-	0.10	10.78	-	10.78	
G10	36.375	0.10	13.67	-	13.67	
G9	36.341	0.10	12.61	-	12.61	
G8	36.305	0.10	14.48	-	14.48	
G7	36.338	0.10	11.20	-	11.20	
G6	36.399	0.10	11.77	-	11.77	
E12	-	0.10	7.60	-	7.60	
E10	36.418	0.10	9.00	-	9.00	
E8	36.353	0.10	14.25	-	14.25	
E7	36.369	0.10	13.25	-	13.25	
E9	36.363	0.10	12.72	-	12.72	
K11	-	0.10	10.80	-	10.80	
K9	36.347	0.10	10.82	-	10.82	
K7	36.430	0.10	8.93	-	8.93	
F6	36.262	0.10	11.80	-	11.80	
F8	36.341	0.10	14.40	-	14.40	
Total	71 locs.	-	-	-	770.31 m	

Note: These soundings were carried out before construction of the test embankment

Table 4-12 Summary of Swedish Soundings Carried out at Test Embankment Area, Sentul

Swedish Sounding No.	Ground Level (RL + m)	Water Table* (GL ± m)	Water Table (16/1/81) (GL ± m)	Sounding Depth (m)	Remarks
SSW-101	37.49	-0.92	-0.64	16.90	
SSW-102	37.43	-0.92	-0.64	16.15	
SSW-103	37.47	-0.94	-0.64	16.55	
SSW-104	37.46	-0.94	-0.64	15.80	
SSW-105	37.49	-0.95	-0.42	14.52	
SSW-106	37.31	-0.90	-0.32	15.80	
SSW-107	37.41	-0.90	-0.27	14.40	
SSW-108	37.28	-0.40	-0.32	17.35	Sand Drain Area
SSW-109	37.23	-0.40	-0.36	15.60	
SSW-110	37.23	+0.10	-0.30	18.85	
SSW-111	37.39	+0.06	-0.42	17.70	
SSW-112	37.32	+0.04	-0.25	15.50	
SSW-113	37.42	-0.96	-0.56	16.70	
SSW-114	37.67	-0.96	-0.49	16.15	
SSW-115	37.43	-0.86	-0.60	16.90	
SSW-116	37.43	-0.44	-0.35	15.75	Sand Drain Area
SSW-117	37.41	-0.40	-0.45	15.70	
SSW-118	37.39	-0.40	-0.45	18.40	
SSW-119	37.50	-0.40	-0.32	16.40	
SSW-120	37.44	-0.86	-0.40	14.90	
SSW-121	37.43	-0.86	-0.32	15.20	
SSW-122	37.39	-0.86	-0.52	13.70	
SSW-123	37.23	-0.36	-0.36	21.50	
SSW-124	37.26	-0.44	-0.44	16.50	
SSW-125	37.26	-0.60	-0.60	16.55	
Total	25 locations	-	-	409.47	

* Concurrent with Swedish Soundings

Note: These soundings were carried out after the first stage of the test embankment construction

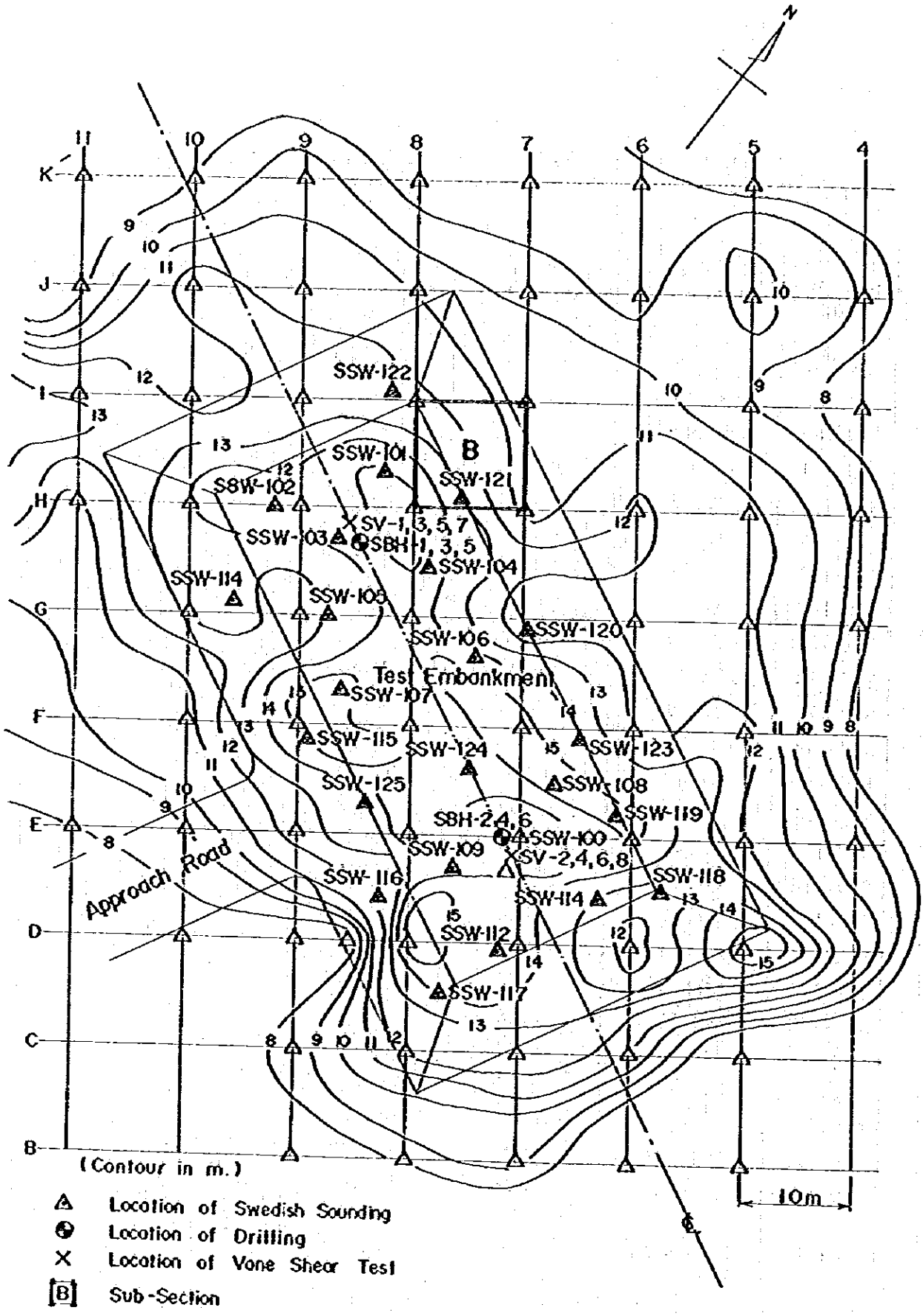


Fig. 4 - 15 Contour Map of Soft Clay Layer Thickness

the thickness of the soft clay layer. As shown in Fig. 4-15 and Table 4-13, 6 check borings were carried out using rotary-type boring machines at the test embankment area during Phase II. A soil profile at the test embankment area is shown in Fig. 4-16 together with the results of vane shear tests and Swedish soundings. At borings SBH-1 and SBH-2, a harder layer was encountered at a depth of 14.5 m. This layer may be heavily decomposed limestone. The data of check borings will be utilised in Section 6.

(2) Laboratory Soil/Rock Tests on Samples from Sentul Site

Laboratory tests were performed on soil samples and rock core samples of the Sentul site. Undisturbed soil samples were obtained by a thin-wall tube sampler and disturbed soil samples were obtained by a split spoon sampler (SPT sampler) and peat sampler. The total quantity of laboratory tests is tabulated in Table 4-14. Samples were subjected to the following laboratory tests:

1) For Soil Samples

- Physical Property Tests

  * Natural Water Content Tests
  * Atterberg Limit Tests
  * Specific Gravity Tests
  * Wet Density Measurements

Table 4-13 Check Boring Performed at Test Embankment

Boring No.	Location	Object
SBH-1	Preloading Area	Obtainment of Initial Soil Properties Before Placement of Test Embankment
SBH-2	Preloading plus Sand Drain Area	
SBH-3	Preloading Area	Obtainment of Soil Properties at End of Test Embankment (1st Stage), December, 1981
SBH-4	Preloading plus Sand Drain Area	
SBH-5	Preloading Area	Obtainment of Soil Properties at End of Test Embankment (2nd Stage), July, 1981
SBH-6	Preloading plus Sand Drain Area	

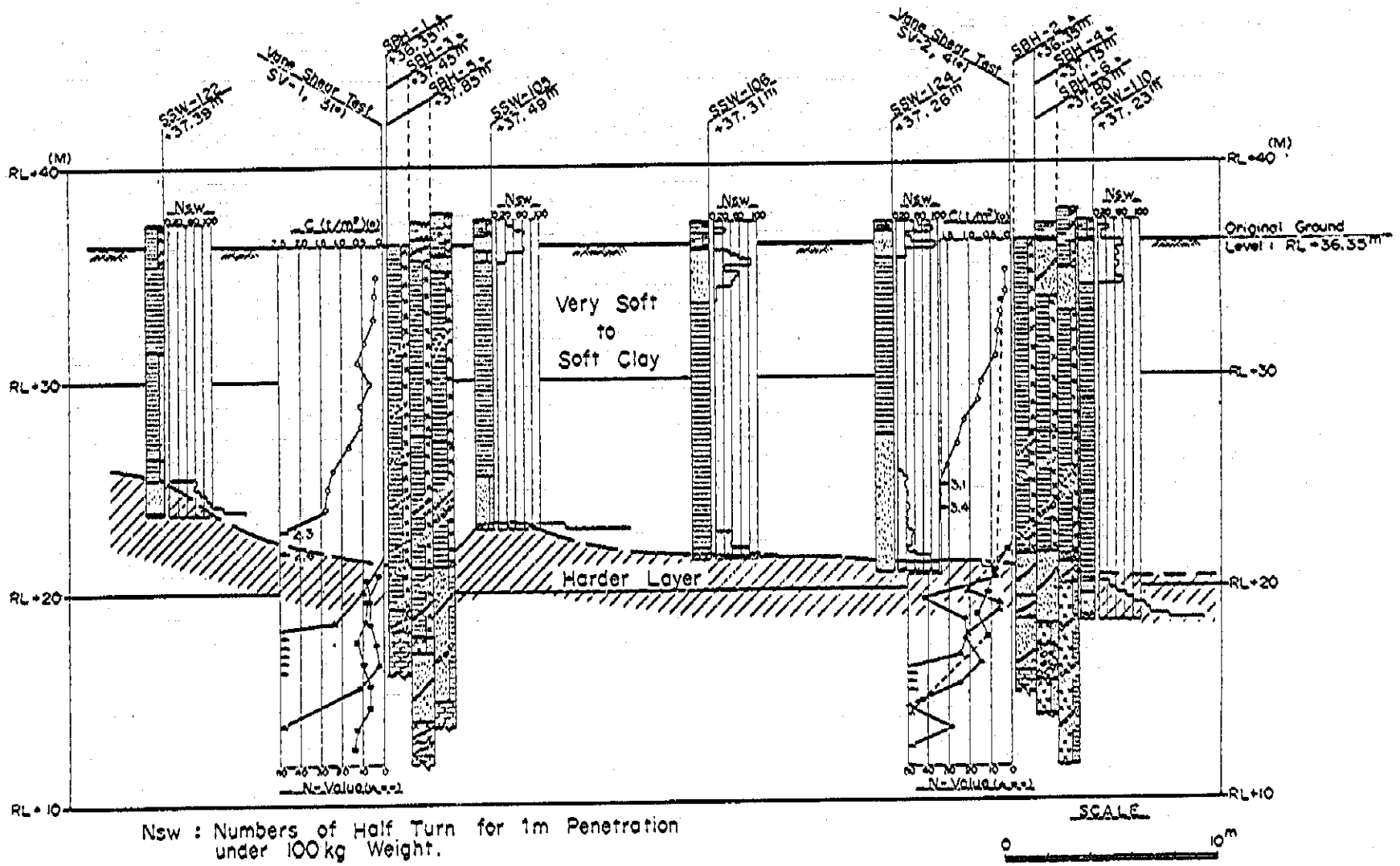


Fig. 4-16 Soil Profile at Test Embankment Area

Table 4-14 Laboratory Works Performed on Samples from Sentul

Site			Sentul																					Total
Area			Pilot Test Area								Entire Area									Pond				
Type of Boring			Rotary								Percussion									Peat Sampler				
Boring No.			Area A	Area B	SBH-1	SBH-2	SBH-3	SBH-4	SBH-5	SBH-6	Area A	SB-1	SB-2	SB-3	SB-4	SB-5	SB-6	SB-7	SB-8	SB-9	MC-4	MC-5	
On Soil Samples	Clay Mineral Analysis (Nos.)		-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	5
On Soil Samples	Chemical Analysis (Nos.)		-	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	5
On Soil Samples	Physical Property Test	Water Content (Nos.)	3	11	8	8	20	11	15	11	16	6	4	5	9	8	2	5	2	7	9	9	169
On Soil Samples	Physical Property Test	Specific Gravity (Nos.)	3	11	8	8	20	11	15	11	16	6	4	5	9	8	2	5	2	7	9	9	169
On Soil Samples	Physical Property Test	Unit Weight (Nos.)	3	11	8	8	20	11	15	11	-	-	-	-	-	-	-	-	-	-	-	-	87
On Soil Samples	Physical Property Test	Atterberg Limits (Set)	3	11	8	8	17	9	12	11	7	5	4	2	3	5	2	-	-	7	9	9	114
On Soil Samples	Physical Property Test	Grain Size Analysis: By Sieve Only (Nos.)	-	-	-	-	1	2	2	-	6	-	-	3	5	2	-	3	2	-	-	-	26
On Soil Samples	Physical Property Test	Grain Size Analysis: By Sieve and Sedimentation (Nos.)	3	11	8	8	19	9	13	11	10	6	4	2	4	6	2	2	-	7	9	9	143
On Soil Samples	Mechanical Property Test	Unconfined Compression Test (Nos.)	8	14	8	8	14	9	3	1	-	-	-	-	-	-	-	-	-	-	-	-	65
On Soil Samples	Mechanical Property Test	Unconsolidated-Undrained Triaxial Compression Test (Set)	3	8	4	4	9	6	8	9	-	-	-	-	-	-	-	-	-	-	-	-	51
On Soil Samples	Mechanical Property Test	Consolidated-Undrained Triaxial Compression Test (Set)	2	3	1	1	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
On Soil Samples	Mechanical Property Test	Consolidation Test (Set)	3	9	8	7	14	6	9	9	-	-	-	-	-	-	-	-	-	-	-	-	65
*	Mechanical Property Test	Unconfined Compression Test (Nos.)	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
Phase			I		II																		

* On rock core samples

- Mechanical Property Tests
  - * Unconfined Compression Tests
  - * Triaxial Compression Tests (U-U Condition and C-U Condition)
  - * Consolidation Tests
  - * Laboratory Vane Shear Tests
- Chemical Analysis
- Clay Mineral Analysis

2) For Rock Cores

* Unconfined Compression Tests

The results of these laboratory soil tests are summarized in Tables 4-15a to 4-15i, and the results of rock tests are shown in Table 4-16. Detailed data of the laboratory tests are presented as Appendix F in a separate volume.

