B.4. Engineering Geology of Huai Phlu Damsite

B.4.1. Location and Topographic Features

The damsite of Huai Phlu is located on the upper part of Huai Seo, one of major tributaries of Lam Chi Noi in the west of the area. It is accessible by fair-weather roads from amphoe Ban Kruat, 20 km northeast.

Drainage area of the dam is 21 sq.km and gradient of the river course is estimated 1:300 by 1:5,000 topo-map. The slope gradient at dam axis ranges from 1:20 to 1:25. Reservoir is partially covered by cultivated fields and the alluvial flood floor is 80 m width with narrow and deep cut river channel.

B.4.2. Foundation Geology

1) Dam Foundation

In accordance with the field investigation and the result of 7 core drillings carried out by RID, damsite is underlain by three different geologic formations, the Slope Detritus, the Alluvial Formation and the Sao Khua Formation. Two of them except the Sao Khua Formation are unconsolidated deposits. The Slope Detritus is exposed in both sides of abutment with gentle slope and consists of 2.2 to 7.7 m of silty sand with thin layer of boulders. The formation is originated by weathering of underlying sandstone and conglomerate. Bearing capacity of the formation presents mostly less than 10 blows by SPT and permeability ranges from 0.1 to 0.001 cm/sec.

The rather deep cut off trench to excavate out the formation up to sandstone should be required for prevention of underseepage through it. The trench depth would be about 8.0 m in maximum. The Alluvial Formation underlies the flood floor of 80 m width with

narrow river channel and consists of silty sand of less than 5 m. Although the flood deposits extend locally more than 100 m width along the river channel, it is not exposed at the dam axis. The Sao Khua Formation is not exposed at the surface but is underlain by the Slope Detritus and Alluvial Formation. It consists of siltstone and fine to medium grained sandstone with dipping to the right side.

In comparison with the right abutment, siltstone is abundant in the left abutment. Permeability ranges from 0.01 to 0.001 cm/sec in the upper part and it becomes impervious, less than 10^{-5} cm/sec, at 10 m below the surface.

2) Spillway

The spillway would be provided at the left bank of abutment because of geologic conditions.

The side channel should be founded on the Sao Khua Formation because the Slope Detritus presents quite loose deposit condition.

Geological map and geologic profile of the damsite are shown in Figure B-4-1 and Drawings respectively. Summarized data of core drilling are also shown in Table B-4-1.

B.4.3. Construction Materials

1) Riprap

Riprap material would be obtained at the mountain site about 1.0 km upstream the damsite. It consists of sandstone and conglomeratic sandstone and outcrops are found at the surface with extremely thin overburden.

Table B-4-1 Data Summary of Core Drilling - Huai Phlu Damsite

Hole No.	Site Elv. (mamsl)	Depth Drilled (m)	Depth to layer (mbgs) Soil	Depth to layer (mbgs) Bedrock	SPT (blows)*2) Range	SPT (blows)*2) Average	Permeability (cm/sec) Soil *1)	Permeability (cm/sec) Bedrock	Remarks
DH-1	243.3	21.6	0∿7.7	7.7∿21.6	2∿12	6	$6.7\times10^{-7}\sim4\times10^{3}$	$1.7\times10^{-3}\sim4.7\times10^{-5}$	No water loss from 12.6m
2	238.7	18.5	0∿6.2	6.2∿18.5	1∿14	5	$4.1\times10^{-2}\sim3\times10^{-2}$	$1.3\times10^{-3}\sim1.5\times10^{-4}$	Depth of Siltstone
3	233.4	21.6	0∿6.3	6.3∿21.6	1∿ 5	3	1.8×10^{-2}	$1.3\times10^{-3}\sim4.3\times10^{-4}$	No water loss from 6.7m depth of siltstone
4	227.0	18.8	0∿0.3	0.3∿18.8	-		-	$3.5\times10^{-4}\sim2.9\times10^{-5}$	
5	231.5	15.05	0∿5.55	5.55∿15.05	1∿40	18	2.3×10^{-2}	6.2×10^{-4}	No water loss from 10m depth of siltstone
6	238.2	14.8	0∿18	1.8∿14.8	-		$3.1\times10^{-2}\sim1.6\times10^{-2}$	$2.7\times10^{-3}\sim4.2\times10^{-5}$	
7	243.5	13.7	0∿4.2	4.2∿13.7	1∿ 9	4	7.2×10^{-3}	$4.9\times10^{-3}\sim1.4\times10^{-4}$	

*1) Appropriate tests in unconsolidated soil were not carried out

*2) Blow values seem small in spite of lithology, silty sand.

2) Aggregate

Sandstone is not adaptive for the concrete aggregate because of its quality. Basalt, underlying the middle part of Lam Plai Mat basin, would be used for the aggregate. Existing quarry near Phu Phra Angkhan, south of Amphoe Nang Rong could supply the concrete aggregate of suitable quality for the Project.

B.4.4. Foundation Treatment

The cut off should be founded on the Sao Khua Formation. Grouting at the upper part of the formation is required for prevention of seepage flow through it.

The curtain grouting is designed by three rows of half of the water depth at the river bed and 5 m in depth at both abutments. Each row is designed 1.5 m interval with 3.0 m hole spacing.

B.5. Engineering Geology of the Diversion Weir

B.5.1. Location and Topographic Features

The weir site is located 10 kilometers east of amphoe Soeng Saeng along the middle Lam Plai mat. The weir would be founded on the alluvial flood floor and it has less than 600 m in width.

Left bank of the flood floor forms alluvial terrace with more than 3 m in height and 500 m in width, and it leads to undulated hill. Right bank of the flood floor forms mountain slope and it leads to comparatively steep ridge.

B.5.2. Foundation Geology

The structure of weir would be founded on the flood floor. Although no subsurface geologic investigation was conducted, following foundation geology of the weir site can be outlined based on the existing geologic information.

Left abutment of weir consists of slope detritus of silt and clay with little pebble which originates siltstone or basalt. Estimated permeability of the layer is comparatively low, about 1×10^{-4} cm/sec and bearing capacity is supposedly ranging from 15 to 20 by SPT.

The right abutment of the weir consists of slope detritus of silt and clay. Estimated permeability and bearing capacity are almost the same as the left abutment. Depth to basement rock at the both abutments is estimated at more than 5m. Flood floor, the foundation of main structures, consists of alluvial clay and fine sand with little pebble. Estimated permeability is about 1×10^{-3} to 1×10^{-4} cm/sec and bearing capacity is about 5 to 15 by SPT. Depth to the basement rock is probably less than 15 m from the river bed.

B.6. Recommendations

B.6.1. Investigation of Foundation Geology of Lam Plai Mat Dam

Core drillings at the alluvial plain along the dam axis shall be conducted for reinvestigation of the lithology of the Alluvial Formation. Basic idea of specifications is listed as follows;

1) Number and depth of drillings

No.	Location	Depth
No.1	50 m from DH-8 to DH-9	20 m
No.2	50 m upstream from DH-8	20 m
No.3	50 m from DH-5 to DH-6	20 m

2) Metal crown bit of minimum 66 mm OD shall be applied for drilling. Circulation liquid for drilling shall be minimized to maintain the high recovery rate.

3) SPT shall be conducted every one meter.

4) In case of standing layer, permeability test shall be conducted by packer method with multiple pressures.

   In case of corruptible layer, casing method with constant injection flow can be applied for permeability test. Casing shall be installed tightly to the bottom.

5) Obtained geologic sample shall be observed carefully whether it is highy weathered bed rock or unconsolidated overburden stratum.

B.6.2. Grouting Test at Lam Plai Mat Damsite

Optimum spacing of the grouting holes can minimize construction cost and time.

Proper grouting spacing can be verified by the grouting test. Following is general idea of the grouting test;

1) Test site shall be located between core hole DH-2 and DH-3

2) Three test holes with 15 m in depth shall be identified initially on the apex of triangle with 5 m in side length.

3) Grouting shall be conducted in the initial three holes by ordinary manner.

4) Secondary three holes which verify effect of grouting by permeability test, shall be drilled on the middle way of initial holes.

5) Next grouting shall be conducted in the secondary holes.

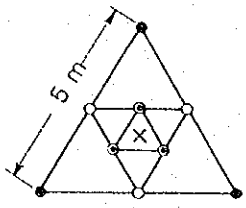
6) Third three holes which verify effect of grouting by permeability test, shall be drilled on the middle way of secondary holes.

7) Next grouting shall be conducted in the third holes.

8) Final hole shall be drilled on the center of the triangle for verification of the grouting. Layout of holes for the grouting test is shown in Figure B-5-1.

Fig. B-5-1

Layout of The Grouting Test Holes



Hole Layout

⊙ Third Drilling Hole
○ Secondary Drilling Hole
● Initial Drilling Hole
× Check Hole

B.6.3. Investigation of Basalt Quarry

The hilly mountain, north of the middle stream of Lam Plai Mat is underlain by basalt. When the basalt would be developed as an exploitable quarry, it can be used for riprap and fine to coarse aggregates for Lam Plai Mat and Nong Lum Puk Sub-Projects. As mentioned before, recommended site to be developed is south of the Nong Lum Puk damsite (refer to B-3-3).

Seismic prospecting prior to drillings is most effective and economical method of investigation.

B.6.4. Investigation of Foundation Geology of Weir

Subsurface investigation for foundation geology of the weir site shall be conducted for the next stage. Basic idea of investigations is as follows;

1) One core drilling with permeability test and SPT shall be conducted on left side of flood floor.

2) Geophysical prospecting, seismic or geo-electric, shall be conducted along the axis of weir. It can reveal physical properties of foundation and depth of basement rock.

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GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank
HOLE NO.	DH-1	DEPTH	15.3 m
SITE EL.	270.7 m	BIT TYPE	DB NWM
WATER TABLE		DATE	Apr. 9 - Apr. 23, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		Siliceous	83	5.0×10^{-3}		
1.7		Sandstone, medium	100			
2.55		Weathered Sandstone, coarse		1.8×10^{-3}		
			72			
			100	1.1×10^{-4}		
5						
5.55		Sandstone, coarse				
6.1		Conglomeratic Sandstone,	97			
6.45		Sandstone, fine-med				
		iron oxide stained		1.6×10^{-3}		
7.8		Sandstone, coarse				
8.7		Sandstone, f - m		1.0×10^{-3}		
		chert pebble	50			
9.55		Conglomerate				
10				5.8×10^{-4}		
11.05		Sandstone, f - m	96			
		Partially clayey cracky		6.4×10^{-4}		
12.3		Sandstone, m	75			
				1.1×10^{-4}		
14.7		Sandstone, m		1.6×10^{-5}		
15						
15.3		Sandstone. c	100			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank
HOLE NO.	DH-2	DEPTH	15.6 m
SITE EL.	261.8 m	BIT TYPE	DB NWM
WATER TABLE		DATE	Apr. 2 - Apr. 8, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.2		dark brown Silty sand			50/20 →	
3.0		Sandstone, f - m	19 0			
4.5		Conglomerate	37 0	4.7×10^{-3}		
5		fractured conglomeratic	83			
7.2		Sandstone, f - m	57	7.6×10^{-4}		
9.0		Sandstone, c	100	8.8×10^{-4}		
10			93	1.1×10^{-3}		
11.1		Sandstone, f - m	53			
		conglomerate interbedded	17			
14.1		Siltstone	20	8.4×10^{-6}		
14.4		Siltstone				
15				7.2×10^{-4}		
15.6		Sandstone, f - m	33			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank
HOLE NO.	DH-3	DEPTH	19.5 m
SITE EL.	252.7 m	BIT TYPE	DB Nxm
WATER TABLE	7.1 mbgs	DATE	Apr. 2 - Apr. 8, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.8		Silty sand		1.5×10^{-3}		
3.0		Clayey sand				
4.4		Gravel w/silt		8.0×10^{-4}		
5		core length 10 cm max.	0	3.1×10^{-3}		
		Fractured	14			
8.6		Sandstone, m	20			
10		core length 50 cm max. slightly weathered in matrix	67	1.1×10^{-4}		
12.0		Conglomerate	13	1.4×10^{-4}		
		heavily weathered	30	2.0×10^{-4}		
			67	2.7×10^{-4}		
15 15.0		Sandstoned, m				
15.4		Conglomerate	0	1.1×10^{-4}		
16.5		Mudstone	83			
17.5		Sandstone, f - m	95	2.9×10^{-5}		
19.5		Conglomerate	95	3.8×10^{-5}		
20						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank, on Terrace
HOLE NO.	DH-4 (1)	DEPTH	25.05 m
SITE EL.	247.8 m	BIT TYPE	DB NXm
WATER TABLE	7.0 mbgs	DATE	Mar. 24 - Mar. 28, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				7.3×10^{-3}		
2.5		Silty Sand				
			39			
		core length 11 cm max.	20	1.6×10^{-3}		
5			18			
		partially heavily weathered cg interbed	23	1.4×10^{-3}		
7.0		Sandstone, f - m	35			
		Conglomerate	0	3.1×10^{-4}		
			64	3.1×10^{-4}		
10			100			
		core length 34 cm max.	91			
		clay bedded	35	3.1×10^{-4}		
13.05		Conglomeratic Sandstone	37			
			40	1.3×10^{-4}		
15		core length 30 cm max. soft, brittle	100			
			77			
		Slightly weathered	100			
20			90	3.0×10^{-5}		

