C-2. Improvement of Crop Cultivation Technology

C-2-1. Basic Concept

Areal spread of crop cultivation has been main measure in the Northeast. This measure was enforced by population pressure and actually the natural forest area was encroached by immigrants. Eventually, serious deforestation has reduced forest area form 42 % to 14 % of the region in 25 years and water resources have decreased. Moreover the newly opened fields from forest land were apt to sustain drought damage due to the typical rainfed condition and the soil condition and fertility became poorer year by year.

To cope with this national problem, the principle of "from quantity to quality" has been set up and being implemented in the policy of Five Year Plan. All the principle in development project should be based on this concept and all technology should be qualitative but not quantitative, and be intensive but not extensive.

C-2-2. Technical Problem

(1) Water Utilization

a) Importance of Irrigation and Land Consolidation

According to the report "Planted acreage and yield of wet season paddy in 1988/87 in RID Project", irrigated field yielded 492 kg/rai of paddy and that of non-irrigated was 244 kg/rai. Irrigation doubled the yield. The same report tells that paddy field which has irrigation facility with land consolidation, could produce nearly 30 % more yield compared with field which has irrigation only. Irrigation with dike and ditch could produce about 15 % more compared with the above. It is obvious that irrigation project with enough facilities for more efficient use of water is rewarding.

b) Efficient Utilization of Water

Late cultivation of rice using photo-period sensitive variety could be shorten the life cycle by cutting so called lag phase. Eventually maturation period can be shortened, saving water and other investment.

According to the report "Increasing the yield of photo-sensitive varieties by modifying their cultural practices" written by Dr. J.

Takahashi and others, transplanting at August 1st or September 1st have highest yield as shown in Tables C-12 and C-13.

Another trials carried on by Ubon Rice Research Center under the title of "Effect of planting data on rainfed lowland" indicates that middle or end of June seeding may expect most favorable high yield, but it is still early for conclusion.

Thai-Australian Tung Kla Ronghai Project which is located to west side of Sebai-Sebok Project, is also very keen about starting time of paddy cultivation. They have concluded as follows;

"In case of variety KDML 105, transplanting would have to be commenced not later than 13th August. This would require 25 daynursery to be planted on 19th July. For a broadcast crop, it is assumed 20 days (minimum 15) are required from sowing to first tiller. Therefore sowing should occur no later than 24th July."

Thus delayed planting might be one of the best counter measures to cope with mid-dry of the rainy season but labour force for ploughing, seeding and transplanting should be considered for the practice in case of extension.

Anyway more studies including breeding of photo-sensitive high yielding varieties and field trial are needed. Short term crop's cultivation utilizing meteorologically assured rainfall or remaining soil moisture in paddy field is another way to be considered.

Each crop has critical stages of watering. In an well facilitated irrigation project, watering can be concentrated on this critical times resulting in water saving. In other words, more area can be cultivated by limited water resources. For that, very efficient O & M organization is necessary.

The information of water saving farming methods such as mulching, deep-ploughing or contour cultivation be examined and their applicability in farmers' fields should be checked in a pilot area. In case of vegetable, pasture or tree crop cultivation, special measures such as trickle or sprinkler method for irrigation may have possibility depending on price of the facilities and marketing environment of the crop.

(2) Soil Improvement

The major soil series prevailing in the basin are very low fertile and very poor in retaining capacity of plant nutrient and water. Since most farmers are applying very limited amount of fertilizer for crop cultivation, sometimes no fertilizer at all, increasing of soil fertility is the most important problem.

Efforts have been given to this problem, such as compost making by Department of Land Development but the effects would be restricted to a certain extent. Generally speaking, increasing soil fertility of farm in tropical condition is very difficult. Some items related to soil improvement are mentioned below.

a) Green Manure Crop

Thai-IRRI (International Rice Research Institute) collaboration on greenmanure for rainfed rice cultivation was started in 1987 in Ubon Ratchathani Rice Research Center, DOA, and several field experiments to evaluate green manure and rice production system have been carried on. So far, Sesbania rostrata has promissing effect to rice yield.

NERAD has also been trying this kind of experiment and the results in 1983~87 are summarized in Table C-14.

This kind of information should be utilized as soon as possible after checking its applicability to farmer's fields.

b) Intercropping

Intercropping of leguminous crop in upland crop has remarkable results to the main crops depending on environment conditions.

Leguminous crop Hamata intercropped in cassava cultivation has shown high positive effect to the yield of cassava according to the trial carried out in Northeast Agricultural Development Research Center, Khon Kaen in 1988.

c) Soil Erosion

Soil erosion means loss of natural resources, and sediment is also a very serious problem for efficiency of reservoir and canal. "Soil

Erosion in Thailand" published by Department of Land Development in 1981 tells that 79% of the area in Yasothon and 54% of Ubon Ratchathani are erodible and about 65% of all these area are very severely erodible (100t ~ 97t of soil/rai/year).
Countermeasures against soil erosion should be taken in any farming practice.

d) Saline Soil

Saline soil is one of the special problems in the Northeast. Yasothon has two levels (slight, moderate) of salty area in southern part and Ubon Ratchthani has three levels (slight, moderate, most) salty soil in the central part of the province covering 10% of whole area.

They say that salinity problem in Northeast is due to raising up of ground water level by deforestation. On the contrary, reforesting effect on lowering ground water level is now being studied in Northeast Agricultural Development Research Center.

Resistance of fruit tree against salt water was checked in the Center with young seedlings and the following results are achieved.

Highly tolerant	:	Passion Fruit, Date Palm, Jujube, Sour Tamerind
Medium tolerant	:	Papaya, Guava, Mango, Jack Fruit
Susceptible	:	Longan, Durian, Rambutan, Pomelo, Sugar Apple, Cashew Nut

As a countermeasure against saline soil in farm land, incorporation of rice husk or ground-nuts' shell in soil, application of manure or compost, green manure cultivation and salt resistance variety planting are being practiced for the time being.

It is necessary to take full care of water use on crop cultivation in the potential area of saline problem, which cover wide area of both provinces.

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (1/8)

(1988)

Unit: Area - rai
Yield - kg/rai

Yasothon

Crop	Amphoe Leong Nok Tha		Tambon Kut Chiang Mee		Tambon Hong Sang	
	Area	Yield	Area	Yield	Area	Yield
Glu. rice	103,951	469	8,398	290	12,713	300
Non g. rice	132,556	464	5,810	310	6,957	320
Sweet corn	-	-	23	1,200	17	1,100
Groundnuts	677	250	140	270	70	180
Cassava	6,100	2,200	-	-	-	-
Sweet potato	-	-	-	-	-	-
Tobacco	-	-	25	270	-	-
Sugarcane	-	-	-	-	54	5,600
Kenaf	3,060	270	-	-	-	-
Sesame	95	68	-	-	-	-
Chilli	-	-	4	240	4	210
Cucumber (long)	-	-	4	1,800	4	1,600
Cucumber (short)	-	-	5	1,600	5	1,500
Water melon	-	-	15	2,500	15	2,500
Red onion	-	-	-	-	-	-
Onion shoot	-	-	-	-	-	-
String bean	-	-	8	1,200	8	1,200
Tomato	-	-	-	-	-	-
Water crest	-	-	-	-	-	-
Garlic	-	-	-	-	-	-
Pumpkin	-	-	-	-	-	-

Source: DOAE, Yasothon

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (2/8)

(1988)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe Trakan Phutphon		Tambon Ka Sem		Tambon Kon Sai		Tambon Ku Sa Korn		Tambon Kha Daen	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield
Glue. rice	111,425	300	10,362	334	9,678	293	4,660	314	6,699	250
Non g. rice	82,613	310	6,884		5,594		1,400	n.a	2,176	
Sweet corn	79	1,500	1	n.a	-	-	1	1,500	-	-
Groundnuts	50	160	-	-	-	-	-	-	-	-
Cassava	110	1,561	-	-	80	-	-	-	-	-
Sweet potato	-	-	-	-	-	-	-	-	-	-
Tobacco	-	-	-	-	-	-	-	-	-	-
Sugarcane	-	-	-	-	-	-	-	-	-	-
Kenaf	1,905	180	-	-	350	-	-	-	-	-
Sesame	-	-	-	-	-	-	-	-	-	-
Chilli	54	2,250	-	-	-	-	-	-	2	271
Cucumber (long)	-	-	-	-	7	n.a	-	-	1	915
Cucumber (short)	-	-	2	2,480	-	-	-	-	-	-
Water melon	-	-	-	-	-	-	-	-	-	-
Red onion	57	1,100	-	-	-	-	-	-	-	-
Onion shoot	11	3,400	-	-	-	-	-	-	-	-
String bean	54	950	3	-	3	-	2	1,000	2	1,192
Tomato	-	-	2	1,450	-	-	-	-	-	-
Water crest	-	-	-	-	6	-	-	-	1	578
Garlic	26	3,000	-	-	-	-	-	-	-	-
Pumpkin	-	-	-	-	-	-	-	-	-	-

Note : n.a - not available

Source: DOAE, Ubon Ratchathani

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (3/8)

(1988)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe Tan Sum		Tambon Na Khai		Tambon Kham Wa	
	Area	Yield	Area	Yield	Area	Yield
Glu. rice	70,210	225	14,156	n.a	7,665	n.a
Non g. rice	11,000	232	969	n.a	1,704	n.a
Sweet corn	25	1,354	5	900	7	n.a
Groundnuts	37	210	3	200	2	180
Cassava	-	-	-	-	-	-
Sweet potato	-	-	1	n.a	1	n.a
Tobacco	-	-	-	-	-	-
Sugarcane	-	-	1	n.a	1	n.a
Kenaf	5	160	-	-	-	-
Sesame	-	-	-	-	-	-
Chilli	35	1,700	3	-	2	n.a
Cucumber (long)	-	-	8	2,000	6	2,000
Cucumber (short)	-	-	-	-	-	-
Water melon	-	-	-	-	-	-
Red onion	-	-	-	-	-	-
Onion shoot	11	2,250	-	-	-	-
String bean	16	1,192	5	2,500	7	n.a
Tomato	-	-	-	-	-	-
Water crest	-	-	-	-	-	-
Garlic	-	-	-	-	-	-
Pumpkin	-	-	3	-	3	n.a

Note : n.a - not available

Source: DOAE, Ubon Ratchathani

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (4/8)

(1988)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe Sri Muang Mai		Tambon Kam Lai		Tambon Don Yai	
	Area	Yield	Area	Yield	Area	Yield
Glu. rice	74,283	326	13,052	n.a	9,719	n.a
Non g. rice	48,685	315	8,045	320	6,150	n.a
Sweet corn	34	1,573	1	1,000	3	1,685
Groundnuts	741	204	-	-	5	n.a
Cassava	336	2,000	2	n.a	-	-
Sweet potato	-	-	-	-	-	-
Tobacco	-	-	-	-	-	-
Sugarcane	-	-	-	-	-	-
Kenaf	1,854	184	5	n.a	-	-
Sesame	-	-	-	-	-	-
Chilli	12	2,560	-	-	-	-
Cucumber (long)	-	-	1	1,600	2	1,957
Cucumber (short)	-	-	-	-	-	-
Water melong	-	-	-	-	-	-
Red onion	34	1,230	-	-	-	-
Onion shoot	15	2,160	-	-	-	-
String bean	21	1,655	1	1,400	3	2,071
Tomato	-	-	-	-	-	-
Water crest	-	-	-	-	2	493
Garlic	17	1,185	-	-	-	-
Pumpkin	-	-	-	-	-	-

Note : n.a - not available

Source: DOAE, Ubon Ratchathani

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (5/8)

(1988/89 Dry Season)

Unit: Area - rai
Yield - kg/rai

Yasothon

Crop	Amphoe: Leong Nok Tha		Tambon: Kut Chiang Mee		Tambon: Hong Sang	
	Area	Yield	Area	Yield	Area	Yield
Soybean	250	156	60	196	25	196
String bean	136	2,800	6	2,800	21	2,800
Pumpkin	40	3,100	-	-	12	3,100
Chilli	133	300	8	300	19	300
Water melon	55	3,200	3	3,200	-	-
	100	3,200	-	-	35	3,200
Cucumber	105	2,000	6	2,000	23	2,000
Tobacco (Turkish)	119	150	37	150		
Shallot	87	2,000	4	2,000	9	2,000
Garlic	56	600	3	600	7	600
Baby corn	133	2,000	-	-	-	-

Source: DOAE, Yasothon

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (6/8)

(1988/89 Dry Season)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe: Trakan Phutphon		Tambon: Ka Sem		Tambon: Kon Sai		Tambon: Ku Sa Korn		Tambon: Kra Daen	
	Area	Yield	Area	Yield	Area	Yield	Area	Yield	Area	Yield
Glutinous rice	-	-	-	-	-	-	-	-	-	-
Non-glu. rice	71	354	-	-	-	-	-	-	-	-
Chilli	100	844	9	900	7	2,300	1	800	2	272
Groundnuts	20	173	-	-	-	-	-	-	-	-
Soybean	10	121	-	-	-	-	-	-	-	-
Watermelon	14	4,000	-	-	-	-	-	-	-	-
Sweet corn	111	1,125	-	-	-	-	1	1,500	-	-
String bean	67	1,078	-	-	-	-	1	1,078	-	-
Garlic	28	1,100	12	1,100	-	-	-	-	-	-
Onion	65	1,015	14	1,100	-	-	-	-	-	-
Cucumber	26	1,217	12	780	-	-	1	1,217	2	996
Other vegetable	266	1,011	16	413	-	-	-	-	-	-

Source: DOAE, Ubon Ratchathani

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (7/8)

(1988/89 Dry Season)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe: Tan Sum		Tambon: Na Khai		Tambon: Kham Wa	
	Area	Yield	Area	Yield	Area	Yield
Glutinous rice	50	397	30	385	-	-
Non-glu. rice	3,928	435	780	460	-	-
Chilli	8	1,234	3	1,350	6	800
Groundnuts	635	293	15	220	5	220
Soybean	10	213	4	210	-	-
Watermelon	18	3,000	-	-	-	-
Sweet Corn	62	921	2	950	6	900
String bean	-	737	-	-	5	800
Garlic	-	-	-	-	-	-
Onion	-	-	-	-	-	-
Cucumber	48	1,820	-	-	3	1,600
Other vegetable	135	1,173	4	1,400	5	500

Source: DOAE Ubon Ratchathani

TABLE C-1. : ANNUAL CROP CULTIVATION IN THE RELATED AMPHOES AND TAMBONS (8/8)

(1988/89 Dry Season)

Unit: Area - rai
Yield - kg/rai

Ubon Ratchathani

Crop	Amphoe: Sri Muang Mai		Tambon: Kam Lai		Tambon: Don Yai	
	Area	Yield	Area	Yield	Area	Yield
Glutinous rice	-	-	-	-	-	-
Non-g. rice	-	-	-	-	-	-
Chilli	46	1,042	-	-	-	-
Sweet corn	68	1,585	2	952	2	1,500
Cucumber	21	1,692	2	2,018	5	1,800
Onion	1	900	-	-	-	-
String bean	63	1,780	2	1,254	6	1,850
Other vegetable	332	2,117	4	1,015	4	1,147

Source: DOAE, Ubon Ratchathani

TABLE C-2. : PERENNIAL CROPS IN THE RELATED AMPHOES

(1988)

Unit: Area - rai
Yield - kg/rai

Crop	Province	Yasothon		Ubon Ratchathani			
	Amphoe	Leong Nok Tha	Province Total	Trakan Phutphon	Tan Sum	Sri Muang Mai	Province Total
Pomelo	Area(rai)	-	37	16	3	-	612
	Yield	-	-	400	890	-	1,132
Mango	Area	1,928	13,403	360	106	406	26,728
	Yield	500	500	1,500	2,812	-	1,724
Sapodilla	Area	15	220	14	10	-	811
	Yield	520	520	250	650	-	385
Guava	Area	38	597	75	15	-	2,957
	Yield	630	630	2,250	1,200	-	900
Jack Fruit	Area	171	1,351	85	66	60	8,091
	Yield	280	280	70	48	-	394
Custard Apple	Area	373	1,931	140	104	114	6,656
	Yield	1,000	1,000	500	-	-	886
Tamarind	Area	894	2,807	135	104	319	11,534
	Yield	-	-	340	1,500	-	1,081
Lemon	Area	107	782	105	35	60	2,807
	Yield	-	-	2,000	9,000	-	4,368
Santol	Area	10	61	-	-	-	-
	Yield	-	-	-	-	-	-
Coconut	Area	120	2,970	145	109	106	19,127
	Yield	-	-	400	2,500	-	1,099
Cashew nuts	Area	2,937	6,860	430	37	170	10,726
	Yield	300	300	500	225	-	316
Kapok	Area	656	2,662	110	75	50	7,263
	Yield	-	-	-	950	-	573
Para Rubber	Area	1	208	-	-	-	-
	Yield	-	-	-	-	-	-
Banana	Area	1,029	3,578	325	52	215	13,294
	Yield	-	-	-	-	-	-
Total	Area	8,279	39,467	1,940	716	1,500	110,606
	Yield	(21%)	(100%)	(1.8%)	(0.6%)	(1.4%)	(100%)