4.2.2 Subsurface Ground Conditions at Sentul

Fig. 4-5 shows the plan of the Sentul site together with locations of borings and soundings, etc. The elevation of the ground surface at the Sentul site is slightly lower than that of the surrounding area. The site is enclosed by rivers and streams and there are many dwellings along the same. The elevation of the ground surface at the site is

Table 4-15a Summary of Soil Tests on Samples from Sentul (1)

Boring No.		Sub-Section A"																			
Type of Boring		Rotary			Percussion																
Sample No.		S-1	S-2	S-3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Sample depth		0.10 ~ 0.90	1.00 ~ 1.80	2.00 ~ 2.73	2.00 ~ 2.45	3.00 ~ 3.45	4.00 ~ 4.45	5.00 ~ 5.45	7.00 ~ 7.45	8.00 ~ 8.45	9.00 ~ 9.45	10.00 ~ 10.45	11.00 ~ 11.45	12.00 ~ 12.45	13.00 ~ 13.45	14.00 ~ 14.45	15.00 ~ 15.45	16.00 ~ 16.45	17.00 ~ 17.45	19.05 ~ 19.50
Condition of sample		Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed
Natural water content, %		83.9	86.6	78.8	78.6	66.5	13.2	13.6	13.5	22.6	6.2	1.5	13.2	27.3	32.0	24.5	41.0	14.5	19.8	18.4
Specific gravity		2.605	2.591	2.604	2.571	2.573	2.622	2.638	2.629	2.635	2.648	2.636	2.639	2.642	2.616	2.614	2.517	2.626	2.691	2.765
Wet density, g/cm³		1.51	1.50	1.53	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Dry density, g/cm³		0.821	0.802	0.856	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Natural void ratio		2.17	2.23	2.04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Degree of saturation, %		100	100	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atterberg limits	Liquid limit, %	78.1	80.9	77.5	72.1	79.9	-	-	-	-	-	-	-	31.1	38.0	30.4	49.0	-	38.4	-
	Plastic limit, %	35.8	36.8	36.2	29.4	29.9	-	-	-	-	-	-	-	18.4	19.8	18.5	26.9	-	25.5	-
	Plasticity index	42.3	44.1	41.3	42.7	50.0	-	-	-	-	-	-	-	12.7	18.2	11.9	22.1	-	12.9	-
Grain size analysis	Gravel, %	0	0	0	0	0	30	33	57	4	82	90	35	12	4	0	0	20	16	16
	Sand, %	0	0	0	0	0	62	64	42	93	15	7	44	28	12	39	11	59	24	42
	Silt, %	24	24	25	21	30	8	3	1	3	3	3	11	35	37	32	40	11	34	29
	Clay & colloid, %	76	76	75	79	70							10	25	47	29	49	10	26	13
	Max. diameter, mm	0.074	0.074	0.074	0.048	0.048	19.1	19.1	19.1	4.76	25.4	19.1	19.1	9.52	4.76	0.84	0.84	9.52	19.1	9.52
	Diam. at 60%	0.0022	0.0022	0.0020	-	-	1.2	1.7	4.2	0.40	9.5	6.1	1.4	0.075	0.011	0.075	0.012	0.60	0.085	0.15
	Diam. at 10%	-	-	-	-	-	0.087	0.22	0.44	0.14	0.65	2.0	0.0040	-	-	-	-	0.0051	-	0.0016
Visual soil description		Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Gravel Sand	Gravel Sand	Sandy Gravel	Sand	Gravel	Gravel	Gravel Sand w/ Silt	Sandy Silt w/ Clay	Silty Clay	Silty Sand w/ Clay	Silty Clay	Gravel Sand w/ Silt	Sandy Silt w/ Clay	Silty Clay
Unified soil classification		MH	MH	MH	CH	CH	(SW-SM)	SW	SW	SP	GW	GP	-	CL	CL	CL	CL	-	ML	-
Unconfined compression test	Undisturbed sample, kg/cm²	0.055 ~0.066	0.050	0.115 ~0.138	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Remoulded sample, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Strain at failure, %	10.0~ 13.0	8.0~ 11.0	2.7~ 3.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Triaxial compression test	Angle of internal friction	0°	0°	9°	0°	9°	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Cohesion, kg/cm²	0.04	0.04	0.07	0.08	0.09	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Condition of drainage	U-U	U-U	C-U	U-U	C-U	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Consolidation test	Preconsolidation pressure, kg/cm²	-	0.20	0.28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Compression index	0.58	0.64	0.59	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4-15b Summary of Soil Tests on Samples from Sentul (2)

Boring No.		Sub-Section B										
Type of Boring		Rotary										
Sample No.*		S-1	S-2	S-3	S-4	S-5 Top	S-5 Bottom	S-6	S-7	S-8	S-9 Top	S-9 Bottom
Sample depth		1.00~1.80m	2.00~2.80m	3.00~3.80m	5.00~5.80m	6.00~6.40m	6.40~6.80m	7.50~8.10m	8.50~9.10m	9.50~10.30m	10.50~11.00m	11.00~11.13m
Natural water content, %		99.2	97.4	90.0	78.1	70.3	63.1	64.6	57.4	49.4	57.1	55.7
Specific gravity		2.606	2.583	2.606	2.618	2.612	2.629	2.637	2.638	2.626	2.603	2.526
Wet density, g/cm3		1.45	1.45	1.49	1.53	1.57	1.61	1.60	1.64	1.71	1.66	1.63
Dry density, g/cm3		0.728	0.735	0.784	0.859	0.922	0.987	0.972	1.04	1.15	1.06	1.05
Natural void ratio		2.58	2.52	2.32	2.05	1.83	1.66	1.71	1.53	1.29	1.46	1.41
Degree of saturation, %		100	100	100	100	100	100	99	99	100	100	100
Atterberg limits	Liquid limit, %	76.2	83.6	87.4	62.0	67.8	59.2	67.0	56.9	56.5	68.1	53.0
	Plastic limit, %	33.8	34.9	34.1	27.1	29.9	26.3	26.1	25.1	25.3	26.3	23.3
	Plasticity index	42.4	48.7	53.3	34.9	37.9	32.9	40.9	31.8	31.2	41.8	29.7
Grain size analysis	Gravel, %	0	0	0	0	0	0	0	0	0	0	0
	Sand, %	0	0	0	7	1	2	4	1	1	1	27
	Silt, %	23	19	18	32	29	28	32	36	35	23	33
	Clay & colloid, %	77	81	82	61	70	70	64	63	64	76	40
	Max. diameter, mm	0.043	0.042	0.074	0.25	0.105	0.105	0.105	0.105	0.105	0.25	0.84
	Diam. at 60%	0.0010	-	-	0.0046	0.0020	0.0027	0.0035	0.0040	0.0036	0.0017	0.057
	Diam. at 10%	-	-	-	-	-	-	-	-	-	-	-
Visual soil classification		Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay w/Sand
Unified soil classification		CH	CH	CH	CH	CH	CH	CH	CH	CH	CH	CH
Unconfined compression test	Undisturbed sample, kg/cm2	-	0.033	0.062~0.065	0.057~0.075	-	-	-	0.108~0.137	0.295~0.305	0.315~0.427	-
	Remoulded samoke, kg/cm2	-	-	-	-	-	-	-	-	-	-	-
	Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-
	Strain at failure, %	-	(15.0)	4.3~5.5	4.0~8.0	-	-	-	9.8~11.5	5.5~8.5	4.9~7.9	-
Triaxial compression test	Angle of internal friction	-	0°	0° / 7°	0°	11°	0°	0°	0°	0° / 14°	0°	-
	Cohesion, kg/cm2	-	0.03	0.035 / 0.10	0.04	0.05	0.05	0.06	0.08	0.19 / 0.12	0.21	-
	Condition of drainage	-	U-U	U-U / C-U	U-U	C-U	U-U	U-U	U-U	U-U / C-U	U-U	-
Consolidation test	Preconsolidation pressure, kg/cm2	-	0.17	0.46	0.25	-	0.28	0.50	0.43	1.3	1.3	-
	Compression index	0.59	0.64	0.66	0.63	-	0.49	0.54	0.46	0.44	0.53	-

* Note: All samples are undisturbed.

Table 4-15c Summary of Soil Tests on Samples from Sentul (3)

Boring No.		SBH-1								SBH-2							
Sample No.*		UD-1	UD-2	UD-3	UD-4	UD-5	UD-6	UD-7	UD-8	UD-1	UD-2	UD-3	UD-4	UD-5	UD-6	UD-7	UD-8
Sample depth		1.00 ~ 1.80	3.00 ~ 3.80	5.00 ~ 5.80	7.00 ~ 7.80	9.00 ~ 9.80	11.00 ~ 11.80	13.00 ~ 13.80	15.00 ~ 15.80	1.00 ~ 1.80	3.00 ~ 3.80	5.00 ~ 5.80	7.00 ~ 7.80	9.00 ~ 9.80	11.00 ~ 11.80	13.00 ~ 13.80	15.00 ~ 15.80
Natural water content, %		115.4	100.6	87.4	76.2	41.8	35.6	38.2	40.1	104.7	96.2	75.4	59.5	49.8	34.0	35.9	19.7
Specific gravity		2.584	2.583	2.556	2.576	2.603	2.605	2.616	2.607	2.555	2.553	2.578	2.589	2.615	2.623	2.625	2.623
Wet density, g/cm³		1.40	1.44	1.49	1.57	1.78	1.82	1.81	1.81	1.46	1.44	1.54	1.64	1.70	1.85	1.83	2.08
Dry density, g/cm³		0.65	0.72	0.80	0.89	1.25	1.34	1.31	1.29	0.71	0.73	0.88	1.03	1.13	1.38	1.35	1.74
Natural void ratio		2.98	2.60	2.21	1.89	1.08	0.94	1.00	1.02	2.58	2.48	1.93	1.52	1.30	0.90	0.95	0.51
Degree of saturation, %		100	100	100	100	99	100	100	100	100	99	100	100	100	99	100	100
Atterberg limits	Liquid limit, %	78.7	85.4	71.3	69.9	43.0	39.5	41.8	43.5	88.0	79.8	70.0	59.5	56.9	42.5	36.3	33.9
	Plastic limit, %	34.3	37.3	33.9	31.4	23.2	20.9	21.9	22.4	35.1	34.8	32.0	27.2	23.5	20.1	18.6	16.5
	Plasticity index	44.4	48.1	37.4	38.5	19.8	18.6	19.9	21.1	52.9	45.0	38.0	32.1	33.4	22.4	17.7	17.4
Grain size analysis	Gravel, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
	Sand, %	0	0	0	0	24	17	14	10	1	1	4	2	4	15	18	42
	Silt, %	27	28	37	39	46	51	50	58	31	31	37	39	44	58	49	17
	Clay & colloid, %	73	72	63	61	30	32	36	32	68	68	59	59	52	27	33	24
	Max. diameter, mm	0.044	0.043	0.063	0.043	0.590	1.19	0.297	1.19	0.210	0.210	0.210	0.210	0.210	0.420	0.420	19.10
	Diam. at 60%	-	0.0011	0.0016	0.0018	0.028	0.024	0.014	0.014	-	-	0.0024	0.0022	0.0035	0.029	0.016	0.33
	Diam. at 10%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Visual soil description		Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Clay w/Sand	Clay w/Sand	Clayey Sand
Unified soil classification		(CH)	(CH)	(CH)	CH	CL	CL	CL	CL	CH	CH	CH	CH	CH	CL	CL	SC
Unconfined compression test	Undisturbed sample, kg/cm²	-	-	0.065	0.050	0.21	0.23	0.32	0.21	-	-	0.058	-	0.016	0.35 ~0.49	0.25	-
	Remoulded sample, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Strain at failure, %	-	-	6.5	(20.0)	5.5 ~5.9	18.0	10.5	(20.0)	-	-	9~12	-	9~12	14~20	12~20	-
Triaxial compression test	Angle of internal friction	-	-	0°	0°	0°	-	0°	-	-	-	-	0°	9°	0°	0°	0°	-
	Cohesion, kg/cm²	-	-	0.030	0.040	0.14	-	0.20	-	-	-	-	0.06	0.28	0.10	0.18	0.18	-
	Condition of drainage	-	-	U-U	U-U	U-U	-	U-U	-	-	-	-	UU	C-U	UU	UU	UU	-
Consolidation test	Preconsolidation pressure, kg/cm²	-	0.13	0.19	0.13	(0.60)	-	-	-	0.11	0.14	0.19	-	0.42	(1.2)	-	-
	Compression index	0.70	0.80	0.66	0.50	0.35	0.31	0.29	0.26	0.88	0.74	0.60	0.48	0.38	0.30	0.22	-
Lab. Vane Shear	Max. Cu. kg/cm²	0.019	0.031	-	-	-	-	-	-	0.020	0.031	0.053	-	-	-	-	-

* Note : All samples are undisturbed.

Table 4-15d Summary of Soil Tests on Samples from Sentul (4)

Boring No.		SBH-3																			
Sample No.		UD-1 Top	UD-1 Bottom	UD-2	UD-3	UD-4	UD-5	UD-6	UD-7	UD-8	UD-9	UD-10	UD-11	UD-12	UD-13	UD-14	UD-15	UD-16	UD-17 Top	UD-17 Middle	UD-17 Bottom
Sample depth		0.00 ~ 0.15	0.15 ~ 0.80	1.00 ~ 1.80	2.00 ~ 2.80	3.00 ~ 3.80	4.00 ~ 4.80	5.00 ~ 5.80	6.00 ~ 6.80	7.00 ~ 7.80	8.00 ~ 8.80	9.00 ~ 9.80	10.00 ~ 10.80	11.00 ~ 11.80	12.00 ~ 12.80	13.00 ~ 13.80	14.00 ~ 14.80	15.00 ~ 15.80	16.00 ~ 16.17	16.17 ~ 16.27	16.27 ~ 16.40
Condition of sample																					
Natural water content, %		20.7	20.5	14.5	93.4	98.7	101.3	91.7	86.4	74.8	70.8	57.7	50.5	44.7	41.8	40.3	37.4	43.6	29.0	47.2	20.1
Specific gravity		2.642	2.652	2.602	2.559	2.545	2.556	2.575	2.564	2.560	2.606	2.603	2.665	2.607	2.630	2.642	2.632	2.652	2.611	2.634	2.671
Wet density, g/cm³		2.00	2.03	2.03	1.46	1.46	1.46	1.46	1.50	1.57	1.56	1.63	1.70	1.75	1.77	1.79	1.81	1.89	1.75	1.80	1.91
Dry density, g/cm³		1.66	1.68	1.77	0.75	0.73	0.73	0.76	0.80	0.90	0.91	1.03	1.13	1.21	1.25	1.28	1.32	1.32	1.36	1.22	1.59
Natural void ratio		0.594	0.574	0.468	2.39	2.46	2.52	2.38	2.19	1.86	1.85	1.52	1.36	1.16	1.11	1.07	1.00	1.01	0.92	1.15	0.68
Degree of saturation, %		92	95	81	100	100	100	99	100	100	100	99	99	100	99	99	99	100	82	100	79
Atterberg limits	Liquid limit, %	38.0	-	-	77.8	79.2	82.4	89.0	74.0	68.7	60.1	51.1	49.7	45.2	44.3	42.9	44.4	51.2	48.1	62.2	-
	Plastic limit, %	18.6	-	-	32.2	33.6	32.7	34.9	31.0	30.4	26.1	21.8	25.0	20.9	20.1	20.2	21.6	21.2	23.3	27.8	-
	Plasticity index	19.4	-	-	45.6	45.6	49.7	54.1	43.0	38.3	33.9	29.3	24.7	24.3	24.2	22.7	22.8	30.0	24.8	34.4	-
Grain size analysis	Gravel, %	1	3	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
	Sand, %	47	59	75	0	0	0	0	0	2	0	0	6	14	10	8	13	11	45	0	41
	Silt, %	17	17	4	11	22	16	17	22	25	31	36	45	38	44	47	42	39	17	25	20
	Clay & colloid, %	35	21		89	78	84	83	78	73	69	64	49	48	46	45	45	50	38	75	20
	Max. diameter, mm	4.76	9.52	9.52	0.020	0.032	0.074	0.043	0.043	0.250	0.041	0.041	0.250	0.250	0.420	0.250	0.250	0.420	2.00	0.074	6.73
	Diam. at 60%	0.11	0.145	1.10	-	0.0012	-	0.0010	0.001	0.0021	0.0029	0.0039	0.011	0.012	0.014	0.014	0.016	0.012	0.095	0.0020	0.30
	Diam. at 10%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Visual soil description		Clayey Sand	Clayey Sand	Sand	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Sandy Clay	Silty Clay	Clayey Sand
Unified soil classification		SC	(SC)	SW	CH	CH	CH	CH	CH	CH	CH	CH	(CH)	CL	CL	CL	CL	(CH)	(SC)	CH	-
Unconfined compression test	Undisturbed sample, kg/cm²	-	-	-	0.034	-	-	-	0.075	0.082	0.082	0.10	0.085	0.23	0.27	-	0.35	0.37	-	-	-
	Remoulded sample, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Strain at failure, %	-	-	-	8.0 ~ 15.0	-	-	-	4.5	10.0	7.0 ~ 15.0	10.5	15.0	9.3	6.5 ~ 8.0	-	13.5	11.5	-	-	-
Triaxial compression test	Angle of internal friction	-	-	-	-	-	-	0°	0°	0° / 8.5°	0°	15.5°	0°	0° / 15°	15°	0° / 16°	0° / 15°	0°	-	-	-
	Cohesion, kg/cm²	-	-	-	-	-	-	0.030	0.050	0.055 / 0.15	0.050	0.04	0.10	0.12 / 0.1	0	0.16 / 0	0.23 / 0.10	0.25	-	-	-
	Condition of drainage	-	-	-	-	-	-	U-U	U-U	U-U / C-U	U-U	C-U	U-U	U-U / C-U	C-U	U-U / C-U	U-U / C-U	U-U	-	-	-
Consolidation test	Preconsolidation pressure, kg/cm²	-	-	-	0.13	0.16	0.16	0.16	0.72	0.92	0.36	-	0.58	-	0.96	-	-	-	-	-	-
	Compression index	-	-	-	0.63	0.63	0.68	0.68	0.88	0.81	0.55	0.45	0.39	0.42	0.33	0.34	0.35	0.34	-	-	-
Lab. Vane Shear Test	Maximum shear strength kg/cm²	-	-	-	0.026	0.020	0.021	-	-	-	-	0.048	-	-	-	-	-	-	-	-	-