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-4 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				1.5×10^{-5}		
22.15		Siltstone	90			
			100	4.6×10^{-5}		
		greenish gray fresh micaceous	76			
			60	3.5×10^{-5}		
25 25.05		Sandstone, fine	40			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank, on Terrace
HOLE NO.	DH-5 (1)	DEPTH	24.85 m
SITE EL.	247.3 m	BIT TYPE	DB Bxm
WATER TABLE	7.3 mbgs	DATE	Mar. 21 - Mar. 31, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				5.6×10^{-4}		
				4.3×10^{-5}		
3.3		Sandy silt				
5				1.4×10^{-3}		
				1.0×10^{-3}		
9.0		Clayey sand				
9.55		Gravel w/clay				
10		Core length 21 cm max.		2.3×10^{-5}		
11.05		Conglomeratic Sandstone	39			
12.05		Sandstone f - m	0			
12.7		Heavily weathered Sandstone, m	28			
		Slightly weathered micaceous Laminated	50	7.9×10^{-5}		
			42			
15				6.3×10^{-5}		
15.7		Sandstone, f - m	37			
				7.6×10^{-5}		
			52			
17.7		Sandstone, m - c				
		Soft & friable	17	7.8×10^{-5}		
20		Mudstone	93			

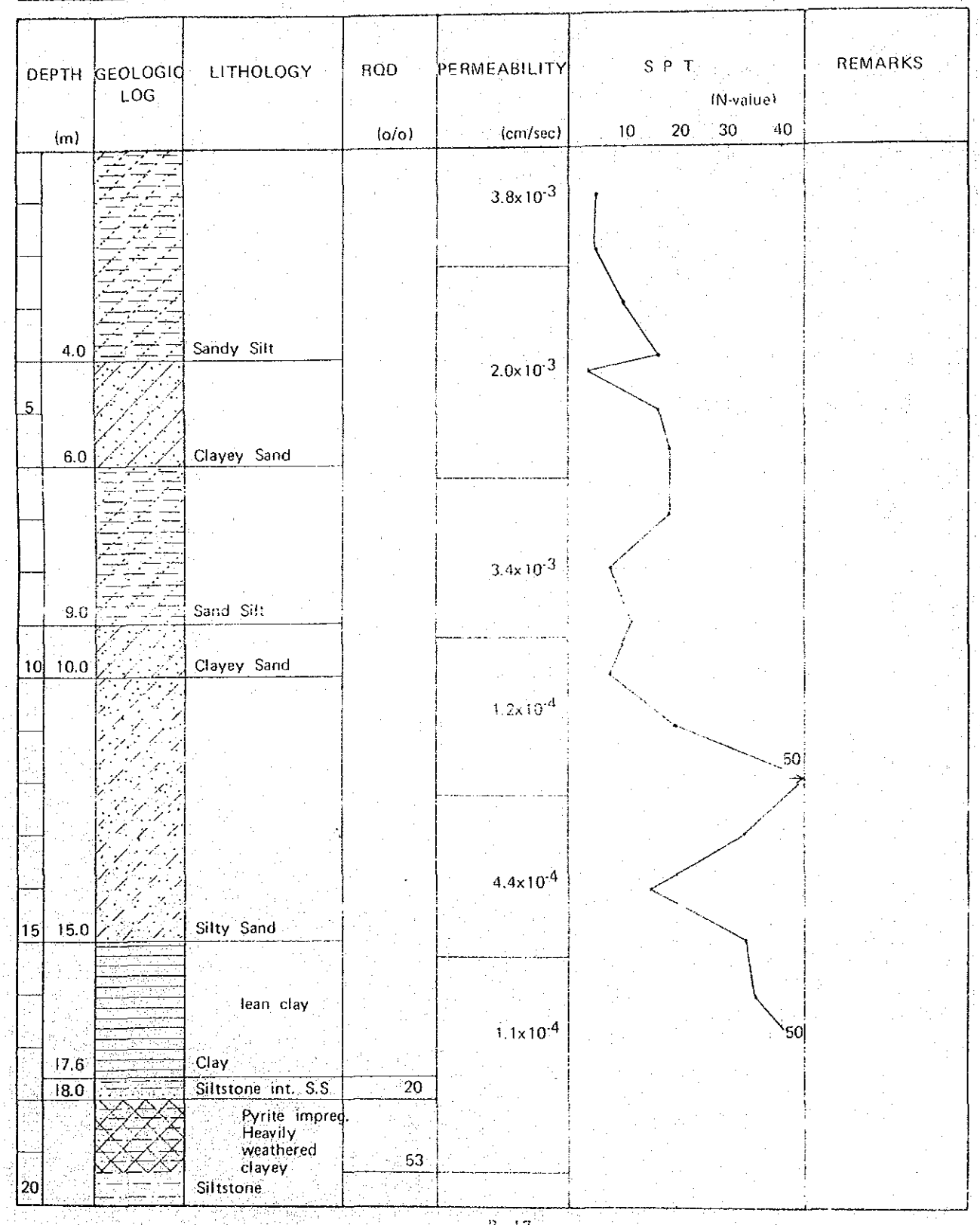
GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-5 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		Core length 10 cm max.	27	8.8×10^{-5}		
			67	8.0×10^{-5}		
25 24.85		Mudstone	53	7.3×10^{-5}		

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, left bank, flood plain
HOLE NO.	DH-6 (1)	DEPTH	29.9 m
SITE EL.	241.8 m	BIT TYPE	DB 8xm
WATER TABLE	6.0 mbgs	DATE	Mar. 21 - Mar. 31, 1981



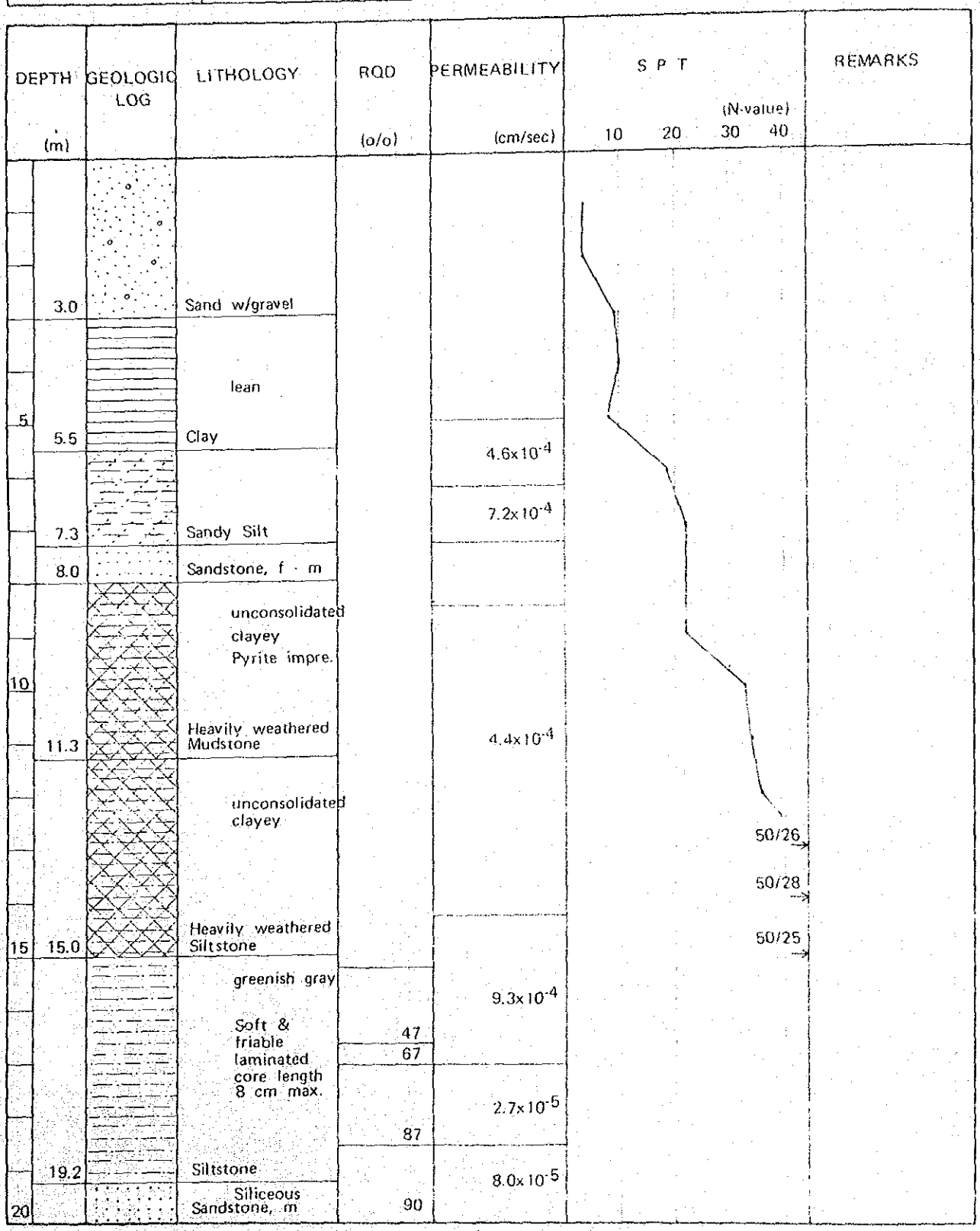
GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-6 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		Core length 8 cm max.	50			
		Soft & friable	17	4.3×10^{-5}		
			50			
24.7		Siltstone		6.1×10^{-5}		
25		micaceous Laminated 26 cm core	77			
27.0		Sandstone, f - m	83	1.8×10^{-5}		
28.0		Sandstone, c	77	3.2×10^{-5}		
		Greenish gray		1.1×10^{-5}		
30 29.9		Siltstone	97			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, river channel
HOLE NO.	DH-7 (1)	DEPTH	30.65 m
SITE EL.	234.4 m	BIT TYPE	DB 8xm
WATER TABLE	0 m	DATE	Apr. 24 - May 9, 1981



