

**THE KINGDOM OF THAILAND**

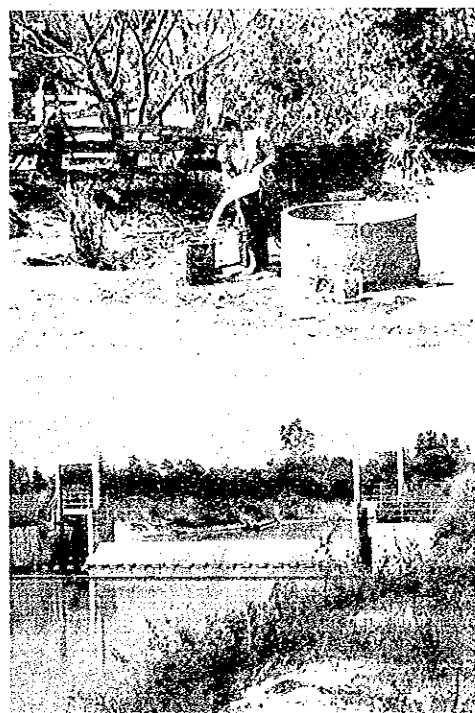
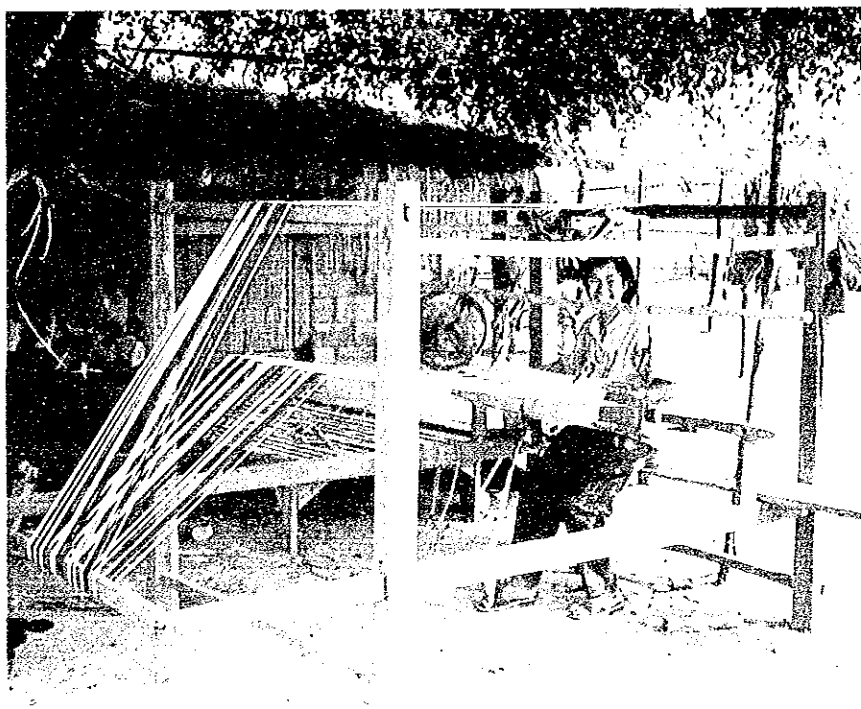
**THE OFFICE OF ACCELERATED RURAL DEVELOPMENT**

**THE FEASIBILITY STUDY ON**

**THE INTEGRATED RURAL DEVELOPMENT PROJECT**

**AT LOWER NORTH THAILAND**

**APPENDIX**



**OCTOBER, 1991**

**JAPAN INTERNATIONAL COOPERATION AGENCY**

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THE KINGDOM OF THAILAND  
THE OFFICE OF ACCELERATED RURAL DEVELOPMENT

**THE FEASIBILITY STUDY  
ON  
THE INTEGRATED RURAL DEVELOPMENT PROJECT  
AT  
LOWER NORTH THAILAND**

**FINAL REPORT**

**APPENDICES**

OCTOBER 1991

JAPAN INTERNATIONAL COOPERATION AGENCY



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**APPENDIX A. METEOROLOGY AND HYDROLOGY**

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## **A-1 GENERAL**

Generally speaking, climate in Thailand is good and beneficial to agriculture with the annual mean rainfall of 1,550 mm and temperature of 32 to 38°C.

Thailand may be divided into two regions; upper and lower regions. The upper Thailand astrides the head of Gulf of Thailand and is extending to the extreme north of the country inclusive of the East Coastal region of the Gulf. In other words, if monthly variations of temperature and rainfall distribution are taken into consideration, two major types of climate; Tropical Savanna Climate and Tropical Rainy Climate. Both of them are effected by Southwest and Northeast Monsoon twice a year.

The study area is located in central part of Upper Thailand which belongs to Tropical Savanna Climate. During the Southwest Monsoon season (May to October) it is rainy and the peak of the wet season is September. During the Northeast Monsoon Season (November to March), it is distinctively dry period and it becomes cool.

As the distribution of rainfall and run-off is variable by zone in the study area, the hydrological analysis has been carried out dividing the study area into five zones; ① Phitsanulok ② Sukhothai ③ Kamphaeng Phet ④ eastern Tak and ⑤ Western Tak.

## **A-2 METEOROLOGY**

### **A-2-1 Meteorological Data**

There are many agencies which are in charge of general meteorological observation; they are National Energy Administration, Department of Agriculture, Agricultural Extension Department, Electric Generating Authority, etc. But the general meteorological analysis for study is carried out using the data of Meteorological Department because they are more reliable with long term observation period.

The following five stations are available for general meteorological analysis in the study area.

<u>Province</u>	<u>Station</u>	<u>Remarks</u>
Phitsanulok	Phitsanulok (Muang)	
Kamphaeng Pet	Kamphaeng Phet (Muang)	
Tak	Tak (Muang)	Eastern Tak
Tak	Mae Sot	Western Tak
Tak	Bhumibol Dam	Eastern Tak

Using the latest ten (10) year data of above stations, following items were analyzed by month; ① temperature, ② relative humidity, ③ evaporation, ④ wind speed, ⑤ pressure ⑥ rainfall and rainy days.

#### **A-2-2 Temperature**

An annual average temperature is approximately 27°C in the study area except for western Tak in which it is 25°C. It is mild in dry season, the mean temperature is 25 to 27°C in dry season, while it is 27 to 30°C in rainy season. The annual mean maximum temperature is 33 °C and the monthly one rises to 37°C in March through May, which is a transitional season between dry and rainy season. On the other hand, the mean minimum temperature falls in December with 16°C. During the dry season, the daily temperature ranges very high with 13°C on the average comparing with that of 7 to 10°C during rainy season.

#### **A-2-3 Relative Humidity**

The relative humidity is about 50 to 60 percent in February to April and 70 to 85 percent in the rest of a year in general. The relative humidity of eastern Tak is less than other area in dry season.

#### **A-2-4 Evaporation**

An annual evaporation is approximately 1,500 to 1,700 mm in the study area, except in the eastern Tak where it is over 1,900 mm. The minimum evaporation occurs during November to January with close to 100 mm and the maximum one in April with over 200 mm per month.

## **A-2-5 Wind Speed and Other Climatological Factors**

A wind speed is almost 1.0 to 6.0 km/sec throughout the year except for eastern and western Tak in which it fluctuates largely. The maximum one is observed in April all-over the study area. General meteorological information is given in Table A-1 to A-7, which include atmospheric pressure, wind speed and rainy days.

## **A-3 Rainfall**

### **A-3-1 Rainfall Data**

The data of 6 stations of Meteorological Department and 53 stations of Royal Irrigation Department (RID) are available, in the study area. Considering the observing period and distribution of area, the 35 stations of RID are chosen for rainfall analysis. The list of those stations is shown in Table A-8.

### **A-3-2 Annual and Monthly Rainfall**

An average annual rainfall is approximately 1,000 to 1,500 mm throughout the study area. In the center zone, the amount of rainfall is less than the eastern and western areas of the study area. In northwest of Sukhothai and northeast of Tak, annual rainfalls is less than 1,000 mm. Whereas in the mountain zone located in the east of Phitsanulok and west of Tak, an annual rainfall over 1,500 mm is registered; especially in the northwest of Tak, it is over 1,800 mm.

The climate of the study area is divided into dry and rainy season clearly. During the southeast monsoon season (May to October), which corresponds to rainy season, 90% of annual rainfall is concentrated. And the peak of the rainfall is observed in September, in which the monthly rainfall averages almost 250 mm. On the other hand northwest monsoon season or dry season (November to April) is distinctively dry. Especially, during December to March, an average monthly rainfall is 5 to 20 mm.

Table A-9 shows an annual and monthly rainfall information, and Figure A-1 shows an annual rainfall distribution of the study area. The original data of each station are attached in data book.

### **A-3-3 Maximum One Day Rainfall**

In order to make flood-analysis, the maximum one day rainfall data of 42 stations are collected. They average 83 mm in central area (eastern Tak) and approximately 90 mm in other areas. Probability analysis has been carried out using above stations' data of the latest 19 year period. The results are summarized in Table A-10 and in Data Book.

### **A-3-4 Probable Rainfall Analysis**

Using annual rainfall data of 23 stations, both drought and high-water probable rainfall were calculated. The rainfall of 5 year return period is 87% for drought and 116% for high-water toward normal year of the study area on the average. Table A-11 shows the probable rainfall of 3, 5, 10, and 20 year return period by zone.

## **A-4 Hydrology**

### **A-4-1 River Basin**

In the central part of the study area, three big rivers run through from north to south; they are Ping River (including Wong River, a branch of Ping River), Nan River and Yom River. In the western part of study area, Moei River runs to the north and Nam Mae Klong to the south. These two rivers constitute a western boundary of the study area as well as national boundary with "MYANMER".

The study area can be divided into six river basins; 74 percent of the study area is covered by big three river basin, 12 and 10 percent by Moei and Nam Mae Klong basin, and the remaining 4 percent by another river basin. Table A-12 and Figure A-2 show the distribution of river basin.

#### **A-4-2 River Flow Data**

The river flow observation has been totally carried out by RID. The discharge data of 41 stations and water level data of 28 stations are available in the study area. Considering location and observing period, 27 stations' data were collected for hydrological analysis.

The list and location of the observing stations are shown in Table A-13 and Figure A-3.

#### **A-4-3 River Discharge**

An average unit run-off (specific discharge) falls between 5.0 and 15.0 liter per second per square kilo-meter (l/s/sq.km), which is equivalent to between 160 and 500 mm/year. The distribution by area is almost the same as that of rainfall; it is less in central zone in comparison with in eastern and western zone. In the northeast of Tak and in the east of Kamphaeng Phet, unit run-off is less than 5 l/s/sq.km. The ratio between run-off and rainfall in a year is about 17 percent in Sukhothai and eastern Tak, but in other parts of the study area, it is 20 to 30 percent.

Table A-14 and A-15 and Figure A-4 show monthly (unit) run-off and distribution of run-off by area.

#### **A-4-4 Reliable Discharge**

Monthly run-off pattern and probable unit run-off for respective zone were calculated. This calculation has revealed that on average, 5 to 6 l/s/sq.km may be available throughout the year in western Tak and Sukhothai, and almost 10 l/s/sq.km in other zones. 65 percent of run-off will be available for 5 year drought return period, and 130 percent of it will be available for high-water.

The monthly run-off pattern and ratio of probable run-off to normal year are shown in Table A-16 and A-17.

#### A-4-5 Discharge Measurement in the Model Areas

In order to provide information for further study and to confirm the river flow in the model areas, the discharge was measured at 4 sites. The unit run-off was 1.8 to 5.6 l/s/sq.km<sup>2</sup>, except for Huai Sam Ru in which it was over 100 l/s/sq.km<sup>2</sup> because it continued raining heavily for one week. Table A-18 shows the result of the measurement.

TABLE A-1 MONTHLY CLIMATE DATA

ITEMS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PRESSURE (hpr)	1013.2	1010.5	1009.0	1007.4	1006.3	1005.6	1006.0	1005.7	1007.9	1009.9	1012.6	1014.7	1,009.1
RELATIVE HUMIDITY (%)	67.1	58.6	54.5	57.8	70.5	79.1	77.3	79.5	81.6	82.8	79.1	72.4	71.7
EVAPORATION (mm)	116.0	146.1	201.0	217.0	183.7	124.5	136.4	125.3	122.5	115.5	102.2	105.9	1,696.3
WIND SPEED (km/hour)	2.45	3.75	5.22	6.22	5.15	4.04	4.99	4.82	3.12	2.37	2.26	2.28	3.89
RAINY DAYS (day)	0.5	1.3	2.0	4.9	13.5	19.6	17.3	19.2	17.5	15.0	5.5	0.7	117.0
TEMPERATURE (°C) Mean	23.4	26.8	29.2	30.8	29.5	27.7	27.7	27.4	27.3	26.7	25.2	22.4	27.0
Max.	31.6	34.8	36.6	37.8	35.4	32.4	32.2	31.4	32.3	31.8	30.8	30.0	33.1
Min.	16.6	19.6	22.4	24.9	25.0	24.4	24.3	24.2	23.7	23.0	20.7	16.2	22.1

AVERAGE ANNUAL RAINFALL (mm)

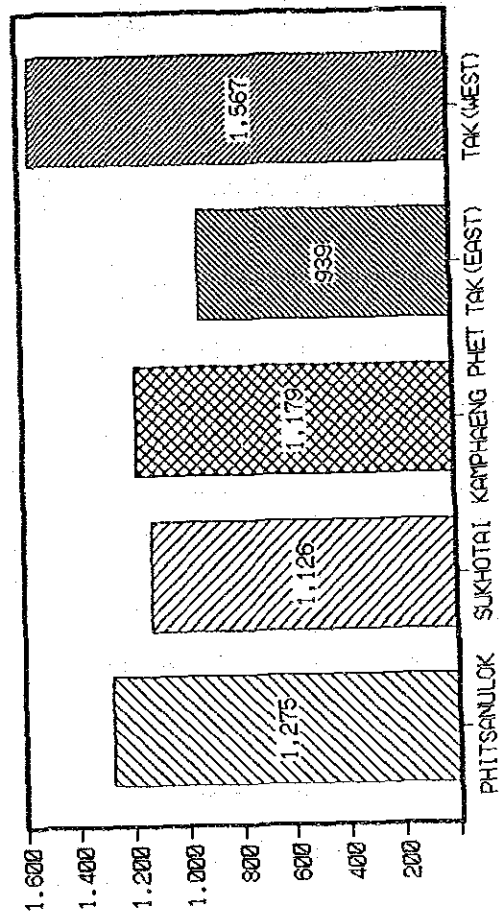
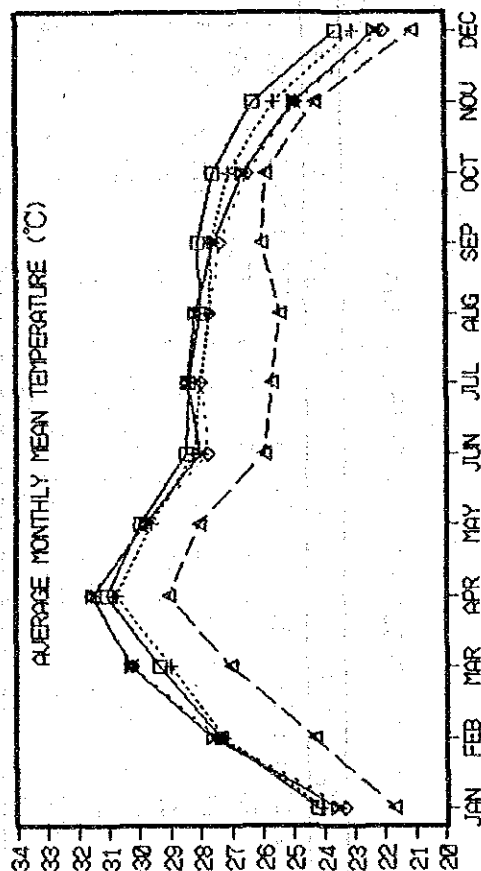