Table 4-15e Summary of Soil Tests on Samples from Sentul (5)

Boring No.	SBH-4											SBH-5						
Sample No.	UD-1	UD-2	UD-3	UD-4 Top	UD-4 Bottom	UD-5	UD-6 Top	UD-6 Bottom	UD-7	UD-8	UD-9	UD-1 Top	UD-1 Bottom	UD-2 Top	UD-2 Bottom	UD-3 Top	UD-3 Bottom	UD-4
Sample depth	0.00 ~ 0.80	1.00 ~ 1.70	2.00 ~ 2.70	4.00 ~ 4.40	4.40 ~ 4.80	6.00 ~ 6.80	8.00 ~ 8.40	8.40 ~ 8.80	10.00 ~ 10.80	12.00 ~ 12.80	14.00 ~ 14.00	0.50 ~ 0.80	0.80 ~ 1.35	1.50 ~ 1.80	1.80 ~ 2.35	2.50 ~ 2.85	2.65 ~ 3.35	5.00 ~ 5.85
Condition of sample	Undisturbed Undisturbed	Undisturbed Undisturbed	Undisturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed	Disturbed Undisturbed
Natural water content, %	19.6	10.5	14.9	73.0	32.2	76.5	69.7	62.9	40.0	30.2	33.2	17.5	18.5	22.7	13.6	15.6	82.5	83.8
Specific gravity	2.679	2.654	2.655	2.602	2.628	2.602	2.623	2.627	2.644	2.668	2.661	2.674	2.684	2.651	2.633	2.629	2.630	2.614
Wet density, g/cm³	2.03	2.08	2.07	1.56	1.72	1.53	1.56	1.60	1.79	1.88	1.86	1.80	2.12	2.14	1.86	1.55	1.51	1.48
Dry density, g/cm³	1.70	1.88	1.80	0.90	1.30	0.87	0.92	0.98	1.28	1.44	1.40	1.53	1.79	1.74	1.64	1.34	0.83	0.81
Natural void ratio	0.58	0.41	0.47	1.89	1.02	2.00	1.85	1.67	1.07	0.85	0.91	0.746	0.50	0.520	0.61	0.96	2.18	2.25
Degree of saturation, %	91	68	84	100	83	100	99	99	99	95	98	64	99	100	59	43	100	98
Atterberg limits: Liquid limit, %	37.3	-	-	83.6	50.8	79.2	70.1	64.0	42.8	38.5	42.7	-	41.3	32.1	-	-	78.8	69.9
Atterberg limits: Plastic limit, %	13.2	-	-	32.3	19.9	34.1	29.5	26.1	18.3	18.8	19.5	-	19.3	14.8	-	-	30.2	28.7
Atterberg limits: Plasticity index	24.1	-	-	51.3	30.9	45.1	40.6	37.9	24.5	19.7	23.2	-	22.0	17.3	-	-	48.6	41.2
Grain size analysis: Gravel, %	5	22	29	2	11	0	0	0	0	0	0	1	1	2	18	19	0	0
Grain size analysis: Sand, %	52	72	65	6	46	4	1	0	11	27	10	44	43	53	77	75	0	1
Grain size analysis: Silt, %	15	(6)	(5)	11	8	20	27	23	52	40	44	36	19	15	5	6	6	21
Grain size analysis: Clay & colloid, %	28			81	35	76	72	77	37	33	46	19	37	30			94	78
Grain size analysis: Max. diameter, mm	9.52	9.52	9.52	4.76	9.52	0.420	0.420	0.041	0.420	0.420	0.420	4.76	4.76	4.76	9.52	9.52	0.0077	0.25
Grain size analysis: Diam. at 60%	0.16	1.20	1.49	0.0011	0.49	-	0.0019	0.0017	0.024	0.035	0.014	0.090	0.085	0.11	1.1	1.2	-	0.0010
Grain size analysis: Diam. at 10%	-	0.14	0.17	-	-	-	-	-	-	-	-	0.0017	-	-	0.12	0.13	-	-
Visual soil description	Clayey Sand	Sand	Sand	Silty Clay	Clayey Sand	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay w/Sand	Silty Clay	Sandy Clay	Sandy Clay	Clayey Sand	Sand	Sand	Silty Clay	Silty Clay
Unified soil classification	SC	SW	SW	CH	SC	CH	CH	CH	CL	CL	CL	(CL)	CL	SC	SW	SW	CH	CH
Unconfined compression test: Undisturbed sample, kg/cm²	-	-	-	0.13	-	0.065	-	0.13	0.21	0.39	0.42	-	-	1.3 ~2.3	-	-	0.12	-
Unconfined compression test: Remoulded sample, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unconfined compression test: Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unconfined compression test: Strain at failure, %	-	-	-	14.5	-	15.0	-	14.0	14.5	14.5 ~15.0	12.0 ~13.5	-	-	5.5 ~7.5	-	-	14	-
Triaxial compression test: Angle of internal friction	-	-	-	-	-	0°	0°	0°	2°	0°	0°	-	(0°)	-	-	-	-	-
Triaxial compression test: Cohesion, kg/cm²	-	-	-	-	-	0.050	0.060	0.065	0.07	0.30	0.35	-	(2.0)	-	-	-	-	-
Triaxial compression test: Condition of drainage	-	-	-	-	-	U-U	U-U	U-U	U-U	U-U	U-U	-	U-U	-	-	-	-	-
Consolidation test: Preconsolidation pressure, kg/cm²	-	-	-	-	-	-	0.32	(0.4)	(0.67)	(0.90)	(0.95)	-	-	-	-	-	(0.29)	0.11
Consolidation test: Compression index	-	-	-	0.55	-	-	0.55	0.45	0.26	0.24	0.27	-	-	-	-	-	0.69	0.76
Laboratory Vane Shear: Max. shear strength, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.033

Table 4-15f Summary of Soil Tests on Samples from Sentul (6)

Boring No.	SBH-5								SBH-6										
Sample No.	UD-5	UD-6 Top	UD-6 Bottom	UD-7	UD-8	UD-9	UD-10	UD-11	UD-1	UD-2	UD-3	UD-4	UD-5 Top	UD-5 bottom	UD-6	UD-7	UD-8	UD-9	UD-10
Sample depth	6.50 ~ 7.35	8.00 ~ 8.15	8.15 ~ 8.85	9.50 ~ 10.35	11.00 ~ 11.85	12.50 ~ 13.35	14.00 ~ 14.85	15.50 ~ 16.35	0.50 ~ 1.35	1.50 ~ 2.35	5.00 ~ 5.85	6.50 ~ 7.35	8.00 ~ 8.30	8.30 ~ 8.85	9.50 ~ 10.35	11.00 ~ 11.85	12.50 ~ 13.35	14.00 ~ 14.85	15.50 ~ 16.30
Condition of sample	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Natural water content, %	82.5	77.6	71.3	51.6	45.2	40.3	40.4	44.8	20.6	19.9	71.3	71.7	69.3	60.2	52.4	38.3	33.2	34.6	36.1
Specific gravity	2.620	2.636	2.659	2.685	2.669	2.664	2.669	2.634	2.661	2.666	2.600	2.592	2.632	2.627	2.632	2.645	2.652	2.677	2.659
Wet density, g/cm³	1.52	1.60	1.56	1.68	1.76	1.81	1.83	1.75	(1.91)	2.04	1.56	1.61	1.60	1.65	1.69	1.82	1.88	1.87	1.86
Dry density, g/cm³	0.83	0.90	0.91	1.11	1.21	1.29	1.30	1.21	1.58	1.70	0.91	0.94	0.95	1.03	1.11	1.32	1.41	1.39	1.37
Natural void ratio	2.15	1.93	1.92	1.42	1.20	1.06	1.05	1.18	0.680	0.567	1.86	1.76	1.78	1.55	1.37	1.01	0.879	0.926	0.946
Degree of saturation, %	100	100	99	100	100	100	100	100	81	94	100	100	100	100	100	100	100	100	100
Atterberg limits: Liquid limit, %	70.0	67.5	61.9	48.9	46.0	42.8	41.5	55.4	33.9	48.2	73.0	71.8	68.3	65.7	58.0	42.3	37.0	40.1	47.0
Atterberg limits: Plastic limit, %	31.3	30.3	28.2	20.2	20.3	19.5	19.0	25.3	18.0	17.8	31.6	30.1	30.4	28.0	24.7	19.8	17.8	20.1	21.2
Atterberg limits: Plasticity index	38.7	37.2	33.7	28.7	25.7	23.3	22.5	30.1	15.9	30.4	41.4	41.7	37.9	37.7	33.3	22.5	19.2	20.0	25.8
Grain size analysis: Gravel, %	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Grain size analysis: Sand, %	1	0	1	0	3	7	7	8	36	41	1	3	2	0	1	12	14	11	4
Grain size analysis: Silt, %	22	22	28	35	45	40	44	33	32	17	21	22	21	19	34	43	50	51	26
Grain size analysis: Clay & colloid, %	77	78	71	65	52	53	49	59	30	41	78	75	77	81	65	45	36	38	70
Grain size analysis: Max. diameter, mm	0.25	0.074	0.105	0.037	0.25	0.25	0.25	0.25	4.76	4.76	0.25	0.25	0.25	0.028	0.105	0.25	0.42	0.84	0.42
Grain size analysis: Diam. at 60%	0.0012	0.0014	0.0024	0.0036	0.0085	0.0088	0.0097	0.0057	0.062	0.081	0.0015	0.0018	0.0016	0.0016	0.0037	0.015	0.029	0.024	0.0026
Grain size analysis: Diam. at 10%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Visual soil description	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Sandy Clay	Sandy Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay
Unified soil classification	CH	CH	CH	CL	CL	CL	CL	CH	CL	CL	CH	CH	CH	CH	CH	CL	CL	CL	CL
Unconfined compression test: Undisturbed sample, kg/cm²	-	-	-	-	-	-	-	-	-	3.95	-	-	-	-	-	-	-	-	-
Unconfined compression test: Remoulded sample, kg/cm²	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unconfined compression test: Sensitivity ratio	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unconfined compression test: Strain at failure, %	-	-	-	-	-	-	-	-	-	9.5	-	-	-	-	-	-	-	-	-
Triaxial compression test: Angle of internal friction	0°	-	0°	0°	0°	0°	0°	0°	-	-	0°	0°	0°	0°	0°	0°	0°	0°	0°
Triaxial compression test: Cohesion, kg/cm²	0.040	-	0.035	0.070	0.060	0.14	0.18	0.18	-	-	0.080	0.050	0.085	0.11	0.14	0.19	0.29	0.30	0.25
Triaxial compression test: Condition of drainage	U-U	-	U-U	U-U	U-U	U-U	U-U	U-U	-	-	U-U	U-U	U-U	U-U	U-U	U-U	U-U	U-U	U-U
Consolidation test: Preconsolidation pressure, kg/cm²	0.42	-	0.36	0.40	-	0.80	0.96	1.1	-	-	0.4	0.52	-	(0.62)	0.84	(1.4)	1.8	1.9	1.8
Consolidation test: Compression index	0.66	-	0.55	0.46	0.35	0.32	0.33	0.48	-	0.12	0.63	0.62	-	0.52	0.51	0.30	0.26	0.29	0.31
Lab. Vane Shear Test: Max. shear strength kg/cm²	0.046	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 4-15g Summary of Soil Tests on Samples from Sentul (7)

Boring No.		SB-1						SB-2				SB-3					SB-4	
Sample No.*		P1/D2	P4	P6	P9	P11	P13	D3/P2	D5/P4	D7/P6	D9/P8	D2/P1	D4/P3	D6/P5	D8/P7	D10/P9	P1/D4	P3/D4
Sample depth		1.00~1.45m	4.00~4.45m	6.00~6.45m	9.00~9.45m	11.00~11.45m	13.00~13.45m	2.00~2.45m	4.00~4.45m	6.00~6.45m	8.00~8.45m	1.00~1.45m	3.00~3.45m	5.00~5.45m	7.00~7.45m	9.00~9.45m	1.00~1.45m	3.00~3.45m
Natural water content	.%	77.3	75.4	73.6	26.0	25.3	6.5	56.2	61.0	78.5	76.8	69.1	89.6	7.4	12.3	3.0	42.2	60.9
Specific gravity		2.598	2.607	2.603	2.649	2.662	2.613	2.663	2.625	2.596	2.600	2.556	2.603	2.622	2.626	2.650	2.615	2.577
Atterberg limits	Liquid limit .%	84.9	79.0	79.0	38.5	40.2	-	68.0	67.6	89.9	77.3	82.0	68.0	-	-	-	51.1	70.7
	Plastic limit .%	37.5	34.8	35.0	20.8	20.4	-	30.5	21.6	35.7	35.5	35.6	32.3	-	-	-	24.9	30.2
	Plasticity index	47.4	44.2	44.0	17.7	19.8	-	37.5	46.0	54.2	41.8	46.4	35.7	-	-	-	26.2	40.5
Grain size Analysis	Gravel .%	0	0	0	14	20	74	2	0	0	0	0	0	35	31	82	0	0
	Sand .%	0	0	0	23	20	12	13	10	0	0	0	20	59	62	16	11	9
	Silt .%	25	26	23	27	23	4	23	28	21	24	23	20	6	7	2	33	28
	Clay & Colloid .%	75	74	77	36	37	10	62	62	79	76	77	80				56	63
	Max. diameter .mm	0.048	0.048	0.048	9.52	19.1	19.1	9.52	2.00	0.048	0.048	0.047	0.048	9.52	9.52	19.1	0.84	2.00
	Diam. at 60%	-	-	-	0.060	0.073	5.2	0.043	0.0043	-	-	0.0010	-	1.7	1.4	5.7	0.0074	0.0072
	Diam. at 10%	-	-	-	-	-	0.0046	-	-	-	-	-	-	0.22	0.13	0.95	-	-
Visual soil description		Silty Clay	Silty Clay	Silty Clay	Silty Clay w/Sand	Silty Clay w/Sand	Gravel with Clay	Silty Clay w/Sand	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Gravel Sand	Gravel Sand	Gravel	Silty Clay	Silty Clay
Unified soil classification		CH	CH	CH	CL	CL	-	CH	CH	CH	CH	CH	CH	(SW-SM)	(SW-SM)	GM	CH	CH