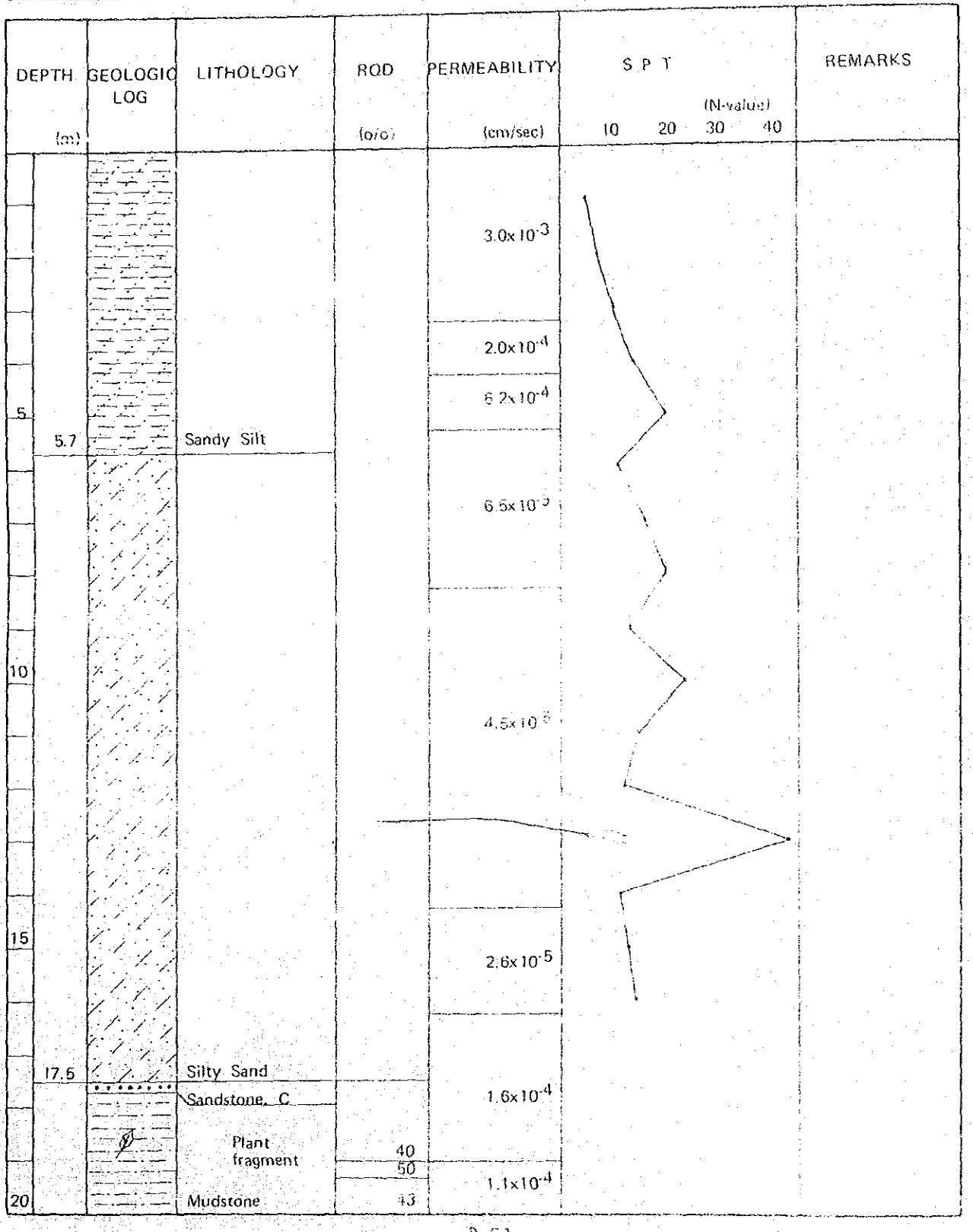
GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-7 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
20.3						
		Soft, friable laminated	43	5.9×10^{-5}		
				1.1×10^{-5}		
				2.6×10^{-5}		
24.5		Siltstone	80			
24.85		Sandstone, f				
25.15		Mudstone		4.0×10^{-6}		
25.5		Sandstone, f				
		Core length 15 cm max. Alternation S.S 60 cm ave. 20 cm		6.2×10^{-6}		
				8.4×10^{-6}		
			93			
		Interbedded Sandstone, f and Mudstone		4.6×10^{-6}		
30.55			100			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank, flood plain
HOLE NO.	DH-8 (1)	DEPTH	29.8 m
SITE EL.	240.7 m	BIT TYPE	DB Bxm
WATER TABLE	1.6 mbgs	DATE	Apr. 5 - Apr. 23, 1981



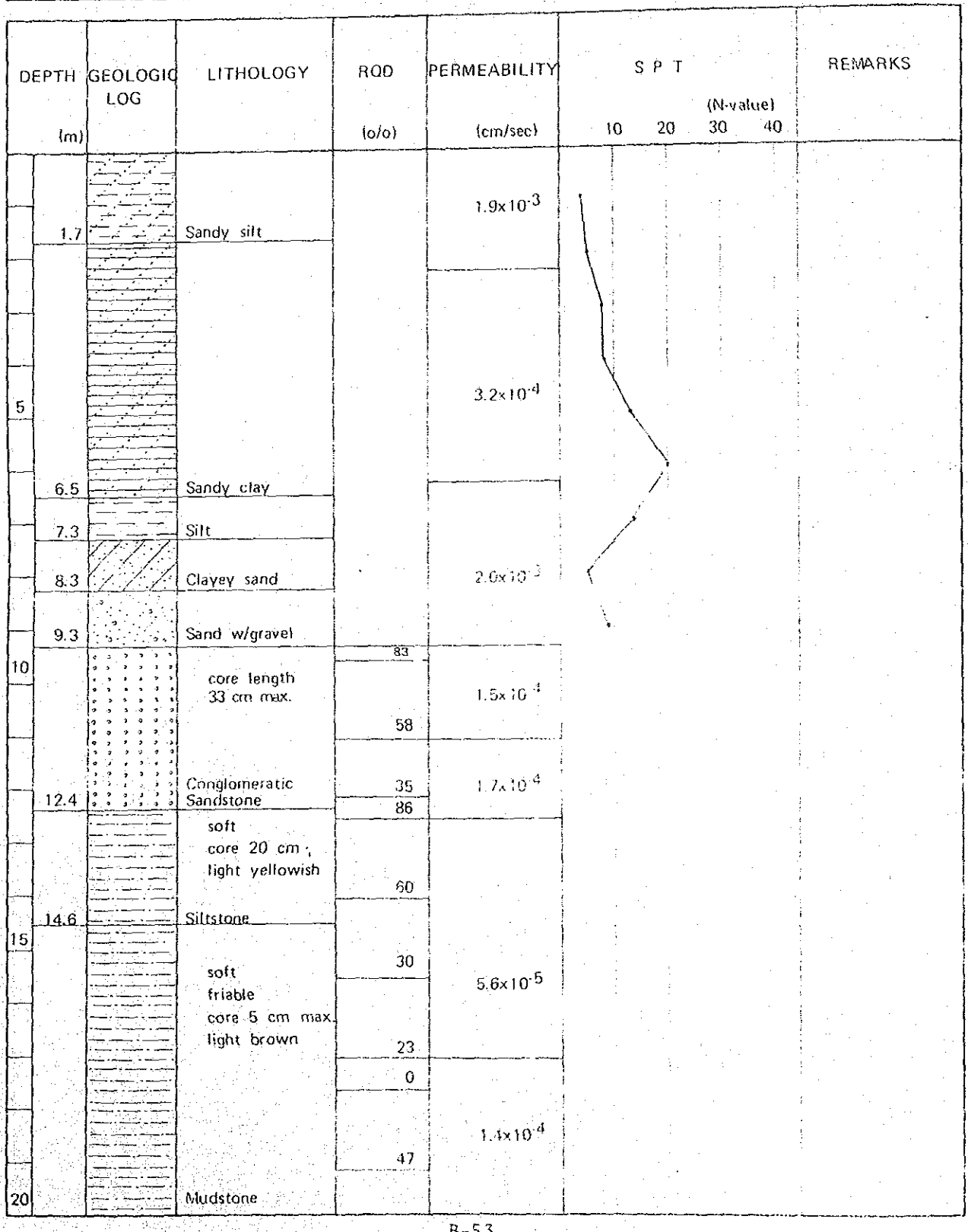
GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-8 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		greenish core length 5 cm max.	23			
		Soft friable	37	1.7×10^{-4}		
25						
25.3		Siltstone	20			
		core length 35 cm max.	43	7.2×10^{-5}		
				5.2×10^{-5}		
28.3		Alternating of Silt - Sandstone, v-f	50			
				1.9×10^{-5}		
29.8		Sandstone, f - m	84			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank, flood plain
HOLE NO.	DH-9 (1)	DEPTH	25.2 m
SITE EL.	240.3 m	BIT TYPE	DB Bxm
WATER TABLE	2.7 mbgs	DATE	May 11 - May 14, 1981



GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-9 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
21.0		Mudstone				
		greenish gray laminated core 4 cm max.	73	1.4×10^{-4}		
			60			
25 25.2		Siltstone	93			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank, flood plain
HOLE NO.	DH-10 (1)	DEPTH	25.6 m
SITE EL.	241.7 m	BIT TYPE	DB 8xm
WATER TABLE	3.8 mbgs	DATE	Apr. 21 - Apr. 28, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	ROD (o.o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				3.2×10^{-5}		
4.0		Sandy Silt				
4.9		Sandstone, f - m	60	2.3×10^{-3}		
		core 55 cm max.	96			
			82	2.9×10^{-4}		
7.9		Conglomeratic Sandstone	89			
8.9		Mudstone	30	8.9×10^{-5}		
10.3		Conglomeratic Sandstone		9.5×10^{-4}		
		Siliceous mudstone core 90 cm	100	1.3×10^{-3}		
12.5		Sandstone, m		4.8×10^{-4}		
		laminated	83			
13.9		Siltstone		3.1×10^{-4}		
			100			
15.65		Sandstone, m		1.1×10^{-4}		
16.3		Cong. Sandstone	81			
		greenish gray fresh plant fragment core 23 cm	0	2.3×10^{-5}		
				9.8×10^{-6}		
		f.ss. Mudstone	100			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	
HOLE NO.	DH-10 (2)	DEPTH	
SITE EL.		BIT TYPE	
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
			100	3.0×10^{-6}		
		interbedded siltstone	70	2.0×10^{-5}		
			90	4.0×10^{-5}		
25				1.9×10^{-5}		
25.6		Mudstone	73			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Ptai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-11	DEPTH	19.8 m
SITE EL.	249.6 m	BIT TYPE	DB Bxm
WATER TABLE	5.1 mbgs	DATE	Apr. 24 - Apr. 29, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0.5		Silt				
0.8		Sandstone, m				
1.2		Conglomerate	70	2.5×10^{-3}		
			100			
			0	1.5×10^{-3}		
		mudstone interbedded				
			10	1.2×10^{-4}		
			70	1.1×10^{-4}		
9.6		Sandstone, m - c				
10.2		Mudstone	80	5.5×10^{-5}		
			20	4.3×10^{-6}		
12.3		Sandstone, m				
12.6		Conglomerate	23	3.0×10^{-5}		
13.8		Sandstone, m				
15.1		Conglomeratic - c Sandstone,	90	2.7×10^{-5}		
15.4		Mudstone				
16.8		Conglomerate	36	1.4×10^{-5}		
18.0		Mudstone	62	7.5×10^{-5}		
18.7		Conglomerate				
19.8		Sandstone, f - m	57	2.2×10^{-5}		