Note : Yield in Ubon Ratchathani is number of fruit per rai
Source: DOAE, Yasothon and Ubon Ratchathani

TABLE C-3. : SOME INFORMATION ON RICE CULTIVATION (1/3)

(1987/88 Rainy Season)

Changwat: Yasothon

Item			Amphoe. : Tambon	Leong Nok Tha: Hong Saeng	Leong Nok Tha: Kut Chiang Mee
1. Total Number of Farm Households				1,401	822
2. Planted Area (rai)					
Irrigable	Non glutinous rice			-	-
	Glutinous rice			-	-
Non irrigable	n.g. rice			12,889	5,752
	g. rice			14,921	8,218
Upland	n.g. rice			-	-
	g. rice			490	389
3. Yield (kg/rai)					
Irrigable	g. rice			-	-
Non irrigable	n.g. rice			330	300
	g. rice			330	280
Upland	g. rice			250	250
4. Variety (%)					
Unknown				-	-
Not recommended				20	-
Recommended, non-photo sensitive				-	-
- do - , photo sensitive				80	100
- do - , both, recommended				-	-
5. Renewal of Seed					
In four seasons				70	100
In more than four seasons				10	-
6. Starting of Cultivation					
- mid May				-	-
mid. May - mid June				40	15
mid. - end June				25	25
begi. July - mid July				10	34
mid. July -				25	26
7. How to prepare seed for coming season (%)					
No special plot				25	-
Setting special plot before harvest				45	100
Setting special from the beginning				35	-
8. Fertilization (%)					
No application				-	-
One time				20	-
More than one time (wrong time)				25	-
- do - (growing stage)				22	100
- do - (booting stage)				-	-
- do - (g. & b. stage)				33	-
9. Amount of applied fertilizer (%)					
- 10 kg/rai				40	-
11 - 20 kg				30	37
21 - 30 kg				25	63
31 -				5	-
10. Harvesting (%)					
Before reipening stage				-	-
At reipening stage				86	74
After reipening stage				14	26
11. Processing (%)					
Drying	1-3 day			100	74
	3 days -				26
Winowing	No winowing				42
	by wind				
	by another method			100	58

Source: DOAE, Yasothon

TABLE C-3. : SOME INFORMATION ON RICE CULTIVATION (2/3)

(1987/88 Rainy Season)

Changwat: Ubon Ratchathani

Item	Amphoe : Tambon	Trakan Phutphon			
		Ka Sem	Kon Sai	Kusakon	Kradien
1. Total Number of Farm Households		1,152	983	498	618
2. Planted Area (rai)					
Irrigable	Non glutinous rice	-	-	-	-
	Glutinous rice	-	-	-	1,686
Non irrigable	n.g. rice	7,440	5,704	1,319	451
	g. rice	8,604	27,210	7,414	10,403
Upland	n.g. rice	-	-	-	-
	g. rice	-	-	-	-
3. Yield (kg/rai)					
Irrigable	g. rice	-	-	-	216
Non irrigable	n.g. rice	315	277	284	324
	g. rice	330	295	255	292
Upland	g. rice	-	-	-	-
4. Variety (%)					
Unknown		-	-	-	-
Not recommended		-	-	3	-
Recommended, non-photo sensitive		-	-	-	-
- do - , photo sensitive		36	100	97	100
- do - , both, recommended		64	-	-	-
5. Renewal of Seed					
In four seasons		36	100	89	100
In more than four seasons		46	-	8	-
6. Starting of Cultivation					
- mid May		-	-	-	-
mid. May - mid June		-	-	-	-
mid. - end June		-	100	83	100
begi. July - mid July		100	-	17	-
mid. July -		-	-	-	-
7. How to prepare seed for coming season (%)					
No special plot		-	-	-	-
Setting special plot before harvest		100	100	100	100
Setting special from the beginning		-	-	-	-
8. Fertilization (%)					
No application		-	-	-	-
One time		33	-	6	38
More than one time (wrong time)		67	-	-	19
- do - (growing stage		-	61	56	11
- do - (booting stage)		-	39	-	2
- do - (g. & b. stage)		-	-	38	29
9. Amount of applied fertilizer (%)					
- 10 kg/rai		29	-	8	42
11 - 20 kg		80	100	92	37
21 - 30 kg		-	-	-	11
31 -		-	-	-	10
10. Harvesting (%)					
Before reipening stage		-	-	-	-
At reipening stage		100	100	100	100
After reipening stage		-	-	-	-
11. Processing (%)					
Drying 1-3 day		100	100	100	100
3 days -		-	-	-	-
Winowing No winowing		-	-	-	-
by wind		-	-	-	-
by another method		100	100	100	100

Source: DOAE, Ubon Ratchathani

TABLE C-3. : SOME INFORMATION ON RICE CULTIVATION (3/3)

(1987/88 Rainy Season)

Changwat: Ubon Ratchathani

Item	Amphoe :	Tan Sum		Sri Muang Mai	
	Tambon	Na Khai	Kham Wa	Don Yai	Kham Lai
1. Total Number of Farm Households		627	412	499	883
2. Planted Area (rai)					
Irrigable Non glutinous rice		-	-	-	-
Glutinous rice		-	-	-	-
Non irrigable n.g. rice		1,225	884	8,851	4,370
g. rice		11,719	9,042	8,725	20,976
Upland n.g. rice		-	-	-	-
g. rice		-	-	-	-
3. Yield (kg/rai)					
Irrigable g. rice		-	-	-	-
Non irrigable n.g. rice		229	254	315	340
g. rice		228	171	300	390
Upland g. rice		-	-	-	-
4. Variety (%)					
Unknown		-	-	-	-
Not recommended		-	-	-	8
Recommended, non-photo sensitive		-	-	-	-
- do - , photo sensitive		100	100	100	88
- do - , both, recommended		-	-	-	4
5. Renewal of Seed					
In four seasons		61	92	100	19
In more than four seasons		39	8	-	73
6. Starting of Cultivation					
- mid May		-	-	-	-
mid. May - mid June		-	-	-	-
mid. - end June		25	21	100	74
begi. July - mid July		74	78	-	26
mid. July -		-	-	-	-
7. How to prepare seed for coming season (%)					
No special plot		100	100	-	88
Setting special plot before harvest		-	-	100	12
Setting special from the beginning		-	-	-	-
8. Fertilization (%)					
No application		-	-	-	-
One time		87	84	100	85
More than one time (wrong time)		-	-	-	-
- do - (growing stage)		2	-	-	6
- do - (booting stage)		-	-	-	-
- do - (g. & b. stage)		11	16	-	9
9. Amount of applied fertilizer (%)					
- 10 kg/rai		51	27	100	74
11 - 20 kg		49	68	-	27
21 - 30 kg		-	5	-	-
31 -		-	-	-	-
10. Harvesting (%)					
Before reipening stage		-	-	-	-
At reipening stage		100	100	100	100
After reipening stage		-	-	-	-
11. Processing (%)					
Drying 1-3 day		100	100	100	100
3 days -		-	-	-	-
Winowing No winowing		-	-	-	-
by wind		100	100	-	3
by another method		-	-	100	97

Source: DOAE, Ubon Ratchathani

TABLE C-4. : SOME INFORMATION ON PADDY CULTIVATION IN THE FIELD SURVEY

Item \ Project	Average	Lam Se	Huai Khum Kham	Huai Kham Phak Wan	Huai Na Khai	Huai Soob
Variety (%)						
H Y V	87.5	77.8	89.0	80.9	96.4	96.0
L I V	6.2	2.2	0	16.1	1.2	4.0
L V	6.2	20.0	11.0	3.0	2.4	0
Total	100.0	100.0	100.0	100.0	100.0	100.0
Seeding	5.2	4.4	6.4	4.2	8.4	4.8
Application of fertilizer (kg/rai)	15.4	21.7	16.5	11.9	19.8	13.7
Application of manure (kg/rai)	146.6	546.7	100.0	113.3	108.0	107.6

Source: Field Survey by RID and JICA Team

TABLE C-5. : NUMBER OF LIVESTOCK IN THE RELATED AMPHOES (1989)

Unit: head

Province / Amphoe / Livestock	Yasothon	Ubon Ratchathani		
	Leong Nok Tha	Trakan Phutphon	Tan Sun	Sri Muang Mai
Buffalo	27,316	24,145	5,794	10,360
Cattle	6,238	12,156	3,978	8,540
Swine	2,163	4,253	1,124	2,540
Chicken	61,023	136,892	44,156	218,000
Duck	2,512	28,674	12,186	14,565

Source: Livestock Development Department

TABLE C-6. : NUMBER OF LIVESTOCK IN THE RELATED TAMBONS (1989)

Unit: head

Province	Yasothon		Ubon Ratchathani							
Amphoe	Leong Nok Tha		Trakan Phut Phon				Tan Sum		Sri Muang Mai	
Livestock / Tambon	Kud Chaing Me	Hong Sang	Ka Sem	Kon Sai	Kusakon	Kradien	Na Khai	Kham Wa	Don Yai	Kham Lai
Buffalo	2,093	2,547	1,684	2,879	442	1,173	1,485	841	1,044	2,145
Cattle	408	581	347	1,507	183	725	1,270	467	804	1,291
Swine	147	238	200	257	176	117	218	178	221	391
Chicken	4,660	10,263	3,202	3,311	1,273	3,420	11,163	2,117	4,005	31,795
Duck	1,218	1,129	1,545	1,514	618	1,766	2,232	785	841	1,884
Goose	-	-	2	-	10	-	4	-	12	10
Horse	-	-	-	-	-	-	-	-	-	2

Source: Livestock Development Department

TABLE C-7. : LIVESTOCK INVENTORY IN A SURVEYED FARM

Unit: head

Livestock \ Project	Average	Lam Se	Huai Khum Kham	Huai Kham Phak Wan	Huai Na Khai	Huai Soob
Buffalo	3.02	3.3	2.85	2.55	2.50	3.90
Cattle	0.66	0.5	0.75	0.55	1.00	0.5
Swine	0.24	0.2	0.20	0.15	0.25	0.4
Chicken	9.29	11.1	9.50	14.20	7.95	3.7
Duck	0.28	0	0.10	0	0	1.3

Source: Field Survey by RID and JICA Team

TABLE C-8. : AGRICULTURAL MACHINERY USE IN NORTHEAST

(1986)

Implement	Total Number		% Increase/Yr		% of Farms	
	N.E.	Nation	N.E.	Nation	N.E.	Nation
Power Tillers	45,286	450,033	27	16	2.2	9.2
Large Tractors	5,428	34,823	17	18	0.3	0.7
Water Pumps	104,236	669,095	14	15	5.1	13.7
Power Threshers	2,937	33,325	16	7	0.1	0.7
Power Sprayers	6,394	123,008	7	24	0.3	2.5
Hand Sprayers	279,854	1.37M.	70	48	13.7	28.2

Source: NERAD Technology Documentation Working Paper NO.TO

TABLE C-9. : AGICULTURAL MACHINARY IN A SURVEYED FARM (1989)

Unit: %

Implement \ Project	Average	Lam Se	Huai Khum Kham	Huai Kham Phak Wan	Huai Na Khai	Huai Soob
Tractor (small)	1.0	5.0	0	0	0	0
Water Pump	2.0	5.0	0	0.5	0	0
Rice Mill	1.0	0	0	0	0	5.0

Source: Field Survey by RID and JICA Team

TABLE C-10. : NUMBER OF CO-OPERATIVES AND NUMBERS BY THE TYPES IN THE RELATED PROVINCES

Province \ Type / Number	Agriculture		Landsettlement		Thift and Credit		Consumer		Services	
	Coopera-tive	Member	Coopera-tive	Member	Coopera-tive	Member	Coopera-tive	Member	Coopera-tive	Member
Yasothon	13	8,077	-	-	5	6,145	4	1,200	1	75
Ubon Ratchathani	32	27,596	1	882	19	25,579	7	8,030	4	681

Source: Agricultural Statistics of Thailand Crop Year 1987/88

TABLE C-11. : COOPERATIVE GROUP IN THE RELATED AMPHOES

Province	Group / Amphoe	Farmers' Group		Housewife Group		Youth Group	
		No.	Member	No.	Member	No.	Member
Yasothon							
	Sri Muang Mai	6	1,047	13	623	11	298
	Total of Province	35	4,645	100	3,911	80	1,861
Ubon Ratchathani							
	Trakan Phutphon	-	-	7	862	5	112
	Tan Sum	-	-	2	261	4	91
	Sri Muang Mai	-	-	7	671	2	49
	Total of Province	43	7,945	81	10,446	114	3,308

Note : Yasothon's figures are in 1986
Ubon Ratchatham's figures are in 1987

Source: Yasothon - Agricultural and Cooperative Development Extension, Yasothon, OAE and DLD
Ubon Ratchathani - based on DOAE Data of Ubon R. Province

TABLE C-12. : MEAN YIELD OF PADDY OF ALL FERTILIZER TREATMENTS AS AFFECTED BY TRANSPLANTING TIME

Unit: kg/ha

Transplanted Time	Location					
	Chainat	Bangkhen	Rangsit	Sakon Nakorn	Khonkaen	Sanpathong
July	3,370	1,804	2,308	2,665	2,464	3,623
August	3,391	2,678	3,050	3,081	2,901	3,934
September	3,009	2,841	3,592	2,797	2,816	3,728

Source: IRC News Letter, vol XVII No.2 June 1967

TABLE C-13. : YIELD OF RICE IN RELATION TO TRANSPLANTING TIME

Unit: kg/ha

Varieties	July	August	September	October	November
Bangkhen 293	229	3,478	4,791	3,386	2,435
Luang Tawng 101	67	2,455	4,121	3,098	2,234
Nang Mon S-4	155	2,222	2,971	2,010	1,174
Puang Nahk 16	4,136	4,104	4,769	3,492	2,388
Jao Luang 11	158	1,791	3,571	2,120	2,681
Khao Dok Mali 105	66	1,219	3,031	3,020	1,820
Bai Lod 104	388	1,758	3,519	2,241	2,019
Khao Pak Maw 17	265	1,537	3,820	2,187	1,528

Source: IRC News letter, vol XVIINo.2 June 1967

TABLE C-14. : RESULTS SUMMARY, NERAD GREEN MANURE TRIALS, 1983-87

Green Manure Crop Material	Site	Yield (kg/rai)			% Increase Over Control
		G.M. Crop	Rice	Fallow-Rice	
Cowpea	ROI ET	4,352	479	435	10
Red Cowpea	ROI ET	1,836	446	435	3
Blackgram	ROI ET	3,728	482	435	11
Sword Bean	ROI ET	2,208	449	435	3
Sesbania	SISAKET	-	543	408	33
Cowpea	SISAKET	-	595	511	16

Source: NERAD Project Technology Documentation Working Paper No.TO

TABLE C-15. : INLAND FISHERY IN THE NORTHEAST REGION

Water Resources	No.	Water Surface		Product		Yield
		rai (x 1,000)	%	t (x 1,000)	%	kg/rai
River	6	305	17.94	4,192	16.83	13.76
Pond	5,435	362	21.32	4,194	16.84	11.58
Reservoir	583	1,032	60.74	16,523	66.33	16.01
Total	6,024	1,699	100.00	24,908	100.00	14.66