Boring No.		SB-4							SB-5								SB-6	
Sample No.*		P5/D6	P7/D8	P9/D10	P11/D12	P13/D14	P16/D17	P19/D20	P1/D2	P3/D4	P6/D7	P8/D9	P10/D11	P12/D13	P14/D15	P16/D17	D-1	D-3
Sample depth		5.00~5.45m	7.00~7.45m	9.00~9.45m	11.00~11.45m	13.00~13.45m	16.00~16.45m	19.00~19.45m	1.00~1.45m	3.00~3.45m	6.00~6.45m	8.00~8.45m	10.00~10.45m	12.00~12.45m	14.00~14.45m	16.00~16.45m	1.00~1.45m	3.00~3.45m
Natural water content	.%	11.4	21.0	6.8	10.4	21.0	20.7	12.0	57.6	18.7	40.3	42.3	51.7	23.5	23.7	15.5	62.9	53.5
Specific gravity		2.625	2.622	2.654	2.635	2.633	2.634	2.632	2.609	2.649	2.654	2.639	2.661	2.707	2.705	2.626	2.605	2.604
Atterberg limits	Liquid limit .%	-	-	-	-	-	35.1	-	64.9	-	-	47.0	63.9	42.1	36.9	-	84.0	71.8
	Plastic limit .%	-	-	-	-	-	19.0	-	27.3	-	-	24.2	29.5	19.2	19.4	-	35.0	31.0
	Plasticity index	-	-	-	-	-	16.1	-	37.6	-	-	22.8	34.4	22.9	17.5	-	49.0	40.8
Grain size Analysis	Gravel .%	42	3	61	59	0	10	48	0	24	0	0	0	7	8	37	0	4
	Sand .%	55	94	38	40	62	42	46	0	67	19	4	0	37	41	58	0	5
	Silt .%	3	3	1	1	24	14	6	38	9	58	48	24	18	16	5	12	19
	Clay & colloid .%					14	34		62		23	48	76	38	35		88	72
	Max. diameter .mm	9.52	4.76	19.1	25.4	4.76	4.76	9.52	0.048	9.52	4.76	0.84	0.046	9.52	9.52	19.1	0.012	9.52
	Diam. at 60%	2.1	0.50	9.6	16	0.13	0.24	2.3	0.0038	0.70	0.044	0.014	0.12	0.12	0.31	1.9	-	0.0026
	Diam. at 10%	0.21	0.14	0.30	0.35	-	-	0.30	-	0.078	-	-	-	-	-	0.25	-	-
Visual soil description		Gravel Sand	Sand	Sandy Gravel	Sandy Gravel	Silty Sand	Clayey Sand	Sandy Gravel	Silty Clay	Gravel Sand	Clayey Silt	Silty Clay	Silty Clay	Sandy Clay	Sandy Clay	Gravel Sand	Silty Clay	Silty Clay
Unified soil classification		SW	SP	GP	GP	-	SC	(GW-GM)	CH	(SP-SM)	-	CL	CH	CL	CL	(SW-SM)	CH	CH

* Note: All samples are disturbed.

Table 4-15h Summary of Soil Tests on Samples from Sentul (8)

Boring No.		SB-7					SB-8		SB-9							MC-4	
Sample No.*		P1/D2	P3/D4	P5/D6	P7/D8	P8/D10	P3/D4	D13	P1/D1	P3/D4	P5/D6	P7/D8	P9/D10	P14/D15	P16/D17	1	2
Sample depth		1.00~1.45m	3.00~3.45m	5.00~5.45m	7.00~7.45m	9.00~9.45m	3.00~3.45m	12.00~12.45m	1.00~1.45m	3.00~3.45m	5.00~5.45m	7.00~7.45m	9.00~9.45m	14.00~14.45m	16.00~16.45m	1.00~1.45m	2.00~2.45m
Natural water content, %		26.7	24.3	10.5	1.7	9.1	13.9	1.2	62.9	50.2	71.2	58.3	47.3	18.0	15.8	71.6	77.1
Specific gravity		2.677	2.657	2.647	2.657	2.785	2.631	2.711	2.612	2.603	2.617	2.635	2.637	2.625	2.628	2.606	2.590
Atterberg limits	Liquid limit, %	-	-	-	-	-	-	-	64.4	52.4	75.7	67.8	58.0	36.3	33.2	60.2	61.8
	Plastic limit, %	-	-	-	-	-	-	-	27.0	26.3	27.4	29.9	29.0	17.2	16.3	29.9	29.2
	Plasticity index	-	-	-	-	-	-	-	37.4	26.1	48.3	37.9	29.0	19.1	16.9	30.3	32.6
Grain size analysis	Gravel, %	11	11	36	87	66	93	17	0	0	0	0	0	21	22	0	0
	Sand, %	48	53	54	10	20	5	72	0	0	0	6	1	39	44	0	0
	Silt, %	30	22	10	3	14	2	11	23	26	27	18	48	15	14	41	44
	Clay & colloid, %	11	14						77	74	73	76	51	25	20	59	56
	Max. diameter, mm	9.52	9.52	9.52	19.1	19.1	25.4	9.52	0.048	0.047	0.048	4.76	0.42	9.52	9.52	0.074	0.048
	Diam. at 60%	0.15	0.17	1.7	9.5	7.2	17	0.82	0.0010	-	-	0.0014	0.0085	0.41	0.77	0.0054	0.0059
	Diam. at 10%	0.0030	0.0012	0.074	1.1	-	3.0	-	-	-	-	-	-	-	-	-	-
Visual soil description		Silty Sand	Clayey Sand	Gravel Sand	Gravel	Sandy Gravel	Gravel	Gravel Sand	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Clayey Sand	Gravel Sand w/Clay	Silty Clay	Silty Clay
Unified soil classification		-	-	(SW-SM)	GW	-	GW	-	CH	CH	CH	CH	CH	SC	SC	CH	CH

Boring No.		MC-4							MC-5								
Sample No.*		3	4	5	6	7	8	9	1	2	3	4	5	6	7	8	9
Sample depth		3.00~3.45m	4.00~4.45m	5.00~5.45m	6.00~6.45m	7.00~7.45m	8.00~8.45m	9.00~9.45m	1.00~1.45m	2.00~2.45m	3.00~3.45m	4.00~4.45m	5.00~5.45m	6.00~6.45m	7.00~7.45m	8.00~8.45m	9.00~9.45m
Natural water content, %		78.4	61.3	68.5	109	85.7	78.0	75.7	118	82.0	98.2	78.3	84.7	79.1	85.7	73.6	94.9
Specific gravity		2.603	2.594	2.583	2.576	2.594	2.600	2.585	2.575	2.592	2.586	2.603	2.586	2.575	2.602	2.582	2.594
Atterberg limits	Liquid limit, %	57.9	65.0	58.9	71.6	66.0	75.0	76.1	78.3	77.4	75.9	76.2	73.3	80.1	74.9	76.2	73.4
	Plastic limit, %	28.9	29.9	24.9	32.3	30.5	32.7	32.7	37.7	33.1	34.9	37.0	31.9	33.9	32.8	34.2	32.1
	Plasticity index	29.0	35.1	34.0	39.3	35.5	42.3	43.4	40.6	44.3	41.0	39.2	41.4	46.2	42.1	42.0	41.3
Grain size analysis	Gravel, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sand, %	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Silt, %	34	43	42	22	26	35	36	26	20	34	19	22	35	33	42	35
	Clay & colloid, %	66	57	58	78	74	65	64	74	80	66	81	78	65	67	58	65
	Max. diameter, mm	0.047	0.047	0.047	0.049	0.048	0.048	0.048	0.045	0.048	0.049	0.048	0.048	0.048	0.048	0.048	0.048
	Diam. at 60%	0.0035	0.0062	0.0055	-	0.0010	0.0015	0.0026	-	-	0.0027	0.0013	-	0.0037	-	0.0060	0.0032
	Diam. at 10%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Visual soil description		Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay	Silty Clay
Unified soil classification		CH	CH	CH	CH	CH	CH	CH	MH	CH	MH	CH	CH	CH	CH	CH	CH

* Note: All samples are disturbed.

Table 4-15i Summary of Soil Tests on Samples from Sentul(9)
Chemical and Clay Mineral Analyses

	Boring No.		Sub-Section B			SB-6	
	Sample No.		S-1	S-5	S-10	D-1	P-3
Chemical Analysis*1	pH at 25°C		6.7	7.5	7.8	6.5	6.6
	Total Sulphates as SO_3	(% w/w)	0.01	0.03	0.23	0.01	0.03
	Water-Soluble Chlorides as Cl^-	(% w/w)	less than 0.001	0.001	less than 0.001	-	-
	Total Chlorides as Cl^-	(% w/w)	0.006	0.004	0.004	0.004	0.004
	Tin, Sn	(mg/kg)	2	less than 1	2	1	1
	Cyanide as CN	(mg/kg)	less than 1	less than 1	less than 1	less than 1	less than 1
	Arsenic, As	(mg/kg)	10	less than 4	40	10	3
	Lead, Pb	(mg/kg)	78	44	78	80	100
	Cadmium, Cd	(mg/kg)	less than 5	less than 5	5	1	2
Clay Mineral*2 Analysis	Kaolinite	(%)	78	74	62	58	54
	Chloride	(%)	-	-	TR		
	Illite	(%)	22	19	35	42	46
	Degraded Illite	(%)	TR	7	3	0	0

Remarks: *1 All results are based on samples dried at 80°C, except for pH value which was based on air-dried samples
*2 TR denotes trace amounts

Table 4-16 Unconfined Compression Tests on Rock Core Samples from Sentul

Boring No.	Sub-Section A"-B						Sub-Section B-A			
Specimen No.	1	2	3	4	5	6	1	2	3	4
Sample Depth (m)	16.85 - 17.1		17.1 - 17.4		17.4 - 17.6		32.5 - 32.7	33.5	33.0 - 33.3	
Diameter of the Specimen (mm)	35	35	35	35	35	35	35	35	35	35
Height of the Specimen (mm)	70	70	69	70	66	67	71	70	69	69
Crushing Strength (kg/cm^2)	780	843	980	865	632	600	210	316	843	949
Bulk Density (g/cm^3)	2.68	2.61	2.55	2.60	2.67	2.69	2.50	2.66	2.64	2.59

higher than the dweller's ground by 2 to 4 m. Fig. 4-17 illustrates the relation of the elevations between the surrounding areas and the site.

It is reported that the site was enclosed by embankments and was used as a dumping area for the tin tailings. There are no village houses on the site although numerous houses are built on narrow corridors between the site and the rivers. This would imply that ground conditions at the site are not suitable for the building of village houses; and that the areas occupied by the dwellers are better drained than those of the pilot test site.

Major investigations in this study were performed within the area enclosed by the embankments. However, ground conditions outside the embankments were also investigated.

All 5 typical types of foundation ground are found at the Sentul site. However Types C, D and E ground are dominant. Most of the Type B ground at Sentul has been reclaimed for a particular development scheme by the City Hall.

The following layers were encountered at the Sentul site:

1) Very Soft to Soft Clay (Including Extremely Soft Clay)

2) Medium Stiff Clay

3) Very Loose to Loose Sand

4) Medium-Dense Sand

5) Limestone Bedrock (Including Weathered Portion)

Brief comments on these layers are summarized in Table 4-17. Ground water tables are found at a depth of -0.5 to +2 m. Engineering properties of the major layers at the Sentul site are summarized in Table 4-18. A description of the layers encountered at the Sentul site follows.

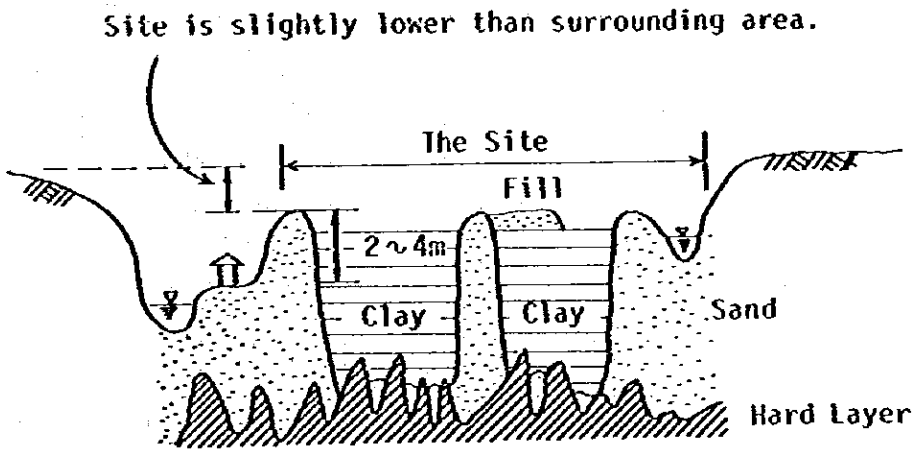


Fig. 4-17 Profile of Sentul Site

Table 4-17 Layers found at Sentul

Layer	Legend	Colour	N-Value	qc (kg/cm^2)
Very Soft to Soft Clay	C_1	Greyish-White to Greyish-Brown	0 - 1 -(3)	≒ 0
Medium Stiff Clay	C_2	Greyish-Brown to Dark Grey	4 - 6 -(10)	2 - 10
Very Loose to Loose Sand	S_1	Grey	2 - 10	20 - 40
Medium-Dense Sand	S_2	Grey to Dark Grey	15 - 30	60 - 120
Limestone Bedrock (Including Weathered Portion)	L_s	Greyish-White to Light Greyish-White	> 30	> 120

Table 4-18 Summary of Subsurface Ground Conditions at Sentul

			Layer	Very Soft to Soft Clay	Very Loose to Loose Sand	Medium Clay	Heavily Decomposed Limestone		Lime-stone
							Clayey Portion	Sandy Portion	
Thickness			(m)	3 ∿ 12	1 ∿ 12	(6.5)	(0.5∿3.5)	(1 ∿ 14)	12<
N-Value				0 ∿ 1	2 ∿ 10	3 ∿ 6	(13∿50≤)	10 ∿ 50≤	Re-fusal
Cone Resistance			(kg/cm²)	0 ∿ (20)	0 ∿ 70	-	(10 ∿ 20)	5 ∿ 40	Re-fusal
Physical Properties	Water Content & Atterberg Limits	PL	(%)	20 ∿ 37	-	15 ∿ 25	-	-	-
		Wn	(%)	35∿115	10 ∿ 20 (=15)	20 ∿ 40	(20)	-	-
		LL	(%)	40 ∿ 90	-	30 ∿ 50	-	-	-
	Grading Analysis (%)	Clay		30 ∿ 80	0 ∿ 10	25 ∿ 35	-	-	-
		Silt		18 ∿ 50		20 ∿ 60	-	-	-
		Sand		0 ∿ 24	10 ∿ 60	0 ∿ 40	-	-	-
		Gravel			30 ∿ 90	0 ∿ 20	-	-	-
	Specific Gravity	GS		2.55∿2.65	=2.64	2.5 ∿ 2.7	=2.75	-	-
	Wet Density	γt	(t/m³)	1.40∿1.80	-	1.81 ∿ 2.08	-	-	2.6 ∿ 2.7
Mechanical Properties	Coefficient of Permiability	k	(cm/sec)	-	1×10^{-2}	1×10^{-4}	-	1×10^{-3} ∿ 1×10^{-2}	-
	Undrained Shear Strength		(t/m²)	0.2 ∿ 1.5 ∿ (2.0)	-	(1.1) ∿ 2.5 ∿ 3.5	-	-	-
	Cu/ P̄			0.1 ∿ 0.3	-	-	-	-	-
	Uniaxial Compress Strength		(kg/cm²)	-	-	-	-	-	200 ∿1000
	Modulus of Deformation		(kg/cm²)	-	-	-	-	-	1000 ∿5000
	Preconsolidation Pressure	P_o	(t/m²)	1 ∿ 5	-	(12) ∿ 13	-	-	-
	Compression Index	Cc		0.35∿0.90	-	0.22 ∿ 0.30	-	-	-
	Over Consolidation Ratio			0.5 ∿ 1.25	-	-	-	-	-
	Coefficient of Consolidation		(cm²/min)	3×10^{-2} ∿ 2×10^{-1}	-	1.5×10^{-1} ∿ 5×10^{-1}	-	-	-
Chemical Properties	PH			6.5 ∿ 7.5	-	-	-	-	-
	Total Sulphate	SO_3	(%, w/w)	0 ∿ 0.3	-	-	-	-	-
	Total Chloride	Cl^-	(%, w/w)	0.004 ∿ 0.006	-	-	-	-	-
	Tin		(mg/kg)	1 ∿ 2	-	-	-	-	-
	Arsenic		(mg/kg)	0 ∿ 40	-	-	-	-	-
	Lead		(mg/kg)	40 ∿ 100	-	-	-	-	-
	Cadmium		(mg/kg)	Less than 5	-	-	-	-	-
Mineral Content	Kaolinite		(%)	60 ∿ 80	-	-	-	-	-
	Illite		(%)	20 ∿ 40	-	-	-	-	-

(1) Extremely Soft to Soft Clay Layers

At the Sentul site, extremely soft to soft clays are deposited, the soil properties of which change gradually with depth. Extremely soft clay is found at the bottom of the pond and very soft clay covers almost all of the site except for certain bands and filled areas. Soft clay is found beneath the very soft clay and is interbedded between other layers. The origin of the majority of these clays is slime deposits derived from tin-mining.