TABLE A-2 MONTHLY AVERAGE TEMPERATURE (°C)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	MEAN	24.3	27.3	29.3	31.1	30.0	28.5	28.4	28.0	27.6	26.3	23.5	27.7
	MAX.	31.8	34.5	36.2	37.6	35.8	33.4	33.1	32.4	32.5	31.4	30.4	33.4
	MIN.	17.8	21.4	23.8	25.7	25.5	24.9	24.8	24.7	24.1	21.9	17.7	23.1
KAMPHAENG PHET	MEAN	24.1	27.3	29.0	30.8	29.6	28.2	28.0	27.7	27.6	27.1	25.6	27.3
	MAX.	31.9	35.0	36.3	37.7	35.5	33.1	33.0	32.5	32.5	31.9	30.9	33.3
	MIN.	17.4	20.1	22.1	24.5	25.1	24.8	24.5	24.1	23.6	21.4	17.1	22.5
MUANG TAK	MEAN	23.3	27.4	30.2	31.6	29.8	27.7	28.0	27.7	27.3	26.5	24.8	27.2
	MAX.	31.9	35.5	37.7	38.7	35.7	32.2	31.5	32.1	32.3	31.5	30.3	33.3
	MIN.	16.2	19.8	23.5	25.9	25.3	24.4	24.4	24.1	23.2	22.3	20.1	15.4
MAE SOT TAK	MEAN	21.7	24.3	27.1	29.1	28.1	26.0	25.7	26.0	25.9	24.2	21.0	25.4
	MAX.	31.0	33.8	35.7	36.7	34.3	30.8	30.4	27.0	31.2	31.6	30.8	32.2
	MIN.	14.4	16.5	19.4	22.9	24.0	23.4	23.1	23.0	22.4	19.4	14.3	20.5
BUHUMBOL DAM TAK	MEAN	23.5	27.6	30.3	31.5	29.8	28.0	28.4	28.2	27.5	26.6	24.9	27.4
	MAX.	31.4	35.0	37.3	38.4	35.6	32.6	33.1	32.9	32.8	31.8	30.7	33.4
	MIN.	17.0	20.3	23.0	25.2	25.1	24.4	24.7	24.4	23.6	22.7	20.4	16.5
AVERAGE	MEAN	23.4	26.8	29.2	30.8	29.5	27.7	27.7	27.4	27.3	26.7	25.2	27.0
	MAX.	31.6	34.8	36.6	37.8	35.4	32.4	32.2	31.4	32.3	31.8	30.8	33.1
	MIN.	16.6	19.6	22.4	24.9	25.0	24.4	24.3	24.2	23.7	23.0	20.7	16.2



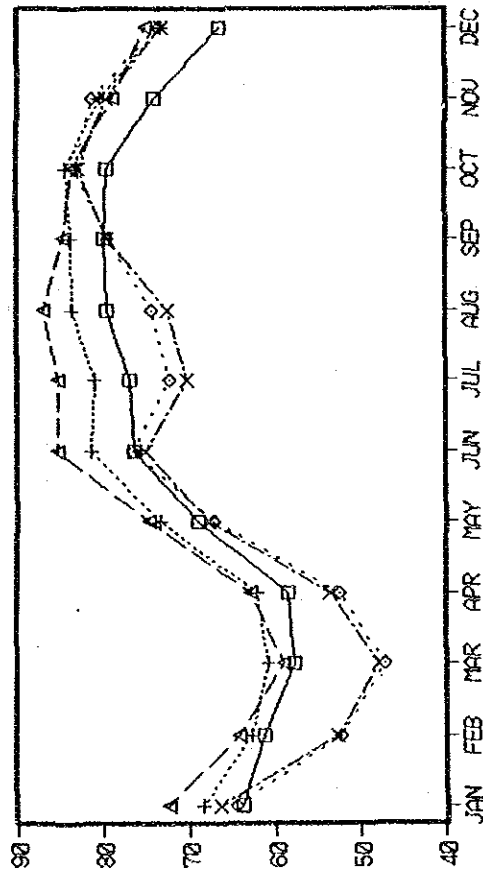
—□— PHITSANULOK ---○--- KAMPHAENG PHET -×- MAE SOT -△- BUMBOL DAM



TABLE A-3 MONTHLY AVERAGE RELATIVE HUMIDITY (%)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	63.8	61.3	57.8	58.5	69.1	76.6	77.0	79.7	80.1	79.6	74.4	66.6	70.4
KAMPHAENG PHET	68.4	62.8	60.9	62.1	73.6	81.4	81.1	83.8	84.0	84.6	80.6	73.3	74.7
TAK	64.5	52.1	47.0	52.4	67.3	76.8	72.5	74.5	79.6	83.4	81.5	73.7	68.8
MAE SOT	72.4	64.2	59.0	62.8	74.8	85.4	85.3	87.1	84.9	83.7	79.2	75.2	76.2
BRUMIBOL DAM	66.3	52.5	47.8	53.4	67.8	75.2	70.4	72.6	79.6	82.9	79.9	73.4	68.5
AVERAGE	67.1	58.6	54.5	57.8	70.5	79.1	77.3	79.5	81.6	82.8	79.1	72.4	71.7

AVERAGE MONTHLY HUMIDITY (%)

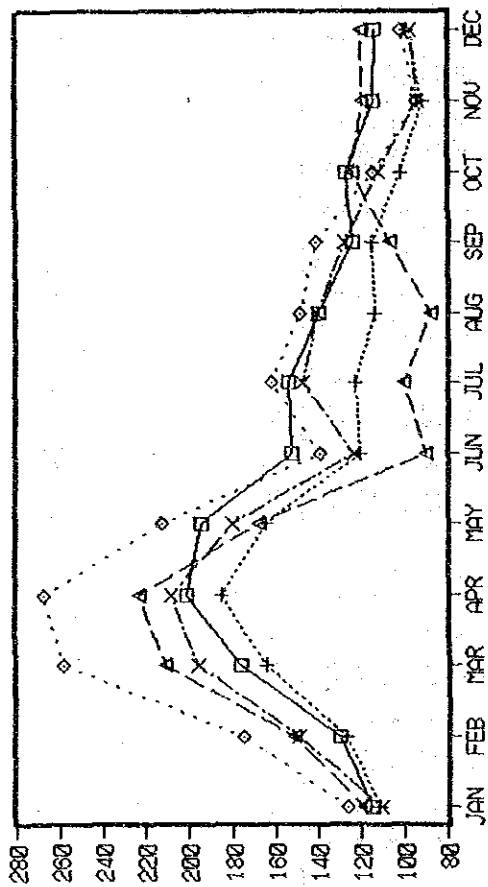


-□- PHITSANULOK ···+· KAMPHAENG PHET -◇- MAE SOT --X-- BRUMIBOL DAM

TABLE A-4 MONTHLY AVERAGE EVAPORATION (mm)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	114.4	129.7	175.8	200.8	194.3	151.5	152.8	138.8	123.8	126.8	113.9	113.0	1735.5
KAMPHAENG PHET	111.3	126.6	164.3	184.7	164.5	119.9	122.0	113.1	114.9	101.7	91.4	98.6	1513.0
TAK	126.1	174.7	258.2	267.6	212.6	138.0	160.9	147.6	140.7	113.8	93.9	101.3	1935.2
MAE SOT	118.1	151.2	211.1	223.3	167.9	90.0	99.9	87.1	106.3	123.6	119.1	120.0	1617.4
BHUMIBOL DAM	110.1	148.5	195.8	208.7	179.4	123.1	146.5	140.0	127.0	111.8	93.0	96.9	1580.6
AVERAGE	116.0	146.1	201.0	217.0	183.7	124.5	136.4	125.3	122.5	115.5	102.2	105.9	1696.3

AVERAGE MONTHLY EVAPORATION (mm)

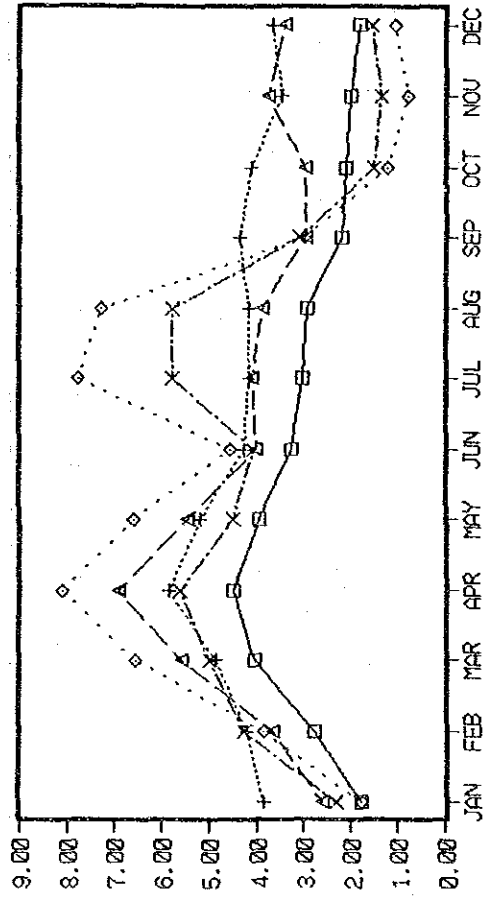


-O- PHITSANULOK ---+--- KAMPHAENG PHET -o- MAE SOT -A- TAK -x- BHUMIBOL DAM

TABLE A-5 MONTHLY AVERAGE WIND SPEED (km/hour)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	1.76	2.74	4.04	4.52	3.97	3.24	3.02	2.91	2.21	2.08	2.00	1.80	2.86
KAMPHAENG PHET	3.85	4.23	4.87	5.87	5.21	4.28	4.19	4.19	4.37	4.13	3.45	3.67	4.36
TAK	1.76	3.85	6.58	8.14	6.60	4.58	7.82	7.30	2.98	1.20	0.78	1.02	4.38
MAE SOT	2.59	3.65	5.60	6.93	5.47	4.00	4.13	3.89	2.95	2.95	3.74	3.37	4.11
BHUMIBOL DAM	2.30	4.28	5.00	5.63	4.52	4.08	5.80	5.82	3.08	1.48	1.32	1.52	3.74
AVERAGE	2.45	3.75	5.22	5.22	5.15	4.04	4.99	4.82	3.12	2.37	2.26	2.28	3.89

AVERAGE MONTHLY WIND SPEED (km/hour)

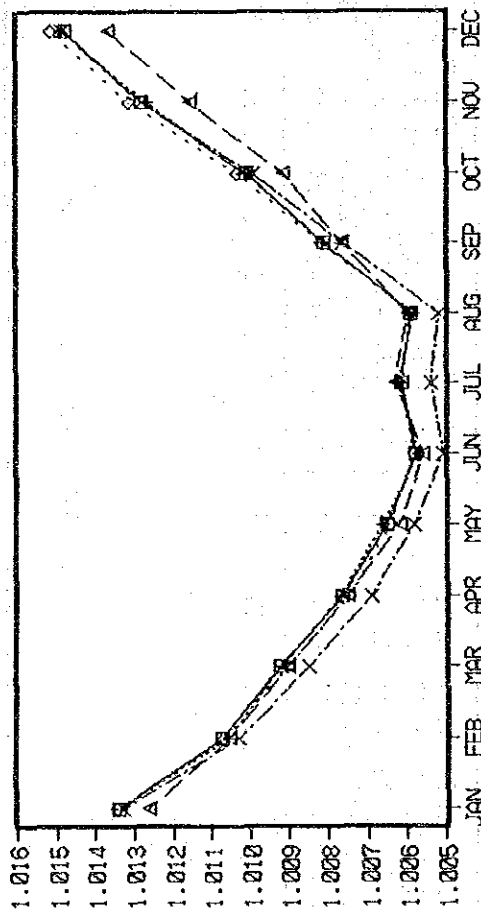


—□— PHITSANULOK    ····◇···· KAMPHAENG PHET    ····△···· MAE SOT    ····×···· BHUMIBOL DAM

TABLE A-6 MONTHLY AVERAGE ATMOSPHERIC PRESSURE (phr)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	1013.4	1010.7	1009.2	1007.6	1006.5	1005.8	1006.2	1005.9	1008.1	1010.1	1012.8	1014.8	1009.2
KAMPHAENG PHET	1013.4	1010.6	1009.2	1007.7	1006.6	1005.7	1006.2	1005.8	1008.1	1010.1	1012.7	1014.9	1009.2
MUAN TAK	1013.4	1010.7	1009.0	1007.5	1006.4	1005.8	1006.2	1005.9	1008.2	1010.3	1013.1	1015.2	1009.3
MAE SOT	1012.6	1010.5	1009.0	1007.5	1006.2	1005.6	1006.3	1006.0	1007.6	1009.1	1011.5	1013.7	1008.8
BHUMIBOL DAM	1013.3	1010.3	1008.5	1006.9	1005.8	1005.1	1005.4	1005.1	1007.6	1009.9	1012.8	1014.9	1008.8
AVERAGE	1013.2	1010.5	1009.0	1007.4	1006.3	1005.6	1006.0	1005.7	1007.9	1009.9	1012.6	1014.7	1009.1

AVERAGE MONTHLY PRESSURE (hpr)