Source: Fishery Resource Research 1987

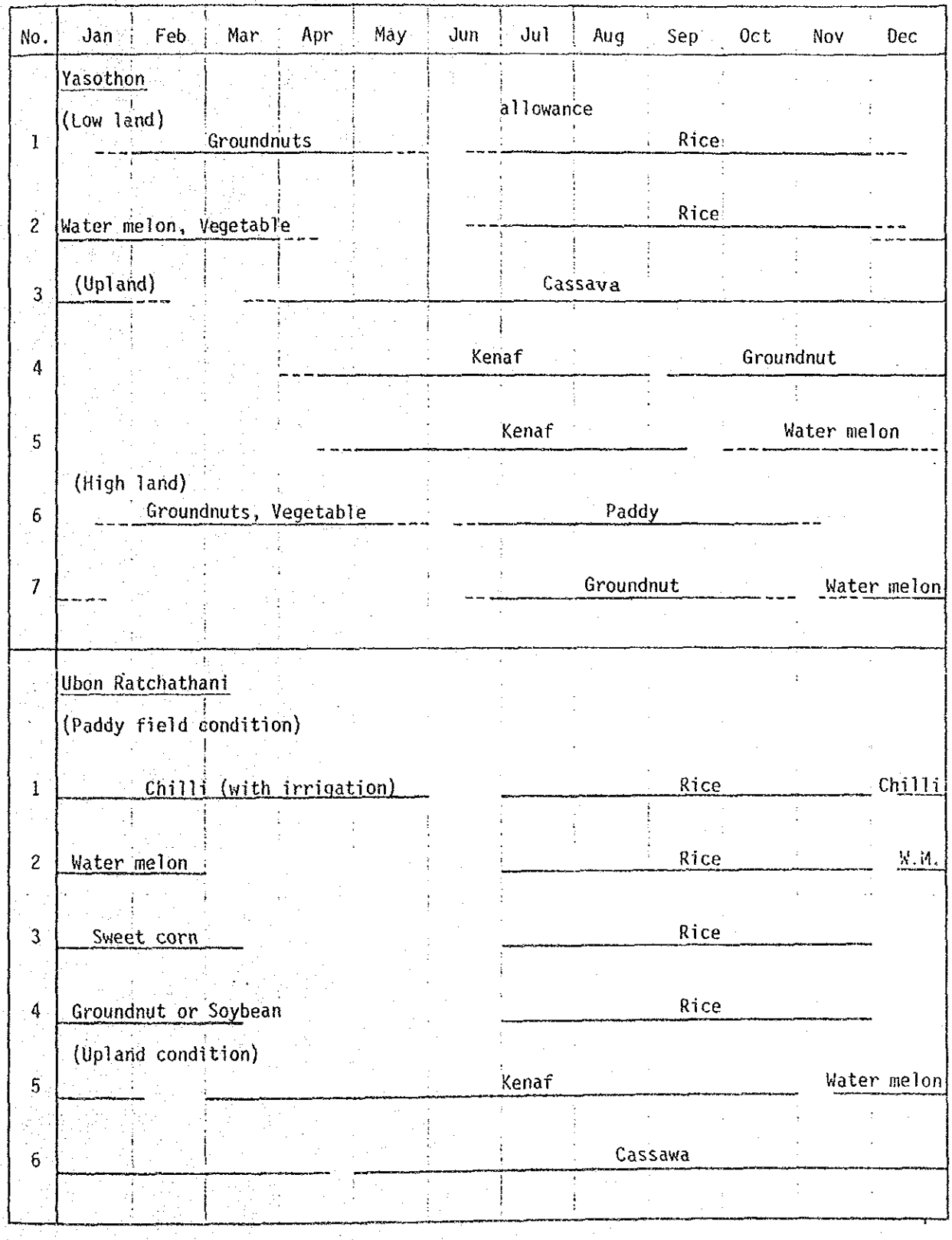
Cited from Statistical data for Agriculture DOAE, Ubon Ratchathani

TABLE C-16. : FISH CULTURE IN YASOTHON AND UBON RATCHATHANI (1984)

Province	Amphoe	Pond			Paddy Field			Value ฿ 1,000
		No. of Household	Tones	Value ฿ 1,000	No. of Household	Tones	Value ฿ 1,000	
Yasothon	Loeng Nok Tha	24	11.6	291.3	3	2.5	70.2	361.5
	Others	130	54.6	1,477.5	20	6.2	171.3	1,648.8
	Total	154	66.2	1,768.8	23	8.7	241.5	2,010.3
Ubon Ratchathani	Trakan Phutphon	52	1.8	52.6	14	2.3	66.7	119.3
	Tan Sum	17	1.5	40.1	3	0.2	4.6	44.8
	Sri Muang Mai	32	0.9	26.3	1	0.1	1.9	28.2
	Others	906	90.3	2,580.2	341	49.7	1,364.6	3,944.7
	Total	1,007	94.5	2,699.2	359	52.3	1,437.8	4,137.0

Source: DOAE, OAE and DOD

FIGURE C-1 : PRESENT CROPPING PATTERN IN YASOTHON AND UBON RATCHATHANI



APPENDIX D. GEOLOGY, SOIL ENGINEERING AND GROUNDWATER

APPENDIX D. GEOLOGY, SOIL ENGINEERING AND GROUNDWATER

D-1. Topography and Geology

D-1-1. Topography

The study area is delimitated by the Phu Phan range in the north and northeast, in the west by the branch of the Phu Phan range and in the south by the flood plains of the Mun river. In the north of the study area, the mountains generally ranging in altitude from 200 to 250 m extend northwestward at the upper Sebok basin and the upper Tung Lung basin, and its extension line is bent to the westward or southwestward at the upper Sebai basin. The peneplanation flat plain ranging in altitude from 100 to 150 m extends in the southern area in the study area.

The Lam Sebai in parallel with the Lam Sebok and Huai Tung Lung which are main rivers in the study area flows toward the southeast, and the tributaries of the rivers run to the southwestward or southward. Therefore, the drainage in the study area is the dendritic pattern assumed to have a parallel character.

D-1-2. Geology

The geology in the study area consists of the Mesozoic sedimentary rocks within the Khorat Group which are widespread in the Khorat Plateau, and the Quaternary which covers the Mesozoic unconformably. The Mesozoic is divided into seven formations called from the base upward; namely Nam Phong Formation, Phu Kradung Formation, Phra Wihan Formation, Sao Khua Formation, Phu Phan Formation, Khok Kruat Formation and Maha Sarakham Formation. But Nam Phong Formation, the lowest formation in the Khorat Group does not exist in the study area.

Table. D-1 shows the stratigraphy and rock facilities of the Khorat Group in the study area.

The Mesozoic in the study area mainly consists of sandstone and includes some intercalated siltstone, shale and lime-nodule conglomerate. But the Phu Kradung Formation mainly consists of micaceous shale with small scaled cross-bedding. The Maha Sarakham Formation includes rock salt, potash, gypsum and anhydrite. These formations are conformable except that

the Phu Phan Formation is in fault contact with the Sao Khua Formation at the east of Amphoe Amnat Charoen.

The study area is divided into two characteristic areas in terms of geological structure. One is the central to southern area where the structure is simple and the bed trends northwest to west and gently dips southward. Another is the northern area characterized by the prevalence of the fold structure. In the upper Sebai basin, the bed are broadly folded with low dips into northwest-trending anticline which plunges southeast and northwest at low angle. In the upper Sebok basin and the upper Tung Lung basin, the geological structure consists of the series of west-trending folds.

D-1-3. Hydrogeology and Groundwater

Shallow groundwater in the depth of less than 10m and deep groundwater in the depth of more than 30 m exist in the study area. The water table of shallow groundwater is subject to fluctuation according to the surface water, and is stored in overburden and weathered material zone above the bed rock as aquifer only during the rainy season and several months later.

The deep groundwater is stored in four kinds of aquifers. Fresh water with yield range of 50 to 200 gpm (approx. 190-7500 l/m) is obtained from more than 90 percent boreholes in the Quaternary aquifers consisting of unconsolidated deposit and alluvium, and fresh water with yield range of 20 to 100 gpm (approx. 75 to 380 l/m) is obtained from 80 to 95 percent boreholes in the upper Khorat aquifers, however, in the flat land flooded in rainy season and lowland where salt bearing bed rocks are present, brackish to salty water is obtained from 50 to 90 percent boreholes.

"The Hydrogeological Map of Northern Thailand (1983)" published by Department of Mineral Resources (DMR) reported that there is large distribution of the brackish to salty water at the south of Amphoe Amnat Charoen in the middle Sebai basin. Moreover, according to the groundwater quality investigated during this study period, the brackish to salty water with maximum conductivity of 9700 u·mho/cm is detected in the south of salty water area mentioned above, viz. in the middle to lower Sebai basin and Sebok basin.

The distribution area of the saline soil is consistent with this salty water area, which is also identical with the distribution of the Maha Sarakham Formation. So, the brackish to salty water and saline soil may mostly originate in the rock salt within the Maha Sarakham Formation. Therefore, the development of groundwater resources may expand the distribution of salty water in the central to southern area in the middle to lower Sebai and Sebok basin

The groundwater in 70 percent of boreholes in the study area contains a large quantity of iron ion. The content of iron ion is more than 1.00 ppm which is the maximum contents acceptable in case of the unavoidable circumstance by WHO and Thailand standards, and in many cases, the content reaches more than ten times of the maximum acceptable contents.

The acceptable content of iron ion as irrigation water has not been standardized in Thailand nor in Japan. Although the groundwater in the study area may be unavailable for the drinking water owing to the high iron ion content, groundwater is available for the irrigation water in the fresh water area under no-influence of salty water, that is , in the Tung Lung basin, the upper Sebai basin and the left stream side in the upper Sebok basin. The Khok Kruat Formation in the upper Khorat aquifers and the middle Khorat aquifers are distributed in the Tung Lung basin and the left stream area in the upper Sebok basin, and their yield is less than 30 gpm (approx. 100 1/min). The lower Khorat aquifers are distributed in the upper Sebai basin and groundwater with yield range from 20 to 100 gpm (approx. 75 to 380 1/min) is obtained in this area.

D-2. Geological Condition in the Project Area

D-2-1. General Geological Condition

(1) Lam Se Project

The Phra Wihan Formation which is composed of sandstone and shale of middle Jurassic is distributed in the catchment area and around dam site, and the Phu Kradung Formation which is composed of shale, siltstone and sandstone of lower Jurassic is widely distributed in the irrigation area.

These beds are folded with low dips into a delineated southeast-trending anticline, which plunges northwest at a low angle at the southern part in the irrigation area. The beds in the catchment area and dam site trend west-northwest to east-northeast and dip 5°to 10°southward.

(2) Huai Khum Kham Project

The Phu Phan Formation which is composed of sandstone, shale and conglomerate (coarse grained sandstone) of lower Cretaceous is distributed in the catchment area and around dam site, and the Khok Kruat Formation which is composed of sandstone of middle Cretaceous is distributed in the irrigation area. These beds strike N 70° W and dip 5° to 10 ° SW.

(3) Huai Kham Phak Wan Project

The Khok Kruat Formation which is composed of sandstone of middle Cretaceous is widely distributed in the catchment area, around dam site and in the northern part of the irrigation area. The Maha Sarakham Formation which is composed of siltstone, shale, sandstone and mudstone of upper Cretaceous is distributed in most of the irrigation area. These beds strike N 60° W and dip 10° SW.

(4) Huai Na Khai Project

The Khok Kruat Formation which is composed of sandstone and siltstone of middle Cretaceous is widely distributed in the whole area. The bed trends northwest and dips southeastward.

(5) Huai Soob Project

The Phu Phan Formation which is composed of sandstone, siltstone and conglomerate (coarse grained sandstone with pebbly lamina) of lower Cretaceouts is distributed in the catchment area and the reservoir area, and the Khok Kruat Formation which is composed of sandstone of middle Cretaceous is distributed in the irrigation area. The beds strike N 50° W and dip 10° SW.

D-2-2. Geologic Investigation

(1) General

The geologic investigation shown on the Table. D-2. was executed for this Feasible Study in cooperation with RID Geotechnical Division.

a) Investigation Drilling

The core drillings by NX size were executed as the investigation drilling. Additionally, the standard penetration tests were carried out at every meter depth in the overburden as materials for the dam foundation.

The results of the drilling are shown on Drawings F-16 ~ F-20 "Geological Profiles along the Dam Axis". The alphabet beside the

geologic log on the drawing shows the kind of rocks classified by the extent of weathering and the criteria are shown on table.D-4.

b) Permeability Test

The permeability tests were executed in conformity with "The Designation E-18 in Earth Manual" edited by U.S. Department of the Interior Bureau of Reclamation.

At the overburden, the test was carried out by "open end method" and the coefficient of the permeability was calculated by the formula (1-1-1). In the bed rock, the test was carried out by the "packer method" and the lugeon value was calculated by the formula (1-1-2)(Figure.D-3). The coefficients of permeability at the over burden were calculated to the lugeon value as follows for the standardization.

[The connection between the coefficient of permeability and lugeon value]

One lugeon means the water loss of one liter per minute per meter at the 10kg/sq·cm pressure , that is, when the test length is three meters, the each numerical value in the formula (1-1-1) is shown as follows;

Q = 1(l/min) x 3 (m) = 3000/60 (cu·cm /sec)
H = 10 (kg/sq·cm) = 100 (m) = 10000 (cm)
r = 7.3 (cm) / 2 = 3.65 (cm)
L = 3 (m) = 300 (cm)

$$k = \frac{Q}{2 \cdot \pi \cdot L \cdot H} \cdot \ln \frac{L}{\gamma}$$

$$= \frac{3000/60}{2*3.14*300*10000} \cdot \ln \frac{300}{3.65}$$

$$= 1.17 \times 10^{-5} (\mathrm{cm/sec})$$

$$1 \text{ Lugeon} = 1.17 \times 10^{-5} \text{ (cm/sec)}$$

The Lugeon Maps shown on Drawing F-21 ~ F-25 are based on the result of permeability test.

c) Investigation of the Construction Materials

At the borrow area, low ridge and hillock in the reservoir area, auger boring was carried out at the cross point of 100 m or 200 m

mesh, and observation and sampling of the construction material by the test pits were undertaken at the cross point of about 300 m mesh.

The samples obtained from the test pits were supplied to the laboratory tests as shown in Table. D-3 (1/5) ~ (5/5), which were performed at the Geotechnical Division RID.

(2) Result of the Investigation

The results of the investigations are shown on the Drawings. Geological conditions at the dam foundation, permeability at the dam foundation and distribution of soil for the construction in the borrow site are recapitulated as below;

a) Lam Se Dam Site

i) Geological condition at the Dam Foundation

Sandstone of the Phra Wihan Formation which rarely intercalates shale and siltstone predominates in the Lam Se dam site. Sandstone is gray to pale gray and fine grained, partly becoming pebbly or coarser grained.

Alluvium deposits as sand, silt and clay are thickly deposited along Lam Se and its feeders. Weathering extends to the deeper part, 7 to 10 m depth, at the hillocks.

The bed rocks which are better in quality than C_L class are present at the deeper part. The good quality bed rocks as C_M or C_H are present at the both side of dam abutment. However, the bed rocks include rich horizontal cracks along the bedding planes (RQD is less than 10%) at the center part in the dam foundation. Therefore, their quality is low grade as C_L class.

ii) Permeability of the Dam Foundation

The unconsolidated deposits at the river bed area are very pervious zone with high lugeon values of more than 100. But the highly weathered zone near the ground surface includes low lugeon values of less than 10 except the right abutment and a local part of the left abutment where there are high permeability zone.

In the bed rocks, the comparatively pervious zone of which lugeon values are 10 to 50 predominates at the left abutment area and river bed area. The impervious zone with low lugeon value of less

than 5 is present at the part deeper than about 10 m in the left saddle dam area, and at the part of 7 to 12 m deep, the permeability of the bed rock is high because of horizontal and parallel rich cracks.

iii) Distribution of Soil for the Construction

The weathering in the Lam Se dam site is salient and the highly weathered zone is comparatively thick (the thickness is about four meters.).

CL (silty clay) is widely distributed and ML (sandy silt), SC (sandy clay) and SM (silty sandy) are locally distributed in the Lam Se dam site, although the weathered materials vary with the extent of weathering. SM and ML are distributed in the area near A-4, A-8, SA-10, near TPA-6, A-6, near SA-11, A-9.

Hard and high quality rock is poor owing to the highly weathering extending to the deeper part, so that, the supply of the pervious material and riprap material from this dam site area is insufficient.

b) Huai Khum Kham Dam Site

i) Geological condition at the Dam Foundation

Sandstone of the Phu Phan Formation predominates in the dam site. Siltstone or shale is alternately intercalated with sandstone in the right abutment to river bed area, and coarse grained sandstone with granule and pebbly lamina is intercalated in both sides of the dam abutment.

Sandstone is gray to pale gray and fine grained, and includes poor cracks (RQD is more than 70%). The rock quality is mainly the C_H class. Siltstone and shale are reddish brown to purplish brown and locally include the rich cracks (RQD is less than 50%). The rock quality is the C_L to C_M class and is inferior to sandstone. The bed rock crops out in the reservoir area and along the river bed in the dam site. The bed rock is present at the shallow depth, and the deeper part than about 4 m depth is underlain by the fresh and hard rock with better quality than C_M class. The maximum thickness of the overburden is about 3 m at the river bed area to right abutment area.

ii) Permeability of the Dam Foundation

The unconsolidated deposits at the river bed area are very pervious zone with high lugeon values of more than 100. The highly weathered zone near the ground surface is also a pervious zone with high lugeon values of more than 50.

Although the shallow part in the bed rock is dominated by the pervious zone with lugeon values of more than 50, the lugeon value in the bed rock is reduced to impervious values in proportion to the deeper depth. The impervious zone is present at 9 to 12 m depth in the right abutment area and at 8 m depth in the left abutment. However, in the river bed area, the pervious values of more than 10 lugeons are obtained at the deeper part and the impervious zone has not been confirmed. Additionally, the deeper part than 12 m depth in the right abutment area is underlain by the pervious zone with comparatively high value of 10 to 20 lugeons.

iii) Distribution of Soil for the Construction

Generally, sandy silt (about 0.5 m thickness) underlies the top soil and overlies the highly weathered laterite bed (sandy clay with lateritic pebbles; GC) with 1 to 2.5m thickness which is adequate to the impervious materials at the borrow area. The highly weathered sandstone (silty sand to sandy clay; SM~CL) which is brittle, is distributed at the deeper part than 2 to 3 m depth.