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-12	DEPTH	20.3 m
SITE EL.	256.1 m	BIT TYPE	DB Nxm
WATER TABLE	10.0 mbgs	DATE	Apr. 29 - May 11, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
			75	5.2×10^{-3}		
			100			
		Core 38 cm				
5			0			
			23			
		S.S. coarse	0			
		Conglomeratic Sandstone	25			
7.9						
8.3		Sandstone, m				
8.7		Conglomerate				
9.1		Mudstone	73	7.2×10^{-4}		
			20			
10				8.1×10^{-5}		
			95			
				8.9×10^{-7}		
		Core 94 cm max.		2.6×10^{-5}		
			100			
15				7.0×10^{-5}		
15.5		Sandstone, m				
15.8		Mudstone	93			
				4.1×10^{-5}		
			35			
				5.8×10^{-5}		
18.4		Sandstone, m				
18.8		Mudstone	93			
19.2		Sandstone, m		3.1×10^{-5}		
20 20.3		Mudstone	60			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-13	DEPTH	15.9 m
SITE EL.	263.2 m	BIT TYPE	DB Nwm
WATER TABLE	10.0 mbgs	DATE	May 27 - May 28, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	ROD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0.6		Sandy Silt				
			100			
			63	1.5×10^{-4}		
			30			
				6.2×10^{-4}		
3.9		Sandstone, m	10			
				6.8×10^{-5}		
5			66			
		Conglomeratic		4.2×10^{-5}		
			91			
				1.2×10^{-4}		
8.4		Sandstone, c	52			
				5.7×10^{-5}		
10			91			
				3.7×10^{-5}		
		Core 95 cm max.	63			
				8.4×10^{-5}		
			26			
				2.1×10^{-5}		
14.6		Conglomerate	93			
15		Siltstone interbedded		1.6×10^{-5}		
15.9		Sandstone, f	63			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-14	DEPTH	14.8 m
SITE EL.	269.1 m	BIT TYPE	DB Nxm
WATER TABLE	11.0 mbgs	DATE	May 9 - May 12, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0.7		Sandy clay		3.4×10^{-4}		
4.5		Clayey sand		4.0×10^{-4}		
5.5		Mudstone	0			
			45	2.4×10^{-4}		
			96			
8.4		Sandstonem f - m		1.1×10^{-4}		
8.8		Conglomeratic S.S	71			
10.2		Sandstone, c - cg	65	4.6×10^{-5}		
10.5		Mudstone				
		Mudstone interbedded	93	2.0×10^{-5}		
12.4		Sandstone, m		2.2×10^{-5}		
			97			
13.9		Sandstone, c - cg		1.7×10^{-5}		
14.8		Sandstone, m	83			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-15	DEPTH	15.2 m
SITE EL.	270.9 m	BIT TYPE	DB Nxm
WATER TABLE	10.1 mbgs	DATE	May 12 - May 17, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	ROD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				1.3×10^{-3}		
				7.8×10^{-4}		
2.4		Silty sand				
3.0		Sandstone, m				
4.4		Mudstone	0			
5						
			63	6.1×10^{-4}		
			100			
6.6		Sandstone, m				
				2.1×10^{-4}		
			79			
			93	7.8×10^{-5}		
9.3		Sandstone, c - cg	100			
		partially heavily weathered	77			
			87			
			39			
12.9		Sandstone, m				
			39			
		Sandstone, c - cg				
15						
15.2		Sandstone, m	69			

GEOLOGIC LOG DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Dam axis, right bank
HOLE NO.	DH-16	DEPTH	16.3 m
SITE EL.	272.5 m	BIT TYPE	DB Nxm
WATER TABLE	5.0 mbgs	DATE	May 16 - May 21, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.0		Silt		5.2×10^{-4}		
4.0		Gravel w/silt		2.3×10^{-4}		
5.0		Clay				
5.5		Silt		3.9×10^{-4}		
7.3		heavily weathered Mudstone	30 0			
		weathered	27	2.4×10^{-4}		
			83	2.1×10^{-5}		
		Mudstone interbedded Core 11 cm max.	67	5.7×10^{-5}		
				2.0×10^{-4}		
			0	2.6×10^{-4}		
16.3		Sandstone, f - m		3.0×10^{-4}		

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Spillway, right bank
HOLE NO.	DH-17	DEPTH	11.0 m
SITE EL.	261.9 m	BIT TYPE	DB 8xm
WATER TABLE		DATE	Apr. 28 - May 3, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.0		Silt		1.6×10^{-3}		
1.7		Gravel w/silt				
		coarse weathered	7	2.7×10^{-3}		
			0			
5 5.0		Sandstone, f - m	49	3.6×10^{-3}		
				5.6×10^{-4}		
		core fragments		3.7×10^{-4}		
		weathered		3.7×10^{-4}		
9.5		Mudstone	0			
10		core 10 cm max.		4.7×10^{-4}		
11.0		Sandstone, c -cg	47			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Lam Plai Mat	LOCATION	Spill way, right bank
HOLE NO.	DH-18	DEPTH	10.0 m
SITE EL.	262.7 m	BIT TYPE	DB Nxm
WATER TABLE		DATE	May 23 - May 24, 1981

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0.7		Silt sand				
		core 60 cm max.	38	4.1×10^{-4}		
			58			
3.8		Sandstone, f - m	86	4.8×10^{-5}		
5			89	2.2×10^{-5}		
		core 90 cm max.	71	1.3×10^{-4}		
8.7		Conglomeratic Sandstone	65	7.7×10^{-5}		
9.3		Sandstone, f - m		6.3×10^{-5}		
10		Mudstone	81			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Dam axis, right bank
HOLE NO.	DH-1	DEPTH	20.0 m
SITE EL.	237.6 m	BIT TYPE	DB 56
WATER TABLE	1.22 mbgs	DATE	Sep. 27 - Oct. 19, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		basalt gravel coarse sand matrix, clayey brownish		No water loss by gravity injection	50/7	Permeability at depth of 2.0 m was tested by the recovery method applying hole bottom.
				1.5 m	50/7	
3.0		Pebble gravel w/clay		2.0×10^{-4}	50/24	
				4.5 m		
5				No water loss by gravity injection		
		White - brown		7.5 m		
8.0		Clay w/granule				
9.0		Silt w/granule				
10		tuffaceous blocky reddish brown			50/21	
11.0		Clay w/granule				
		blocky basalt lot of clayey contents				
15						
17.0		Heavily altered Clayey Basalt				
				9.9×10^{-4}		
20		blocky Basalt				
20.0						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Dam axis, right bank
HOLE NO.	DH-2	DEPTH	13.2 m
SITE EL.	237.2 m	BIT TYPE	DB 56
WATER TABLE	5.32 mbgs	DATE	Sep. 22 - Sep. 25, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.85		Loamy reddish brown Silty sand w/pebble			50/27 50/16	
4.5		brown Silty clay w/pebble		6.0×10^{-4}	50/24	
6.9		tuffaceous Clay w/pebble		No water loss by gravity injection 4.6×10^{-4}	50/21	
13.2		core length 36 cm max. 7 - 10 cm ave. blocky Basalt		2.2×10^{-3} 6.1×10^{-4}		

GEOLOGIC LOG DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Damaxis, right bank
HOLE NO.	DH-3	DEPTH	12.4 m
SITE EL.	230.7 m	BIT TYPE	DB 56
WATER TABLE	1.54 mbgs	DATE	Sep. 17 - Sep. 20, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		white gray		No water loss by gravity injection		
4.5		Silty clay w/pebble				
5		core length 7 cm max. Heavily weathered Basalt			50/24	
6.4						
		core length 12 cm max.		1.4×10^{-3}		
10		Cracky Vesicular		2.3×10^{-3}		
12.4		Basalt				
15						

GEOLOGIC LOG DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Dam axis, river channel
HOLE NO.	DH-4	DEPTH	16.6 m
SITE EL.	224.9 m	BIT TYPE	DB 56
WATER TABLE	0.58 mbgs	DATE	Sep. 22 - Sep. 24, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		Sticky clay angular gravel 4 cm max. reddish brown		6.2×10^{-5}		
				7.2×10^{-5}	50/1	
4.2		Clay w/pebble		5.6×10^{-5}		
5		blocky		2.8×10^{-3}		
9.1		Basalt				
10		Pale brownish white with basalt fragments				
15		Heavily altered				
16.6		Tuff				
20						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Dam axis, left bank
HOLE NO.	DH-5	DEPTH	10.7 m
SITE EL.	233.3 m	BIT TYPE	DB 56
WATER TABLE	4.0 mbgs	DATE	Sep. 26 - Sep. 28, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	ROD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		angular gravel size 2 cm max. reddish		2.0×10^{-3}		
				1.1×10^{-4}	50	
3.2		Silt w/pebble				
		white gray		7.7×10^{-4}	50/15	
4.2		Clayey silt				
5				2.1×10^{-3}		
		blocky core length 10 cm max.				
10						
10.7		Basalt				

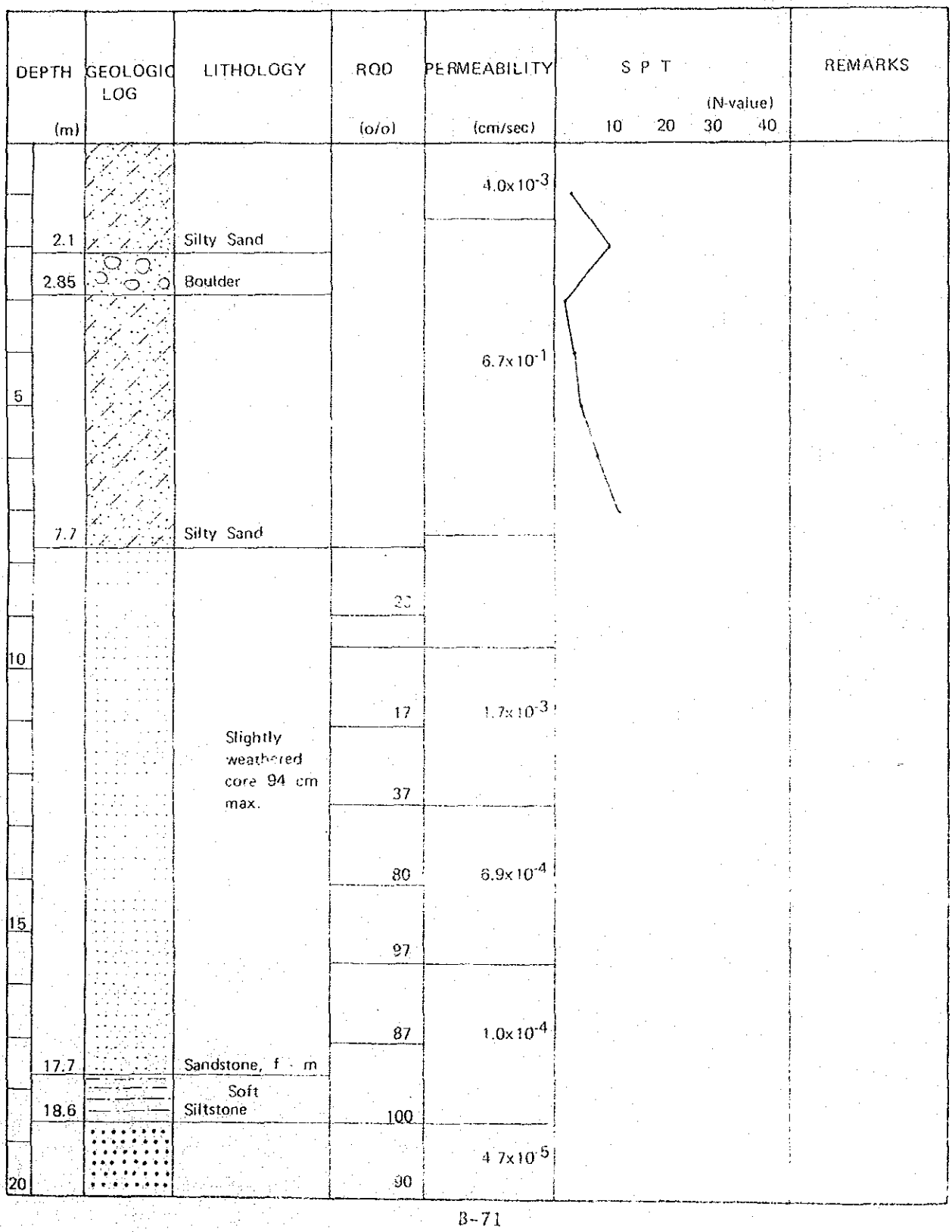
GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Nong Lum Puk	LOCATION	Dam axis, left bank
HOLE NO.	DH-6	DEPTH	15.7 m
SITE EL.	235.3 m	BIT TYPE	DB 56
WATER TABLE	2.65 mbgs	DATE	Sep. 16 - Sep. 20, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
5		little pebble rounded size 5 mm white gray		No water loss by gravity injection		
6.0		Clay w/pebble		No water loss by gravity injection	47 →	
		tuffaceous little pebble white gray		1.8×10^{-4}	50 →	
9.15		Silty clay			50/15 →	
10		Basalt tuffaceous				
11.2		Heavily altered Basalt				
		core length 16 cm max.				
14.2		Basalt		1.5×10^{-3}		
15		blocky vesicular				
15.7		Basalt				