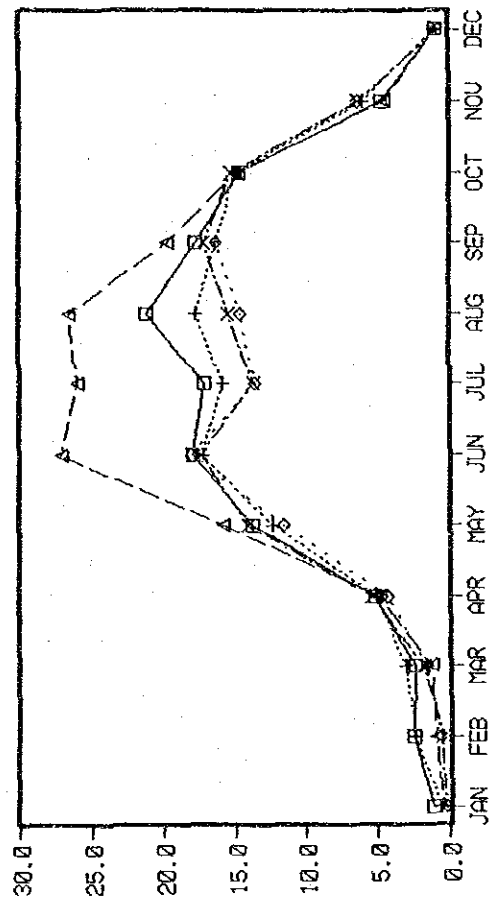


-□- PHITSANULOK ---+---KAMPHAENG PHET --◇-- MUAN TAK -△- MAE SOT --x--BHUMIBOL DAM

TABLE A-7 MONTHLY AVERAGE NUMBER OF RAINY DAYS (day)

STATION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
PHITSANULOK	1.1	2.4	2.3	5.1	13.7	18.0	17.3	21.2	17.8	14.7	4.7	0.8	119.1
KAMPHAENG PHET	0.5	2.3	3.0	5.0	12.3	17.4	15.9	17.8	16.4	14.9	6.0	0.9	112.4
TAK	0.2	0.6	1.5	4.2	11.5	18.1	13.6	14.6	16.4	14.9	6.3	0.6	102.5
MAE SOT	0.4	0.9	1.2	4.8	15.8	27.2	26.1	26.7	19.8	15.0	4.4	0.8	143.1
BHUMIBOL DAM	0.3	0.4	1.8	5.3	14.1	17.5	13.7	15.5	17.3	15.3	6.3	0.6	108.1
AVERAGE	0.5	1.3	2.0	4.9	13.5	19.6	17.3	19.2	17.5	15.0	5.5	0.7	117.0

AVERAGE MONTHLY RAINY DAY (day)



—□— PHITSANULOK ····+··· KAMPHAENG PHET ···◇··· MUAN TAK -△- MAE SOT ·-x- BHUMIBOL DAM

TABLE A-8 LIST OF RAINFALL STATION

METEOROLOGICAL DEPARTMENT

( 1 / 2 )

Province	Code	Station Name	Period	REMARKS	Collected Data		
					A	B	C
Phitsanulok Sukothai Kamphaeng Phet Tak (East) Tak (West)			1980 to 1989		○		
			1980 to 1989		○		
			1980 to 1989		○		
		Muan Tak	1980 to 1989		○		
		Bumibol Dam	1980 to 1989		○		
		Mae Sot	1980 to 1989		○		

ROYAL IRRIGATION DEPARTMENT

Province	Code	Station Name	Period	REMARKS	Collected Data		
					A	B	C
Phitsanulok	39013	A. Muang	1952 to 1987		○	○	○
	39022	A. Bang Ra Kam	1952 to 1987		○		○
	39032	A. Wang Thong	1952 to 1987		○	○	○
	39042	A. Nakhon Thai	1952 to 1987		○	○	○
	39052	A. Phrom Phiram	1952 to 1987		○	○	○
	39062	A. Bang Krathum	1956 to 1987		○		○
	39072	A. Wat Bot	1959 to 1987		○	○	○
	39082	Phitsanulok Agriculture Experimental Station	1967 to 1987		○		○
	39091	Ban Yang, A. Wat Bot	1965 to 1987	N-22	○		
	39101	Wang Nok Aen, A. Wang Thong	1965 to 1987	N-24	○		○
	39132	Khao Krayang Forest Plantation, A. Wang Thong	1971 to 1987		○		○
	39142	A. Chattrakarn	1973 to 1987		○	○	
	39151	Nan River Alter Condition Unit, A. Muang	1973 to 1987	N-5A	○		
	39161	Ban Nong Bon, A. Wat Bot	1978 to 1987	N-40	○		
	39175	Nam Khek, A. Wang Thong	1981 to 1987		○		
	39180	Naresuan Dam, A. Phrom Phiram	1981 to 1987		○		
Sukothai	59012	A. Muang	1952 to 1987		○	○	○
	59022	A. Si Satchanalai	1952 to 1987		○	○	○
	59032	A. Sawankhalok	1952 to 1987		○	○	○
	59042	A. Kong KraiLat	1952 to 1987		○		○
	59052	Tha Chai Agrometeorological Station	1952 to 1987		○		
	59062	A. Ban Dan Lan Hoi	1952 to 1987		○		○
	59072	Si Sam Rong Agrometeorological Station	1970 to 1987		○	○	○
	59082	A. Kirimat	1967 to 1987		○	○	○
	59092	A. Thung Saliang	1966 to 1987		○	○	○
	59102	A. Si Sam Rong	1952 to 1987		○		
	59110	Nong Pla Mo Project, A. Sawankhalok	1970 to 1987		○		○
	59121	Kaeng Luang, A. Si Satchanalai	1953 to 1987	Y- 6	○		○
	59131	Don Rabiang,	1965 to 1987	Y-14	○		○
	59140	Si Chaliang Weir,	1970 to 1987		○		○
	59154	Ban Dan Lan Hoi Forest Plantation	1972 to 1987		○		○
59162	A. Si Nakhon	1976 to 1987		○			
59170	Khlong Pak Rao Outlet, A. Si Satchanalai	1976 to 1987		○			
59182	Sukhothai Agricultural Object	1982 to 1987		○			

TABLE A-8 LIST OF RAINFALL STATION

( 2 / 2 )

Province	Code	Station Name	Period	REMARKS	Collected Data		
					A	B	C
Kamphaeng Phet	12012	A. Muang	1952 to 1986		○	○	○
	12022	A. Khlong Khlung	1952 to 1986		○	○	○
	12032	A. Phran Kratai	1952 to 1987		○	○	○
	12042	A. Khanu Woralakburi	1953 to 1987		○	○	○
	12052	Thung Pho Thale Self-Supporting Settlement	1966 to 1987		○		○
	12061	Khlong Suanmak, A. Muang	1971 to 1987	P-26	○		○
	12081	Ban Pangmakha, A. Khanu Woralakburi	1970 to 1987	Ct-5A	○		○
	12091	Ban Pang Wai, A. Khlong Khlung	1976 to 1986	P-35	○		○
	12102	A. Sai Ngam	1980 to 1987		○		
	12112	Kamphaeng Phet Agro-meteorological Station	1980 to 1987		○		
	12121	Ban Pong Nam Ron, A. Khlong Lan	1984 to 1987	P-47	○		
	12132	A. Khlong Lan	1986 to 1987		○		
	12142	A. Lan Krabu	1986 to 1987		○		
	Tak (East)	63013	A. Muang	1952 to 1987		○	○
63022		A. Ban Tak	1952 to 1987		○	○	○
63062		A. Sam Ngao	1952 to 1987		○	○	○
63073		Phummiphon Dam	1959 to 1987		○		○
63100		Chiang Ngoeng, A. Muang	1955 to 1957		○		
63111		Wang Kra Chao, A. Sam Ngao	1952 to 1962	P-12	○		
63120		Huai Mae Rakam, A. Muang	1971 to 1987	P-32	○		
63132		Ban Na, A. Sam Ngao	1971 to 1987		○		○
63152		Tak Animal Supporter	1972 to 1987		○		
63162		Ban Samong, A. Sam Ngao	1968 to 1987		○		
63172	Ban Um Wab, A. Sam Ngao	1977 to 1987		○			
Tak (West)	63032	A. Mae Sot	1952 to 1987		○	○	○
	63042	A. Umphang	1952 to 1987		○	○	○
	63052	A. Mae Ramat	1952 to 1987		○	○	○
	63082	Doi Musoe Tribe-hill Development Center	1961 to 1987		○		○
	63092	A. Tha Song Yang	1967 to 1987		○	○	○
	63142	Doi Musoe Agriculture Experimental Center	1972 to 1987		○		○
	63181	Mae Lamao, A. Mae Sot	1977 to 1987		○		

A : Average monthly data

B : Annual data

C : 1 day maximum data

○ : Data collected

TABLE A-9 AVERAGE MONTHLY RAINFALL (mm)

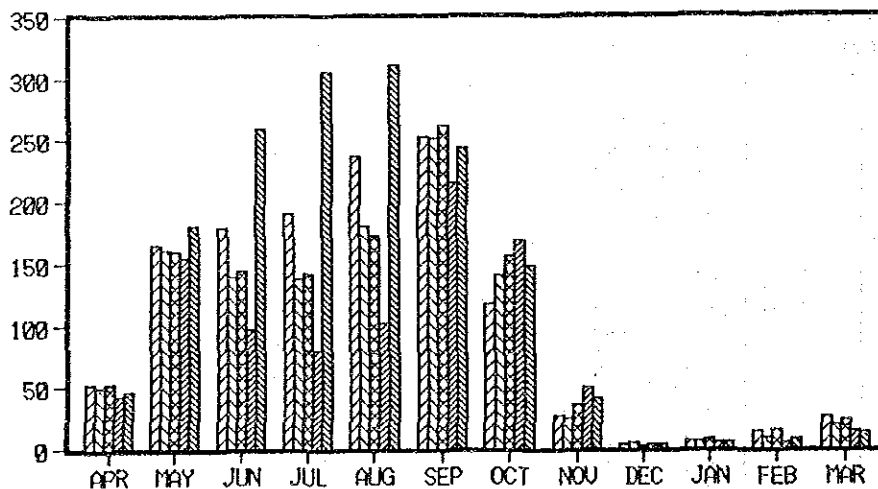
( mm )

REGION	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
PHITSANULOK	52.7	165.9	178.9	190.9	237.3	253.6	117.8	26.7	3.6	6.8	14.8	26.1	1275.1
SUKHOTA I	49.8	162.0	139.1	137.9	180.5	251.6	141.2	25.0	4.9	6.2	8.6	19.3	1126.1
KAMPHAENG PHET	53.2	160.7	144.8	142.5	172.9	262.4	156.1	36.7	3.0	7.8	15.9	22.8	1178.8
TAK (EAST)	42.3	155.2	97.0	80.4	101.8	215.3	168.9	49.9	4.4	4.9	5.6	13.8	939.4
TAK (WEST)	46.5	180.8	259.6	305.9	311.9	243.7	148.1	40.7	4.2	5.0	7.5	13.3	1567.0
AVERAGE	48.9	164.9	163.9	171.5	200.9	245.3	146.4	35.8	4.0	6.1	10.5	19.1	1217.3

( % )

REGION	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL
PHITSANULOK	4.1	13.0	14.0	15.0	18.6	19.9	9.2	2.1	0.3	0.5	1.2	2.0	100.0
SUKHOTA I	4.4	14.4	12.4	12.2	16.0	22.3	12.5	2.2	0.4	0.6	0.8	1.7	100.0
KAMPHAENG PHET	4.5	13.6	12.3	12.1	14.7	22.3	13.2	3.1	0.3	0.7	1.3	1.9	100.0
TAK (EAST)	4.5	16.5	10.3	8.6	10.8	22.9	18.0	5.3	0.5	0.5	0.6	1.5	100.0
TAK (WEST)	3.0	11.5	16.6	19.5	19.9	15.5	9.5	2.6	0.3	0.3	0.5	0.8	100.0
AVERAGE	4.0	13.5	13.5	14.1	16.5	20.2	12.0	2.9	0.3	0.5	0.9	1.6	100.0
					(89.8 %)					(10.2 %)			

AVERAGE MONTHLY RAINFALL (mm)



PHITSANULOK SUKHOTAI KAMPHAENG PHET TAK (EAST) TAK (WEST)



TABLE A-10 PROBABLE 1 DAY MAXIMUM RAINFALL

STATION	CODE	AVG	IN [ STUDY AREA ] ( 1 / 6 )				
			1/5	1/10	1/20	1/50	1/100
PHITSANULOK		89.9	111.5	131.9	152.6	181.1	204.0
SUKHOTAI		89.0	109.7	127.4	145.7	168.6	187.2
KAMPHAENG PHET		92.1	116.5	139.1	162.1	193.5	218.5
TAK (EAST)		82.6	100.6	118.0	135.5	159.9	179.6
TAK (WEST)		92.0	117.0	137.2	156.6	181.8	201.1
PHITSANULOK AVERAGE		89.1	111.0	130.7	150.5	177.0	198.0

STATION	CODE	AVG	IN [ PHITSANULOK ] ( 2 / 6 )					REMARKS
			1/5	1/10	1/20	1/50	1/100	
A. Muang	39013	104.2	132.9	164.8	198.5	246.7	286.3	
A. Bang Rakam	39022	83.8	110.2	146.7	187.9	250.7	305.2	
A. Wang Thang	39032	92.4	116.5	136.3	155.3	180.0	198.7	
A. Nakhon Thai	39042	78.4	95.4	110.0	122.5	138.4	150.1	
A. Phrom Phiram	39052	89.2	106.0	118.7	130.6	145.7	156.9	
A. Bang Krathum	39062	78.2	90.9	99.4	106.9	116.2	122.8	
A. Wat Bot	39072	99.8	123.1	140.1	155.9	175.7	190.3	
PSL A. E. Station	39082	101.3	130.1	156.2	181.9	216.4	243.2	Agri. Experimental Station
Wang Nok Aen	39101	88.9	110.5	133.3	157.2	190.9	218.5	A. Weng Thong (N-40)
Khao Krayang	39132	83.2	98.4	113.5	129.1	150.6	167.9	Forest Plantation
PHITSANULOK AVERAGE		89.9	111.5	131.9	152.6	181.1	204.0	