GC is widely distributed on the hillock in whole borrow site. Most of the highly weathered sandstone retains rock texture and is composed of SM~ML. CL predominates in southeast area of borrow site, enclosed area by SA-1, SA-2, SA-11 and SA-12.

c) Huai Kham Phak Wan Dam Site

i) Geological Condition at the Dam Foundation

Sandstone of the Khok Kruat Formation which rarely intercalates siltstone predominates in the dam site. Sandstone is brown to reddish brown and includes poor cracks (RQD is more than 70 %). The rock quality is mainly composed of the C_H class. Intercalated siltstone is reddish brown to purplish brown and the

rock quality is inferior to sandstone owing to rich cracks as C_L class.

The unconsolidated deposits, silty sand or sandy clay, are distributed along Huai Dam Meg and Huai Phak Wan. The thickness of the deposits is as thin as 2 to 3 m. The highly weathered zone on the hillock is also thin (the thickness is about 3 m). The bed rocks crop out in places along the river bed and in the reservoir area. Therefore, the bed rocks with better quality than C_M class are present at the shallow depth about 3 m.

ii) Permeability of the Dam Foundation

The unconsolidated deposits at the river bed area and the highly weathered zone near the surface are pervious zone with high lugeon values of 50 to 100. The whole bed rock is a pervious zone; especially the shallow area from the left abutment to river bed and the deeper part (9 to 12 m depth) in river bed area is dominated by very pervious zone with high lugeon values of more than 100. Furthermore, the pervious zone with the comparatively high values of more than 20 lugeons is distributed at this high pervious zone. The impervious zone is confirmed only at the deeper part (10 to 15 m depth) in the right abutment area, and has not been confirmed in river bed area to left abutment area. Although the bed rock is composed of better quality than C_M class, it is presumed that the opened cracks extend widely in the dam foundation.

iii) Distribution of Soil for the Construction

The general distribution of construction materials at the borrow area is similar to the Huai Na Khai site. The silty sand to sandy silt (SM) with about 1.0 m thickness underlies the top soil and overlies the highly weathered laterite (sandy clay with lateritic pebbles; GC), which is adequate to the impervious materials. The weathered sandstone underlies the laterite layer. The weathering of this bed rock is slight and gentle in comparison with other dam sites, therefore, this weathered sandstone is more massive and more sandy.

About fifty percent quantity of construction materials in this borrow site are composed of GC , SC and CL which are adequate to impervious materials. This is a lower rate than the other dam sites.

GC is widely distributed in the borrow site A but locally distributed in the borrow area B. SC and CL are partly distributed in both borrow areas.

d) Huai Na Khai Dam Site

i) Geological Condition at the Dam Foundation

Sandstone of the Khok Kruat Formation with alternately intercalated siltstone bed predominates in the dam site. Sandstone is reddish brown and fine grained. The shallow part less than 10 m depth in this dam site is dominated by C_M to C_L class sandstone with rich cracks. Good quality rocks as C_H class is mainly distributed in deeper part than 10 m depth. Intercalated siltstone is reddish brown to purplish brown and the rock quality is inferior to sandstone owing to rich cracks as C_L class.

The bed rocks crop out in places along the river bed and the thickness of the alluvium deposits is about 2 m thin. The highly weathered zone is also distributed thinly with the thickness of 3 to 4 m. Therefore, the rocks with better quality than C_L class are present at the shallow depth of about 3 m.

ii) Permeability of the Dam Foundation

The unconsolidated deposits at the river bed area are very pervious zone with high lugeon values of more than 100. Most of the highly weathered zone near the ground surface is a pervious zone with more than 50 lugeons although the local part is impervious.

The bed rocks in whole shallow part are composed of the pervious zone with 10 to 50 lugeons, especially at BO-BO18 - 5 drilling hole. The high lugeon values of more than 20 are obtained even at the bottom of the hole. The impervious zones less than 10 lugeons are confirmed at the deeper part (7 to 10m depth) in the right abutment area and the left abutment area.

iii) Distribution of Soil for the Construction

The yellowish brown silty sand underlies the top soil and overlies the weathered laterite layer within about 1 m thickness.

Moreover, the laterite layer overlies the weathered zone of the bed rock, highly weathered sandstone.

The laterite layer has been altered to GC by the high weathering and to GM by the comparatively heavy weathering.

The highly weathered sandstone has been altered to CL or SC except near SA-1, SA-21 and TPA-9 where the weathered sandstone altered to SM or CM by comparatively heavy weathering.

e) Huai Soob Dam Site

i) Geological Condition at the Dam Foundation

Sandstone of the Phu Phan Formation with alternately intercalated siltstone and shale mainly predominates in the dam site. The coarse grained sandstone with granule and pebbly lamina is intercalated in the left abutment to the river bed area. Sandstone with poor cracks is gray to pale gray and intercalates the thin lamina of siltstone. Shale and alternated layer are dark gray to black and include rich cracks along the bedding planes which are horizontal and parallel. Therefore the rock quality of this layer is inferior to the sandstone and is composed of C_M to C_L class rocks (RQD is less than 30 %).

The bed rock and sandstone crop out at the river bed and alluvium deposits are thin. Furthermore, the highly weathered zone in whole dam site area is also thin (thickness is 3 to 4 m). Therefore, the bed rock with the better quality than C_L class rocks is present at the shallow part.

ii) Permeability of the Dam Foundation

The unconsolidated deposits at the river bed area are very pervious zone with high lugeon values of more than 100. The highly weathered zone near the ground surface is also very pervious zone more than 100 lugeons in the left abutment area to the river bed area. The right abutment area is dominated by the comparatively impervious zone with the lugeon values of less than 10 and locally impervious zone with the one of less than 1.

The bed rocks are composed of the pervious zone. The comparatively high lugeon values of more than 20 are obtained at the whole shallow area in the dam site and at the deeper part

(10 to 15 m depth) in the left abutment to the river bed area. The impervious zone within less than 1 lugeon is confirmed at the deeper part of more than 10 m depth in the river bed area to right abutment and the comparatively impervious zone within 5 to 10 lugeons is also confirmed in the left abutment area.

iii) Distribution of Soil for the Construction

Silty sandy to clayey sand (SM~SC) underlies the top soil at the shallow part and overlies the highly weathered laterite layer which is composed of silty clay with lateritic pebbles (GC) transformed by the comparatively heavy weathering and grayish brown silty clay with mottled reddish brown transformed by very heavy weathering.

Sandstone crops widely out at the upper reservoir area. Therefore, the pervious materials and the riprap materials are easily obtained in this site.

TABLE D-1 : STRATIGRAPHY IN THE STUDY AREA

Era	Period	Epock	Formation	Rock Facilities
Cenozoic	Quaternary			Alluvial deposits: Gravel, sand, silt, and clay
Mesozoic	Cretaceous	Upper	Maha Sarakham Formation	Siltstone, shale, sandstone, and mudstone, brick-red, purplish-red, weathered to white and gray, thin- to thick-bedded, with rock salt, potash, gypsum, and anhydrite
		Middle	Khok Kruat Formation	Sandstone, brown, reddish-brown, grayish-green mottled, weathered to brown and grayish-black, fine- to medium-grained, poor-sorted; shale and siltstone, pale-brown, micaceous; lime-noduled conglomerate
		Lower	Phu Phan Formation	Sandstone, white, pale-orange, commonly pebbly with pebbles of quartz, chert, red siltstone, and igneous rocks of up to 5 cm. in diameter, cross-bedded, with shale and conglomerate interbedded
	Jurassic	Upper	Sao Khua Formation	Sandstone, reddish-brown and gray, micaceous; siltstone, gray and brown; lime-noduled conglomerate; shale, purplish-brown and brick-red
		Middle	Phra Wihan Formation	Sandstone, white and pink, orthoquartzitic, pebble layering on the upper bed, massive, cross-bedded, with some reddish-brown and gray shale
		Lower	Phu Kradung Formation	Shale, brown, reddish-brown, and purplish-red, micaceous; siltstone and sandstone, brown and gray, micaceous, small scale cross-bedded; and some lime-noduled conglomerate

TABLE D-2 : QUANTITY OF GEOLOGICAL INVESTIGATION

Project	Lam Se	Huai Khum Kham	Huai Kham Phak Wan	Huai Na KHai	Huai Soob
- Dam site area					
Investigation Drilling	15 m × 6 holes	15 m × 5 holes	15 m × 5 holes	15 m × 4 holes 10 m × 3	15 m × 4 holes 10 m × 2
Total	90 m	75 m	75 m	90 m	80 m
Standard Penetration Test	33 times	3 times	7 times	17 times	17 times
Permeability Test					
Open-end Method	31 times	5 times	5 times	17 times	21 times
Packer Method	19	23	22	22	19
Total	50	28	27	39	40
- Borrow site area					
Test Pit	13 pits	13 pits	12 pits	11 pits	13 pits
	44.5 m	32.1 m	25.0 m	29.0 m	40.5 m
Auger Boring	37 holes	40 holes	50 holes	24 holes	47 holes
	130.5 m	85.1 m	114.6 m	60.1 m	122 m
Laboratory Test	cf. Table D-3				

TABLE D-3 : LIST OF LABORATORY TESTS (1/5) - LAM SE PROJECT

Item \ Test Pit	TPA-1 ①	TPA-2 ⑤	TPA-3 ⑥	TPA-4	TPA-5 ④	TPA-6 ③	TPA-7	TPA-8 ②	TPA-9	TPA-10	Total
(1) Test for Earth Material											
- Gradation Analysis	◎ ◎	◎ ◎	◎	○	○ ○	◎	○ ○	◎	- ○	○	Note
- Atterberg Limits	◎ ◎	◎ ◎	◎	○	○ ○	◎	○ ○	◎	- ○	○	① - ⑥ show
- Moisture Content	◎ ○	◎ ◎	◎	○	○ ○	○	○ ○	○	- ○	○	minimum requirements
- Specific Gravity	◎ ◎	◎ ◎	◎	○	○ ○	◎	○ ○	◎	- ○	○	for physical and
- Compaction	◎					◎		◎			mechanical soil test
- Permeability	◎					◎		◎			
- Direct Shear	◎					◎		◎			
- Dispersive Clay	- ◎	- ◎	◎	○	◎ ◎	-	○ -	◎	○ ○	○	○ requested by
- Identification Test	SM CL	SM CL	CL	CL	SC CL	SM	CL SM	CL	CL CL	CL	JICA team
(2) Test for Shale, Mudstone & Sandstone											◎ executed by RID
- Specific Gravity & Absorption											
- Unconfined Compression											
- Soundness											
- Abrasion											

TABLE D-3 : LIST OF LABORATORY TESTS (2/5) - HUAI KHUM KHAM PROJECT

Item \ Test Pit	TPA-1 ④	TPA-2	TPA-3 ⑤	TPA-4 ①	TPA-5 ②	TPA-6	TPA-7	TPA-8	TPA-9 ⑥	TPA-10	TPA-11 ③	Total
(1) Test for Earth Material												
- Gradation Analysis	◎	○	◎ ◎	◎	◎	○	- ○	○ ○	◎ ◎	○	◎ ◎	
- Atterberg Limits	◎	○	◎ ◎	◎	◎	○	- ○	○ ○	◎ ◎	○	◎ ◎	
- Moisture Content	◎	○	◎ ◎	○	○	○	- ○	○ ○	◎ ◎	○	○ ○	
- Specific Gravity	◎	○	◎ ◎	◎	◎	○	- ○	○ ○	◎ ◎	○	◎ ◎	
- Compaction				◎	◎						◎ ◎	
- Permeability				○	○						○ ○	
- Direct Shear				◎	◎						◎ ◎	
- Dispersive Clay	◎	-	- ◎	◎	◎	○	- ○	○ ○	○ ◎	○	◎ ◎	
- Identification Test	GC	SM	SM CL	GC	CL	GC	SM GM	SC CL	SC GC	GC	GC CL	
(2) Test for Shale, Mudstone & Sandstone												
- Specific Gravity & Absorption												
- Unconfined Compression												
- Soundness												
- Abrasion												

TABLE D-3 : LIST OF LABORATORY TESTS (3/5) - HUAI KHAM PHAK WAN PRIJECT

Item \ Test Pit	TPA-1 ①	TPA-2 ⑤	TPA-3 ②	TPA-4	TPA-5	TPA-6	TPA-1 ⑥	TPA-2 ③	TPA-3 ④	TPA-4	Total
(1) Test for Earth Material											
- Gradation Analysis	◎ ◎	◎ ◎	◎ ◎	○ ○	○		◎	◎ ◎	◎ -	○	
- Atterberg Limits	◎ ◎	◎ ◎	◎ ◎	○ ○	○		◎	◎ ◎	◎ -	○	
- Moisture Content	○ ◎	◎ ◎	○ ◎	○ ○	○		◎	○ ◎	○ -	○	
- Specific Gravity	◎ ◎	◎ ◎	◎ ◎	○ ○	○		◎	◎ ◎	◎ -	○	
- Compaction	◎		◎					◎	◎		
- Permeability	○		○					○	○		
- Direct Shear	◎		◎					◎	◎		
- Dispersive Clay	◎ ◎	◎ ◎	◎ ◎	○ ○	○	○	-	◎ ◎	○ -	○	
- Identification Test	GC CL	GC CL	GC CL	GC CL	CL	CL	SM	SC CL	GM	ML	
(2) Test for Shale, Mudstone & Sandstone											
- Specific Gravity & Absorption						○					
- Unconfined Compression											
- Soundness						○					
- Abrasion						○					

TABLE D-3 : LIST OF LABORATORY TESTS (4/5) - HUAI NA KHAI PROJECT

Item \ Test Pit	TPA-1	TPA-2 ①	TPA-3 ④	TPA-4	TPA-5 ⑥	TPA-6	TPA-7	TPA-8 ⑤	TPA-9 ②	TPA-10	TPA-11 ③	Total
(1) Test for Earth Material												
- Gradation Analysis	- - ○	- ◎ -	◎ ◎	○ -	- ◎ ◎		○ -	◎	○ ◎ ◎	- ○	○ ◎ -	
- Atterberg Limits	- - ○	- ◎ -	◎ ◎	○ -	- ◎ ◎		○ -	◎	○ ◎ ◎	- ○	○ ◎ -	
- Moisture Content	- - ○	- ○ -	◎ ◎	○ -	- ◎ ◎		○ -	◎	○ ○ ○	- ○	○ ○ -	
- Specific Gravity	- - ○	- ◎ -	◎ ◎	○ -	- ◎ ◎		○ -	◎	○ ◎ ◎	- ○	○ ◎ -	
- Compaction		◎							◎ ◎		○ ◎ -	
- Permeability		◎							◎ ◎		○ ◎ -	
- Direct Shear		◎							◎ ◎		○ ◎ -	
- Dispersive Clay	- - ○	- ◎ ○	- ◎	- ○	- ◎ ◎		- ○	◎	- ○ ○	- ○	- ◎ ○	
- Identification Test	SM GL CL	SM SC GM	SM SC	SM CL	SM GM CL		SM CL		SM GC CL	SM GM	SM SC CL	
(2) Test for Shale, Mudstone & Sandstone												
- Specific Gravity & Absorption												
- Unconfined Compression												
- Soundness												
- Abrasion												

TABLE D-3 : LIST OF LABORATORY TESTS (5/5) - HUAI SOOB PRIJECT

Item \ Test Pit	TPA-1	TPA-2	TPA-3 ①	TPA-4 ②	TPA-5 ⑤	TPA-1	TPA-2 ④	TPA-3	TPA-4 ③	TPA-6 ⑥	Total
(1) Test for Earth Material											
- Gradation Analysis	○	○	◎ ◎	◎ ◎ ◎	◎ ◎	- ○	◎ ◎	○ ○	◎	◎ ◎ ◎	
- Atterberg Limits	○	○	◎ ◎	◎ ◎ ◎	◎ ◎	- ○	◎ ◎	○ ○	◎	◎ ◎ ◎	
- Moisture Content	○	○	○ ○	◎ ○ ◎	◎ ◎	- ○	◎ ◎	○ ○	○	◎ ◎ ◎	
- Specific Gravity	○	○	◎ ◎	◎ ◎ ◎	◎ ◎	- ○	◎ ◎	○ ○	◎	◎ ◎ ◎	
- Compaction			◎ ◎	◎					◎		
- Permeability			◎ ◎	◎					◎		
- Direct Shear			◎ ◎	◎					◎		
- Dispersive Clay		○	- ◎	- ◎ ○	- ◎	○ ○	◎ ◎	○ ○	◎	◎ ◎	
- Identification Test	SM	CL	SM GC	SM CL GM	SM CL	CL CL	CL GC	SC CL	SC	SM SC SC	
(2) Test for Shale, Mudstone & Sandstone											
- Specific Gravity & Absorption											
- Unconfined Compression											
- Soundness											
- Abrasion											

TABLE D-4 ROCK QUALITY CLASSIFICATION

MOAF, JAPAN

Class		Description
A		◦ Perfectly sound rock without crack nor joint. ◦ None of rock forming mineral (or component particles in the case of sedimentary rock) shows weathering.
B		◦ Fresh and sound rock. ◦ Almost all rock forming minerals (or particles) has not been weathered or affected. ◦ Some cracks or joints are weathered but there is no opened crack or joint. ◦ It cause clean and metalic sound by hammering.
C	C_H	◦ Slightly weathered rock. ◦ Generally rock quality is fresh and sound but some of rock forming minerals (or particles) like a feidsper and/or colored mineral (mica, hornblend, pyroxine etc.) slightly weathered or affected. ◦ Cracks and jointa are existing commonly but usually their planes are almost tight. However joint planes or crack surface are weathered and stained by oxidization, and sometime include or be filled by weathered materials and/or secondary mineral. ◦ By hammering, it sounds still metaric but a little dull.
	C_M	◦ Common weathered rock. ◦ Rock forming mineral (or component particles of sedimentary rock) excepting quartz were weathered or sffected, and show brown or reddish brown color. ◦ Most of cracks or joints are opened, and the opened spaces are filled by weathered materials or clay sometimes. ◦ This class includes a rock which has many hair cracks, and a rock condition which shows heavily open-cracked or open-jointed nevertheless rock quality itself is rather fresh and hard. ◦ It cause dull sounds by hammering.
	C_L	◦ Heavily weathered rock. ◦ Rock shows brown or reddish brown color as a total by weathering. ◦ Cracks and joints are opened and generally filled by clay or other weathered materials. ◦ Rock is easily broken by hammering.
D		◦ Completely weathered rock. ◦ It shows a sand or soil like appearance but still retains a rock texture. ◦ Broken or crashed by hand sometime.