(a) Extremely Soft Clay

Extremely soft clay was found at the bottom of the pond at this site. The thickness of this layer is about 5 to 8 m with the natural water content being higher than that of the very soft clayey layer. However, other physical properties are similar. The physical properties of the materials distributed at the bottom of the pond at the Sentul site are summarized as follows.

Clay Content	60 ∿ 80%
Silt Content	20 ∿ 40%
Natural Water Content	Wn = 60 ∿ 120%
Liquid Limit	LL = 60 ∿ 80%
Plastic Limit	PL = 30 ∿ 40%
Specific Gravity	Gs = 2.58 ∿ 2.60

(b) Very Soft to Soft Clay Layers

The ground at the site is generally covered by a very soft clayey layer with N-values of 0 to 1. In general, cone resistance is almost 0 kg/cm^2. The layer is either off-white or brownish in colour. The thickness of the layer is generally 2.8 to 6.8 m with an average of 4 to 5 m. However, the thickness of the very soft clay at the test embankment area is 11 to 13 m. Engineering properties change gradually with depth in this layer. In the northern area outside the enclosure embankment at Sentul, the distribution of the soft clayey layer is much less than that at the area enclosed by the embankment. Interbedded layers of very soft clay with N-values of about 1 were found at Sub-Section A (depth of 9.8 to 10.7 m), SB-5 (depth of 5.8 to 10.9 m) and SB-6 (depth of 17.0 to 18.0 m).

i) Physical Properties

Physical properties of soil versus depth are shown in Fig. 4-18, and grading texture versus depth are shown in Fig. 4-19. Major physical properties are summarized below:-

* Water Content:

W_n = 50 to 110% (Ave. 70%)
(before installation of sand drains and test embankment)

* Specific Gravity: Gs = 2.55 to 2.65 (Ave. 2.60)
* Grain Size Distribution : 50 to 90% Clay
10 to 50% Silt

* Liquid Limit: LL = 50 to 90%
* Plastic Limit: PL = 25 to 40%
* Unified Soil Classification: CH (See Fig. 4-20)

According to the results of pore-pressure sounding carried out at subsection B, the upper 5 m of the layer is very homogeneous, while at lower 5 m, thin and relatively permeable layers may be embedded.

ii) Strength Properties

Undrained shear strength obtained by laboratory soil tests and in-situ vane tests are plotted versus

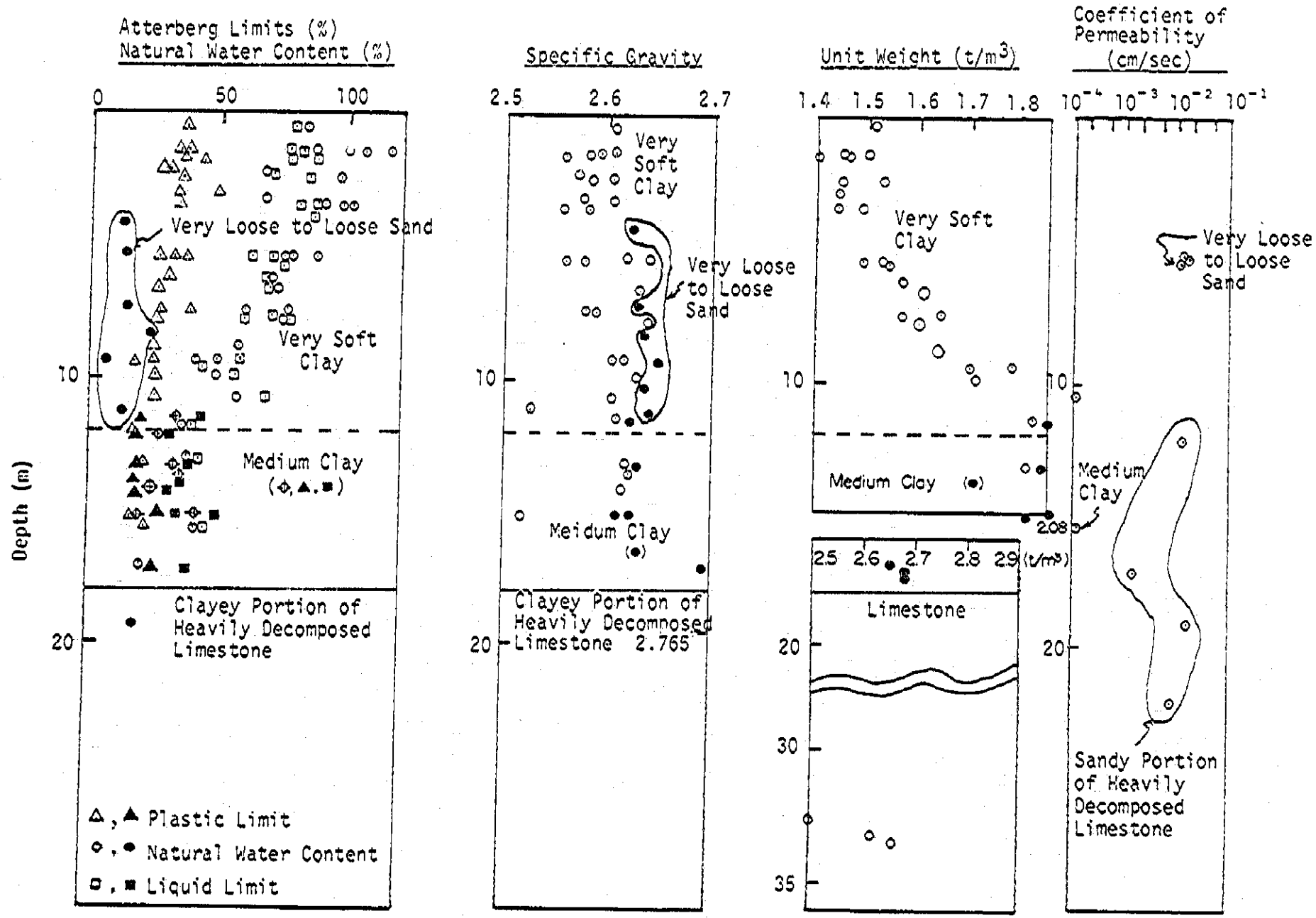


Fig. 4-18 Depth v.s. Results of Physical Properties Tests at Pilot Test Area

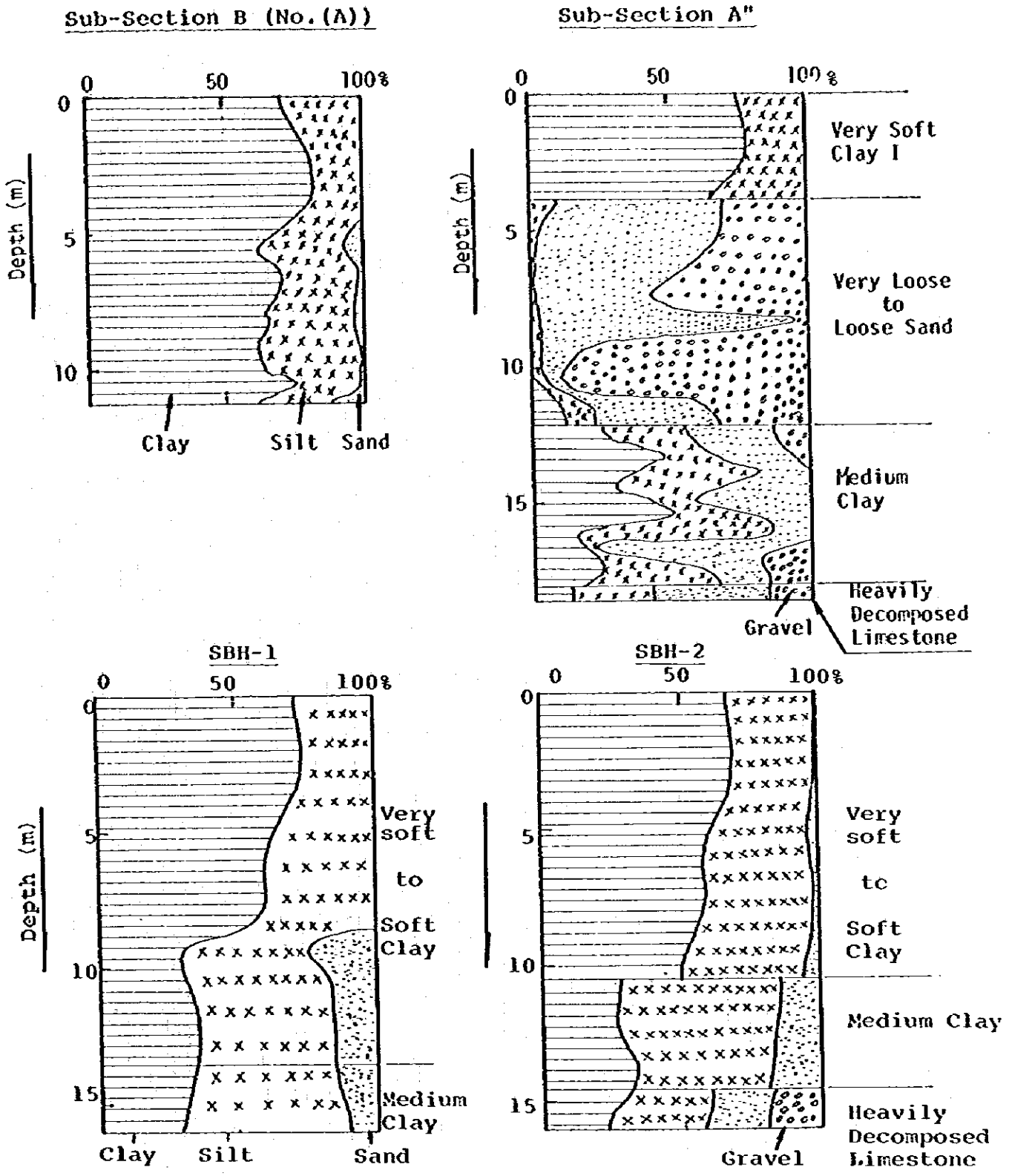
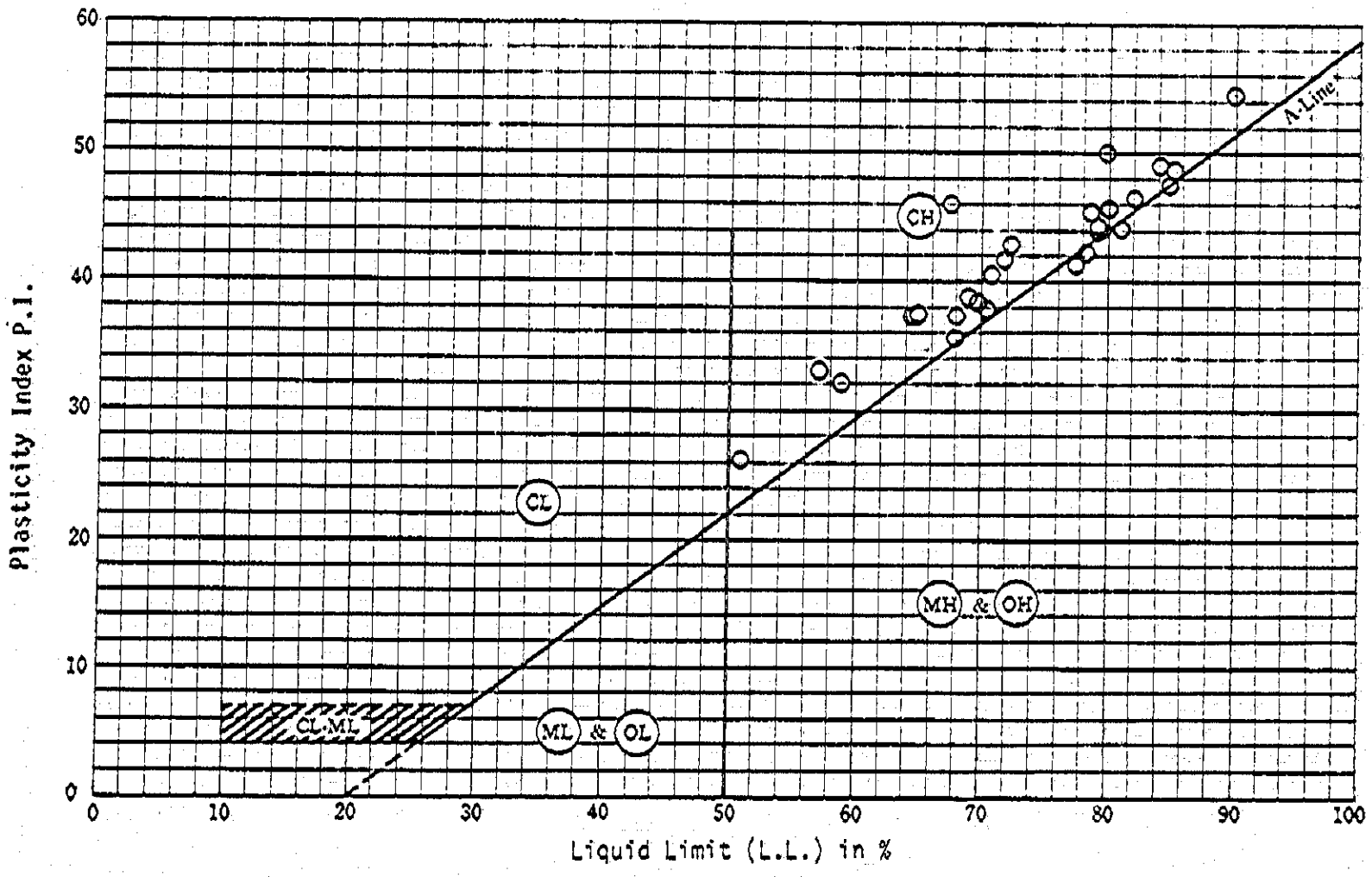


Fig. 4-19 Grading Texture verses Depth, Pilot Test Area



ML: Inorganic silt with some plasticity, very fine sand, rock flour, silty or clayey fine sand and clayey silt
CL: Clay containing gravels with low or middle plasticity, sandy clay and silty clay
OL: Organic silt with low plasticity and organic silty clay
MH: Inorganic silt with middle or high plasticity, micaceous or diatomaceous fine sandy soil and silty soil
CH: Inorganic clay with high plasticity
OH: Organic clay with middle or high plasticity and organic silt

Fig. 4-20 Plasticity Chart for Very Soft to Soft Clay Layers

depth in Fig. 4-21. From the detailed soil explorations, it seems reasonable to divide the soft clay stratum into two, i.e. upper and lower parts. As a first approximation, the undrained shear strength of these clay layers is expressed as follows:

$$0 < Z < 8 \sim 9 \text{ m} \qquad c_u = 0.07Z + 0.08$$

$$8 \sim 9 \text{ m} < Z \qquad c_u = 0.28Z - 1.6$$

where, Z : Depth from the Ground Surface (m)
c_u: Undrained Shear Strength (t/m^2)

It must be noted that the undrained shear strength is extremely low. The ratios of the increase in undrained shear strength to the increase in effective pressure, c_u/P, for both layers obtained from above equations are 0.13 and 0.47 respectively, using the average unit density of soil, $\gamma_t = 1.6\ t/m^3$.