STATION	CODE	AVG	IN [ SUKHOTHAI ] ( 3 / 6 )					
			1/5	1/10	1/20	1/50	1/100	
A. Muang	59012	80.5	102.0	115.7	137.7	142.1	152.2	
A. Si Satchanalai	59022	88.3	109.5	125.4	140.3	159.2	173.3	
A. Sawankhalok	59032	90.7	116.9	146.3	177.7	222.8	260.2	
A. Kong Krailat	59042	89.5	106.2	118.5	129.9	144.2	154.8	
A. Ban Da Lan Hoi	59062	79.8	96.1	105.5	113.5	122.9	129.3	
Si Sam Rong	59072	92.8	109.7	118.6	125.9	134.2	139.7	Agrometeorological Station
A. Kirimat	59082	87.9	109.5	125.7	140.8	160.0	174.2	
A. Thung Salian	59092	85.1	102.4	115.5	127.7	143.2	154.7	
Nong Pla Mo Project	59110	105.7	136.7	166.8	197.6	240.2	274.3	A. Sawan Khalok
Kaeng Luang	59121	95.6	117.7	143.0	170.2	209.6	242.4	A. Si Sachanalai (Y-6)
Don Rebiang	59131	90.1	107.8	129.4	153.0	187.9	217.4	A. Si Sachanalai (Y-14)
Si Chaliang Weir	59140	92.8	117.3	141.3	166.0	200.1	227.5	A. Si Sachanalai
Ban Dan Lan Hoi	59154	77.4	93.7	104.3	113.7	125.0	133.0	Forest Plantation
SUKHOTAI AVERAGE		89.0	109.7	127.4	145.7	168.6	187.2	

TABLE A-10 PROBABLE 1 DAY MAXIMUM RAINFALL

IN [ KAMPHAENG PHET ] ( 4 / 6 )

STATION	CODE	AVG	1/5	1/10	1/20	1/50	1/100	
A. Muang	12012	91.2	115.2	136.9	158.4	187.3	209.8	
A. Khlong Khlung	12022	100.9	124.0	141.5	157.9	178.8	194.2	
A. Phran Kratai	12032	83.4	103.0	117.5	131.0	147.9	160.3	
A. Khanu Woraiakburi	12042	102.5	129.8	159.1	190.0	233.9	270.0	
Thung Pho Thale	12052	83.5	104.3	119.9	134.5	153.1	166.9	Self-Supporting Settlement
Khlong Suanmak	12061	89.8	112.3	132.9	153.6	181.5	203.4	A. Muang (P-26)
Ban Pangmakha	12081	81.3	100.8	120.8	141.5	170.3	193.5	A. Khanu Woraiakburi (Ct-5A)
Ban Pang Wai	12091	104.5	142.4	184.4	229.5	295.0	349.7	A. Khulong Khulong (P-35)
KAMPHAENG PHET AVERAGE		92.1	116.5	139.1	162.1	193.5	218.5	

IN [ TAK (EAST) ] ( 5 / 6 )

STATION	CODE	AVG	1/5	1/10	1/20	1/50	1/100	
A. Muang	63013	87.5	108.3	126.3	143.9	167.9	185.3	
A. Ban Tak	63022	82.8	101.0	117.5	133.7	155.5	172.4	
A. Sam Ngao	63062	102.8	125.5	163.8	207.5	275.3	334.9	
Phummiphon Dam	63073	80.2	99.5	115.6	131.2	151.6	167.2	
Huai Mae Rakam	63121	76.3	90.6	101.4	111.5	124.3	133.8	A. Muang (P-32)
Ban Na	63132	70.0	81.6	90.5	98.9	109.6	117.7	A. Sam Ngao
Tak Animal Supporter	63152	88.3	109.8	129.7	149.6	176.7	198.0	
Ban Samong	63162	73.1	88.6	98.9	108.0	119.1	127.1	A. Sam Ngao
TAK (EAST) AVERAGE		82.6	100.6	118.0	135.5	159.9	179.6	

IN [ TAK (WEST) ] ( 6 / 6 )

STATION	CODE	AVG	1/5	1/10	1/20	1/50	1/100	
A. Mae Sot	63032	78.0	94.5	103.9	111.9	121.1	127.4	
A. Umphang	63042	67.0	81.5	92.8	103.4	116.9	127.1	
A. Mae Ramat	63052	83.3	105.6	124.8	143.4	167.9	186.8	
Doi Musoe	63082	107.2	144.8	173.8	201.0	235.9	262.0	Tribe Hill Development Center
A. Tha Song Yang	63092	98.5	130.4	158.3	185.6	222.1	250.4	
Doi Musoe A. E. Station	63142	118.2	145.2	169.6	194.0	226.9	252.7	Agri. Experimental Station
TAK (WEST) AVERAGE		92.0	117.0	137.2	156.6	181.8	201.1	

TABLE A-11 PROBABLE ANNUAL RAINFALL

PROBABLE RAINFALL IN STUDY AREA ( 1 / 6 )

Unit [mm/year]

PROVINCE	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
		1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
PHITSANULOK	1,316	1,208	1,119	1,031	963	1,422	1,538	1,673	1,795
SUKHOTHAI	1,098	980	889	782	779	1,202	1,327	1,476	1,611
KAMPHAENG PHET	1,179	1,090	970	849	754	1,367	1,512	1,678	1,823
TAK (EAST)	939	854	775	697	637	1,040	1,140	1,257	1,360
TAK (WEST)	1,567	1,567	1,567	1,567	1,567	1,567	1,567	1,567	1,567
AVERAGE	1,220	1,140	1,064	985	940	1,320	1,417	1,530	1,631

PROBABLE RAINFALL IN PHITSANULOK ( 2 / 6 )

Unit [mm/year]

STATION CODE	STATION NAME	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
			1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
39013	A. Muang	1,347	1,248	1,164	1,079	1,014	1,443	1,546	1,663	1,766
39032	A. Wang Thang	1,340	1,215	1,141	1,070	1,017	1,394	1,494	1,611	1,719
39042	A. Nakhon Thai	1,262	1,105	1,005	904	827	1,337	1,460	1,601	1,726
39052	A. Phrom Phiram	1,082	993	890	791	714	1,252	1,397	1,573	1,733
39072	A. Wat Bot	1,408	1,285	1,204	1,125	1,065	1,484	1,593	1,723	1,840
39142	A. Chattrakan	1,459	1,402	1,308	1,215	1,143	1,620	1,736	1,869	1,986
Average		1,316	1,208	1,119	1,031	963	1,422	1,538	1,673	1,795

PROBABLE RAINFALL IN SUKHOTHAI ( 3 / 6 )

Unit [mm/year]

STATION CODE	STATION NAME	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
			1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
59012	A. Muang	1,116	999	907	816	746	1,215	1,331	1,465	1,583
59032	A. Sawankhalok	1,037	869	755	654	653	1,185	1,303	1,438	1,588
59072	Si Sam Rong Agr	1,210	1,126	1,063	889	948	1,270	1,344	1,427	1,499
59082	A. Krinat	1,281	1,139	1,046	954	885	1,362	1,483	1,625	1,752
59092	A. Thung Salian	1,069	946	850	756	684	1,177	1,304	1,452	1,585
59022	A. Si Satchnalai	876	798	711	624	558	1,005	1,117	1,246	1,361
Average		1,098	980	889	782	779	1,202	1,327	1,476	1,611

TABLE A-11 PROBABLE ANNUAL RAINFALL

## PROBABLE RAINFALL IN KAMPHAENG PHET ( 4 / 6 )

Unit [mm/year]

STATION CODE	STATION NAME	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
			1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
12012	A. Muang	1,095	1,019	899	776	679	1,287	1,423	1,575	1,705
12022	A. Khlong Khlung	1,023	1,055	913	768	645	1,362	1,513	1,679	1,819
12032	A. Phran Kratai	1,276	1,201	1,108	1,017	947	1,422	1,542	1,681	1,805
12042	A. Khanu Woralak	1,289	1,086	959	836	744	1,397	1,570	1,776	1,963
Average		1,179	1,090	970	849	754	1,367	1,512	1,678	1,823

## PROBABLE RAINFALL IN TAK(EAST) ( 5 / 6 )

Unit [mm/year]

STATION CODE	STATION NAME	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
			1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
63013	A. Muang	1,020	970	897	821	761	1,135	1,219	1,313	1,393
63022	A. Ban Tak	861	826	757	687	633	988	1,074	1,172	1,259
63062	A. Sam Ngao	866	765	672	583	517	997	1,128	1,285	1,429
Average		939	854	775	697	637	1,040	1,140	1,257	1,360

## PROBABLE RAINFALL IN TAK(WEST) ( 6 / 6 )

Unit [mm/year]

STATION CODE	STATION NAME	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
			1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
63032	A. Mae Sot	1,656	1,264	1,160	1,063	992	1,527	1,679	1,865	2,037
63042	A. Umphang	1,371	1,284	1,199	1,115	1,050	1,481	1,586	1,706	1,812
63052	A. Mae Ramat	1,509	1,337	1,227	1,120	1,040	1,605	1,754	1,930	2,089
63092	A. Tha Song Yang	1,843	1,548	1,357	1,178	1,049	2,040	2,327	2,679	3,010
Average		1,567	1,567	1,567	1,567	1,567	1,567	1,567	1,567	1,567

TABLE A-12 DISTRIBUTION OF RIVER BASIN

Unit: Sq. Km<sup>2</sup>

BASIN	PROVINCE PHIT- SANULOK	SUKHO- THAI	KAMPHAEN PHET	TAK	T O T A L [%]	
PING RIVER (MAE NAM WANG)	---	---	5,790	6,690 (900)	12,480 (900)	29.4 (2.1)
YOM RIVER	1,440	6,600	1,560	160	9,760	23.0
NAN RIVER (KWAE NOI)	9,170 (5,830)	---	---	---	9,170 (8,830)	21.6 (13.7)
MOEI RIVER	---	---	---	5,130	5,130	12.1
NAM MAE KLONG	---	---	---	4,420	4,420	10.4
OTHERS	200	---	1,260	---	1,460	3.4
TOTAL	10,810	6,600	8,610	16,400	42,420	100.0

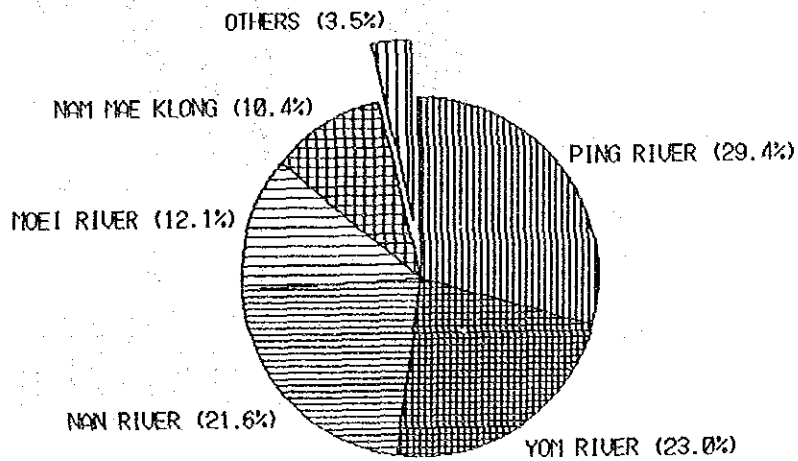


TABLE A-13 LIST OF HYDROLOGICAL STATION ( 1 / 2 )

Code No	Catchment Area (km <sup>2</sup> )	River Name	Stream Name	OBSERVED YEAR	Available Discharge Data													
					1950	1970						1980						1990
					7	8	9	0	1	2	3	4	5	6	7	8	9	0
Sw-1	1.426	Nam Mae Moei	Huai Mae Lamao	1966-cont.														
Sw-4A	1.060	Nam Mae Moei	Huai Mae Lamao	1969-1971														
Sw-5	1.038	Nam Mae Moei	Huai Mae Lamao	1971-Cont.														
P-2A	38.862	Ping		1952-Cont.	=													
P-7	42.704	Ping		1954-1960	=													
P-1A	42.700	Ping		1960-Cont.														
P-12	26.396	Ping		1952-Cont.														
P-15	43.805	Ping		1964-1970														
P-16	45.677	Ping		1960, 1964-1975, 1979														
P-17	45.851	Ping		1954-1979														
P-18	40.273	Ping		1957-1959, 1963-1969														
P-18A	650	Ping	Khlong Wang Chad	1954-1955														
P-26	968	Ping	Khlong Suan Mak	1964, 1967-1971														
P-36A	969	Ping	Khlong Suan Mak	1972-1974, 1978-Cont.														
P-32	342	Ping	Khlong Mue Raka	1971-Cont.														
P-35	730	Ping	Khlong Kuitung	1974-Cont.														
P-47	521	Ping	Khlong Suan Mak	1983-Cont.														
N-4A	10.507	Wang		1971-Cont.														
Y-3A	13.583	Yom		1967-Cont.														
Y-4	17.731	Yom		1950-1960, 1962-Cont.														
Y-6	12.658	Yom		1952-Cont.														
Y-14	12.131	Yom		1964-Cont.														
Y-15	19.936	Yom		1967-1969														
Y-16	20.841	Yom		1967-1969														
Y-17	21.415	Yom		1967-1980														
Y-26	785	Yom	Nam Mae Mok	1979-Cont.														
N-4	19.384	Nan		1946-1947, 1951-1974														
N-4A	19.384	Nan		1975-1982														
N-5	25.294	Nan		1950-1965														
N-5A	25.286	Nan		1966-Cont.														
N-7	29.153	Nan		1944-1947, 1951-Cont.														
N-22	4.841	Nan	Khwaee Noi	1963-1982														
N-24	1.861	Nan	Khwaee Noi	1965-Cont.														
N-25	875	Nan	Khlong Wat Ta	1965-1973														
N-27	19.549	Nan		1965-1979														
N-27A	19.540	Nan		1980-Cont.														
N-29	5	Nan	Lam Nam Than	1971-1980														
N-34	712	Nan	Khlong Chom Phu	1966-1968														
N-35	1,651	Nan	Khwaee Noi	1963-Cont.														
N-36	343	Nan	Lam Nam Khan	1967-1970														
N-40	4,340	Nan	Khwaee Noi	1967-Cont.														