Note) applied for the most of volcanic rocks and pre-tertiary sedimentary rocks.

FIGURE D-1 : GEOLOGICAL MAP AT THE PROJECT (1/5)

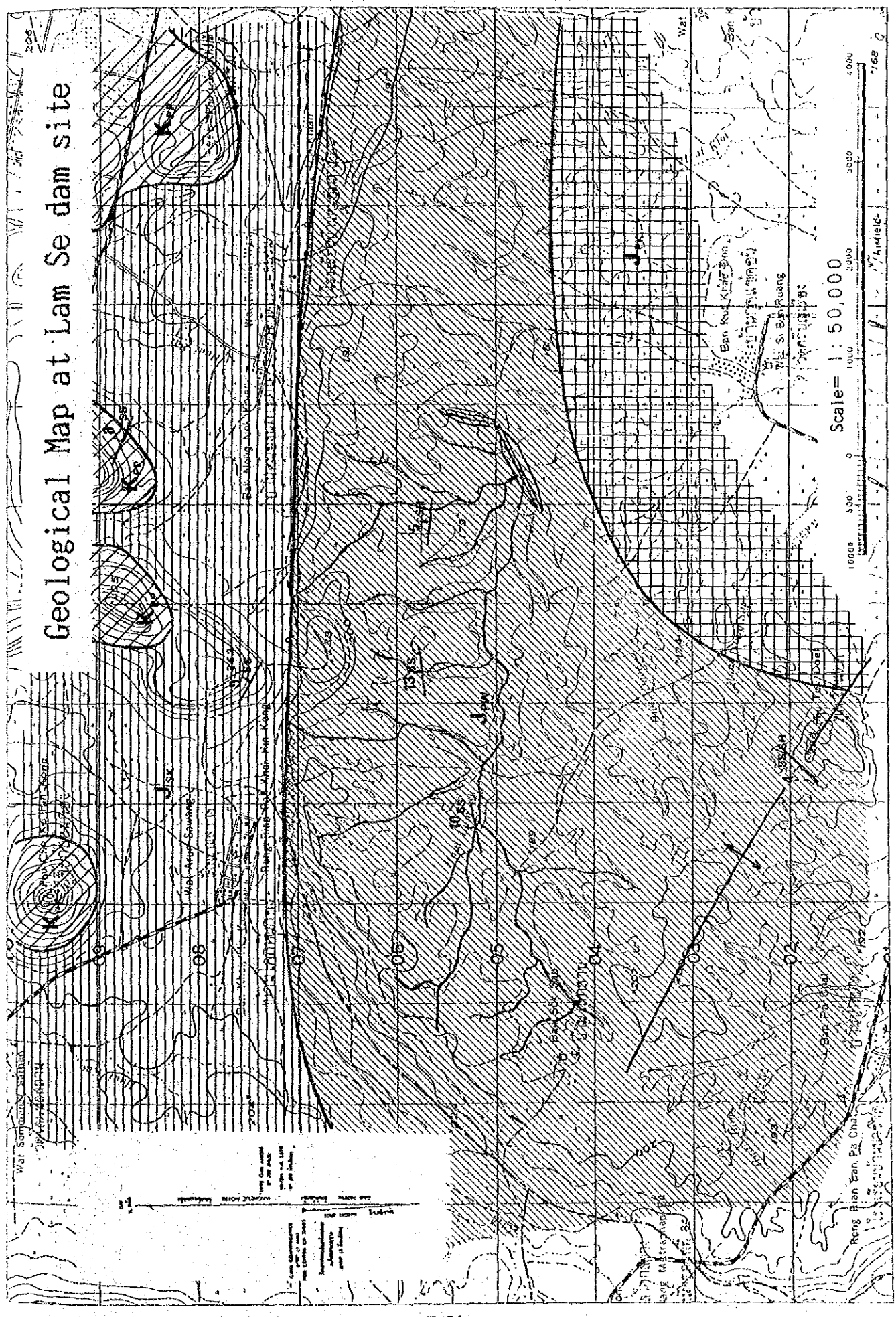


FIGURE D-1 : GEOLOGICAL MAP AT THE PROJECT (2/5)

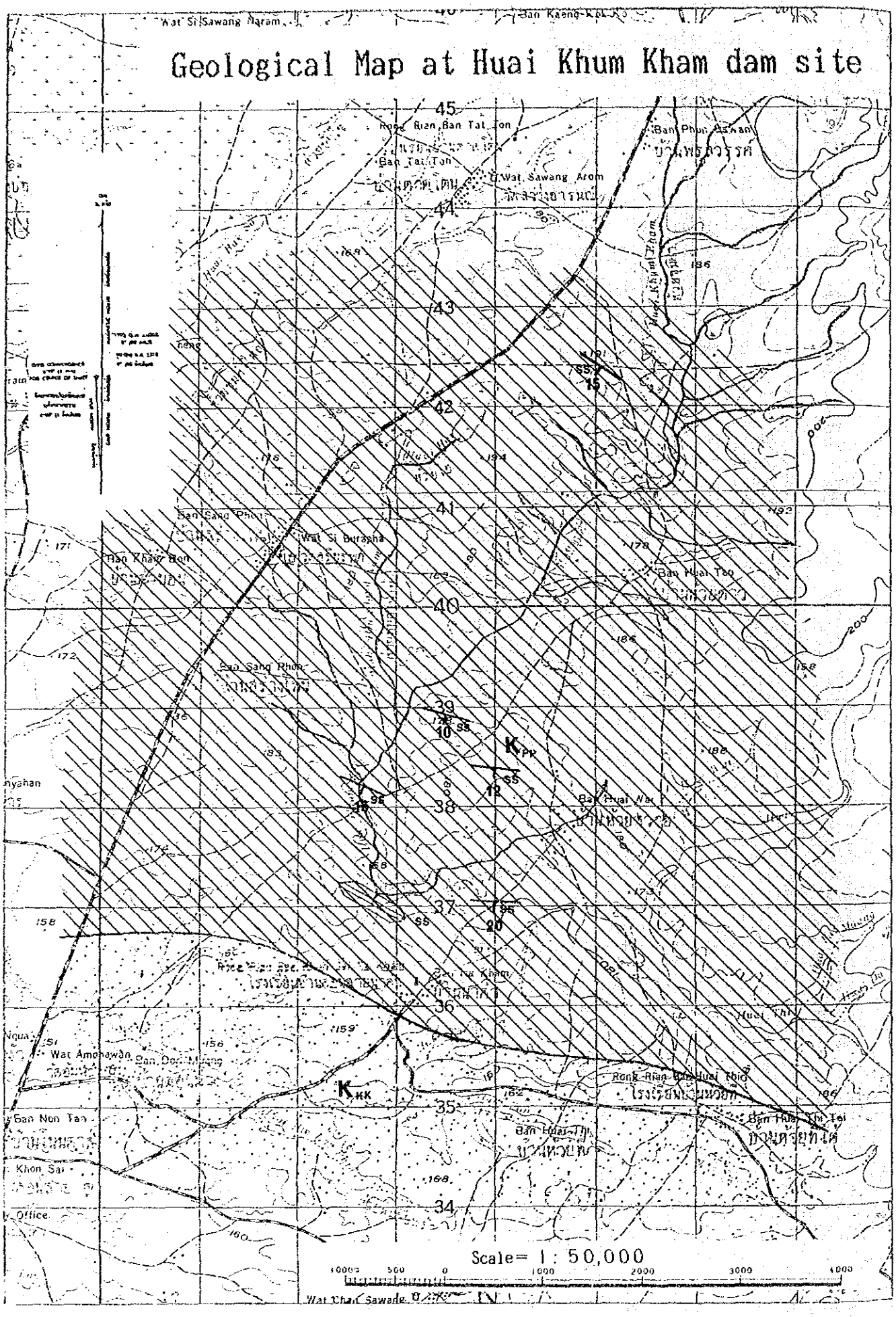


FIGURE D-1 : GEOLOGICAL MAP AT THE PROJECT (3/5)

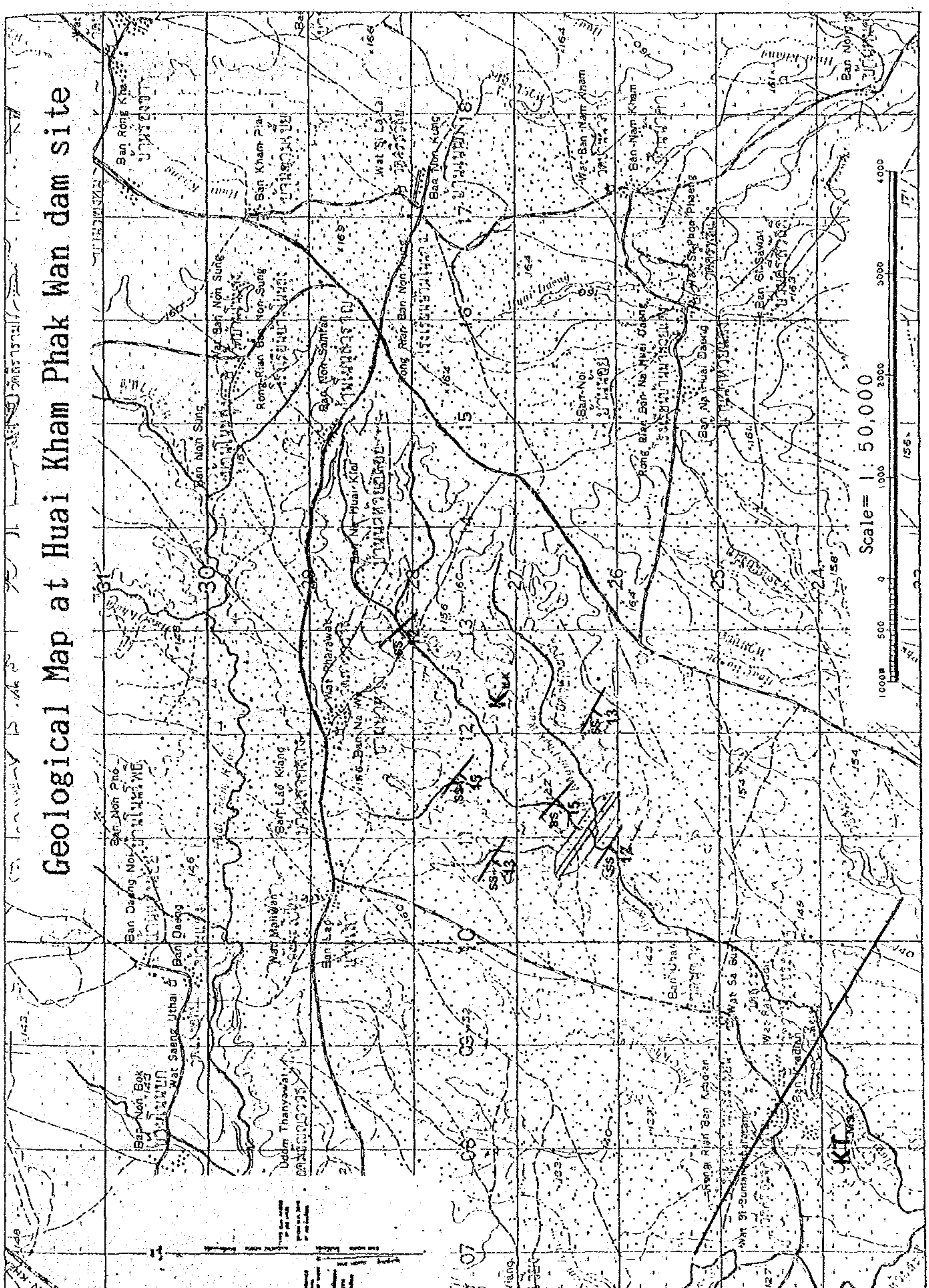


FIGURE D-1 : GEOLOGICAL MAP AT THE PROJECT (4/5)

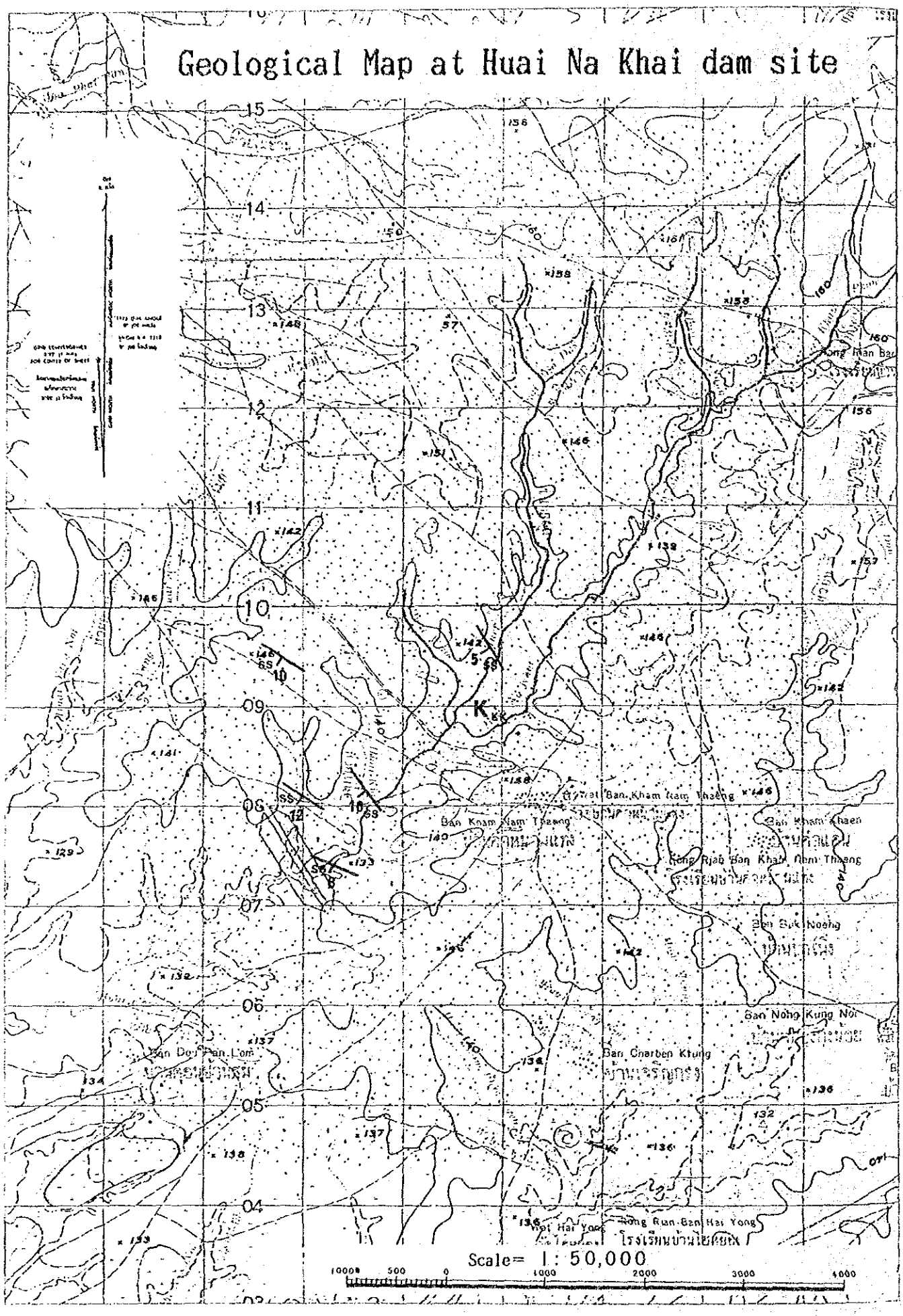


FIGURE D-1 : GEOLOGICAL MAP AT THE PROJECT (5/5)