Fig. 4-22 also shows the relation between c_u/P and depth, obtained from consolidated undrained triaxial compression tests. From this figure, c_u/P is found to be 0.28 for the upper part of the soft clay stratum and 0.40 for the lower part.

As already explained, in Section 3 the properties of ex-mining deposits are very much dependent on mining methods. The composition, stress history, and the state of stress will be different from layer to layer and/or location to location. Therefore, the strength properties summarized above cannot automatically be applied to other ex-mining sites.

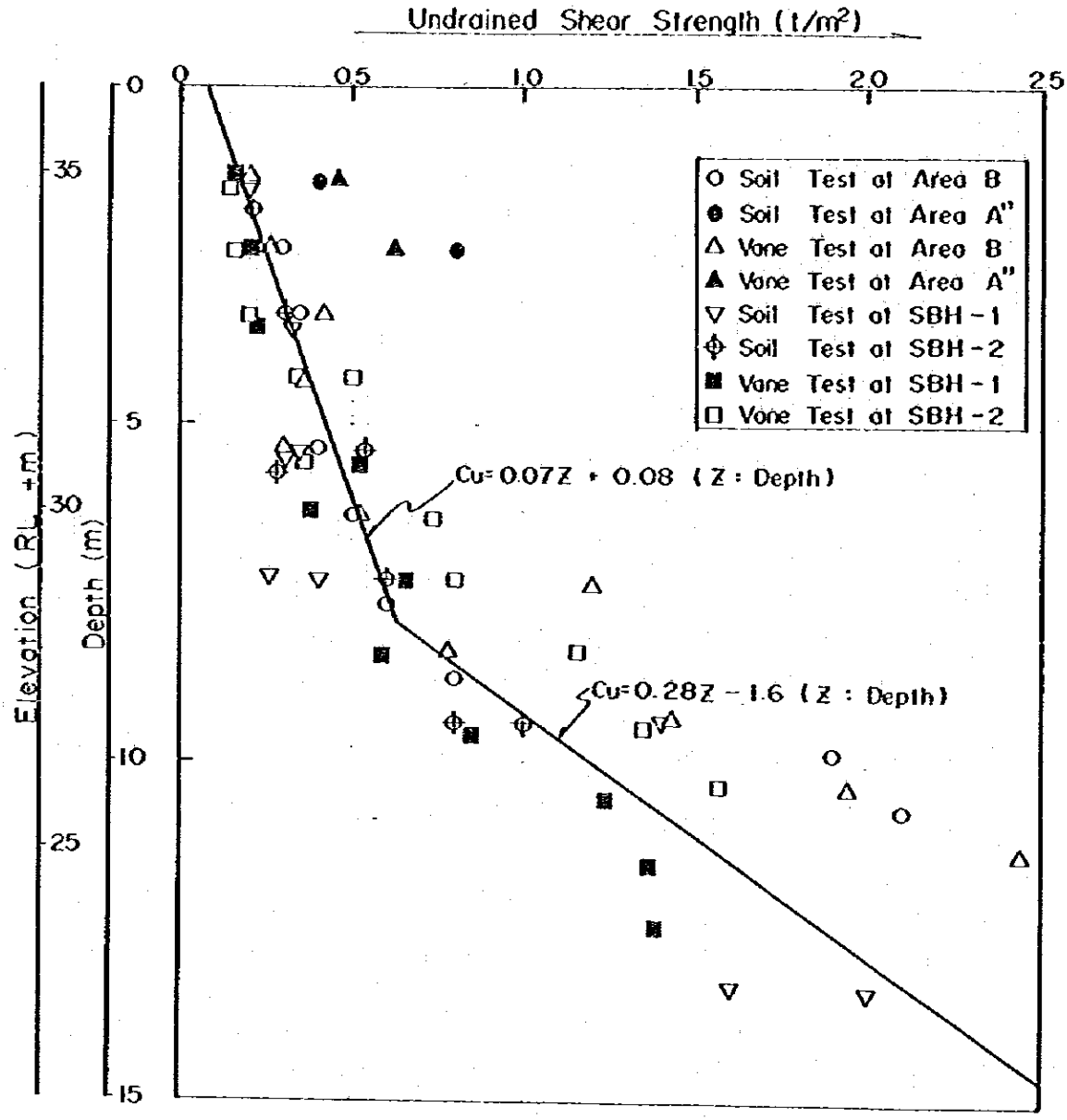


Fig. 4-21 Depth v.s. Undrained Shear Strength (Vane and U-U Triaxial Tests)

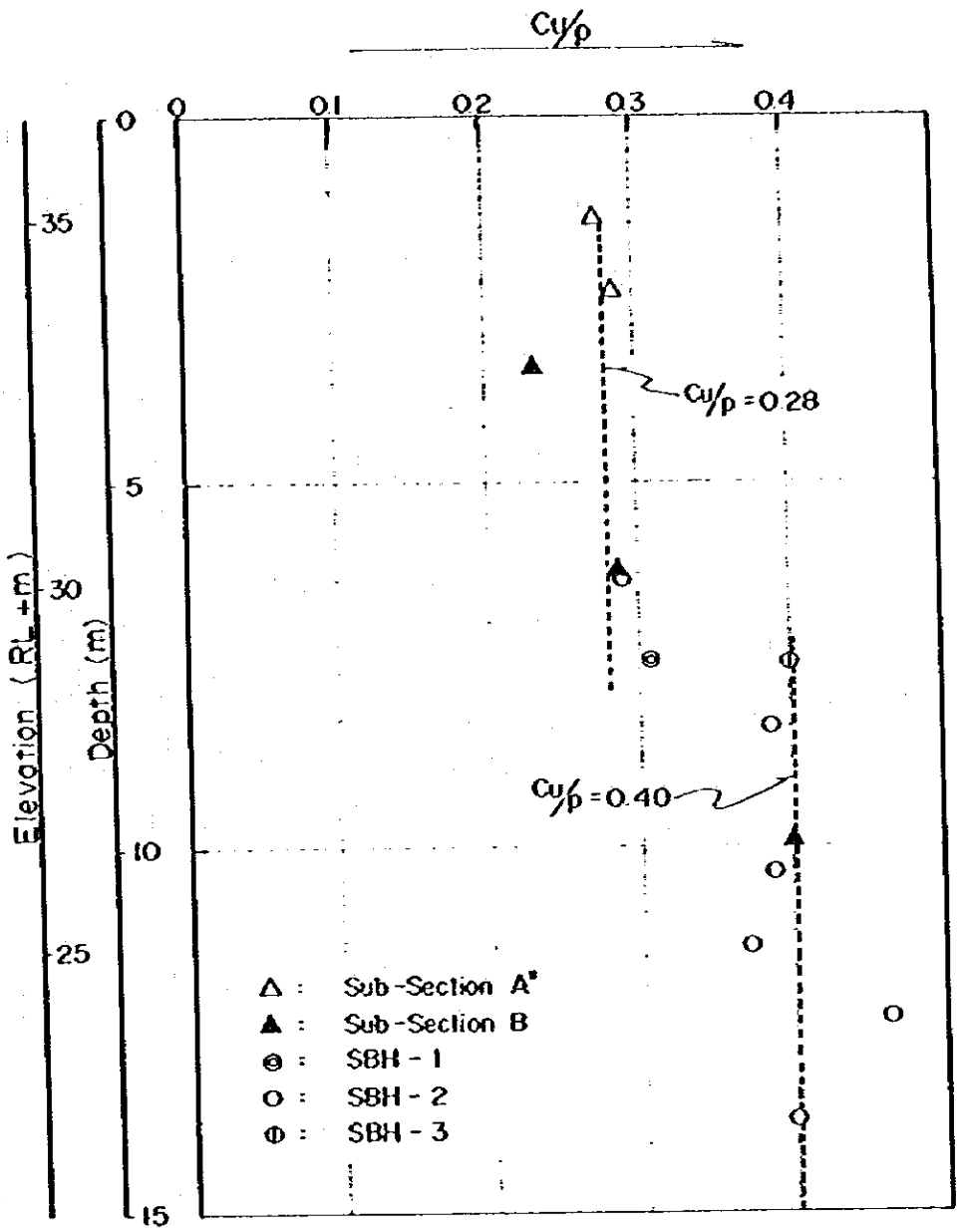


Fig. 4-22 Cu/p after Consolidated-Undrained Triaxial Compression Tests v.s. Depth

iii) Consolidation Properties

Fig. 4-23 shows the compression index, preconsolidation pressure and overconsolidation ratio of the very soft clay. The compression index is within the range of 0.35 to 0.9. As shown in the figure of preconsolidation pressure versus depth, the layer can be considered as normally consolidated. Figs. 4-24 and 4-25 show e ∿ log p curves and coefficients of consolidation versus pressure for very soft clay in the pilot test area (investigated in Phase I study). e ∿ log p curves and coefficients of consolidation versus pressure for very soft clay and medium clay in the test embankment area (investigated in Phase II study) are plotted in Figs. 4-26 and 4-27 , respectively.

Major consolidation characteristics are summarized below:-

Compression Index, $Cc = 0.35 \sim 0.9$

Overconsolidation Ratio, $0.5 \sim 1.25$ ($\fallingdotseq 1$)

Coefficient of Consolidation, $Cv = 3\times10^{-2} \sim 2\times10^{-1}$ $cm^2/min.$

iv) Chemicals Properties and Clay Mineral Content

Fig. 4-28 shows results of chemical and mineral analyses performed on samples from the very soft clay. The clay mineral is mostly kaolinite and illite.

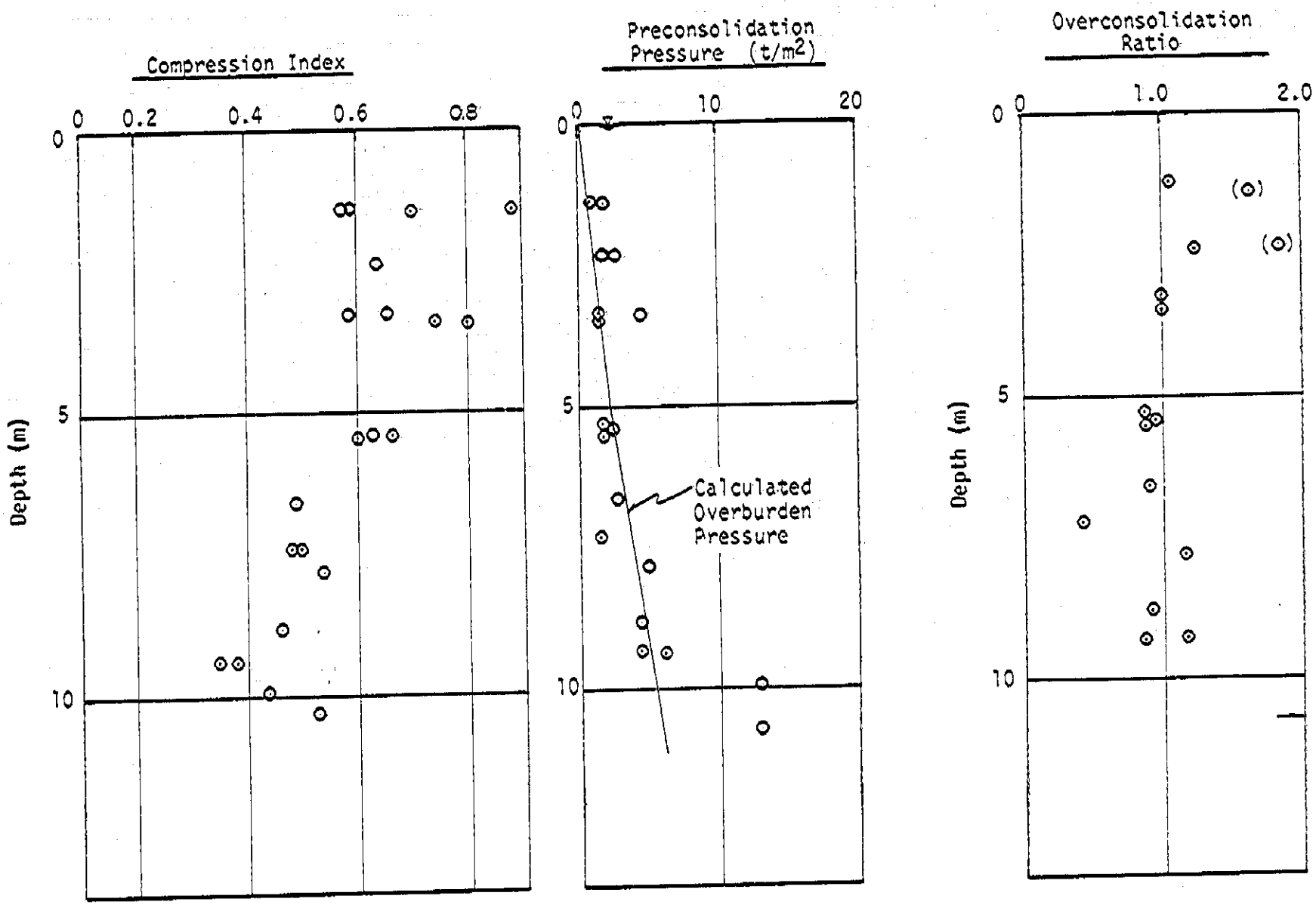


Fig. 4 - 23 Depth vs. Compression Index, Preconsolidation Pressure and Overconsolidation Ratio