□ Data collected station

TABLE A-13 LIST OF HYDROLOGICAL STATION

( 2 / 2 )

Code No.	Catchment Area (Km <sup>2</sup> )	River Name	Stream Name	OBSERVED YEAR	Available Water-level Data													
					1960		1970		1980		1990							
					7	8	9	0	1	2	3	4	5	6	7	8	9	0
Sw. 3	3. 418	Salawin	Nam Mae Maei	1966-Cont														
Sw. 4	1. 061	Nam Mae Moei	Huai Mae Lamao	1969-1971														
Sw. 8	48	Nam Mae Moei	Huai Pae Pai	1983-Cont														
P. 2	38. 212	Ping	—	1932-1953														
P. 8	25. 197	Ping	—	1952-1954														
P. 9	22. 261	Ping	—	1952-1957														
P. 10	2. 954	Ping	Tun	1952-1956														
P. 11	37. 517	Ping	—	1951-1955, 1962-1968														
P. 12A	26. 343	Ping	—	1952-1955														
P. 12B	26. 364	Ping	—	1954-1955														
P. 46	403	Ping	Huai Mae Tho	1982-Cont														
P. 50	477	Ping	Khlong Wang Chao	1983-Cont														
P. 51	521	Ping	Khlong Pra Dang	1983-Cont														
P. 52	341	Ping	Huai Tak	1983-Cont														
P. 62	84	X. Suan Mak	Khlong Phrai	1986-Cont														
Y. 3	13. 583	Yom	—	1950-1959, 1964-1967														
Y. 7	12. 659	Yom	—	1953-Cont														
Y. 9	802	Yom	Nam Mae Mok	1972-Cont														
Y. 10	1. 194	Yom	Nom Mae Lamphan	1954-1956														
Y. 28	303	Yom	Huai Tha Phae	1982-Cont														
Y. 29	57	Yom	Huai Mae Hu	1983-Cont														
Y. 32	749	Yom	Nam Mae Ramphan	1986-Cont														
N. 43	431	Nan	Khlong Chom Phu	1978-Cont														
N. 55	967	Nan	Nam Phak	1983-Cont														
N. 56	42	Nan	Nam Pat	1983-Cont														
N. 58	322	Khwaie Noi	Nam Fua	1984-Cont														
N. 59	405	Khwaie Noi	Lam Nam Khan	1984-Cont														
N. 62	350	Khwaie Noi	Huai Nam Khung	1986-Cont														

TABLE A-14 MONTHLY DEPTH OF RUN-OFF

( 1 / 6 )

PROVINCE	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL Mean/Total	Runoff Percentage	
PHITSANULOK	Average Runoff (1/s/km <sup>2</sup> )	3.70	5.21	8.60	13.89	24.96	32.75	18.89	8.03	3.90	2.78	2.99	3.24	10.90	
	Depth of Runoff (mm)	9.7	14.1	22.6	37.7	67.7	85.9	51.2	21.1	10.6	7.5	7.4	8.5	342.9	
	Rainfall (mm)	52.7	165.9	178.9	190.9	237.3	253.6	117.8	26.7	3.6	6.8	14.8	26.1	1,275.1	27.0 %
SUKHOTHAI	Average Runoff (1/s/km <sup>2</sup> )	0.29	2.55	5.12	5.22	13.78	22.65	15.26	4.85	1.43	0.64	0.32	0.19	6.05	
	Depth of Runoff (mm)	0.8	7.1	13.3	14.0	36.9	58.7	40.9	12.6	3.8	1.7	0.8	0.5	191.0	
	Rainfall (mm)	49.8	162.0	139.1	137.9	180.5	251.6	141.2	25.0	4.9	6.2	8.6	19.3	1,126.1	17.0 %
KAMPHAENG PHET	Average Runoff (1/s/km <sup>2</sup> )	3.03	6.95	8.02	7.80	9.48	26.82	37.68	19.89	8.10	3.37	2.89	2.88	10.71	
	Depth of Runoff (mm)	7.5	17.7	19.8	19.9	24.2	66.2	96.1	48.6	15.6	8.6	6.7	7.1	338.0	
	Rainfall (mm)	53.2	160.7	144.8	142.5	172.9	262.4	156.1	36.7	3.0	7.8	15.9	22.8	1,178.8	28.7 %
TAK(EAST)	Average Runoff (1/s/km <sup>2</sup> )	3.81	4.28	4.55	4.07	5.13	9.88	10.69	5.30	2.46	2.24	3.17	4.05	4.95	
	Depth of Runoff (mm)	9.9	11.4	11.8	10.9	13.7	25.6	28.6	13.7	6.6	6.0	7.7	10.5	156.3	
	Rainfall (mm)	42.3	155.2	97.0	80.4	101.8	215.3	168.9	49.9	4.4	4.9	5.5	13.8	939.4	16.6 %
TAK(WEST)	Average Runoff (1/s/km <sup>2</sup> )	2.81	4.69	6.78	8.73	16.07	21.24	20.71	12.17	6.87	5.05	3.87	3.03	9.56	
	Depth of Runoff (mm)	7.5	12.8	18.0	23.9	44.0	56.3	56.7	32.2	18.8	13.8	9.7	8.0	301.7	
	Rainfall (mm)	46.5	180.8	259.6	305.9	311.9	243.7	148.1	40.7	4.2	5.0	7.5	13.3	1,567.0	19.3 %
AVERAGE	Average Runoff (1/s/km <sup>2</sup> )	2.73	4.76	6.61	7.94	13.88	22.67	20.65	10.01	4.15	2.82	2.65	2.68	8.43	
	Depth of Runoff (mm)	7.0	12.6	17.1	21.3	37.3	58.5	54.7	25.6	11.1	7.5	6.5	6.9	266.2	
	Rainfall (mm)	48.9	164.9	163.9	171.5	200.9	245.3	146.4	35.8	4.0	6.1	10.5	19.1	1,217.3	21.3 %

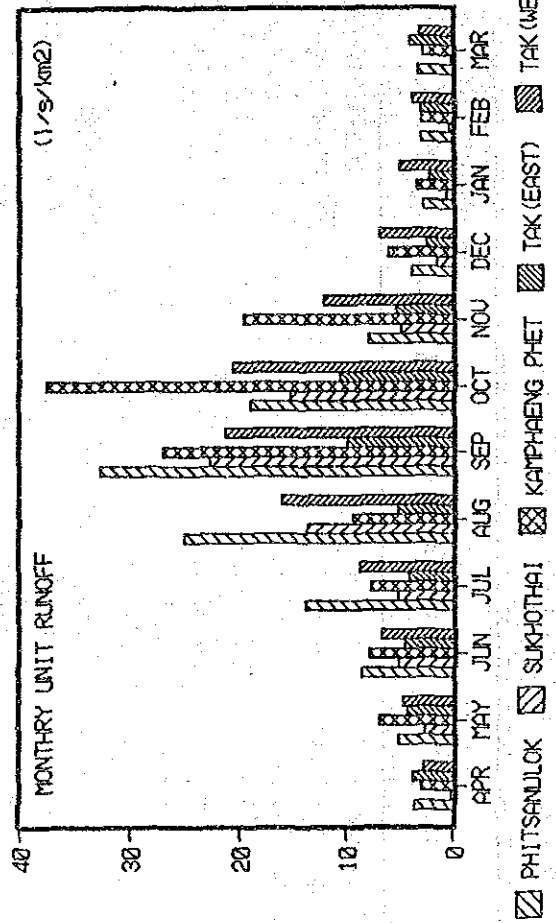




TABLE A-14 MONTHLY DEPTH OF RUN-OFF  
IN PHITSANULOK

( 2 / 6 )

LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	Unit [l/sec/km <sup>2</sup> ]												Annual Mean
PROV.	STREAM			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
PSL	Lam Nam Kha	N-38	243	2.87	6.86	14.18	27.61	48.48	48.27	23.74	7.61	3.88	2.52	1.75	1.56	16.82
PSL	K. Cham Phu	N-25	875	0.32	1.17	7.94	15.76	26.47	34.56	16.29	6.50	1.96	0.77	0.44	0.35	9.41
PSL	Khuae Noi	N-36	1,651	1.97	4.43	9.60	16.20	33.50	42.51	23.02	7.94	3.87	2.73	2.20	1.77	12.37
PSL	Khhek	N-24	1,861	0.82	4.27	11.26	16.23	31.94	46.75	27.46	9.09	3.17	1.58	0.94	0.64	12.89
PSL	Khuae Noi	N-40	4,340	1.37	4.52	8.40	14.74	27.79	41.28	23.69	7.66	3.22	1.98	1.45	1.14	11.48
PSL	Khuae Noi	N-22	4,841	1.30	3.20	6.61	11.58	25.74	37.96	21.25	7.87	3.47	2.23	1.60	1.27	10.61
URD	Nan River	N-4/4a	19,384	7.62	7.61	9.82	15.22	26.20	30.35	16.95	9.91	6.50	5.62	6.58	7.49	12.29
PSL	Nan River	N-27a	19,540	12.58	10.98	8.36	8.52	10.39	11.73	6.27	6.45	4.09	5.18	9.47	10.91	8.73
PSL	Nan River	N-27	19,549	6.36	7.27	8.27	12.85	22.85	26.24	13.65	7.73	5.00	3.82	4.12	5.59	10.50
PCT	Yom River	Y-17	21,415	0.17	0.81	2.47	3.54	7.37	14.94	16.29	7.44	1.89	0.52	0.19	0.10	4.66
PCT	Nan River	N-7	29,153	5.27	6.20	7.69	10.55	18.82	25.63	19.19	10.11	5.82	3.63	4.18	4.84	10.12
Average Runoff (1)		(l/s/km <sup>2</sup> )		1.44	4.08	9.67	17.02	31.49	41.90	22.58	7.78	3.26	1.97	1.39	1.12	12.26
Average Runoff (2)		(l/s/km <sup>2</sup> )		6.40	6.58	7.32	10.14	17.12	21.78	14.47	8.33	4.66	3.75	4.91	5.79	9.26
Average Runoff (3)		(l/s/km <sup>2</sup> )		3.70	5.21	8.60	13.89	24.96	32.75	18.89	8.03	3.90	2.78	2.99	3.24	10.90
Depth of Runoff		(mm)		9.7	14.1	22.6	37.7	67.7	85.9	51.2	21.1	10.6	7.5	7.4	8.5	343.9
Rainfall		(mm)		52.7	165.9	178.9	190.9	237.3	253.6	117.8	26.7	3.6	6.8	14.8	26.1	1,275.1
																27.0%

( 3 / 6 )

IN SUKHOTRAI

LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	Unit [l/sec/km <sup>2</sup> ]												Annual Mean
PROV.	STREAM			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
LPG	Nam Mae Mok	Y-25	785	0.02	3.22	7.75	2.52	3.86	14.59	19.20	5.02	0.93	0.31	0.13	0.01	4.81
SKT	Yom River	Y-14	12,131	0.47	2.44	3.76	6.68	19.06	26.25	12.68	4.44	1.65	0.85	0.46	0.32	6.61
SKT	Yom River	Y-6	12,558	0.39	2.29	3.86	6.35	18.41	27.11	13.88	5.10	1.71	0.76	0.37	0.25	6.73
Average Runoff (1)		(l/s/km <sup>2</sup> )		0.02	3.22	7.75	2.62	3.86	14.59	19.20	5.02	0.93	0.31	0.13	0.01	4.81
Average Runoff (2)		(l/s/km <sup>2</sup> )		0.43	2.37	3.81	6.51	18.74	26.68	13.28	4.77	1.68	0.81	0.41	0.28	6.67
Average Runoff (3)		(l/s/km <sup>2</sup> )		0.29	2.65	5.12	5.22	13.78	22.65	15.26	4.85	1.43	0.64	0.32	0.19	6.05
Depth of Runoff		(mm)		0.8	7.1	13.3	14.0	36.9	58.7	40.9	12.6	3.8	1.7	0.8	0.5	191.0
Rainfall		(mm)		49.8	162.0	139.1	137.9	180.5	251.6	141.2	25.0	4.9	6.2	8.6	19.3	1,126.1
																17.0%

TABLE A-14 MONTHLY DEPTH OF RUN-OFF  
IN KAMPAENG PHET

( 4 / 6 )

LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	Unit [l/sec/km <sup>2</sup> ]												Annual Mean
PROV.	STREAM			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
KPP	K. Suan Mak	P-47	521	3.75	11.80	11.44	9.91	10.50	35.04	59.44	38.77	9.53	5.46	4.06	3.02	14.25
KPP	K. Khulug	P-35	730	0.93	9.30	11.75	10.37	12.24	46.22	57.23	25.03	5.44	2.80	1.28	0.79	15.33
KPP	K. Suan Mak	P-26	968	1.06	4.38	4.90	5.26	9.59	26.69	31.65	14.94	6.77	2.50	1.24	0.70	9.17
KPP	K. Suan Mak	P-26a	969	1.17	4.92	8.53	9.29	11.23	33.54	47.81	25.71	6.23	2.54	1.18	0.87	13.04
KPP	Ping River	P-7a	42,700	5.20	5.88	5.73	6.08	6.62	9.02	9.37	6.55	3.91	3.56	5.09	6.61	6.22
PCT	Ping River	P-17	45,851	5.04	5.40	5.79	5.89	6.58	10.43	10.58	7.13	4.69	3.59	4.52	5.25	6.25
	Average Runoff (1)	(l/s/km <sup>2</sup> )		1.73	7.60	9.15	8.71	10.89	35.37	51.53	26.11	7.00	3.27	1.94	1.34	12.95
	Average Runoff (2)	(l/s/km <sup>2</sup> )		5.62	5.64	5.76	5.98	6.65	9.72	9.98	6.84	4.30	3.58	4.80	5.94	6.24
	Average Runoff (3)	(l/s/km <sup>2</sup> )		3.03	6.95	8.02	7.80	9.48	26.82	37.68	19.69	6.10	3.37	2.89	2.88	10.71
	Depth of Runoff	(mm)		7.5	17.7	19.8	19.9	24.2	66.2	96.1	48.6	15.6	8.6	6.7	7.1	338.0
	Rainfall	(mm)		53.2	150.7	144.8	142.5	172.9	262.4	155.1	35.7	3.0	7.8	15.9	22.8	1,178.8
																28.7%

( 5 / 6 )

IN TAK(EAST)

LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	Unit [l/sec/km <sup>2</sup> ]												Annual Mean
PROV.	STREAM			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
TAK	K. Mae Roko	P-32	342	0.02	3.36	4.53	0.86	1.79	11.81	15.93	4.14	0.34	0.05	0.03	0.03	3.67
TAK	Wang River	W-4a	10,507	0.36	1.10	2.06	2.50	5.47	12.12	9.52	5.07	1.46	0.74	0.41	0.51	3.45
TAK	Ping River	P-12	26,396	8.50	7.02	6.27	7.15	6.73	6.46	6.81	5.91	4.26	4.49	6.96	8.91	6.54
TAK	Ping River	P-2a	38,862	6.34	5.62	5.33	5.77	6.55	9.11	9.51	6.06	3.80	3.66	5.27	6.76	6.15
	Average Runoff (1)	(l/s/km <sup>2</sup> )		0.02	3.36	4.53	0.86	1.79	11.81	15.93	4.14	0.34	0.06	0.03	0.03	3.67
	Average Runoff (2)	(l/s/km <sup>2</sup> )		5.07	4.58	4.55	5.14	6.25	9.23	8.61	5.68	3.17	2.96	4.22	5.39	5.38
	Average Runoff (3)	(l/s/km <sup>2</sup> )		3.81	4.28	4.55	4.07	5.13	9.88	10.59	5.30	2.46	2.24	3.17	4.05	4.95
	Depth of Runoff	(mm)		9.9	11.4	11.8	10.9	13.7	25.6	28.6	13.7	6.6	6.0	7.7	10.5	156.3
	Rainfall	(mm)		42.3	155.2	97.0	80.4	101.8	215.3	158.9	49.9	4.4	4.9	5.6	13.8	938.4
																16.5%