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, right bank
HOLE NO.	DH-1 (1)	DEPTH	21.6 m
SITE EL.	243.3 m	BIT TYPE	DB Nxm
WATER TABLE	5.1 mbgs	DATE	Nov. 14 - Nov. 21, 1983



GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis
HOLE NO.	DH-1 (2)	DEPTH	m
SITE EL.	m	BIT TYPE	DB Nxm
WATER TABLE	mbgs	DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
		core 110 cm max.				
21.6		Sandstone, m	93			
5						
10						
15						
20						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, right bank
HOLE NO.	DH-2	DEPTH	18.5 m
SITE EL.	238.7 m	BIT TYPE	DB Nxm
WATER TABLE	2.5 mbgs	DATE	Nov. 22 - Nov. 25, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				3.0×10^{-2}		
4.25		Silty Sand				
4.75		Boulder		4.1×10^{-2}		
6.2		Silty Sand				
			7	1.4×10^{-3}		
		Slightly weathered core 55 cm max.	43			
			97	6.9×10^{-4}		
			97			
13.3		Sandstone, f - m				
		Soft weathered	67	7.6×10^{-4}		
14.85		Siltstone				
		Soft brittle slightly weathered core 47 cm max.	80			
			47	1.5×10^{-4}		
18.5		Sandstone, f	93			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, right bank
HOLE NO.	DH-3 (1)	DEPTH	21.6 m
SITE EL.	233.4 m	BIT TYPE	DB Nxm
WATER TABLE	1.6 mbgs	DATE	Nov. 28 - Dec. 2, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0				1.8×10^{-2}		
5						
6.3		Silty Sand				
		Slightly weathered Soft & brittle Core 17 cm max.	3	1.4×10^{-3}		
			10			
10			50			
			7	4.3×10^{-4}		
12.6		Sandstone, m	30			
		reddish brown Slightly weathered Core 57 cm max.	27	No water loss		
			57			
15			30			
			24			
20			57			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis
HOLE NO.	DH-3 (2)	DEPTH	
SITE EL.		BIT TYPE	DB Nxm
WATER TABLE		DATE	

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
21.6		Siltstone	63			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis at river channel
HOLE NO.	DH-4	DEPTH	18.8 m
SITE EL.	227.0 m	BIT TYPE	DB Nxm
WATER TABLE	0 mbgs	DATE	Dec. 4 - Dec. 5, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	RQD (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
0.3		Boulder				
		fresh to slightly weathered core 31 cm max.	47	3.5×10^{-4}		
			13			
5 5.0		Sandstone, f - m	27	2.9×10^{-5}		
			93			
			57	No water loss		
10		reddish brown Slightly weathered Soft & brittle max. core 30 cm	70			
			20			
			13			
15			67			
			83			
			63			
18.8		Siltstone	80			
20						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, left bank
HOLE NO.	DH-5	DEPTH	15.05 m
SITE EL.	231.5 m	BIT TYPE	DB Nxm
WATER TABLE	1.6 mbgs	DATE	Nov. 22 - Nov. 24, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	CORE RECOVERY (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
2.2		Silty sand		2.3×10^{-2}		
3.4		Boulder				
5.55		Silty sand				
		highly weathered core 19 cm max.	67	6.2×10^{-1}		
			50			
10.55		Sandstone, f	30	No water loss		
12.05		weathered core 19 cm max. Siltstone	53			
		weathered core 13 cm max.	97			
15.05		Mudstone	73			

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, left bank
HOLE NO.	DH-6	DEPTH	14.8 m
SITE EL.	238.2 m	BIT TYPE	DB Nxm
WATER TABLE	1.3 mbgs	DATE	Nov. 25 - Nov. 29, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	CORE RECOVERY (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
1.8		Silty sand		3.1×10^{-2}		
		moderately weathered				
		core 37 cm max.		1.6×10^{-2}		
5			33			
5.8		Sandstone, f	0			
		highly weathered white	43	2.7×10^{-3}		
		reddish brown core 42 cm max.	27			
10			100			
10.8		Siltstone		1.0×10^{-3}		
11.8		Sandstone, f	100			
		reddish brown core 30 cm max.				
13.3		Siltstone	93	4.2×10^{-5}		
		reddish brown core 22 cm max.				
15 14.8		Mudstone	79			
20						

GEOLOGIC LOG OF DRILLING HOLE

NAME OF PROJECT	Huai Phlu	LOCATION	Dam axis, left bank
HOLE NO.	DH-7	DEPTH	13.7 m
SITE EL.	243.5 m	BIT TYPE	DB Nxm
WATER TABLE	2.8 mbgs	DATE	Dec. 1 - Dec. 2, 1983

DEPTH (m)	GEOLOGIC LOG	LITHOLOGY	CORE RECOVERY (o/o)	PERMEABILITY (cm/sec)	S P T (N-value) 10 20 30 40	REMARKS
				7.2×10^{-3}		
4.2		Silty sand				
5 5.2		Sandstone, f	80			
		highly weathered reddish brown core 32 cm max.	100	4.9×10^{-3}		
10 10.7		Siltstone	73	1.1×10^{-3}		
		core 51 cm max.		1.4×10^{-4}		
13.7		Sandstone, f	80			
15						
20						

ANNEX C SOIL AND LAND CLASSIFICATION

ANNEX C. SOIL AND LAND CLASSIFICATION

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ANNEX C. SOIL AND LAND CLASSIFICATION

C.1. Landforms

The area is situated on the Korat Plateau which is a young, saucer-shaped plateau of which surface is gently undulating, with low hills occurring as well as numerous small shallow lakes. Although the bedrock locally influences the surface forms, topography and drainage pattern, the geomorphological features are predominantly determined by the tremendous alluvial deposits of major rivers system, this is, the Mae Nam Mun and its tributaries such as Lam Plai Mat and Lam Chi Noi.

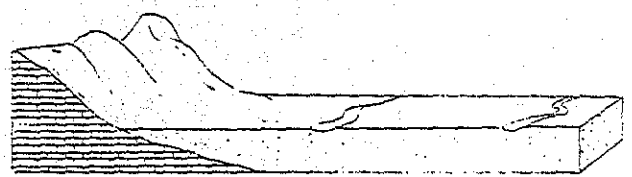
The characteristics and distribution patterns of the Project Study area soils are closely related to the landforms. The principal landforms in the areas are floodplains, low terraces (older floodplains), and middle to high terraces (uplands).

The cycle of sedimentation and erosion and the consequent formation of different terrace levels are schematically shown in Figure C-1.

The floodplains are nearly flat, lowlying lands which extend in parallel with the rivers and their tributaries. Most of these lands consist of the active floodplain surfaces which are inundated frequently by overflow of the rivers during rainy seasons. The floodplains are youngest surface in the area, with parent materilas of deep, silty or clayey, recent riverine alluvial deposits.

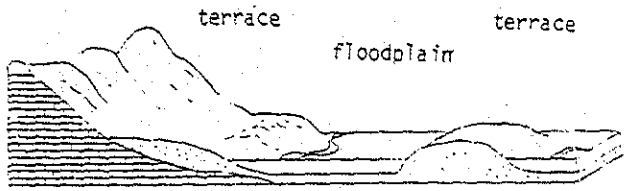
The low terraces occur on the wide, slightly undulating plains between floodplains and middle terraces. Generally, these lands stand one to two meters above adjoining floodplains and undergo natural flooding only when runoff is exceptionally high during rainy seasons. The general relief and slopes of the low terraces are similar to those of the floodplains. Their parent materials consist

FIGURE C-1. CYCLE OF SEDIMENTATION AND EROSION, RESULTING IN THE FORMATION OF TERRACES



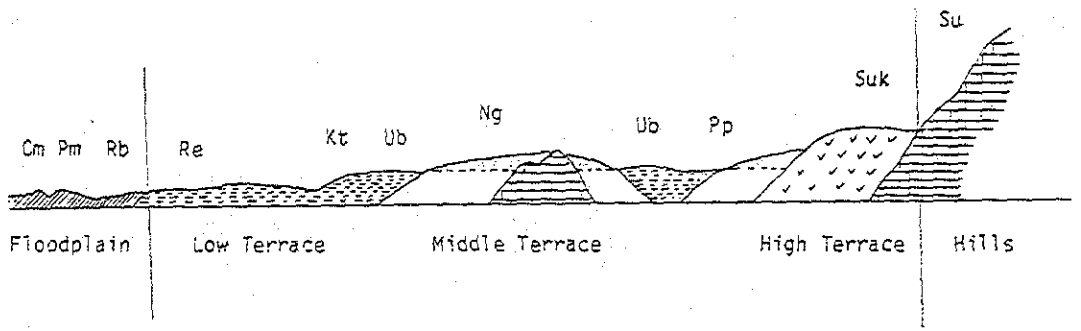
1. Sedimentation Stage

2. Erosion Stage



3. Sedimentation Stage

SCHEMATIC CROSS-SECTION, INDICATING THE PHYSIOGRAPHIC POSITION OF PRINCIPAL SOIL SERIES



Source: Soil of Northeastern Thailand, A Key to Their Identification and Survey, by F.R.Moormann et al. (1964)

of deep, older riverine alluvial deposits. The slightly higher parts are mainly composed of medium to coarse textured sediments, whereas in the lower parts fine deposits dominate in the surface layers.

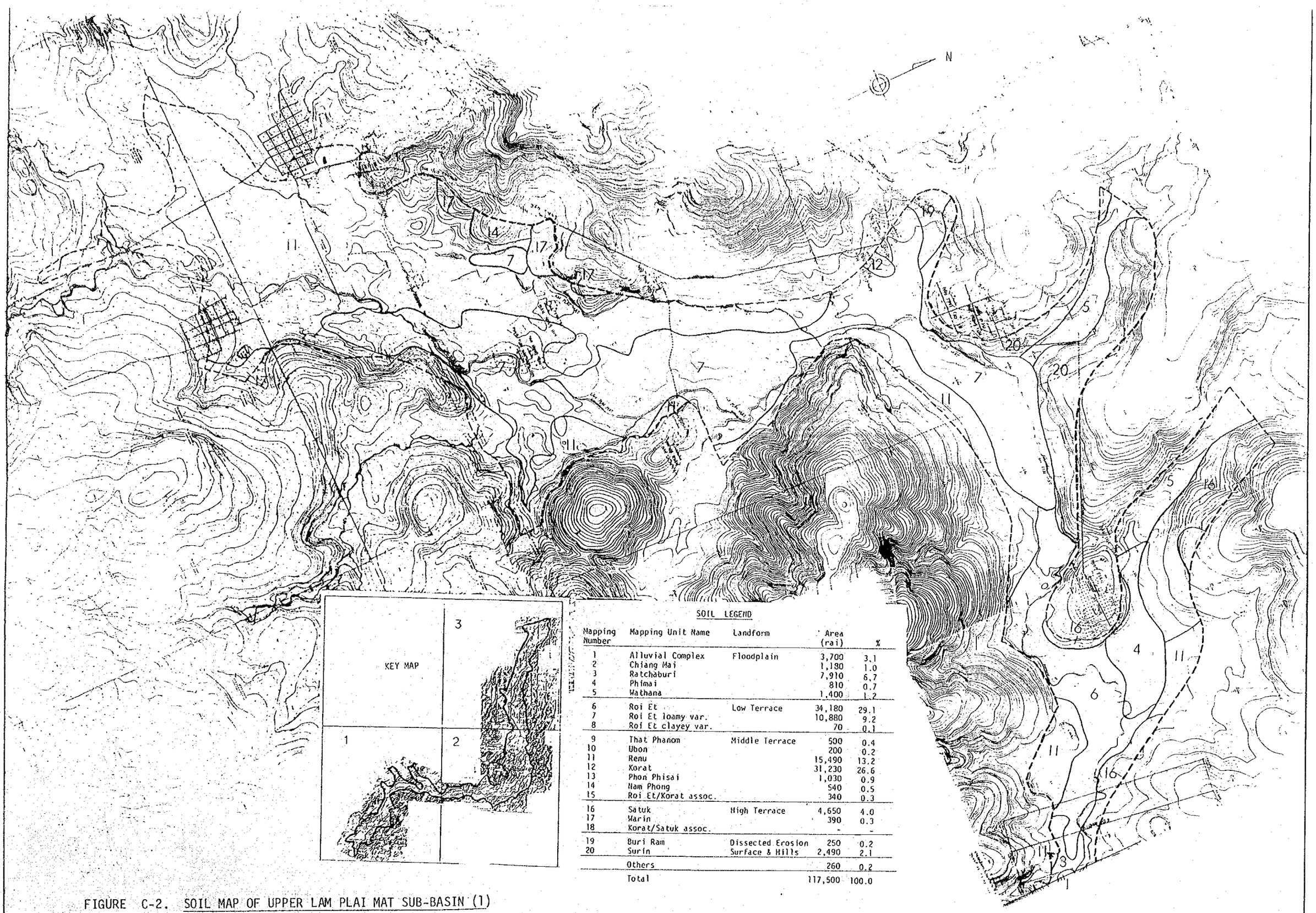
The middle to high terraces form the side slopes of the river valley. These lands have nearly level or gently sloping relief. The parent materials originated from unconsolidated old alluvial deposits and are generally coarser texture than those of floodplains and low terraces.