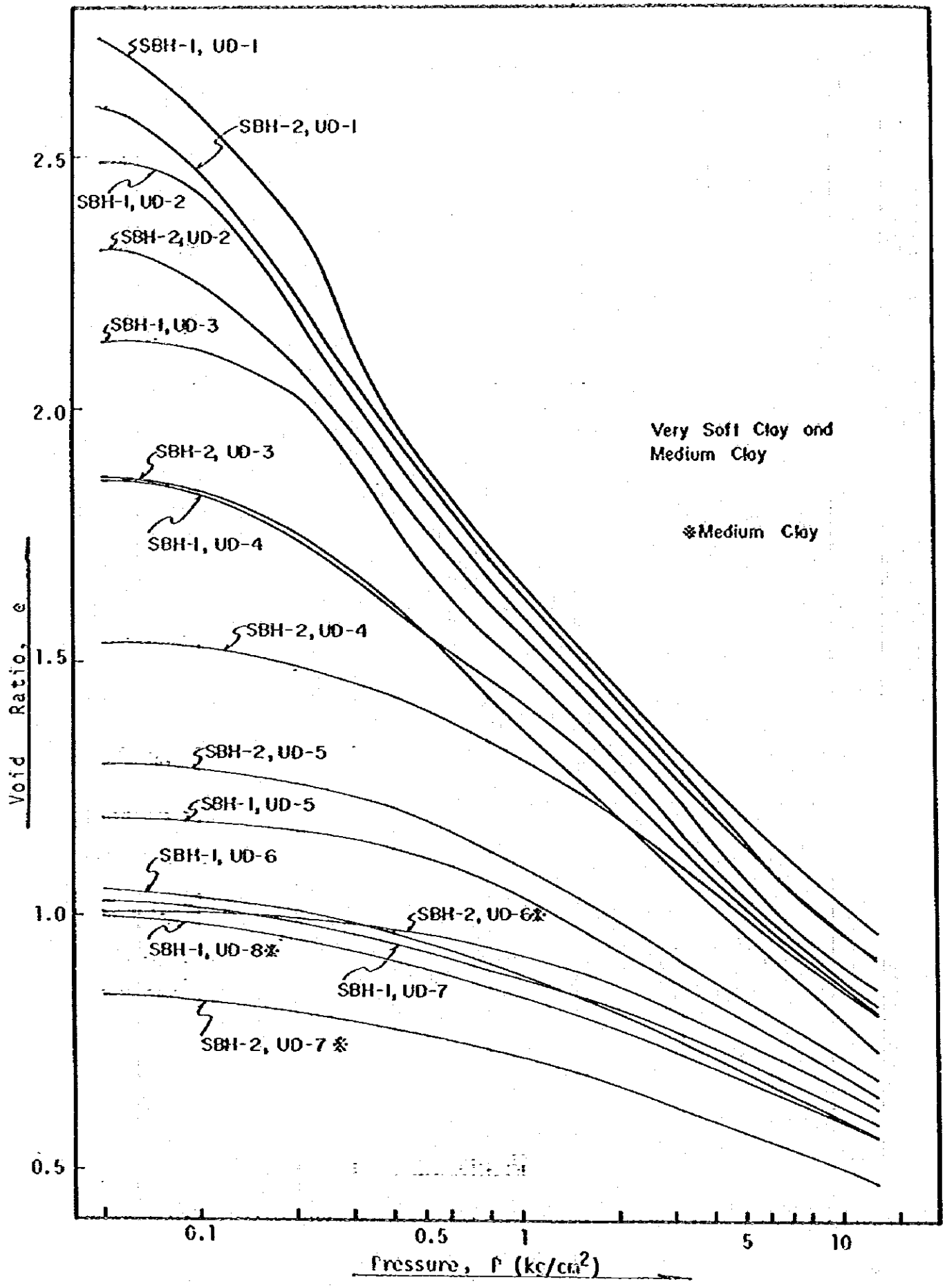


Fig. 4-24 e~log P Curves
- Pilot Test Area -

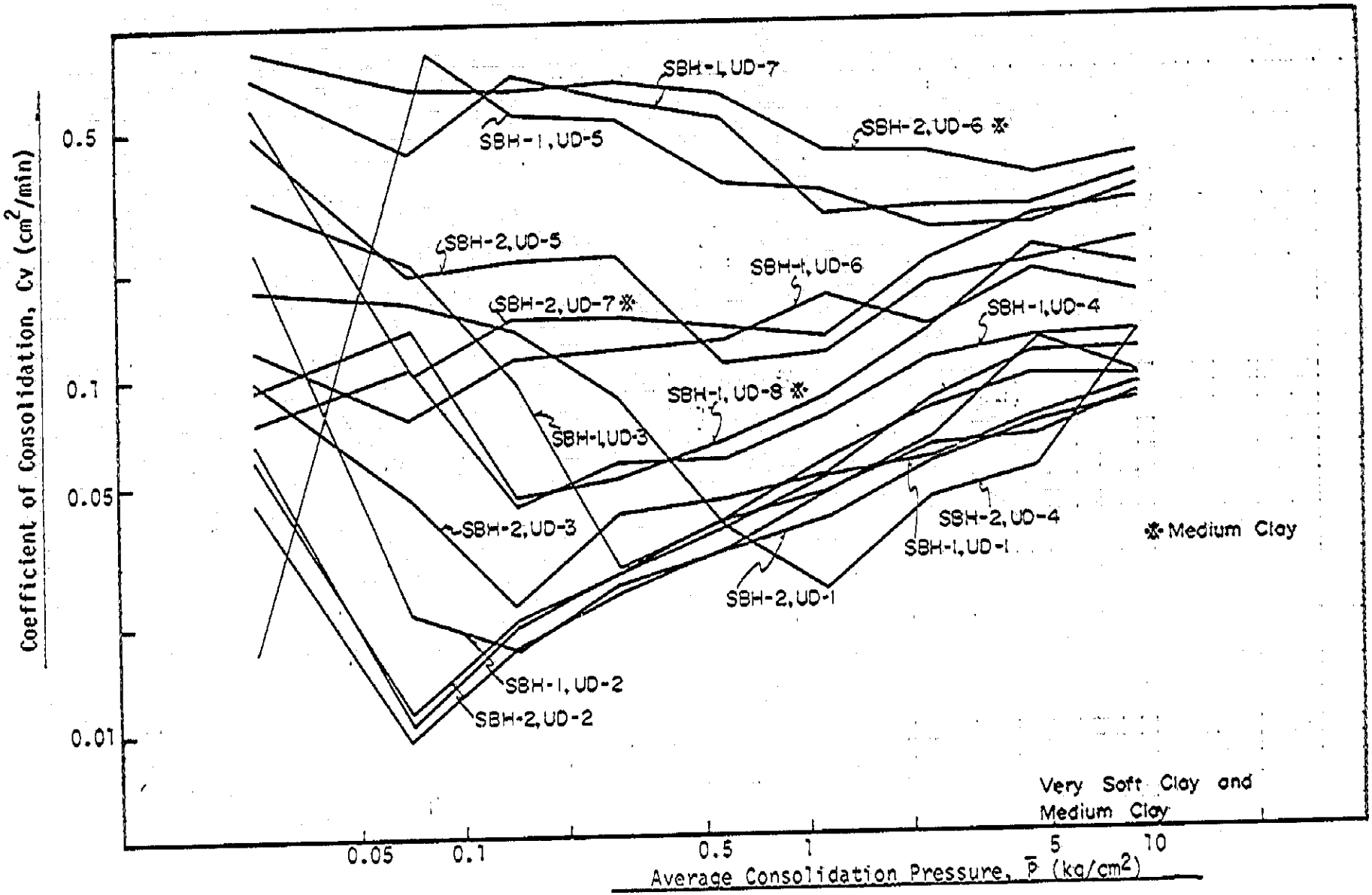


Fig. 4-25 Coefficient of Consolidation v.s. Average Consolidation Pressure
- Pilot Test Area -

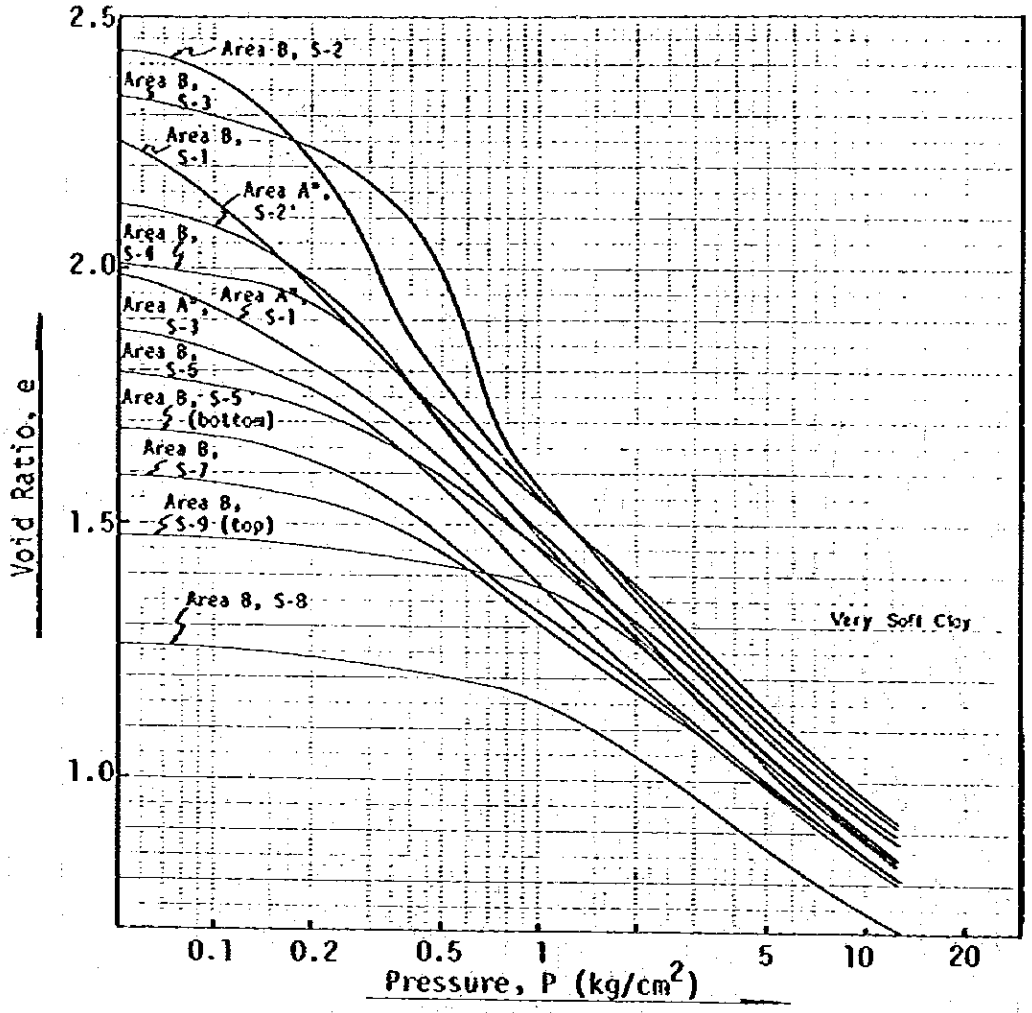


Fig. 4-26 e∿log P Curves
- Test Embankment Area -

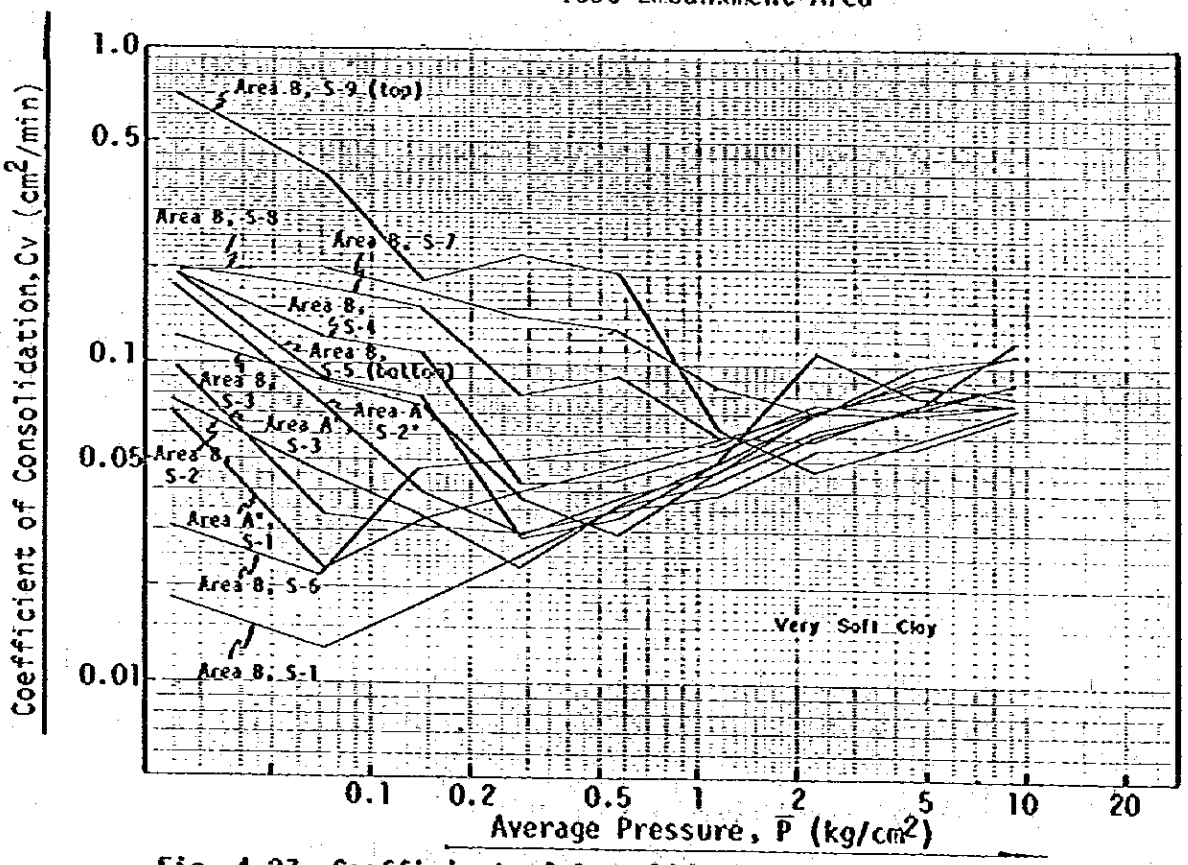


Fig. 4-27 Coefficient of Consolidation v.s. Average Consolidation Pressure
- Test Embankment Area -

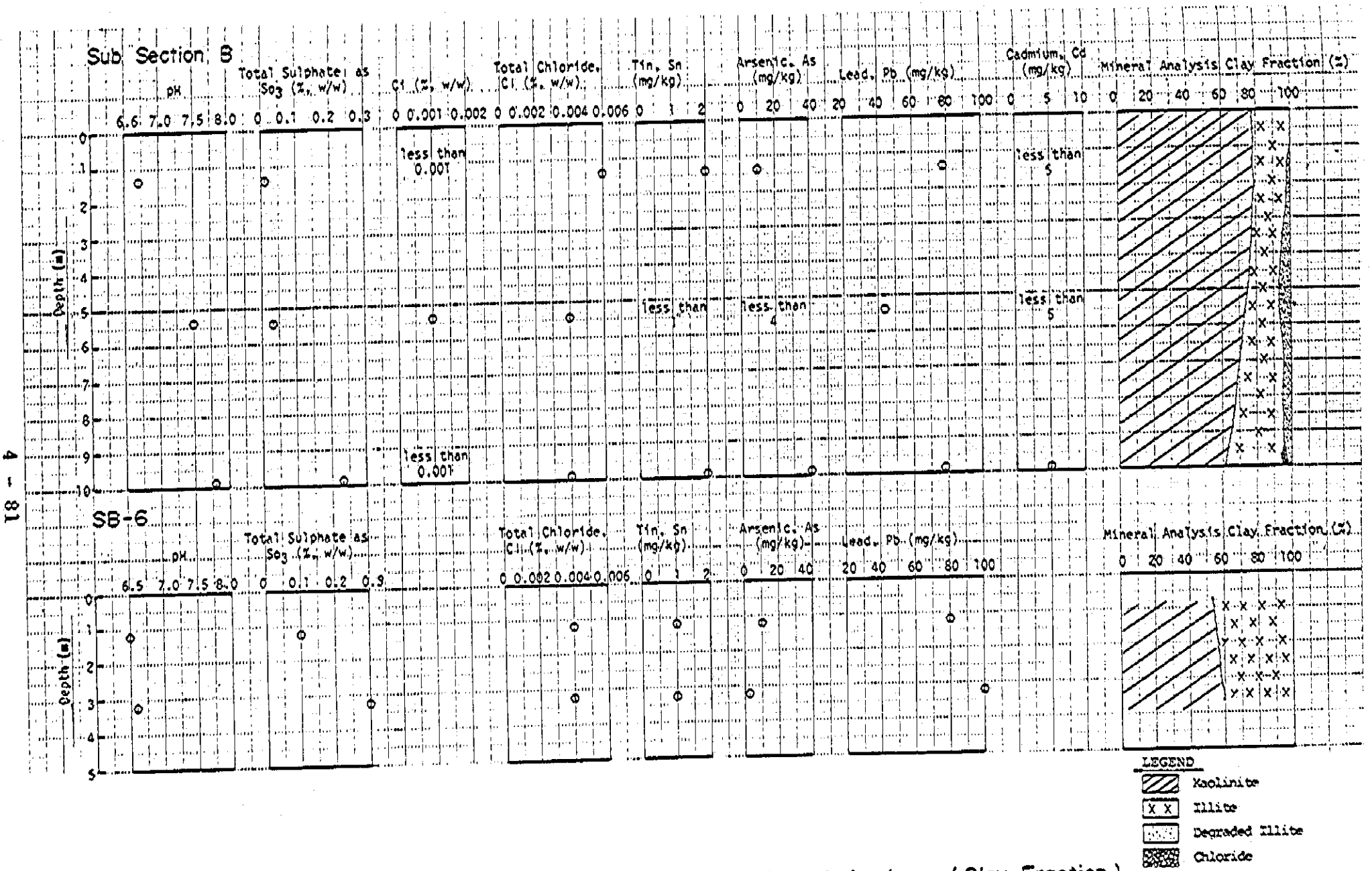


Fig. 4-28 Results of Chemical and Mineral Analyses (Clay Fraction)

(c) Soft Clay Layers

In addition to the above-mentioned very soft clayey layer, different types of clayey layers were found below it.