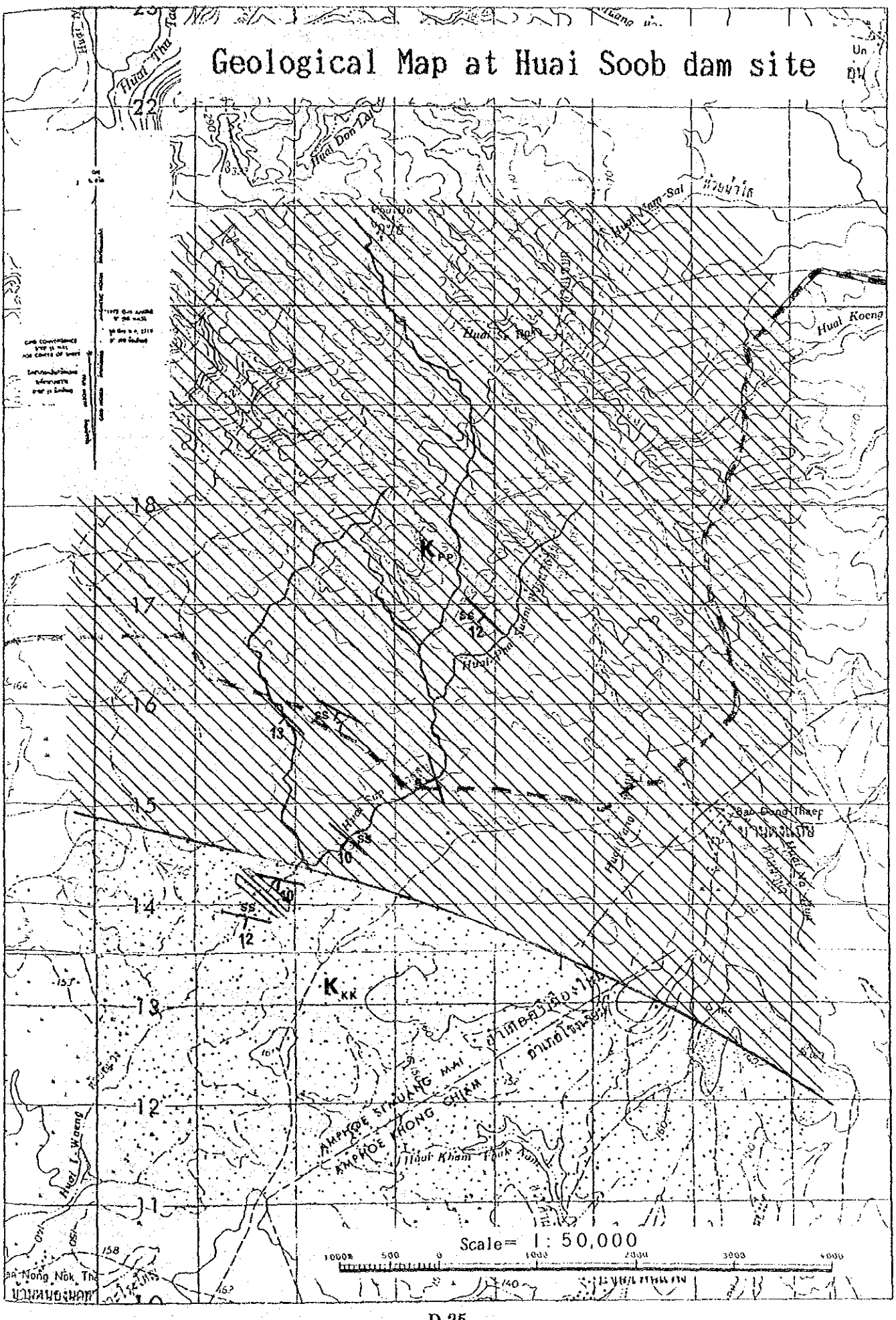
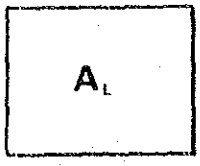
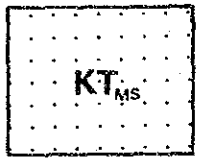


FIGURE D-2 : LEGEND ON GEOLOGICAL MAP

Legend on Geological Map

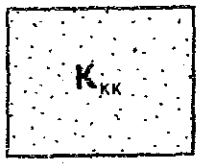


Alluvial deposits: Gravel, sand, silt, and clay



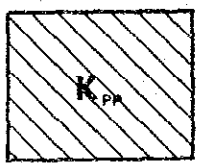
Maha Sarakham Formation

Siltstone, shale, sandstone, and mudstone, brick-red, purplish-red, weathered to white and gray, thin- to thick-bedded, with rock salt, potash, gypsum, and anhydrite



Khok Kruat Formation

Sandstone, brown, reddish-brown, grayish-green mottled, weathered to brown and grayish-black, fine- to medium-grained, poor-sorted; shale and siltstone, pale-brown, micaceous; lime-noduled conglomerate

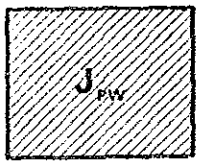


Phu Phan Formation

Sandstone, white, pale-orange, commonly pebbly with pebbles of quartz, chert, red siltstone, and igneous rocks of up to 5 cm. in diameter, cross-bedded, with shale and conglomerate interbedded

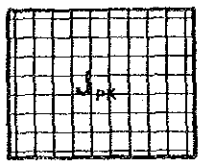
Sao Khua Formation

Sandstone, reddish-brown and gray, micaceous; siltstone, gray and brown; lime-noduled conglomerate; shale, purplish-brown and brick-red



Phra Wihan Formation

Sandstone, white and pink, orthoquartzitic, pebble layering on the upper bed, massive, cross-bedded, with some reddish-brown and gray shale

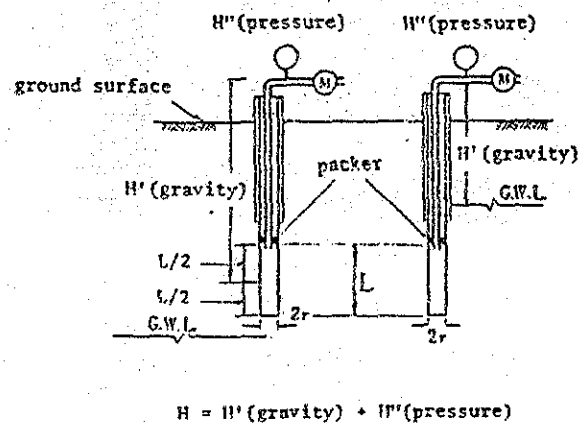


Phu Kradung Formation

Shale, brown, reddish-brown, and purplish-red, micaceous; siltstone and sandstone, brown and gray, micaceous, small scale cross-bedded; and some lime-noduled conglomerate

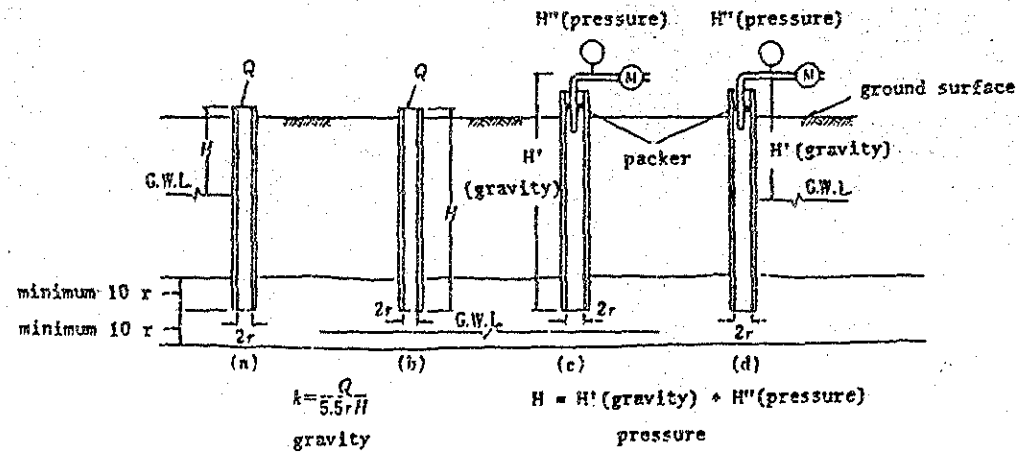
FIGURE D-3 : WATER PRESSURE TEST BY THE DESIGNATION E-18 IN THE EARTH MANUAL

(a) packer method



H = H'(gravity) + H"(pressure)

(b) open end method



$k=\frac{Q}{5.5rH}$

gravity

H = H'(gravity) + H"(pressure)

pressure

$$k=\frac{Q}{2\pi LH}\ln\frac{L}{r_0} \quad : L \geqq 10\,r_0 \quad \cdots\cdots\cdots\cdots (1\cdot2\cdot1)$$

$$k=\frac{Q}{2\pi LH}\sinh^{-1}\frac{L}{2r_0} \quad : 10\,r_0 > L \geqq r_0 \quad \cdots\cdots\cdots\cdots (1\cdot2\cdot2)$$

Q : quantity of injected water (cm³/sec)

L : test length (cm)

H : water head (cm)

r_0 : radius of the drilling hole (cm)

$$Lu = 10\cdot Q/(H\cdot L) \quad \cdots\cdots\cdots\cdots (1\cdot2\cdot3)$$

Q : quantity of injected water (1/min)

L : test length (m)

H : water head (kg/cm²)

$$k=\frac{Q}{5.5\,r\,H} \quad \cdots\cdots\cdots\cdots (1\cdot1\cdot1)$$

k : coefficient of the permeability (cm/sec)

Q : quantity of water loss (cm³/sec)

r : radius of the casing pipe (cm)

H : water head (cm)

FIGURE D-4 : GEOLOGICAL LOG OF TEST PITS (1/5) - LAM SE PROJECT

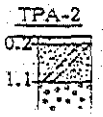
FIGURE D-4 : GEOLOGICAL LOG OF TEST PITS (2/5) - HUAI KHUM KHAM PROJECT

TPA-1

top soil; dark gray, silty sand

weathered laterite; reddish brown, GC

weathered sand stone; sandy silt, brown with mottled gray, ML



TPA-2

top soil; dark gray, silty sand

silty sand, yellowish brown, SM

laterite; hard, compacted, reddish brown

TPA-3

top soil; dark gray, silty sand

silty sand, grayish brown, SM

weathered sand stone; silt stone interbedded, sandy-silty clay, brown, CL

TPA-4

top soil; dark gray, silty sand

weathered laterite, reddish brown, GC

weathered laterite, hard, dark brown, GM

weathered sand stone; brown, ML

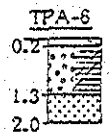
TPA-5

top soil; dark gray, silty sand

silty sand, yellowish gray, SM

weathered laterite; silty clay with gravel, reddish brown, dark brown, GC

weathered sand stone; sandy silt, ML



TPA-6

top soil; dark gray, silty sand

weathered laterite; reddish brown, GC

sand stone; weathered, brittle

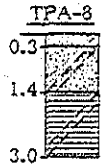
TPA-7

top soil; dark gray, silty sand

silty sand, yellowish brown, SM

weathered laterite; reddish brown, GC

sand stone; weathered, brittle, brown with mottled gray

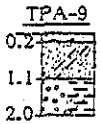


TPA-8

top soil; dark gray, silty sand

silty sand, yellowish brown, SM

silty clay, grayish brown, CL

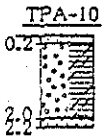


TPA-9

top soil; dark gray, silty sand

silty sand, yellowish brown, SM

weathered laterite, grayish brown, GM-GP

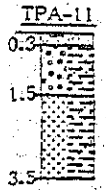


TPA-10

top soil; dark brown, silty sand

weathered laterite; silty clay with gravel, reddish brown-dark brown, GC-GM

sand stone; weathered, brittle

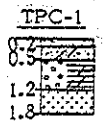


TPA-11

top soil; dark gray, silty sand

weathered laterite, dark brown, GM-GP

weathered sand stone; sandy-clayey silt, brown with mottled gray, ML



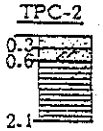
TPC-1

top soil; dark gray, silty sand

silty sand, yellowish brown, SM

weathered laterite, reddish brown, GC

sand stone; weathered, brittle, brown



TPC-2

top soil; dark gary, silty sand

silty sand, grayish brown, SM

sandy clay, brown with mottled gray, SC

LEGEND

top soil

sand

silt

clay

sandy

silty

clayey

weathered rock (almost soil but retains texture)

laterite

sand stone

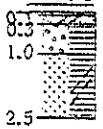
silt stone

FIGURE D-4 : GEOLOGICAL LOG OF TEST PITS (3/5) - HUAI KHAM PHAK WAM PROJECT

TPA-1

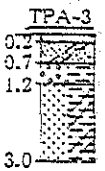
top soil; dark gray, silty sand
silty sand, brown, SM
weathered laterite, dark brown, GC
weathered sand stone; sandy silt, light grayish brown, ML

TPA-2



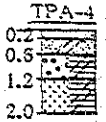
top soil; dark gray, silty sand
silty sand, brown, SM
weathered laterite, dark brown, GC
weathered sand stone; silty clay, brown with mottled gray, CL

TPA-3



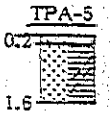
top soil; dark gray, silty sand
silty sand, yellowish brown, SM
weathered laterite, reddish brown, GM
weathered sand stone; clayey - sandy silt, grayish brown, ML

TPA-4



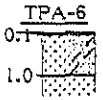
top soil; dark gray, silty sand
silty sand, yellowish brown, SM
weathered laterite, dark brown, GC-GM
weathered sand stone; silty clay, grayish brown, CL-ML

TPA-5



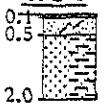
top soil; dark brown, silty sand
weathered sand stone; silty clay, reddish brown with mottled gray, CL

TPA-6



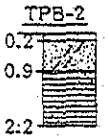
weathered laterite, dark brown, GM
weathered sand stone; silty sand, ML
sand stone; weathered, hard, brownish gray

TPB-1



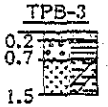
top soil; dark gray, silty sand
silty sand, yellowish brown, SM
weathered sand stone; sandy-clayey silt, brown with mottled gray, GM

TPB-2



top soil; dark gray, silty sand
silty sand, light brown, SM
sandy-silty clay, light brown, SC-CL

TPB-3

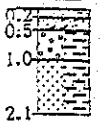


top soil; gray, silty sand
weathered laterite, grayish brown, GC
weathered sand stone; clayey-sandy silt, brown with mottled gray, ML-CL

TPB-4

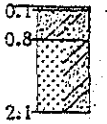
top soil; dark brown, silty sand
weathered laterite, dark yellowish brown, GM
weathered sand stone; sandy-clayey silt, brown with mottled gray, ML-CL

TPC-1



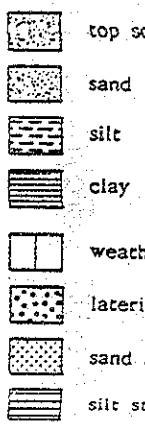
top soil; dark gray, silty sand
silty sand, yellowish brown, SM
weathered laterite, reddish brown, GM
weathered sand stone; sandy-clayey silt, brown with mottled gray, ML

TPC-2



top soil; dark gray, silty sand
silty sand, light yellowish gray, SM
weathered sand stone; clayey sand, brownish gray with mottled reddish brown, SC

LEGEND



top soil
sand — sandy
silt — silty
clay — clayey
weathered rock (almost soil but retains texture)
laterite
sand stone
silt stone