The dissected erosion surface and hills are found only in the uppermost portion of the area surrounding narrow river valleys. Their parent materials are residuum or colluvium from basalt origin.

C.2. Soils

The prevailing soils in the Upper Lam Plai Mat and the Huai Seo sub-basins have been formed of alluvium under the climatic condition of Tropical Savanna. The soils of the areas are distributed complicatedly because of the various influences of micro-climate, relief, drainage conditions, and nature of parent materials. The general characteristics and distribution patterns of the soils are closely correlated with the landforms that they occupy. Figures C-2, C-3, and C-4 are detailed reconnaissance soil maps for the Upper Lam Plai Mat sub-basin, and Figure C-5 is for the Huai Seo sub-basin.

These soil maps have been compiled from the data obtained during the present field survey made by the RID as a supplement of the existing detailed reconnaissance soil maps of Nakhon Ratchasima province and Buri Ram province scaled 1:100,000 prepared by the Department of Land Development.



SOIL LEGEND

Mapping Number	Mapping Unit Name	Landform	Area (rai)	%
1	Alluvial Complex	Floodplain	3,700	3.1
2	Chiang Mai		1,180	1.0
3	Ratchaburi		7,910	6.7
4	Phimai		810	0.7
5	Wathana		1,400	1.2
6	Roi Et	Low Terrace	34,180	29.1
7	Roi Et loamy var.		10,880	9.2
8	Roi Et clayey var.		70	0.1
9	That Phanom	Middle Terrace	500	0.4
10	Ubon		200	0.2
11	Renu		15,490	13.2
12	Korat		31,230	26.6
13	Phon Phisai		1,030	0.9
14	Nam Phong		540	0.5
15	Roi Et/Korat assoc.		340	0.3
16	Satuk	High Terrace	4,650	4.0
17	Warin		390	0.3
18	Korat/Satuk assoc.		-	-
19	Buri Ram	Dissected Erosion Surface & Hills	250	0.2
20	Surin		2,490	2.1
	Others		260	0.2
	Total		117,500	100.0

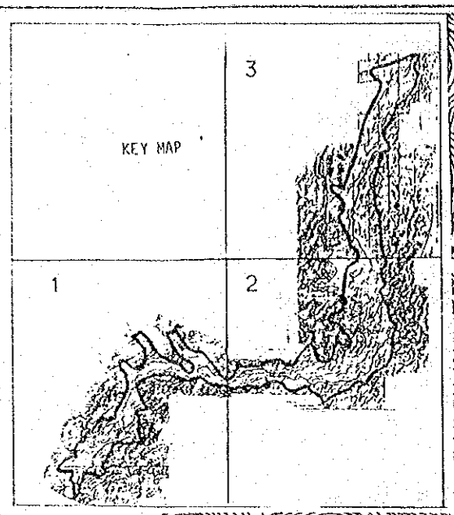
FIGURE C-2. SOIL MAP OF UPPER LAM PLAI MAT SUB-BASIN (1)

- THE LOWER NORTHEAST MEDIUM SCALE IRRIGATION PACKAGE PROJECT -

SCALE 1:50,000

SOIL LEGEND

Mapping Number	Mapping Unit Name	Landform	Area (rai)	%
1	Alluvial Complex	Floodplain	3,700	3.1
2	Chiang Mai		1,180	1.0
3	Ratchaburi		7,910	6.7
4	Phimai		810	0.7
5	Wathana		1,400	1.2
6	Roi Et	Low Terrace	34,180	29.1
7	Roi Et loamy var.		10,880	9.2
8	Roi Et clayey var.		70	0.1
9	That Phanom	Middle Terrace	500	0.4
10	Ubon		200	0.2
11	Renu		15,490	13.2
12	Korat		31,230	26.6
13	Phon Phisai		1,030	0.9
14	Nam Phong		540	0.5
15	Roi Et/Korat assoc.		340	0.3
16	Satuk	High Terrace	4,650	4.0
17	Warin		390	0.3
18	Korat/Satuk assoc.		-	-
19	Buri Ram	Dissected Erosion Surface & Hills	250	0.2
20	Surin		2,490	2.1
	Others		260	0.2
	Total		117,500	100.0

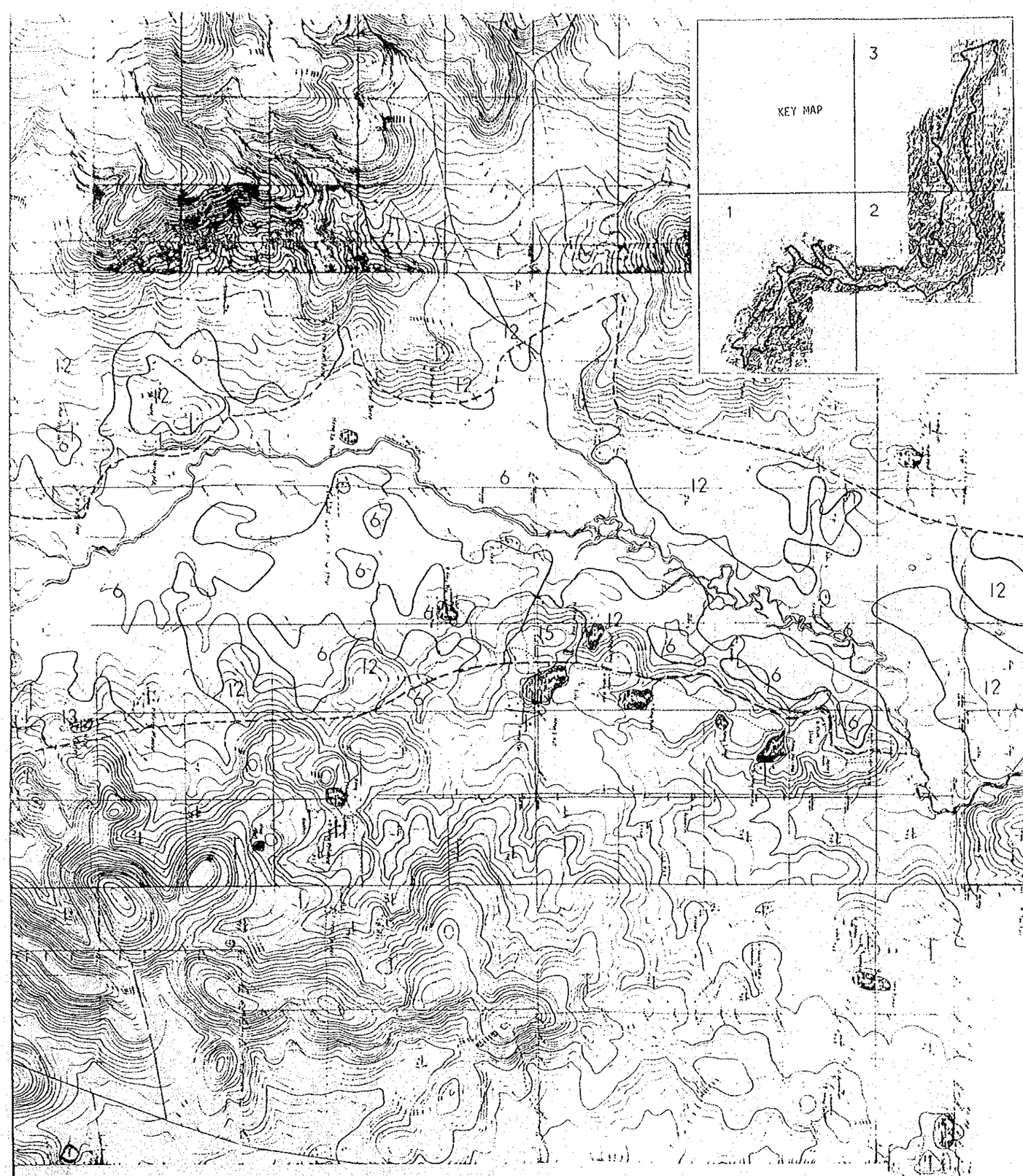


N

SCALE 1:50,000

FIGURE C-3. SOIL MAP OF UPPER LAM PLAI MAT SUB-BASIN (2)