The clay layers are greyish-brown and soft with N-values of 1 to 3 found at SB-2 (depth of 4.5 to 8.5 m) and SB-9 (depth of 3.0 to 11.0 m). Grain size distribution is similar to that of the overlying very soft clay, and classification by the plasticity chart also indicates the same group as the very soft clay. Specific gravity is in the range of 2.60 to 2.64. Therefore, the original material of this layer is considered to be similar to that of the overlying very soft clay. The difference is seen in higher N-values (1 to 3) and slightly lower water content (45 to 80% with average of 65%).

An interbedded layer of soft clay with N-values of 3 to 4 was found at Sub-Section A" (depth 13.7 to 15.8 m).

(2) Medium Stiff Clay

Medium stiff clay layers were found at Sub-Section A" (depth of 11.9 to 12.9 m), SB-1 (depth of 6.5 to 11.5 m), SB-5 (depth of 11.5 to 17.0 m), SB-6 (depth of 18.0 to 23.0 m), SBH-1 (depth of 13.5 to 14.5 m) and SBH-2 (depth of 10.5 to 14.5 m). At Sub-Section A", a medium stiff clay layer

with a thickness of about 7 m was found at the location of percussion boring, whereas it is only about 0.5 m at the rotary drilling location (Sub-Section A) and 0 m at rotary drilling location (Sub-Section B).

The N-value of these layers are 4 to 6 in general. However, the N-values of the stiff clay layer found at SB-5 is slightly higher than the other location, i.e. 7 to 10, 50% of which contains sand and gravel size particles.

The samples from these layers are classified as CL (liquid limit of about 40% and plasticity index of about 20). Engineering properties of these layers are as follows:-

Grain Size Distribution	25 to 35% Clay
	20 to 60% Silt
	0 to 10% Sand
	0 to 20% Gravel
Water Content	Wn = 20 ∿ 40%
Specific Gravity	Gs = 2.5 ∿ 2.7
Liquid Limit	LL = 30 ∿ 50%
Plastic Limit	PL = 15 ∿ 25%
Unified Soil Classification	CL
Permeability	($k = 1 \times 10^{-4}$ cm/sec)
Undrained Shear Strength	$c_u = (1.1) \sim 2.5 \sim 3.5$ t/m^2
Compression Index	Cc = 0.22 ∿ 0.30
Coefficient of Consolidation	$Cv = 1.5 \times 10^{-1} \sim 5 \times 10^{-1}$ cm2/min.

(3) Very Loose to Loose Sandy Layers

Sandy layers are extensively distributed at the northern part of the Sentul site with varying thicknesses of 1 to 15 m. N-values and cone resistance are plotted versus depth in Fig. 4-29. N-values vary from 2 to 10 and cone resistance varies from 20 to 70 kg/cm^2. Major engineering properties of this layer are summarised below:-

N-Value	2 to 10 (Very Loose to Loose)
	N = 0 (In Some Cases)
Cone Resistance	qc = 20 to 40 kg/cm^2
Grain Size Distribution	5% Silt and Clay
	45 to 65% Sand
	30 to 50% Gravel
Permeability	1×10^{-2} cm/sec
Water Content	wn = 9 to 27%
Specific Gravity	Gs = 2.55 to 2.71

(4) Medium Dense Sand Layers

Layers of medium desne sand with N-values of 15 to 30 were interbedded between the other layers. The thickness of these layers is 1 to 9 m, but 1 to 3 m is common.

(5) Limestone Bedrock (Including Weathered Portion)

According to rotary core borings, the bedrock is found to be limestone. The depth of the layer with N-values greater than 50 is 8.5 to 34 m with an average of about 17 m.

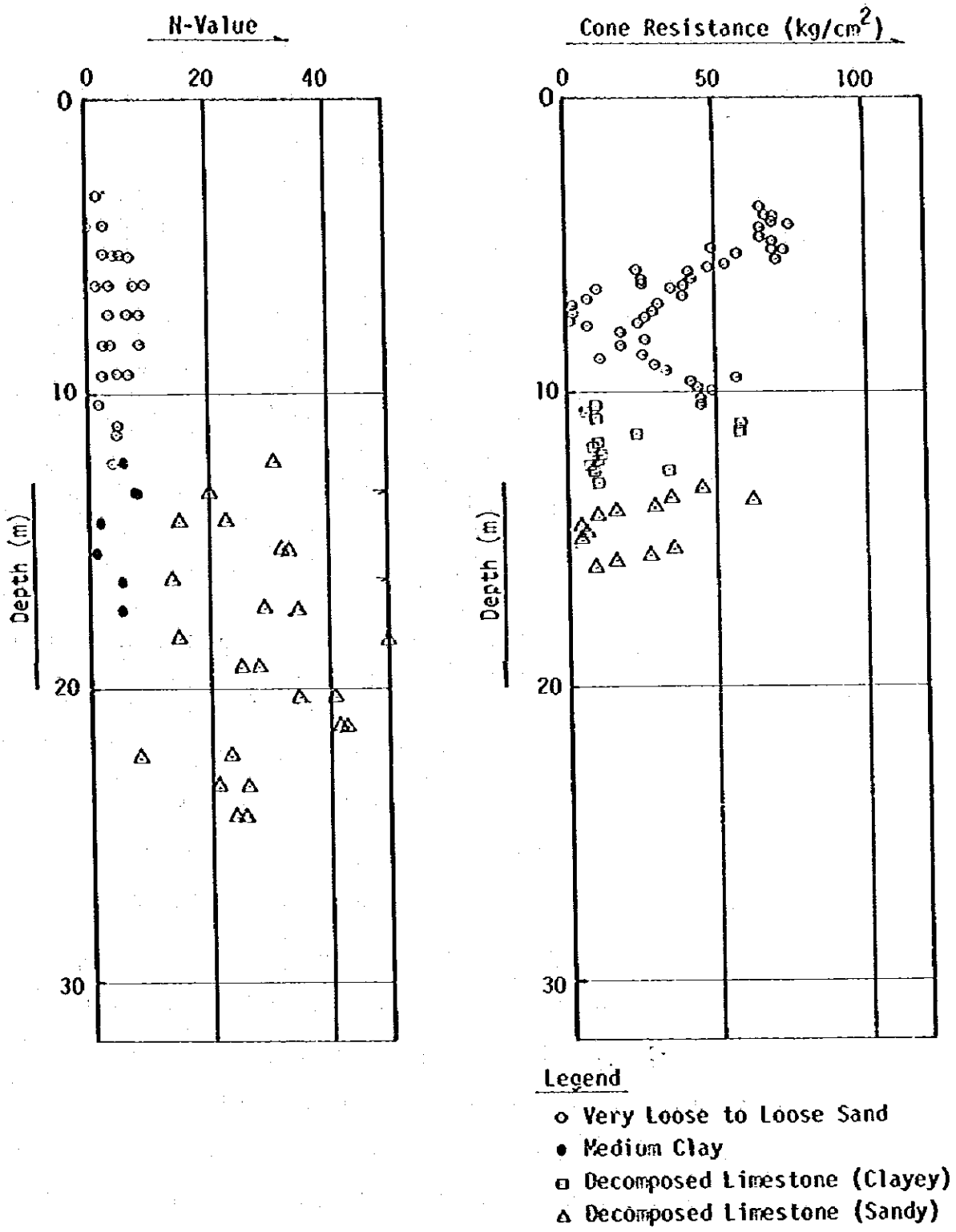


Fig. 4-29 Depth v.s. N-Value and Cone Resistance

The depth to which a 10-ton Dutch cone penetrometer could penetrate was 7 to 27 m with an average of 17 m. At the area outside the enclosure embankments, the average depth to the hard layer is about 9.5 m. Very stiff clay and hard clay encountered at SB-6 and SBH-1 may be portions of heavily decomposed limestone.

It is very important to know the depth of hard layer for the support of pile foundations. However, as mentioned in Section 3, the configuration of the bedrock surface is very complex. In this investigation, various methods were adopted to determine the depth of the hard layer/bedrock formation at the pilot test area.

(a) Electrical Soundings and Microgravity Measurements

In the pilot test area, electrical soundings at the grid point of 25 m by 25 m and microgravity measurements at the grid point of 10 m by 10 m were performed. Through these two types of geophysical surveys, a similar tendency of bedrock depth was obtained as is illustrated in Fig. 4-30. Results of the electrical soundings are interpreted and are presented in Fig. 4-10 as a contour map of the depth to the bedrock. Results of the microgravity measurements are also interpreted and presented in Fig. 4-11 as a contour map of the residual anomaly.

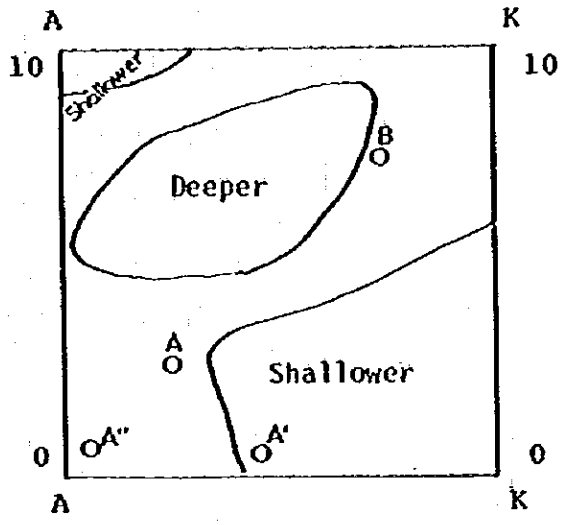


Fig. 4-30 Tendency of Bedrock Depth at Pilot Test Area

(b) Swedish Sounding Results

In order to determine the depth of hard layer in detail, numerous Swedish sounding were carried out at the pilot test area and the test embankment area (Fig. 4-14). Tables 4-11 and 4-12 show a summary of the Swedish soundings. A contour map of the thickness of the soft clay layer was made using the results of the Swedish soundings and is shown in Fig. 4-15. The contour lines are of a similar pattern to those of the electrical soundings and microgravity measurements.

(c) 10-Ton Dutch Cone Penetrometer Tests and Dynamic Cone Tests

At Sub-Section A", 10-ton Dutch cone penetrometer tests and dynamic cone tests reached their maximum penetration capacity at the top of the limestone layer. However, at Sub-Section B, the tests were terminated at the upper portion of the decomposed limestone, where N-values are about 50. The top of the fresh limestone is about 10 m below the final depth of the Dutch cone penetrometer or dynamic cone tests.

(d) Exploratory Borings

The difference of the depth to the limestone between 2 drillings perfomred at a distance of 4 m from each other is 5.5 m at Sub-Section A" and 2 m at Sub-Section B. Percussion borings were terminated when further boring became impossible through encountering harder material. The final depth of the percussion boring was almost same as that of the top of the limestone which was confirmed by rotary drillings. The unit weight of fresh rock cores is 2.5 to 2.7 g/cm^3. Unconfined compression strength is 600 to 1,000 kg/cm^2 and the modulus of deformation obtained by pressuremeter tests is 1,000 to 5,000 kg/cm^2 as shown in Fig. 4-31. Permeability of the weathered zone (sandy portion) is 1×10^{-3} to 1×10^{-2} cm/sec.

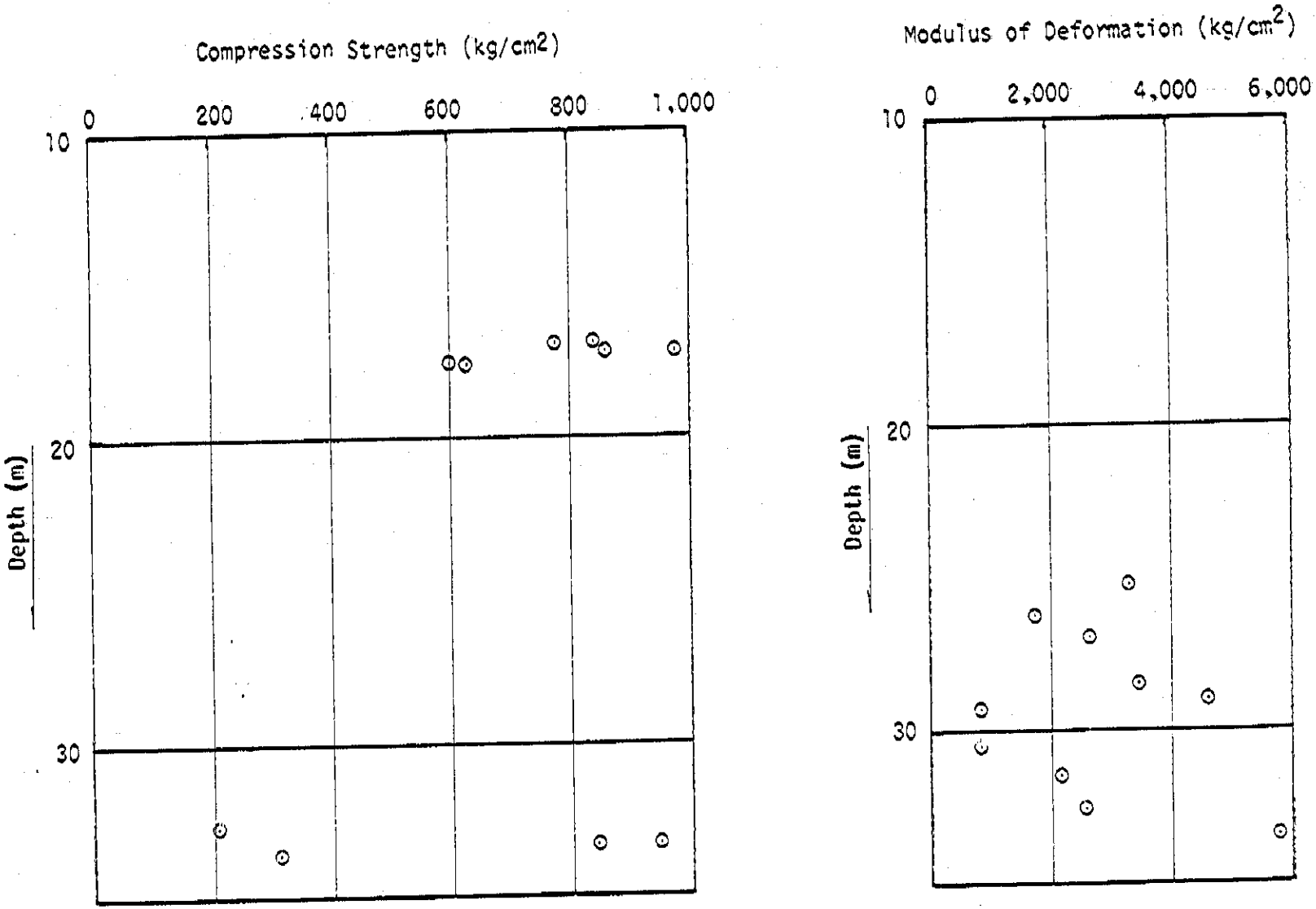


Fig. 4-31 Depth v.s. Compression Strength of Rock Core Samples and Modulus of Deformation Measured by Pressuremeter