TABLE A-14 MONTHLY DEPTH OF RUN-OFF

IN TAK (WEST)

( 6 / 6 )

LOCATION		STATION	C/AREA	Unit [l/sec/km <sup>2</sup> ]												
PROV.	STREAM	CODE	(km <sup>2</sup> )	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual Mean
TAK	Nam Mae Moei	Sw-6	1,038	3.00	5.29	7.53	8.85	16.41	24.72	26.86	14.79	7.73	5.35	4.02	3.09	10.67
TAK	Nam Mae Moei	Sw-1	1,426	2.63	4.09	6.02	8.61	15.73	17.77	14.56	9.54	6.02	4.75	3.73	2.97	8.46
Average Runoff (1) (l/s/km <sup>2</sup> )				2.81	4.69	6.78	8.73	16.07	21.24	20.71	12.17	6.87	5.05	3.87	3.03	9.56
Average Runoff (2) (l/s/km <sup>2</sup> )				2.81	4.69	6.78	8.73	16.07	21.24	20.71	12.17	6.87	5.05	3.87	3.03	9.56
Average Runoff (3) (l/s/km <sup>2</sup> )				7.5	12.8	18.0	23.9	44.0	56.3	56.7	32.2	18.8	13.8	9.7	8.0	301.7
Depth of Runoff (mm)				46.5	180.8	259.6	305.9	311.9	243.7	148.1	40.7	4.2	5.0	7.5	13.3	1,567.0
Rainfall (mm)																19.3%

Notes: Average (1) : Whole catchment area is in study area (Tributary of Pin, Yom, Nan and other River)  
 Average (2) : Some catchment area is in study area partly (Main stream of Pin, Yom and Nan River)  
 Average (3) : Grand average

Unit [m<sup>3</sup>/sec]

TABLE A-15 MONTHLY (UNIT) RUN-OFF

PROV.	LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	MONTHLY (UNIT) RUN-OFF												Mean (cms)	Total (mcm)
	AMPHOE				Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar		
TAK	Nam Mae Moei	Sw-1	1,426	3.7	5.8	8.6	12.3	22.4	25.3	20.8	13.6	8.6	6.8	5.3	4.2	12.1	381	
TAK	Nam Mae Moei	Sw-6	1,038	3.1	5.5	7.8	9.2	17.0	25.7	27.9	15.4	8.0	5.6	4.2	3.2	11.1	349	
TAK	Ping River	P-2a	38,862	246.5	218.5	207.0	224.2	254.7	354.1	369.5	235.5	147.6	142.1	205.0	252.7	239.0	7,541	
KPP	Ping River	P-7a	42,700	264.9	251.0	244.7	259.6	282.5	385.2	399.9	279.9	167.0	152.1	217.2	282.4	265.6	8,381	
TAK	Ping River	P-12	26,396	224.4	185.4	165.5	188.6	177.5	170.5	179.8	155.9	112.3	118.6	183.8	235.2	172.7	5,450	
PCT	Ping River	P-17	45,851	231.2	247.5	265.4	269.9	306.3	478.1	485.3	326.9	214.9	164.6	207.0	241.4	286.7	9,047	
KPP	K.Suan Mak	P-26	968	1.0	4.2	4.7	5.1	9.3	25.8	30.6	14.5	6.6	2.4	1.2	0.7	8.9	280	
KPP	K.Suan Mak	P-26a	969	1.1	4.8	8.3	9.0	10.9	32.5	46.3	24.9	6.0	2.5	1.1	0.8	12.6	399	
TAK	K.Mae Roko	P-32	342	0.0	1.1	1.6	0.3	0.6	4.0	5.8	1.4	0.1	0.0	0.0	0.0	1.3	40	
KPP	K.Khulug	P-35	730	0.7	6.8	8.6	7.8	8.9	33.7	41.8	18.3	4.0	1.9	0.9	0.6	11.2	353	
KPP	K.Suan Mak	P-47	521	2.0	6.1	6.0	5.2	5.5	18.3	36.2	20.2	5.0	2.8	2.1	1.6	7.4	234	
TAK	Wang River	W-4a	10,507	3.8	11.6	21.7	25.7	63.6	132.5	104.2	52.7	15.3	7.7	4.2	5.1	36.3	1,144	
SKT	Yom River	Y-6	12,658	4.9	28.9	48.6	79.9	231.7	341.2	174.7	64.2	21.5	9.6	4.6	3.2	84.7	2,673	
SKT	Yom River	Y-14	12,131	5.7	29.4	45.4	80.6	229.8	316.6	152.9	53.5	19.9	10.3	5.5	3.8	79.7	2,516	
PCT	Yom River	Y-17	21,415	3.5	19.0	52.0	71.1	155.4	319.8	348.9	159.4	40.5	12.3	4.2	2.2	99.8	3,150	
LPG	Nam Mae Mok	Y-26	785	0.0	3.3	6.3	1.8	3.0	11.8	12.8	3.3	0.7	0.2	0.1	0.0	3.8	119	
URD	Nan River	N-4/4a	19,384	147.7	147.5	190.3	295.0	507.9	588.3	323.5	192.1	126.1	108.9	127.5	145.3	238.2	7,515	
PCT	Nan River	N-7	29,153	153.6	180.7	224.0	307.5	548.7	747.2	559.4	294.8	169.6	105.9	121.9	141.0	295.0	9,308	
PSL	Khuae Noi	N-22	4,841	6.3	15.5	32.0	56.0	124.6	183.7	102.9	38.1	16.8	10.8	7.7	6.1	51.4	1,621	
PSL	Khek	N-24	1,861	1.5	8.0	21.0	30.2	59.4	87.0	51.1	16.9	5.9	2.9	1.7	1.2	24.0	757	
PSL	K.Cham Phu	N-25	875	0.4	1.1	6.7	12.6	23.2	30.2	14.3	5.7	1.7	0.7	0.4	0.3	8.2	260	
PSL	Nan River	N-27	19,549	124.4	142.1	161.7	251.2	446.6	512.9	266.9	151.1	97.8	74.6	80.5	109.2	205.3	6,479	
PSL	Nan River	N-27a	19,540	245.8	214.6	163.3	166.5	202.9	229.2	122.6	126.0	79.9	101.3	185.0	213.2	170.5	5,382	
PSL	Khuae Noi	N-29	6	0.2	0.2	0.2	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	8	
PSL	Khuae Noi	N-36	1,651	3.3	7.3	15.9	26.7	55.3	70.3	38.0	13.1	6.4	4.5	3.6	2.9	20.4	645	
PSL	Lam Nam Kha	N-38	243	0.7	1.7	3.4	6.7	10.6	11.7	5.8	1.8	0.9	0.6	0.4	0.4	4.1	129	
PSL	Khuae Noi	N-40	4,340	5.9	19.6	36.5	64.0	120.6	179.1	102.8	33.3	14.0	8.6	6.3	4.9	49.8	1,572	

TABLE A-15 MONTHLY (UNIT) RUN-OFF

LOCATION		STATION CODE	C/AREA (km <sup>2</sup> )	Unit [l/sec/km <sup>2</sup> ]												
PROV.	AMPHOE			Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
TAK	Nam Mae Moei	Sw-1	1,426	2.63	4.09	6.02	8.61	15.73	17.77	14.56	9.54	6.02	4.75	3.73	2.97	8.46
TAK	Nam Mae Moei	Sw-6	1,038	3.00	5.29	7.53	8.85	16.41	24.72	26.86	14.79	7.73	5.35	4.02	3.09	10.67
TAK	Ping River	P-2a	38,862	6.34	5.62	5.33	5.77	6.55	9.11	9.51	6.06	3.80	3.66	5.27	6.76	6.15
KPP	Ping River	P-7a	42,700	6.20	5.88	5.73	6.08	6.62	9.02	9.37	6.55	3.91	3.56	5.09	6.61	6.22
TAK	Ping River	P-12	26,336	8.50	7.02	6.27	7.15	6.73	6.46	6.81	5.91	4.26	4.49	6.96	8.91	6.54
PCT	Ping River	P-17	45,851	5.04	5.40	5.79	5.89	6.68	10.43	10.58	7.13	4.69	3.59	4.52	5.26	6.25
KPP	K. Suan Mak	P-26	968	1.06	4.38	4.90	5.26	9.59	26.69	31.65	14.94	6.77	2.50	1.24	0.70	9.17
KPP	K. Suan Mak	P-26a	969	1.17	4.92	8.53	9.29	11.23	33.54	47.81	25.71	6.23	2.54	1.18	0.87	13.04
TAK	K. Mae Roko	P-32	342	0.02	3.36	4.53	0.86	1.79	11.81	16.93	4.14	0.34	0.06	0.03	0.03	3.67
KPP	K. Khulug	P-35	730	0.93	9.30	11.75	10.37	12.24	46.22	57.23	25.03	5.44	2.60	1.23	0.79	15.33
KPP	K. Suan Mak	P-47	521	3.75	11.80	11.44	9.91	10.50	35.04	69.44	38.77	9.53	5.46	4.06	3.02	14.25
TAK	Wang River	W-4a	10,507	0.36	1.10	2.06	2.50	5.47	12.12	9.52	5.07	1.46	0.74	0.41	0.51	3.45
SKT	Yom River	Y-6	12,658	0.39	2.29	3.86	6.35	18.41	27.11	13.88	5.10	1.71	0.76	0.37	0.25	6.73
SKT	Yom River	Y-14	12,131	0.47	2.44	3.76	6.68	19.06	26.25	12.68	4.44	1.65	0.85	0.46	0.32	6.61
PCT	Yom River	Y-17	21,415	0.17	0.81	2.47	3.54	7.37	14.94	16.29	7.44	1.89	0.52	0.19	0.10	4.66
LPG	Nam Mae Mok	Y-26	785	0.02	3.22	7.75	2.62	3.86	14.59	19.20	5.02	0.93	0.31	0.13	0.01	4.81
URD	Nan River	N-4/4a	19,384	7.62	7.61	9.82	15.22	26.20	30.35	16.95	9.91	6.50	5.62	6.58	7.49	12.29
PCT	Nan River	N-7	29,153	5.27	6.20	7.69	10.55	18.82	25.63	19.19	10.11	5.82	3.63	4.18	4.84	10.12
PSL	Khuae Noi	N-22	4,841	1.30	3.20	6.61	11.58	25.74	37.96	21.25	7.87	3.47	2.23	1.60	1.27	10.61
PSL	Khhek	N-24	1,861	0.82	4.27	11.26	16.23	31.94	46.75	27.46	9.09	3.17	1.58	0.94	0.64	12.89
PSL	K. Cham Phu	N-25	875	0.32	1.17	7.94	15.76	26.47	34.56	16.29	6.50	1.96	0.77	0.44	0.35	9.41
PSL	Nan River	N-27	19,549	6.36	7.27	8.27	12.85	22.85	26.24	13.65	7.73	5.00	3.82	4.12	5.59	10.50
PSL	Nan River	N-27a	19,540	12.58	10.98	8.36	8.52	10.39	11.73	6.27	6.45	4.09	5.18	9.47	10.91	8.73
PSL	Khuae Noi	N-29	6	33.94	28.50	29.80	37.66	53.50	63.49	44.03	31.59	27.82	27.72	27.02	31.01	41.00
PSL	Khuae Noi	N-36	1,651	1.97	4.43	9.60	16.20	33.50	42.61	23.02	7.94	3.87	2.73	2.20	1.77	12.37
PSL	Lam Nam Kha	N-38	243	2.87	6.86	14.18	27.61	43.48	48.27	23.74	7.61	3.88	2.52	1.75	1.56	16.82
PSL	Khuae Noi	N-40	4,340	1.37	4.52	8.40	14.74	27.79	41.28	23.69	7.66	3.22	1.98	1.45	1.14	11.48

( 1 / 2 )

TABLE A-16 MONTHLY RUN-OFF PATTERN AND PROBABLE RUN-OFF

Unit : l/s/km<sup>2</sup>

	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	ANNUAL	
													MEAN	MEAN
PHITSANULOK	3.70	5.21	8.60	13.89	24.96	32.75	18.89	8.03	3.90	2.78	2.99	3.24	10.90	
SUKHOTHAI	0.29	2.65	5.12	5.22	13.78	22.65	15.26	4.85	1.43	0.64	0.32	0.19	6.05	
KAMPHAENG PHET	3.03	6.95	8.02	7.80	9.48	26.82	37.68	19.69	6.10	3.37	2.89	2.88	10.71	
TAK (EAST)	3.81	4.28	4.55	4.07	5.13	9.88	10.69	5.30	2.46	2.24	3.17	4.05	4.95	
TAK (WEST)	2.81	4.69	6.78	8.73	16.07	21.24	20.71	12.17	6.87	5.05	3.87	3.03	9.56	
AVERAGE	2.73	4.76	6.61	7.94	13.88	22.67	20.65	10.01	4.15	2.82	2.65	2.68	8.43	

( 2 / 2 )

Unit : Percent

	ANNUAL MEAN	PROBABILITY IN DROUGHT				PROBABILITY IN HIGH-WATER			
		1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
PHITSANULOK	10.90	78.0	66.6	59.5	49.1	105.5	121.3	140.4	158.7
SUKHOTHAI	6.05	71.9	59.9	49.5	42.5	108.2	132.9	166.6	201.9
KAMPHAENG PHET	10.71	70.6	57.5	46.3	38.7	109.5	137.4	172.2	208.8
TAK (EAST)	4.95	78.9	66.4	54.9	46.4	111.7	131.3	156.2	179.9
TAK (WEST)	9.56	84.7	74.0	63.7	55.9	110.6	125.1	142.5	158.6
AVERAGE	8.43	76.8	64.9	54.8	46.5	109.1	129.6	155.6	181.6

TABLE A-17 PROBABLE RUN-OFF BY STATION

IN PHITSANULOK

( 1 / 5 )

Unit [l/sec/km<sup>2</sup>]