FIGURE D-4 : GEOLOGICAL LOG OF TEST PITS (4/5) - HUAI NA KHAI PROJECT

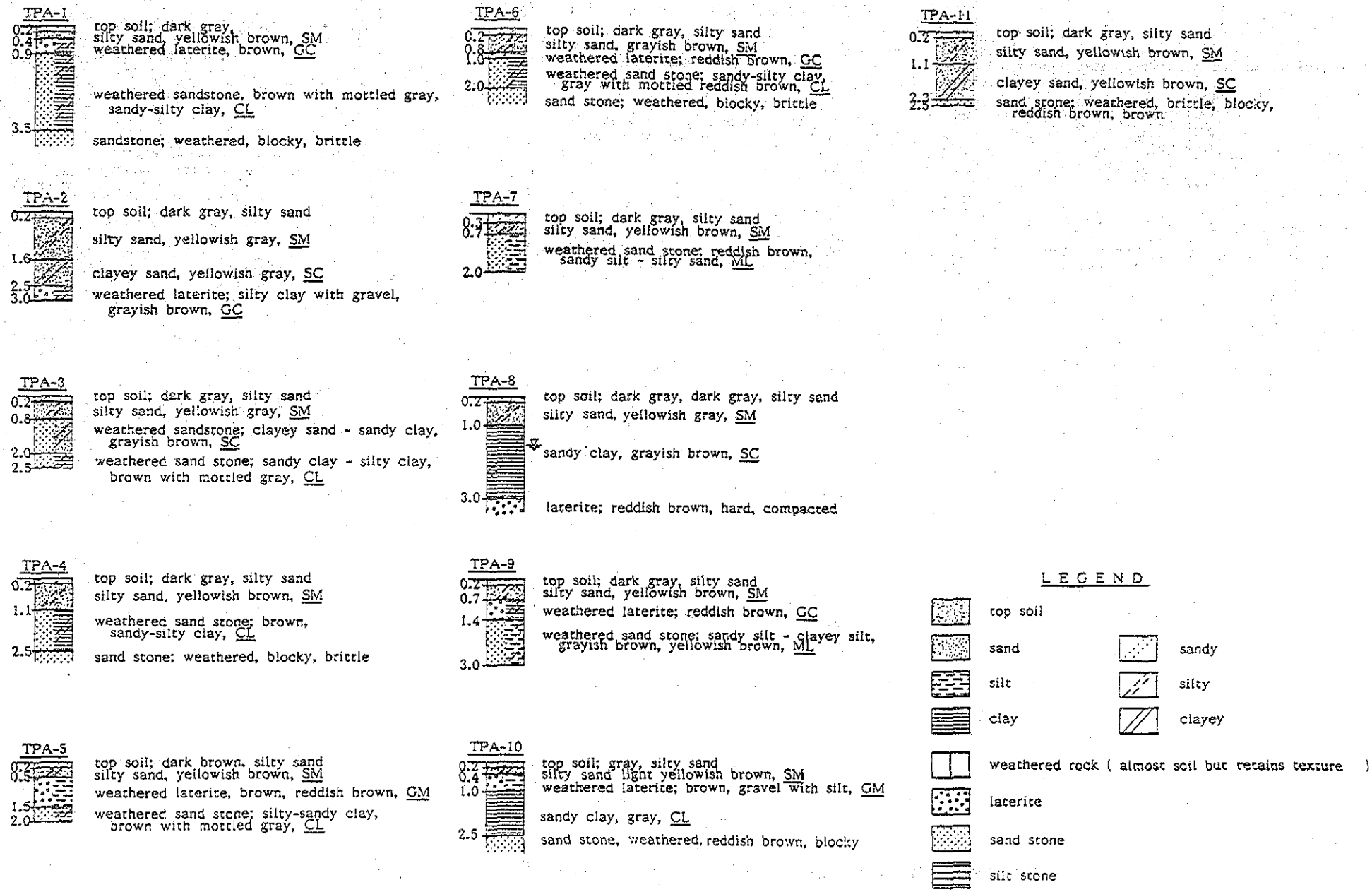


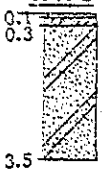
FIGURE D-4 : GEOLOGICAL LOG OF TEST PITS (5/5) - HUAI SOOB PROJECT

TPA-1

top soil; dark gray, silty sand

sandy silt,light yellowish brown, SM

TPA-2



top soil; dark gray

silty sand, grayish brown, SM

clayey sand, grayish brown, SC

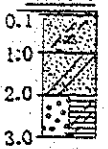
TPA-3

top soil; dark gray, silty sand

silty sand, light brown, SM

weathered laterite; sandy silt with gravel, dark brown, SC-GC

TPA-4



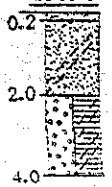
top soil; dark gray

silty sand, grayish brown, SM

clayey sand, grayish brown, SC

weathered laterite; silty clay with gravel, grayish brown - reddish brown, GC

TPA-5

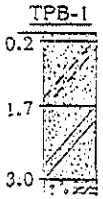


top soil; dark gray

silty sand; light yellowish brown, SM

weathered laterite; silty clay, grayish brown with mottled reddish brown CL

TPB-1



top soil; dark gray

silty sand, light brown, SM

clayey sand, light brown, SC

weathered laterite; silty clay with gravel, brown, reddish brown, GC

TPB-2

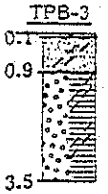
top soil; dark gray

clayey sand, dark brown, SC

silty clay, brown, dark brown,CL

weathered laterite, silty clay with gravel, brown with mottled gray, GC

TPB-3



top soil; dark gray

silty sand, yellowish brown, SM

weathered laterite, sity clay with gravel, dark brown, reddish brown, GC

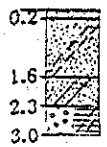
TPB-4

top soil; dark gray

clayey sand, yellowish gray, SC

weathered laterite, silty clay with gravel, reddish brown with mottled gray, GC

TPB-5



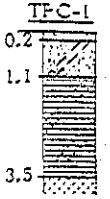
top soil; dark gray

silty sand, yellowish brown,SM

clayey sand, yellowish brown, SC

weathered laterite; silty clay with gravel, brown with mottled gray, GC

TPC-1



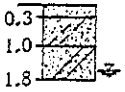
top soil; dark gray, silty sand

silty sand, grayish brown, SM

sandy-silty clay, grayish brown, SC-CL

sand stone; weathered, Phu Phan Formation.

TPC-2

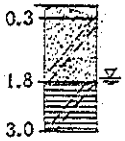


top soil; dark brown, silty sand

silty sand, grayish brown, SM

clayey sand, grayish brown, SC

TPC-3



top soil; dark brown, silty snad

silty sand, grayish brown, SM

silty clay, brown, CL

LEGEND

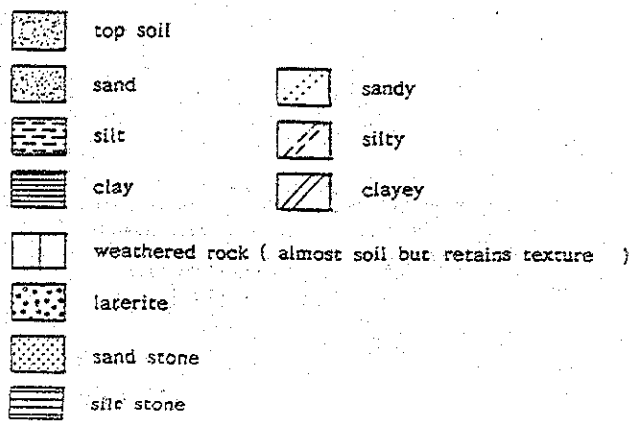


FIGURE D-5 : LACATION MAP OF SOIL INVESTIGATION (1/5)

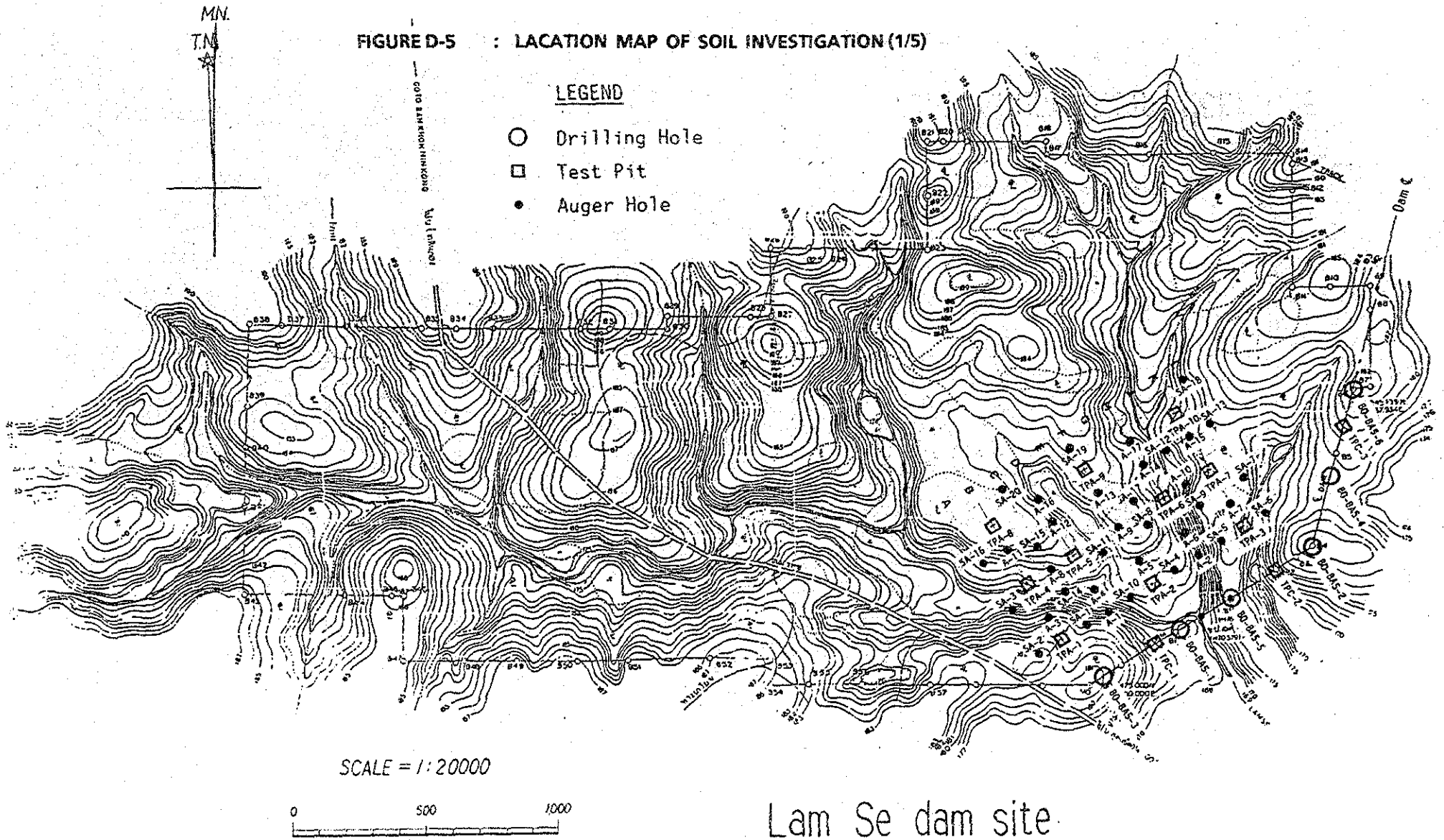


FIGURE D-5 : LACATION MAP OF SOIL INVESTIGATION (2/5)

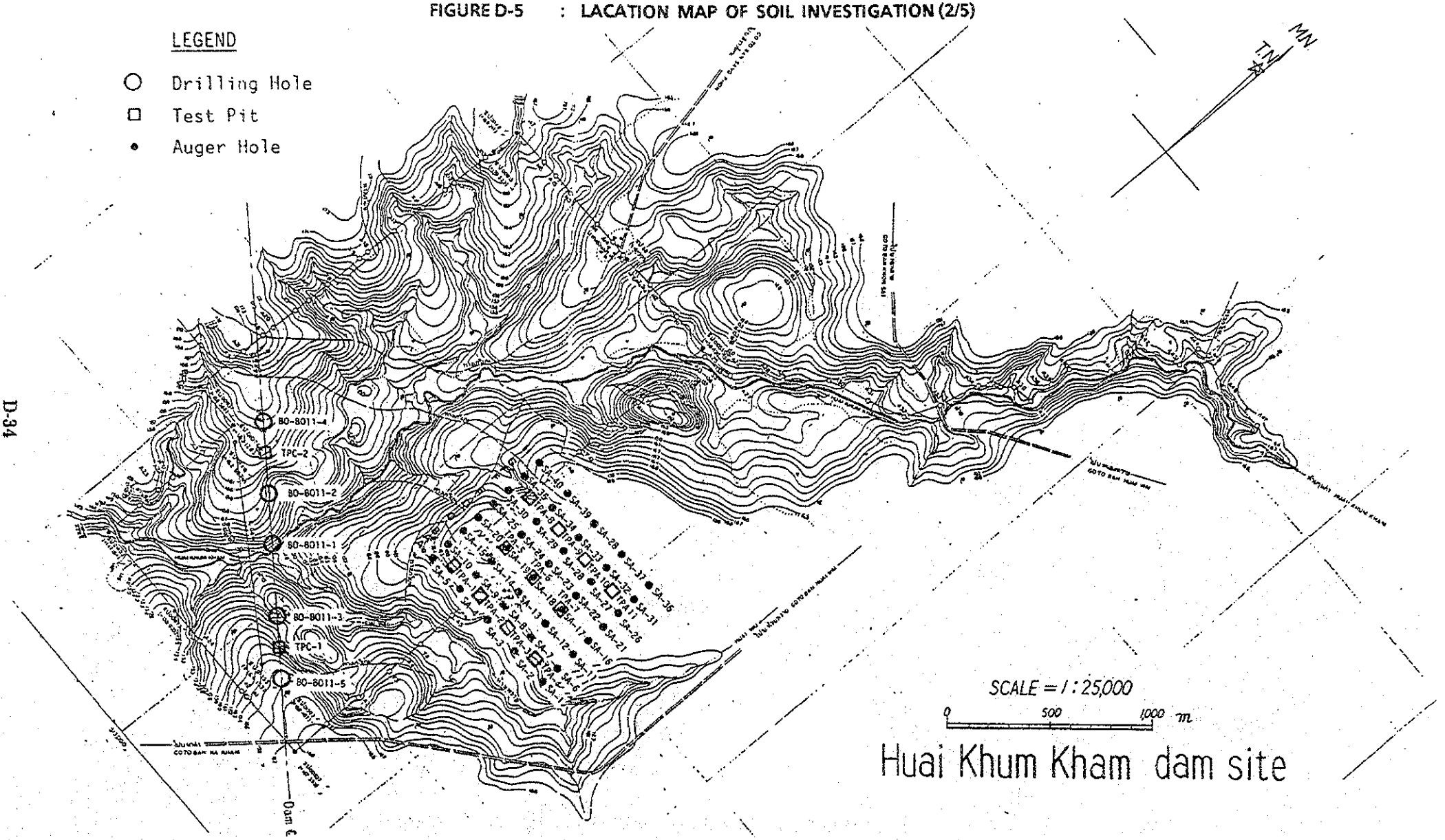


FIGURE D-5 : LACATION MAP OF SOIL INVESTIGATION (3/5)

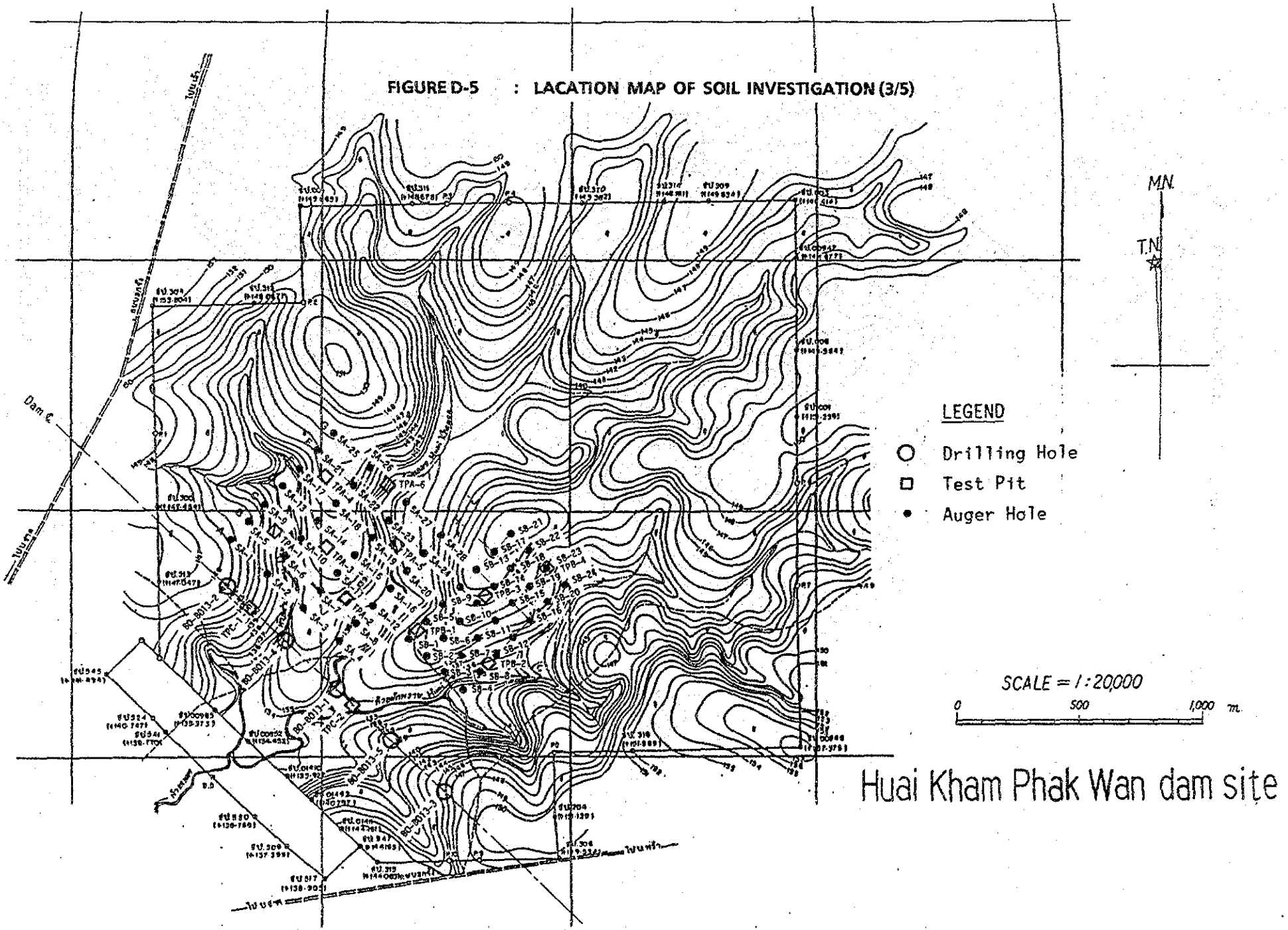


FIGURE D-5 : LACATION MAP OF SOIL INVESTIGATION (4/5)