- THE LOWER NORTHEAST MEDIUM SCALE IRRIGATION PACKAGE PROJECT -



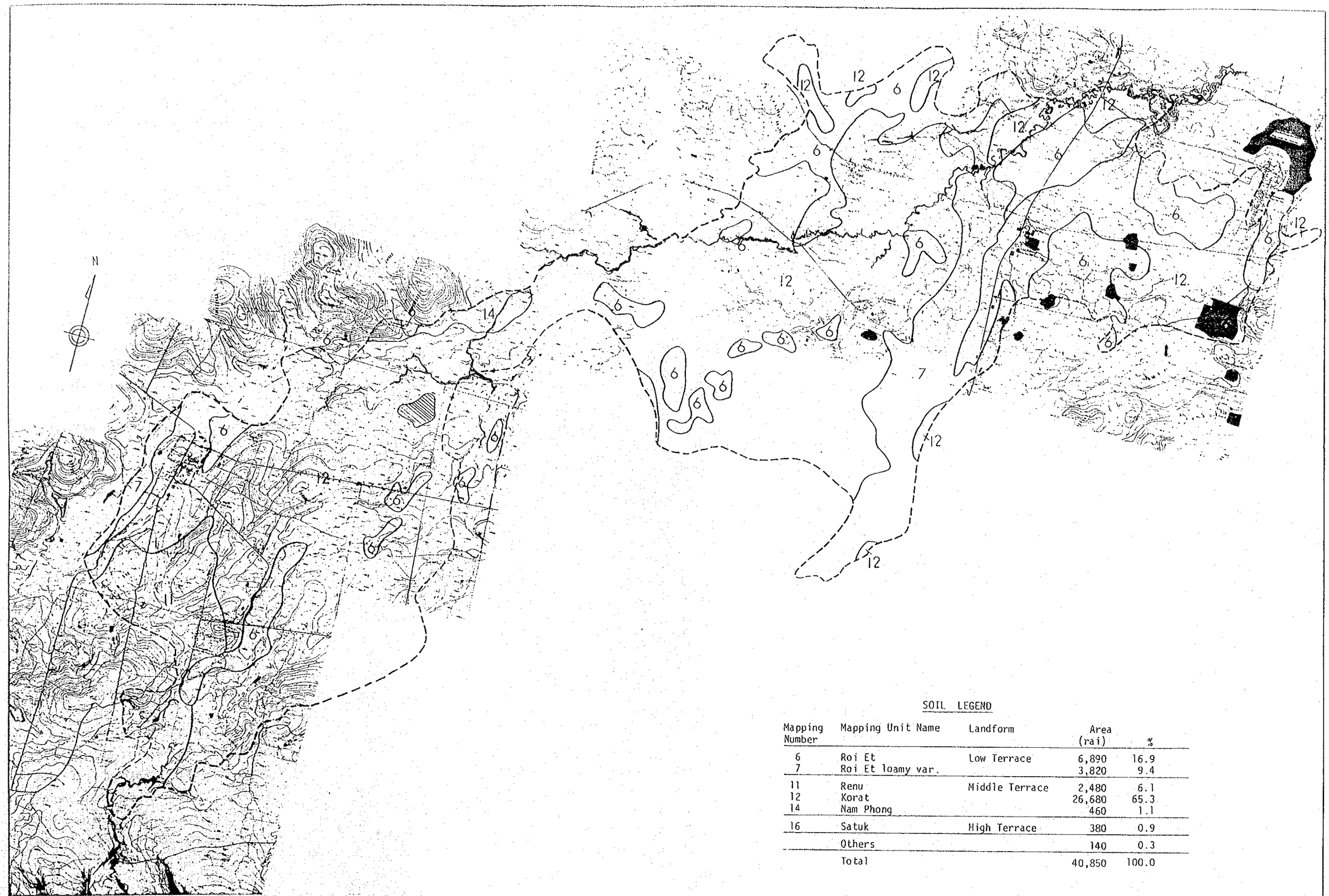
SOIL LEGEND

Mapping Number	Mapping Unit Name	Landform	Area (rai)	%
1	Alluvial Complex	Floodplain	3,700	3.1
2	Chiang Mai		1,190	1.0
3	Ratchaburi		7,910	6.7
4	Phimai		810	0.7
5	Wathana		1,400	1.2
6	Roi Et	Low Terrace	34,180	29.1
7	Roi Et loamy var.		10,880	9.2
8	Roi Et clayey var.		70	0.1
9	That Phanom	Middle Terrace	500	0.4
10	Ubon		200	0.2
11	Renu		15,490	13.2
12	Korat		31,230	26.6
13	Phon Phisai		1,030	0.9
14	Nam Phong		540	0.5
15	Roi Et/Korat assoc.		340	0.3
16	Satuk	High Terrace	4,650	4.0
17	Warin		390	0.3
18	Korat/Satuk assoc.		-	-
19	Buri Ram	Dissected Erosion Surface & Hills	250	0.2
20	Surin		2,490	2.1
	Others		260	0.2
	Total		117,500	100.0

FIGURE C-4. SOIL MAP OF UPPER LAM PLAI MAT SUB-BASIN (3)

- THE LOWER NORTHEAST MEDIUM SCALE IRRIGATION PACKAGE PROJECT -

SCALE 1:50,000



SOIL LEGEND

Mapping Number	Mapping Unit Name	Landform	Area (rai)	%
6	Roi Et	Low Terrace	6,890	16.9
7	Roi Et loamy var.		3,820	9.4
11	Renu	Middle Terrace	2,480	6.1
12	Korat		26,680	65.3
14	Nam Phong		460	1.1
16	Satuk	High Terrace	380	0.9
	Others		140	0.3
	Total		40,850	100.0

FIGURE C-5. SOIL MAP OF HUAI SEO SUB-BASIN

- THE LOWER NORTHEAST MEDIUM SCALE IRRIGATION PACKAGE PROJECT -

The soil series found on each landform and their extents are summarized in Table C-1, and their major characteristics are in Table C-12.

C.2.1. Soils of Floodplains

The soils of floodplains are Hydromorphic Alluvial soils (Ustifluvents and Tropaquepts in USDA Soil Taxonomy, see Table C-13). They occupy nearly flat areas that are poorly drained. Their parent materials originated from the recent or semi-recent riverine alluvium deposited by the annual floods. These soils are deep and commonly have fine texture such as silty clay loam, silty clay and clay throughout the profile. A peculiar feature of these soils is grayish (or some brownish) color and often show distinct mottlings. The surface layers are usually very plastic and sticky when wet, and very hard when dry. Small, soft manganese concretions are common in the subsoils. The floodplain soils have relatively high natural fertility. Transplanted paddy rice is cultivated on most lands during the rainy season under local irrigation system and gives satisfactory yield when flooding is not destructive.

These soils cover the considerable area of a central portion as well as the valley bottoms of small tributaries of the Upper Lam Plai Mat sub-basin (15,000 rai or 13% of total area), but not found in the Huai Seo sub-basin. The soil series included in the floodplains are Chiang Mai, Ratchaburi, Phimai, and Wathana series.

- Ratchaburi series

The soils have been composed of recent alluvium and occur in floodplains forming a transitional zone between the river levees and the river basins. Relief is flat and the general slopes are 0-1%. These soils are a member of the fine-loamy, mixed, non-acid family of Hydromorphic Alluvial Soils (Aeric Tropaquepts). They are very deep, somewhat poorly drained but not so poor as the adjacent soils such as

Table C-1. Summary of Soil Classification

Landform	Mapping Number	Mapping Unit Name	Project Study Area			
			Upper Lam Plai Mat		Huai Seo	
			rai	%	rai	%
Flood Plain	1	Alluvial Complex	3700	3.1	-	-
	2	Chiang Mai	1180	1.0	-	-
	3	Ratchaburi	7910	6.7	-	-
	4	Phimai	810	0.7	-	-
	5	Wathana	1400	1.2	-	-
		Sub total	(15000)	(12.7)	(-)	(-)
Low Terrace	6	Roi Et	34180	29.1	6890	16.9
	7	Roi Et loamy variant	10880	9.2	3820	9.4
	8	Roi Et clayey variant	70	0.1	-	-
		Sub total	(45130)	(38.4)	(10710)	(26.3)
Middle Terrace	9	That Phanom	500	0.4	-	-
	10	Ubon	200	0.2	-	-
	11	Renu	15490	13.2	2480	6.1
	12	Korat	31230	26.6	26680	65.3
	13	Phon Phisai	1030	0.9	-	-
	14	Nam Phong	540	0.5	460	1.1
	15	Rio Et/Korat association	340	0.3	-	-
		Sub total	(49330)	(42.1)	(29620)	(72.5)
High Terrace	16	Satuk	4650	4.0	380	0.9
	17	Warin	390	0.3	-	-
	18	Korat/Satuk	-	-	-	-
		Sub total	(5040)	(4.3)	(380)	(0.9)
Dissected Erosion Surface & Hills	19	Buri Ram	250	0.2	-	-
	20	Surin	2490	2.1	-	-
		Sub total	(2740)	(2.3)	-	-
Others			260	0.2	140	0.3
Total			117500	100.0	40850	100.0

Chiang Mai and Phimai series. The soils have no distinct genetic horizons other than A1- or Ap-horizon. Most commonly, the texture is clayey throughout, but locally they may contain thin stratified lighter textured layers at varying depth. Colors are dark gray to dark grayish brown in the Ap, and grayish grown to brown below. The profiles show mottling which is most pronounced in the surface layers. Mostly, they are subject to periodic flooding. Reaction is usually slightly acid, with a gradual increase of pH values with depth. The lands of this series are in use for irrigated paddy rice and give excellent yields, provided the crop is not damaged by flooding. The natural fertility is considered to be moderate, and the paddy suitability group is P-IIf.

The Ratchaburi series occupy 6.7% of the Project study area of the Upper Lam Plai Mat sub-basin, and the soils of master sites PM-5 and PM-6 belong to this series.

C.2.2. Soils of Low Terraces

The soils of low terraces are Low Humic Gley Soils (Paleaquults) which have developed on older alluvial deposits under poorly drained condition. These soils have formed well developed A- and B-horizons, and texture of the A-horizon is usually loamy, that is, sandy loam, loam, or silty clay loam. The texture of B-horizon ranges from sandy clay loam to clay. These soils have grayish brown color in common, and include prominent reddish or brownish mottlings throughout the profiles. Their surface layers are usually slightly or moderately sticky and plastic when wet, and slightly hard when dry. Practically, all of the soils prevailing on low terraces are used for transplanted paddy rice cultivation.

These soils cover great extent of the Study area; 45,130 rai or 38% and 10,710 rai or 26% of the Upper Lam Plai Mat and Huai Seo sub-basins, respectively. The soil series found in the low terraces is Roi Et series and its variants.

- Roi Et Series

The soils have been formed of old alluvium and occur on low terraces of which relief is nearly flat, namely the slopes are 2% or less. These soils are a member of the fine-loamy, kaolinitic, acid family of Low Humic Gley Soils (Aeric Paleaquults). They are deep and poorly drained soils, and characterized by variable colors, but dominant color is a grayish brown or light brown sandy loam A-horizon overlying a light brown grading to pinkish sandy clay loam or loam argillic B-horizon which in turn overlies a light gray or whitish clay loam or clay C-horizon. They are mottled throughout the profile, with common to many, strong brown or yellowish brown mottling at the surface and strong brown and/or yellowish brown or dark brown and some red mottling in the subsoil. Reaction is medium acid over strongly to very strongly acid.

The soils are subject to flooding by impounded rain water up to about 30 cm deep for 3 to 4 months, while the groundwater table decends below 3 m during mid-dry seasons. The lands of these soils are commonly used for transplanted paddy rice in the rainy seasons.

The soils of master sites PM-3, PM-8, and HS-1 belong to this series. As shown in Table C-10, their natural fertility seems to be low. The Roi Et series with their variants occupy the largest extent in the Upper Lam Plai Mat sub-basin (38.4%), and the second largest extent following to Korat series in the Huai Seo sub-basins (26.3%).

C.2.3. Soils of Middle and High Terraces

In the middle terraces, the soils are predominantly Gray Podzolic Soils and Low Humic Gley Soils (Paleustults and Paleaquults) which have developed in imperfectly drained positions from old riverine alluvium. The natural vegetation on these soils is mainly brush or low open forest, but paddy rice is also grown in a few

places where water can be collected. Upland crops such as cassava, maize, kenaf, and upland rice are grown on better drained soils. These soils have loamy surface layer and clay loam or clay subsoil, and grayish brown or brown color with prominent reddish or brownish mottling.

In the relatively higher positions of upland area, on the other hand, the soils are Red-Yellow Podzolic Soils (Paleustults) which have originated from unconsolidated old alluvial deposits under relatively well drained condition. Having undergone severe weathering and leaching after the deposition of the coarse-texture sediments, these soils are of relatively low fertility. Most lands are covered by low open forests, and upland crops mainly cassava and maize are grown on these soils, but no paddy rice. The soils have coarse-textured surface layers, that is, loamy sand, sandy loam, or loam, and the texture changes slightly finer with depth. The surface layers are usually slightly sticky or non-sticky and slightly plastic or non-plastic when wet, and slightly hard or loose when dry.

These soils occupy the largest extent in both Upper Lam Plai Mat and Huai Seo sub-basins, that is, 54,370 rai or 46.4% and 30,000 rai or 73.4%, respectively. The principal soil series on the middle terraces are Korat series and Renu series, and on the high terraces is Satuk series. Brief descriptions of the above three series are as follows:

- Korat series

The soils have been formed of old alluvium and occur on middle terraces of which relief is undulating, that is, the slopes are ranging from 2 to 6%. They are a member of the fine-loamy, siliceous, acid family of Gray Podzolic Soils (Oxic Paleustults). They are deep and moderately well drained soils. The permeability is moderate to rapid, and the surface runoff is usually rapid. The soils have a peculiar feature characterized by a grayish brown or

very dark grayish brown sandy loam or loamy sand A-horizon overlying a brown or light brown or pale brown sandy clay loam B-horizon. Few to common fine faint strong brown and/or reddish yellow mottling occurs in the deeper B-horizon. Reaction is medium acid to strongly acid over strongly acid to very strongly acid.