STATION CODE	C/AREA (km <sup>2</sup> )	Stream	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
				1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
N-25	875	K. Cham Phu	9.41	7.66	6.69	5.79	5.14	10.16	11.63	13.44	15.14
N-36	1,651	Khuae Noi	12.37	10.20	8.88	7.66	6.78	13.62	15.64	18.13	20.48
N-24	1,861	Khek	12.89	10.97	9.49	8.04	6.92	14.33	16.13	18.20	20.60
N-40	4,340	Khuae Noi	11.48	9.44	8.15	6.93	6.04	12.70	14.57	16.83	18.93
N-22	4,841	Khuae Noi	10.61	8.23	6.95	5.80	4.99	11.71	13.84	16.54	19.16
N-4/4a	19,384	Nan River	12.29	9.88	8.36	6.93	5.88	13.74	15.96	18.67	21.19
N-27a	19,540	Nan River	8.73	8.43	7.15	8.94	5.05	11.70	13.58	15.87	18.00
N-27	19,549	Nan River	10.50	7.66	6.69	5.79	5.14	10.16	11.63	13.44	15.14
Y-17	21,415	Yom River	4.66	3.57	2.28	2.08	1.53	5.40	6.41	7.60	8.67
N-7	29,153	Nan River	10.12	8.96	7.91	6.86	6.06	11.44	12.76	14.28	15.62
Runoff	(l/s/km <sup>2</sup> )		10.90	8.50	7.26	6.48	5.35	11.50	13.22	15.30	17.29
Depth of Runoff	(mm)		343.9	268.2	229.0	204.6	168.9	362.8	417.0	482.8	545.7
Rainfall	(mm)		1,275	1,208	1,119	1,031	963	1,422	1,538	1,673	1,795
Percentage of Rnoff	(%)		27.0	22.2	20.5	19.8	17.5	25.5	27.1	28.9	30.4

Table A - 17 (2/5)

IN SUKHOTHAI

( 2 / 5 )

Unit [l/sec/km<sup>2</sup>]

STATION CODE	C/AREA (km <sup>2</sup> )	Stream	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
				1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
Y-26	785	Nam Mae Mok	4.81	3.15	2.59	2.15	1.89	5.17	6.75	9.12	11.82
Y-14	12,131	Yom River	6.61	4.91	4.13	3.45	2.99	7.20	8.70	10.68	12.69
Y-6	12,658	Yom River	6.73	5.00	4.15	3.38	2.84	7.28	8.67	10.44	12.14
Runoff	(l/s/km <sup>2</sup> )		6.05	4.35	3.62	2.99	2.57	6.55	8.04	10.08	12.22
Depth of Runoff	(mm)		191.0	137.4	114.3	94.5	81.2	206.7	253.7	318.1	385.5
Rainfall	(mm)		1,126	1,016	924	814	823	1,242	1,369	1,521	1,661
Percentage of Rnoff	(%)		17.0	13.5	12.4	11.6	9.9	16.6	18.5	20.9	23.2

IN KAMPAENG PHET

( 3 / 5 )

Unit [l/sec/km<sup>2</sup>]

STATION CODE	C/AREA (km <sup>2</sup> )	Stream	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
				1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
P-47	521	K. Suan Mak	14.25	10.43	9.20	8.28	7.74	14.95	19.61	24.26	30.82
P-35	730	K. Khulug	15.33	9.34	6.68	4.45	2.99	17.43	22.95	30.51	38.35
P-26	968	K. Suan Mak	9.17	6.30	4.79	3.47	2.57	10.56	13.29	16.85	20.39
P-26a	969	K. Suan Mak	13.04	8.99	7.21	5.72	4.74	14.40	18.08	23.12	28.35
P-7a	42,700	Ping River	6.22	5.52	4.98	4.45	4.04	6.76	7.41	8.17	8.83
P-17	45,851	Ping River	6.25	4.76	4.07	3.35	2.76	6.24	6.97	7.76	7.43
Runoff	(l/s/km <sup>2</sup> )		10.71	7.56	6.16	4.95	4.14	11.72	14.72	18.45	22.36
Depth of Runoff	(mm)		338.0	238.5	194.2	156.3	130.6	370.0	464.5	582.1	705.7
Rainfall	(mm)		1,179	1,090	970	849	754	1,367	1,512	1,678	1,823
Percentage of Rnoff	(%)		28.7	21.9	20.0	18.4	17.3	27.1	30.7	34.7	38.7

TABLE A-17 PROBABLE RUN-OFF BY STATION

IN TAK(EAST)

( 4 / 5 )

Unit [l/sec/km<sup>2</sup>]

STATION CODE	C/AREA (km <sup>2</sup> )	Stream	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
				1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
P-32	342	K. Mae Roko	3.67	2.19	1.51	0.94	0.56	4.16	5.52	7.31	9.14
W- 4a	10,507	Wang River	3.45	2.64	2.15	1.70	1.36	3.97	4.74	5.79	6.77
P-12	26,396	Ping River	6.54	5.50	4.76	4.05	3.51	7.27	8.23	9.37	10.40
P- 2a	38,862	Ping River	6.15	5.31	4.73	4.18	3.77	6.73	7.52	8.47	9.34
Runoff	(l/s/km <sup>2</sup> )		4.95	3.91	3.29	2.72	2.30	5.53	6.50	7.74	8.91
Depth of Runoff	(mm)		156.3	123.4	103.7	85.8	72.6	174.6	205.2	244.1	281.3
Rainfall	(mm)		939	854	775	697	637	1,040	1,140	1,257	1,360
Percentage of Rnoff	(%)		16.6	14.5	13.4	12.3	11.4	16.8	18.0	19.4	20.7

IN TAK(WEST)

( 5 / 5 )

Unit [l/sec/km<sup>2</sup>]

STATION CODE	C/AREA (km <sup>2</sup> )	Stream	Annual Mean	PROBABILITY OF DROUGHT				PROBABILITY OF HIGH-WATER			
				1/3	1/5	1/10	1/20	1/3	1/5	1/10	1/20
Sw-6	1,038	Nam Mae Moei	10.67	9.50	8.47	7.40	6.54	11.73	12.83	14.05	15.07
Sw-1	1,426	Nam Mae Moei	8.46	6.70	5.69	4.78	4.14	9.42	11.09	13.20	15.25
Runoff	(l/s/km <sup>2</sup> )		9.56	8.10	7.08	6.09	5.34	10.58	11.96	13.63	15.16
Depth of Runoff	(mm)		301.7	255.6	223.4	192.2	168.5	333.7	377.4	430.0	478.4
Rainfall	(mm)		1,567	1,358	1,236	1,119	1,033	1,663	1,837	2,045	2,237
Percentage of Rnoff	(%)		19.3	18.8	18.1	17.2	16.3	20.1	20.6	21.0	21.4



TABLE A-18 DISCHARGE MEASUREMENT

Site : PHITSANULOK  
 Huai Sam Ru/Nak Hon Thai  
 Date : Oct. 19 1990  
 Catchment Area : 45 km<sup>2</sup>  
 Total Discharge: 6.236 m<sup>3</sup>/s  
 (138 l/s/sq. km<sup>2</sup>)

No.	Measur- ing Point	Water Depth	Velocity (m/sec)	Discharge (m <sup>3</sup> /sec)
0	1.00	0.00	---	---
1	1.50	0.30	0.20	0.035
2	2.00	0.75	0.63	0.357
3	3.00	1.00	0.14	0.132
4	4.00	0.63	0.14	0.097
5	5.00	0.70	0.00	0.000
6	6.00	1.30	0.68	0.869
7	7.00	1.70	0.36	0.575
8	8.00	1.40	0.66	0.945
9	9.00	1.30	0.58	0.757
10	10.00	1.25	0.53	0.659
11	11.00	1.05	0.48	0.528
12	12.00	1.30	0.26	0.336
13	13.00	1.50	0.16	0.236
14	14.00	1.50	0.39	0.558
15	15.00	0.80	0.23	0.159
16	15.50	0.00	---	---

Site : SKHOTHAI  
 Ban Dan Lon Hi/Huai Nong Kh  
 Date : Oct. 8 1990  
 Catchment Area : 46 km<sup>2</sup>  
 Total Discharge: 0.257 m<sup>3</sup>/s  
 (5.6 l/s/sq. km<sup>2</sup>)

No.	Measur- ing Point	Water Depth	Velocity (m/sec)	Discharge (m <sup>3</sup> /sec)
0	1.00	0.00	---	---
1	1.50	0.10	0.26	0.013
2	2.00	0.13	0.42	0.028
3	2.50	0.18	0.49	0.045
4	3.00	0.24	0.56	0.063
5	3.50	0.20	0.51	0.051
6	4.00	0.19	0.47	0.044
7	4.50	0.14	0.22	0.013
8	4.80	0.00	---	---

Note : It continues raining heavily for one week in this area.

Site : TAK  
 Khlong Sai/Muang  
 Date : Oct. 6 1990  
 Catchment Area : 51 km<sup>2</sup>  
 Total Discharge: 0.090 m<sup>3</sup>/s  
 (1.8 l/s/sq. km<sup>2</sup>)

No.	Measur- ing Point	Water Depth	Velocity (m/sec)	Discharge (m <sup>3</sup> /sec)
0	1.00	0.00	---	---
1	1.50	0.20	0.00	0.000
2	2.00	0.19	0.22	0.020
3	2.50	0.12	0.30	0.020
4	3.00	0.18	0.28	0.024
5	3.50	0.21	0.29	0.025
6	3.90	0.10	0.00	0.000
7	4.00	0.00	---	---

Site : TAK  
 Khlong Padang/Muang  
 Date : Oct. 6 1990  
 Catchment Area : 116 km<sup>2</sup>  
 Total Discharge: 0.620 m<sup>3</sup>/s  
 (3.7 l/s/sq. km<sup>2</sup>)

No.	Measur- ing Point	Water Depth	Velocity (m/sec)	Discharge (m <sup>3</sup> /sec)
0	1.00	0.00	---	---
1	1.50	0.24	0.05	0.007
2	2.00	0.40	0.42	0.084
3	2.50	0.54	0.63	0.165
4	3.00	0.55	0.52	0.141
5	3.50	0.52	0.46	0.119
6	4.00	0.44	0.31	0.068
7	4.50	0.40	0.09	0.018
8	5.00	0.34	0.06	0.010
10	5.50	0.25	0.05	0.006
11	6.00	0.14	0.04	0.003
12	6.50	0.10	0.00	0.000
13	7.00	0.00	---	---

FIGURE A-1 MEAN ANNUAL RAINFALL (1952 - 1985)