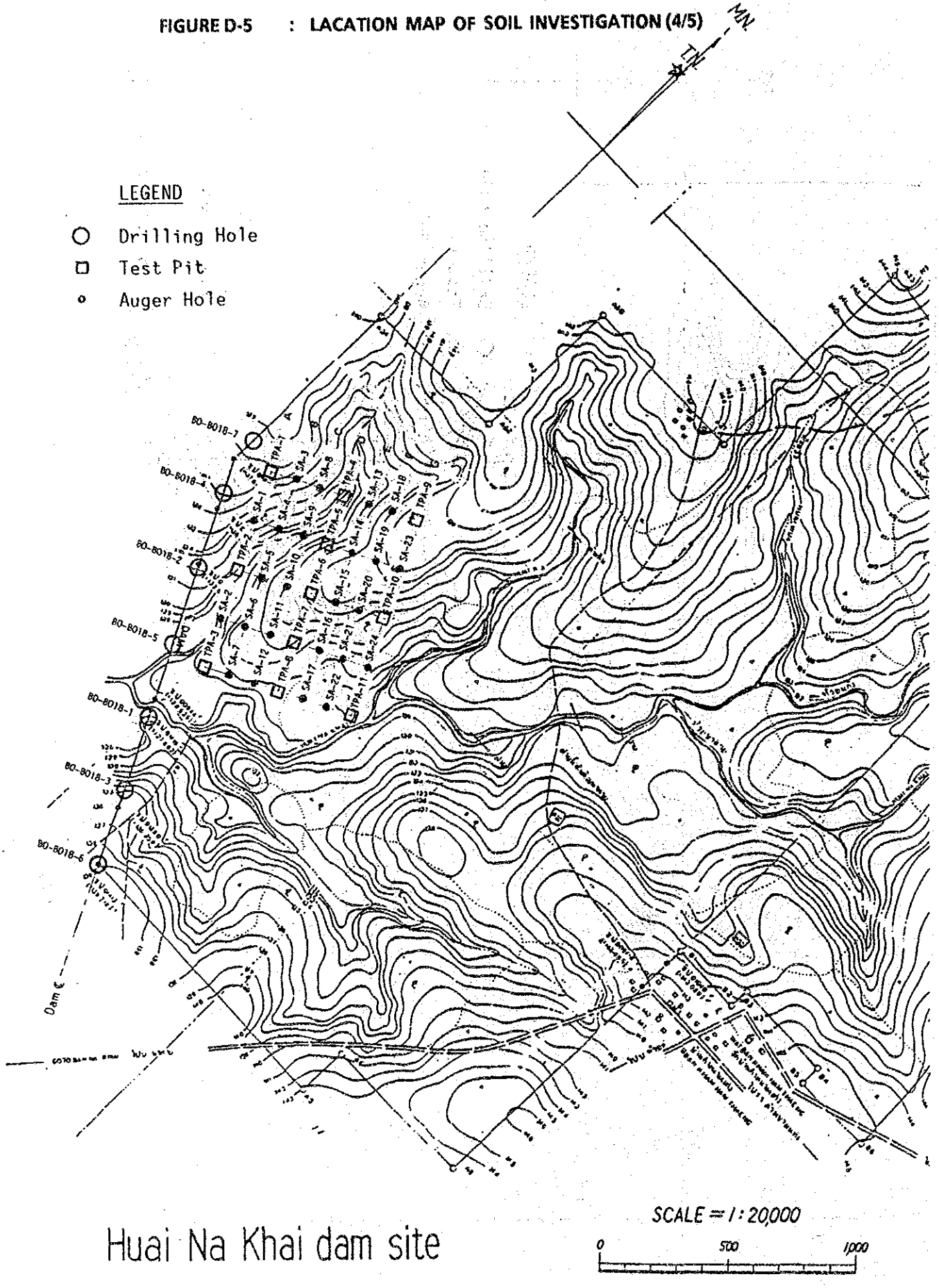
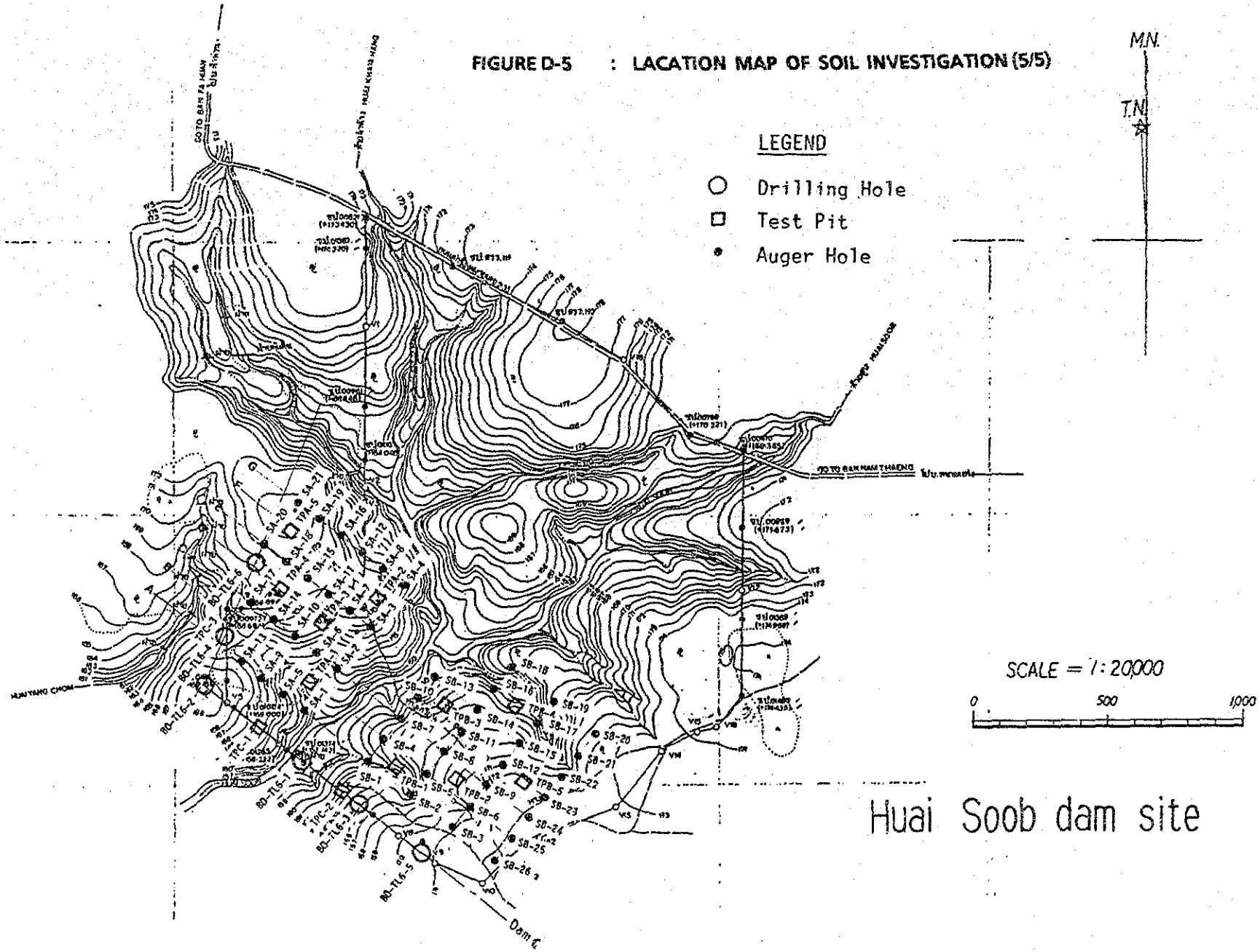


FIGURE D-5 : LACATION MAP OF SOIL INVESTIGATION (5/5)



APPENDIX E. IRRIGATION AND DRAINAGE

APPENDIX E. IRRIGATION AND DRAINAGE

E-1. Percolation Test

Percolation tests during Phase I field survey were conducted at three sites as shown in Figure E-1 "Location Map of Percolation Test" to obtain the percolation rate of paddy plots under cropping.

As the results, the percolation rate of 2 mm/day on an average was obtained as shown in Figure E-2.

The location and measuring method are as follows:

- Location and condition;

Site	Basin	Amphoe and Village	Growing Stage	Soil Texture
1. Huai Sa Dao	Sebai	A. Loeng Nok Tha Ban Koksamran	flowering	Fine Sand
2. Huai Tee	Sebok	A. Trakan Ban Non	"	Silty Sand
3. Huai Tung Lung	H.T.L	A. Si Muang Mai Ban Lao Pak Hon	"	Silty Sand

*... Huai Pra Lao site was canceled due to scattering data.

- Method; Reading of a hook gage at 24 hours interval

$P = D - ETcrop$

where; P = Percolation rate (mm/day)
D = Consumptive use observed (mm/day)
ETcrop = Evapotranspiration at flowering stage: 5.8 mm/day (Modified Penman ETo = 153 mm/m, Kc = 1.17)

E-2. Infiltration Test

In order to obtain the basic soil data for upland crop irrigation, an infiltration test was conducted at the existing upland filed in the selected project area.

Results of the test are shown as follows;

Cylinder Intake Rate Test

Site	Basin	Location	Basic Intake Rate (Average)
① Lam Se	Sebai	A. Loeng Nok Tha Ban Hong Dang	17.3~51.1 mm/hr (34.2)
② Huai Khum Kham	Sebok	A. Trakan Phutphon Ban Kon Sai	21.8 ~ 49.4 mm/hr (35.6)
③ Huai Na Khai	Sebok	A. Tan Sum Ban Na Khai	46.6 ~ 137.4 mm/hr (92)
④ Huai Soob	Huai Tung Lung	A. S. Muang mai Ban Nong Chuaka	11.1~15.6 mm/hr (13.4)

Infiltration Capacity and Total Readily Available Moisture are tabulated in Table E-1 (1/4) ~ (4/4) and Figure E-3.

E-3. Evapotranspiration

Based on the climatological data for the period of 1956 - 1985 at Ubon Ratchathani, the evapotranspiration was estimated by applying the Modified Penman Method as shown in Table E-2.

E-4. Water Requirement

E-4-1. Irrigation

The proposed cropping calendar for the study area and relevant irrigation factors are shown in Table E-3 (1/3 ~3/3).

The field water requirements on the 10-day basis for paddy (LV and HYV) and upland crop were calculated as shown in Table E-4 depending on the methodology described in the FAO irrigation and drainage paper No.24.

E-4-2. Other Water Use

(1) Village Pond Plan

As a part of rural development plan, village ponds are proposed for the purpose of multiple use of water by providing small reservoirs for supplying drinking, domestic and livestock and fisheries.

The scale of village pond was determined basing on water requirements necessary for fisheries as follows;

a) The production target of each Muban is calculated on the basis of the forecasted population in 1999 at 2.0 kg per capita which is about 10% of the national target of 20 kg/year per capita.

b) The yield of a fishpond is set at 2,500 kg/ha

c) Three sizes of fishpond are set up for 10 rai (1.6 ha), 5 rai (0.8 ha) and 3 rai (0.48 ha).

d) The location of village pond is selected taking into account the following conditions;

- Location of the main canal
- One for each village
- The existing ponds are given with high priority in utilization. Scale and number of village ponds are shown in Table E-5 and E-6.

(2) Other Water Use

Water supply plan for drinking and domestic use of cattle and buffaloes, and for fisheries is proposed as shown in Table E-7 to E-9.

E-4-3. Upland Crop Irrigation

Irrigation for upland crop shall be practised in 12 hours in daytime, whereas the canal capacities are designed based on 24-hour supply. Water duty for upland crop irrigation is calculated to be 3.0 l/s/ha (or 0.48 l/s/rai) as given below;

$$Qu = \frac{D \times Au}{8{,}640} \times \frac{1}{1 - C} \times \frac{24}{(24 - T)}$$

where; Qu = Water duty (l/s/ha)
D = ETcrop = 6.5 mm/day (March)
Au = Irrigation area (ha)
C = Irrigation efficiency, 0.5
T = Irrigation Operation hour, 12 hours

$$\therefore \quad Qu = \frac{6.5 \times 1}{8{,}640} \times \frac{1}{1 - 0.5} \times \frac{24}{12} = 3.0 \ \ell/s/ha$$
$$= 0.48 \ \ell/s/ha$$

Water duty for upland crop irrigation of 3.0 l/s/ha is equivalent to 1.9 times of water duty of main canal system (1.6 l/s/ha). In principle, regulation ponds are need to store water during the night time when upland crop irrigation is suspended.

The Sebai-Sebok project does not aim to supply irrigation water for dry season-paddy cropping, but to supply water for dry season upland cropping in the 20% project area on an average. Thus, during the dry season, the main canal system with the water duty of 1.6 l/s/ha is used only for upland crop irrigation with the water duty of 3.0 l/s/ha.

Without any regulation ponds, upland crop irrigation on the 12 hours per day operation basis is available on the condition that, for each irrigation canal, upland crop area is to be limited to less than 53% of the service area as calculated below;

$$Au = \frac{At \times Qp}{Qu}$$

where; Au = Irrigable area of upland crops
At = Service area of canal
Op = Water duty for canal system, 1.6 l/s/ha
Qu = Water duty for upland crop irrigation, 3.0 l/s/ha

$$\therefore \quad Au = \frac{1.6}{3.0} At = 0.53 \, At$$

E-5. Reservoir Operation

The result of reservoir operation study for 20 years from 1968 to 1987 is summarized in Table E-10. The irrigable area of upland crops in the dry season varies from 0 to 35% of the total project arable land year by year. Average cropping intensity of each project is about 120%.

TABLE E-10. IRRIGABLE AREA BY PROJECT

Project	Arable Area (ha)	Irrigable Area (ha)		Cropping Intensity (Average)
		Rain Season Paddy	Dry Season Upland Crop	
Lam Se	1,100	1,100 (100%)	55 ~ 385 (5 ~ 35%)	1,320 (120%)
Huai Khum Kham	2,600	2,600 (100%)	260 ~ 910 (10 ~ 35%)	3,120 (120%)
Huai Kham Phak Wan	950	950 (100%)	142 ~ 330 (15 ~ 35%)	1,140 (120%)
Huai Na Khai	2,100	2,100 (100%)	0 ~ 730 (0 ~ 35%)	2,500 (120%)
Huai Soob	920	920 (100%)	0 320 (0 ~ 35%)	1,100 (120%)

The operation guideline by reservoir water level is also proposed for proper dam gate operation. The operation guideline of each project would be set up based on the result of reservoir operation simulation data except for two to three years which correspond to extremely drought years during 20 years. The operation guideline and result of reservoir operation study is as shown in Figure E-4 and E-5.

E-6. Layout of Potential Projects

Layout of the following potential projects listed are shown in Figure E-6 (1/19) - (19/19).

Basin

Sebia	Sebok	Huai Tung Lung
BA-1. Huai Phong	BO-2. Huai Si Tho	TL-1. Huai Tung
BA-5. Lam Se	BO-5. Huai So Phra	TL-2. Huai Khut
BA-6. Huai Yang	BO-6. Huai Kum Bi	TL-3. Huai Nugu Luan
BA-7. Huai Mak Kha	BO-7. Huai Hin Kong	TL-5. Huai Chalung
BA-8. Huai Sun	BO-8. Huai Saen Si	TL-6. Huai Soob
BA-9. Huai Hin Lat	BO-9. Huai Na Pho	
	BO-10. Huai Khu Lu	
	BO-11. Huai Khum Kham	
	BO-12. Huai Thi	
	BO-13. Huai Kham Phak Wan	
	BO-14. Huai Tham	
	BO-15. Huai Phai Ban	
	BO-16. Huai Hin	
	BO-17. Huai Yang	
	BO-18. Huai Na Khai	
	BO-19. Huai Ba Hung	