The lands occupied by these soils are originally dry dipterocarp forest and mixed deciduous forest. Partially the forest have been cleared for upland crops such as cassava, maize and kenaf, etc.

The soils of master sites PM-1 and HS-2 were classified into this series, and their natural fertility was estimated to be low. This series occupy large extent, that is, 26.5% and 65.3% of the total study areas of the Upper Lam Plai Mat and the Huai Seo sub-basins, respectively.

- Renu series

Genesis and occurrence of this series are similar to those of Korat series. Relief is undulating to gently rolling; the slopes are ranging between 1-4%. These soils are a member of fine-loamy, mixed family of Low Humic Gley Soils (Plinthic Paleaquults). They are very deep soils with somewhat poor drainage, and characterized by dark grayish brown or grayish brown sandy loam overlying brown or light brown which in turn light gray or pinkish gray sandy clay loam grading to sandy clay in deep subsoil. The profiles are mottled throughout with strong brown to yellowish red at the surface and yellowish red or red in subsoils. The lands of this series are used for whether paddy rice or upland crops, depending on the irrigation water availability. The paddy suitability is P-IVt better than Korat series (P-Vt).

The soils of master site PM-10 belongs to this series and the natural fertility was estimated as moderately low after the soil analysis. The Renu series occupy 13.2% and 6.1% of the study areas in the Upper Lam Plai Mat and the Huai Seo sub-basins, respectively.

- Satuk Series

The soils have been formed of old alluvium and occur on the high terrace. Relief is undulating to gently rolling; the slopes are ranging from 2 to 8%. These soils are well drained, and the groundwater table falls below 1.5 m from the surface in most of the years. These soils are a member of fine-loamy, kaolinitic family of Red-Yellow Podzolic Soils (Oxic Paleustults). They are deep soils and characterized by a very dark grayish brown, dark grayish brown or dark brown sandy loam A-horizon overyling a strong brown or yellowish brown or reddish yellow sandy clay loam or clay loam argillic B-horizon. Reaction is slightly acid to medium over strongly acid to very strongly acid.

The lands covered by these soils are mainly dipterocarp and mixed deciduous forest with partly cleared for the cropping.

C.2.4. Soils of Dissected Erosion Surface and Hills

The soils on the dissected erosion surface are distributed in higher elevation lands, that is, the fringe of the area. These colluvium and residuum soils are insignificant in their extent within the irrigable area by the Project. These soils have been formed from residuum of basalt, and contain a considerable quantity of gravels and laterite concretions also. The secondary dipterocarp forests cover these soils predominantly, and parts of these forests have been cleared for upland crops such as cassava and maize.

These soils occupy the smallest extent only in the Upper Lam Plai Mat sub-basin, that is, 2,740 rai or 2.3% of the total area. The soil series found on the dissected erosion surface and hills are Buri Ram series and Surin series.

- Surin series

The soils have been formed in residuum and local colluvium from basalt and occur on dissected lava flow or erosion surface of which relief is undulating to rolling, namely the slopes are ranging from 2 to 8%. These soils are a member of the clayey-skeletal, mixed, acid family of Reddish Brown Lateritic Soils (Rhodic Paleustalfs or Oxic Haplustalfs). These soils are gravelly and moderately deep, and well drained. They are characterized by a dark brown or dark reddish brown loam or clay loam, gravelly A-horizon overlying a yellowish red or red gravelly clay loam or gravelly clay argillic B-horizon which in turn overlies weathering zone and grades to bedrock at some depth between 60 cm and 120 cm. Reaction is neutral to medium acid over medium to strong acid.

The lands of this series are mainly mixed deciduous and dipterocarp forests which have been partially cleared for upland crops cultivation.

C.2.5. Soil Suitability Groups for Paddy Rice

The soil suitability groups for paddy have been developed by the Land Classification Div., D.L.D. In this system, soils are placed in five broad groups numbered P-I to P-V as follows:

Group P-I: Soils very well suited for paddy, having no significant limitations that restrict their use for paddy rice.

Group-II: Soils well suited for paddy, having slight limitations that restrict their use for paddy rice.

Group-III: Soils moderately well suited for paddy, having moderate limitations that restrict their use for paddy rice.

Group-IV: Soils poorly suited for paddy, having severe hazards or limitations that restrict their use for paddy rice.

Group-V: Soils generally not suited for paddy.

Furthermore, the suitability groups for paddy are divided into subgroups according to the kinds of dominant limitation for the production of paddy rice as below:

s - Soil limitation in the root zone - Soils in subgroup "s" have such features as shallowness, unfavorable texture, rapid permeability, gravel and stones, and low fertility that is difficult to correct.

m - Lack of water for plant growth - Soils in subgroup "m" have limitations which result from periods with insufficient rainfall or from insufficient rainfall and streamflow in the normal growing season. Plant growth is reduced by lack of available water.

f - Flooding - Soils in subgroup "f" are susceptible to flash floods or excessively prolonged and deep flooding which damages the crop. Frequency, duration, depth of water, speed with which the water moves, rate of rise and possibility of salt water from the sea must be considered in determining degree of flood hazard.

t - Unfavourable topography - Soils in subgroup "t" have high topographic position or distinct micro-relief which limits use for crops. It may be difficult or impossible to impound water on these soils, and land levelling may be necessary for paddy.

Table C-11 is the guideline for classification of soil suitability groups for paddy which have been made by the Land Classification Div., D.L.D.

C.3. Land Classification

C.3.1. Land Classification Specifications

Because of insufficient water resources to cover the entire arable lands, the Project will provide the irrigation water only the lands on floodplains and low to middle terraces which are presently used for paddy rice cultivation under rainfed or local irrigation systems. Accordingly, the land classification specifications were made to select the lands having slow or very slow internal drainage suited for paddy rice cultivation with irrigation. Table C-2 show the land classification specifications for irrigated land use made especially for the Project Study area.

C.3.2. Land Classes for Irrigated Paddy Rice

Following are brief descriptions of various land classes for irrigated paddy rice cultivation in the area:

Class R1: The lands are capable of producing sustained high yield of paddy rice at relatively low cost when the lands are provided with essential irrigation and surface drainage facilities and if good crop-soil-water management practices are introduced. In other words, these lands would have relatively high net income.

Most lands consist of floodplain areas along the major rivers although significant areas are also found on the low terraces. The soil of Class R1 lands have high inherent fertility. Textural classes of the surface layer are usually fine or medium silty over fine clayey in sub-surface layers. The CEC values of root zone are more than 10 meq./100g of soil, which indicate that these soils could preserve significant quantity of nutrients. The Class R1 lands lie in the area

Table C-2. Land Classification Specifications for Irrigated Paddy Rice

- The Lower Northeast Medium Scale Irrigation Package Project -

LAND CHARACTERISTICS	CLASS R1	CLASS R2	CLASS R3
SOIL FACTORS			
Texture*1	Fine texture in surface and fine textures with less than 30 cm. medium texture in subsurface or medium silty texture in surface and fine textures in subsurface	Medium or fine textures in surface and medium or fine textures with more than 30 cm. fine texture in subsurface	Loamy sand or fine textures throughout profile (loamy sand less than 15 cm.)
Depth to subsurface horizon	< 30 cm.	< 40 cm.	< 50 cm.
to laterite or base rock	> 90 cm.	> 60 cm.	> 30 cm.
Chemical properties			
EC×10^3(0-100 cm.)	< 2 m.mhos/cm.	< 4	< 8
pH (0-30 cm.)	5.5 to 8	5 to 9	4 to 9
CEC (0-30 cm.)	> 10 meq./100g	> 5	> 3
Profile drainage*2	Very poorly drained to imperfectly drained	Very poorly drained to moderately well drained	Very poorly drained to well drained
TOPOGRAPHIC FACTORS			
General land slope	< 2%	< 3	< 6
Micro-relief (hummocks)	Little leveling required	Moderate leveling may be required	Much leveling may be required
Trees or brush cover	None	Very sparse	Sparse
DRAINAGE FACTORS			
Surface drainage	No restriction to surface water disposal	Surface water disposal requires ditching (intermittent pending during wet season)	Surface water disposal requires extensive or deep ditching (ponding frequent during wet season).
Flooding hazard	No restriction	Periodic but relatively frequent shallow floods of short duration	Periodic but relatively frequent shallow floods of short duration

Class R6; Lands that does not meet these specifications

Notes: *1 Soil texture: Fine: SC, C, SiC, CL$^+$, SiCl$^+$, Medium: SCL, CL, SiCL, L, SiL, Si, SL$^+$, Coarse: S, LS, SL$^-$, SL

*2 Drainage classes by the FAO Guideline.

with general slopes less than 2%. These lands would not be subject to destructive flooding after the Project. Their very slow surface and internal drainage characteristics will make it easy to obtain the submergence required for paddy rice cultivation.

Classes R2 & R3: These lands are considered to be suitable for paddy rice production under irrigation, but to a lesser degree than Class R1 lands. Among them, the Class R2 lands have much suitable characteristics for irrigated land use than the Class R3 lands. They are measurably lower than Class R1 lands in productivity or are more costly to farmers because of soil or topographic limitation. However, they will generate satisfactory net returns. Large portions of these lands are identified on the low and middle terraces.

Based on the kind of limitation, the subclasses that are delineated within the Class R2 or R3 lands are R2s, R2sd, R2std, R3s, and R3st. The principal limitation of the subclasses R2s and R3s is soil fertility. The CEC of their soils is moderately low or low. These characteristics indicate that crop yields would be lower, or that fertilizer and soil amendment costs would be higher than for the Class R1 lands. General slopes of R2s and R3s lands are similar to that of Class R1 lands, but they often have uneven surfaces. Although their internal drainage is commonly faster than that of Class R1 lands, surface submergence for paddy rice cultivation would be attained.

The soils of subclasses R2st and R3st have significant limitation of topography, that is, their general slopes are ranging from 2 to 6% in addition to the characteristics similar to those of R2s or R3s lands. Therefore, greater care and higher labor cost would be involved in farming these lands as compared with the Class R1 lands.

Class R6: The lands consist of areas that are considered to be unsuitable for paddy rice production under irrigation because their soils, topographic, and/or drainage conditions do not meet the minimum requirements of the irrigable classes. Most of these lands are found in the middle to high terraces and dissected erosion surface and hills. They consist largely of abandoned clearings, partially cleared crop fields, low open forests, or brush covers.

Most unsuitable lands for irrigated land use have coarse textured soils with very low CEC. The inherent infertility of these soils prevents sustained profitable irrigated agriculture. The Class R6 also include the lands with slopes greater than 6%, shallow, rough, broken lands, and hummocky, severely chanelled lands along rivers and streams.

Others: Densely populated areas such as village complex, and local ponding and swamp areas are excluded from the land classification.

C.3.3. Land Classification for Irrigated Paddy Rice

At first, airphotos having a scale of 1:15,000 approximately were collected to cover the entire Project Study areas. Interpreting these airphotos, the landform patterns were superimposed on the overlyaing paper. Field survey was carried out in accordance with the specifications using the airphotos as the base maps by the staff from Land Classification Branch, Soil and Geology Div., RID.

The density of auger borings had been determined as one per 100 ha, therefore, the numbers of auger borings were 147 for the Upper Lam Plai Mat and 45 for the Huai Seo sub-basins. Out of these auger borings, ten master sites in the Upper Lam Plai Mat and three master sites in the Huai Seo sub-basin were selected for detailed descriptions of soil profiles as well as other land features. Figures C-14 and C-15 are the location maps of the master sites for the Upper Lam Plai Mat and the Huai Seo sub-basins, respectively.

The soil profiles of master sites are shown in Figures C-16 and C-17, and their descriptions were recorded as Tables C-5 and C-6 for the Upper Lam Plai Mat and the Huai Seo sub-basins, respectively.