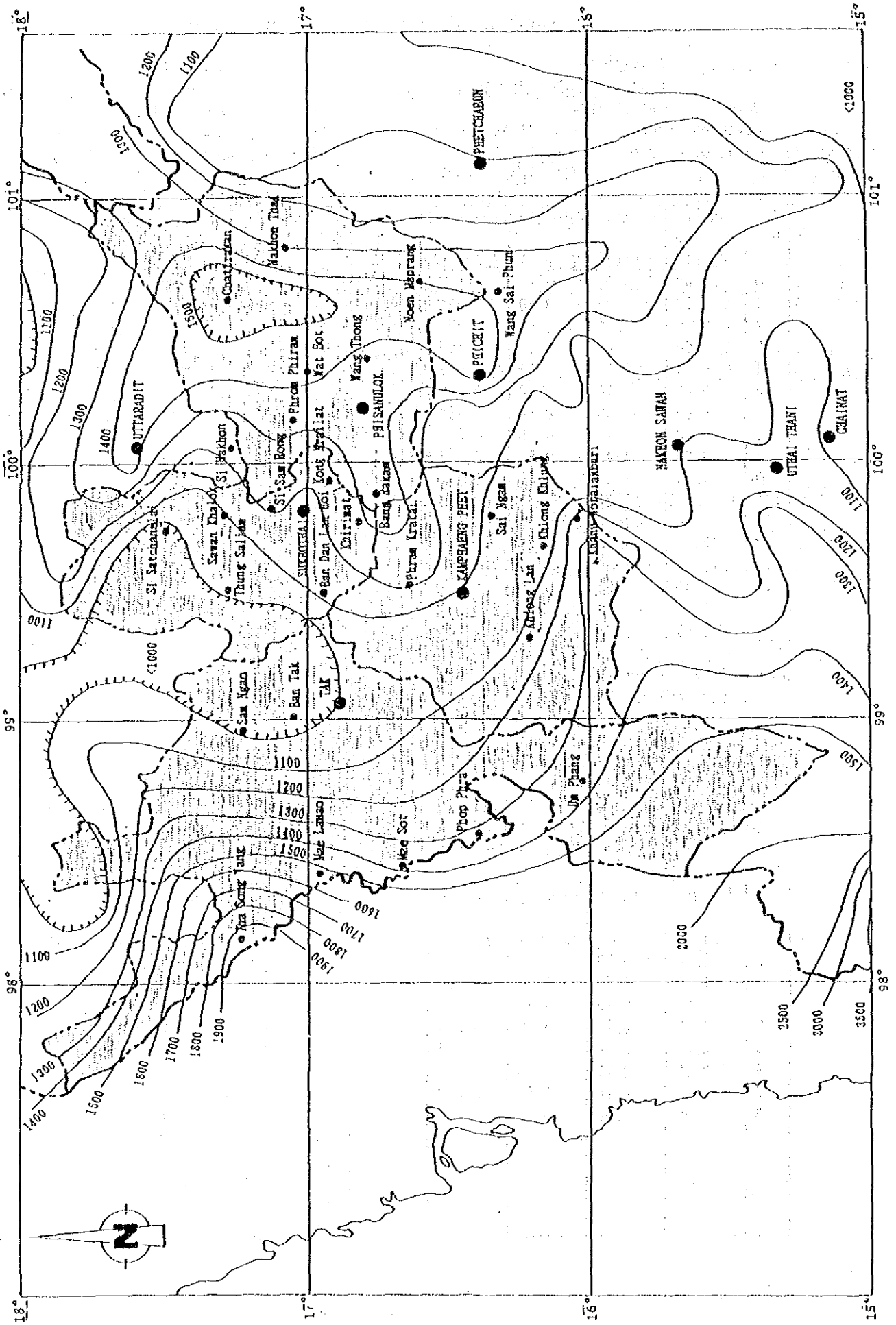


FIGURE A-2 RIVER BASIN

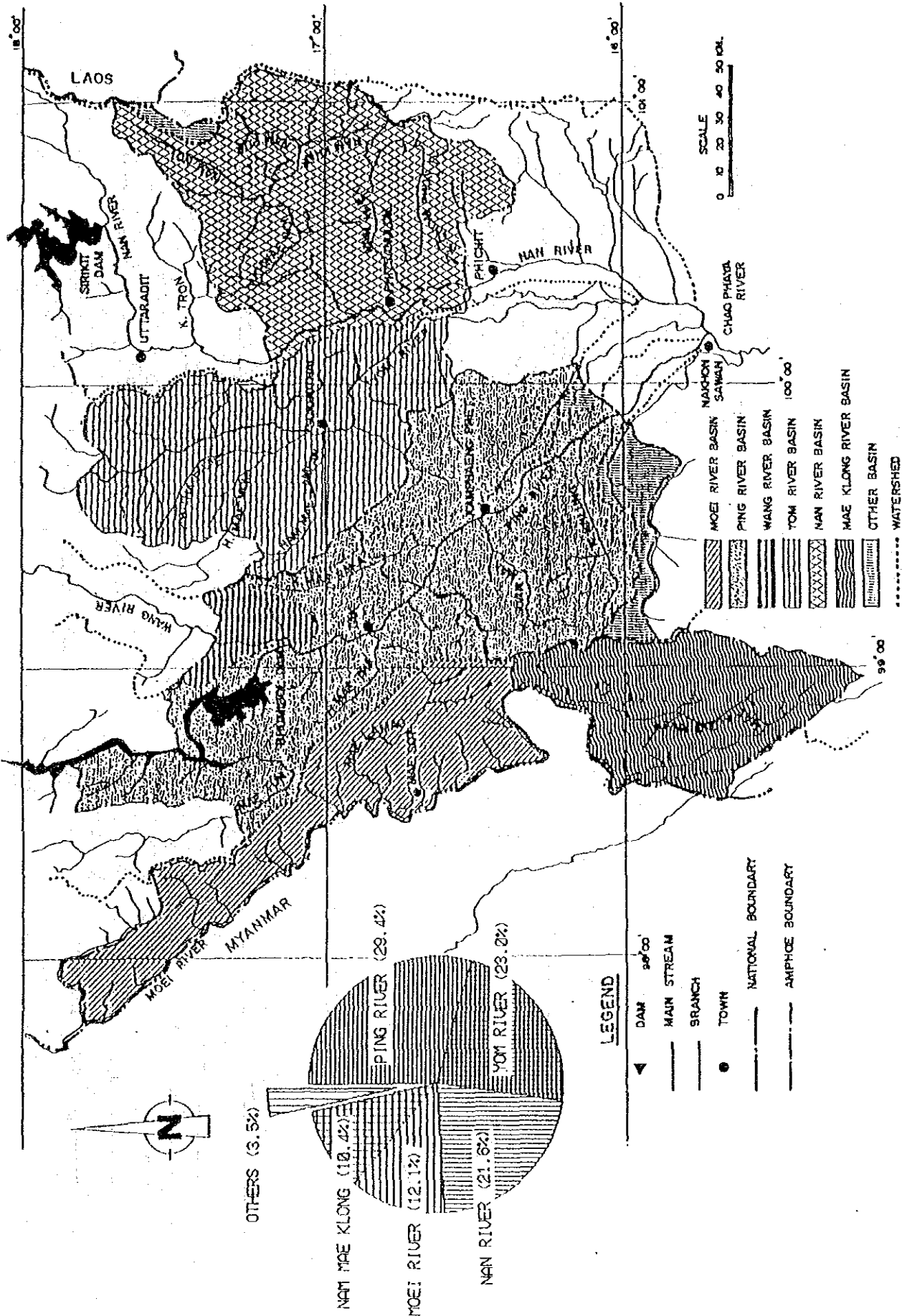


FIGURE A-3 LOCATION OF HYDROLOGIC OBSERVATION STATION

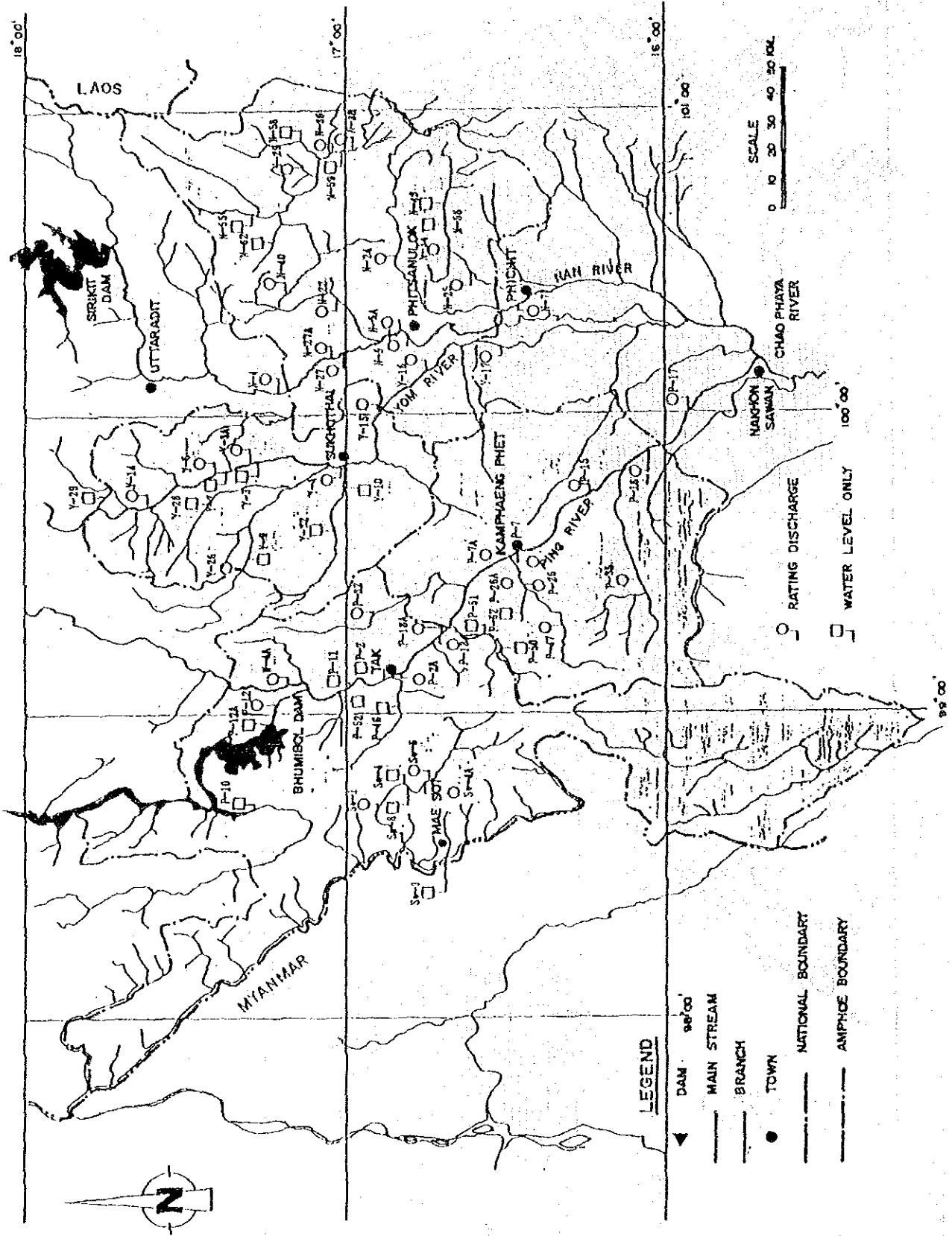
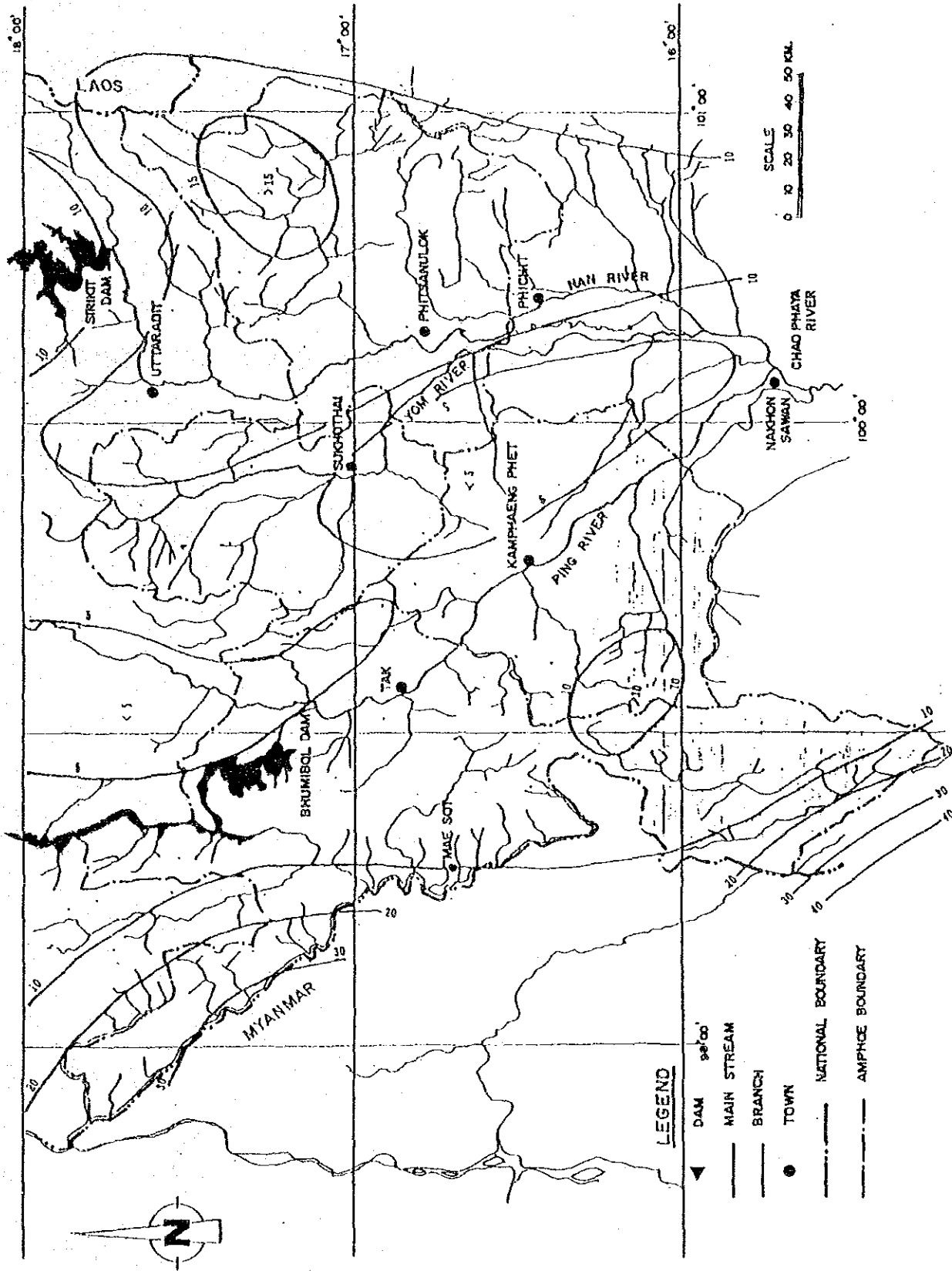


FIGURE A-4 AVERAGE YIELD OF RUN-OFF UNIT ( 1/sec / km<sup>2</sup> )





## **APPENDIX B : TOPOGRAPHY, GEOGRAPHY AND GROUNDWATER**





**APPENDIX B. TOPOGRAPHY, GEOGRAPHY AND GROUNDWATER**

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## **B-1 TOPOGRAPHY**

### **B-1-1 Summary**

In Thailand, the topographic regions, according to the report by F.R. Moormann and S. Rojanasoonthon in 1972, are indicated in Figure B-1. These regional divisions are as follows:

- (1) Central Plain
  - (2) Southeast Coast
  - (3) Northeast Plateau
  - (4) Central Highlands
  - (4) North and West Continental Highlands
  - (6) Peninsular Thailand
- (formed by SOIL SURVEY DIVISION report : The Soils of the kingdom of Thailand, Report SSR-72A, Bangkok 1972)

In study area, among above-mentioned regions, three topographic regions are conformed to the study area.

The three regions are as follows:

- (1) Central Plain
- (4) Central Highlands
- (5) North and West Continental Highlands

### **B-1-2 Regional Division**

The regional divisions are only described about the three regions concerned with the study area.

#### **(1) Central Plain**

This region occupies the lower central part of Thailand; It is bordered by hilly areas on the east, north and west, and by the Gulf of Thailand on the south.

In study area, the north central part of the region is conformed to the some parts of three provinces, they are Phitsanulok, Sukhothai and Khampaeng Phet. This part is mainly occupied by the alluvial terraces of three rivers, Mae Nam Nan, Mae Nam Yom and Mae Nam Ping. the land form is a combination of flatlands, natural levees, backswamps and isolated hills.

(a) Slope

Slope : > about 1/10,000

(b) Land Utilization

Field, orchard, woodland and communities.

(c) Soil and Ground Feature

The large majority of alluvial soils in study area are composed of clay; few percent have a loamy texture, whereas sandy alluvial soils are rare. Soils are with alternate clayey, loamy or sandy layers occur, especially in narrow stream valleys.

The grounds are mainly solid and firm excluding from the backswamp regions.

(2) Central Highlands (northern portion)

This region has a complex landform, including diverging landscape elements such as hills, plateaux, peneplains and a number of valleys.

The Central Highlands are bordered to the east by the Northeast Plateau and to the west by the North and West Continental Highlands, the Central Plain and the Southeast Coast. The boundary with the North and West Continental Highlands is rather arbitrary.

This region is usually subdivided into three subregions; the northern portion, the middle portion and the southern portion.

And then, the northern portion is mostly conformed to the some parts of Phitsanulok Province.

The northern portion of the region is mainly composed of hills and more or less strongly incised plateaux or peneplains, found at varying levels from approximately 1,200 to about 300 meters. The plateau areas are undulating to rolling; the intervening hilly area are steep, with some very steep areas of craggy limestone buttes.

(a) Slope

Slope: from about 1/10,000 to about 1/1,000 (excluding the some hilly areas with craggy limestone buttes). The general topography is undulating to gently rolling, with locally a steep relief due to the presence of outcropping rocks, mainly limestone which frequently form steep and craggy hills.

(b) Land Utilization

The distributions on field, paddy and others, are mainly in concert with the communities.

(c) Soil and Ground Feature

Soils are Red-Brown Earths, on residue and colluvium from basic rocks (mainly limestone). A large part of the ground is to be considered as a peneplain with an unconsolidated soil cover derived from or at least influenced by limestones.

**(3) North and West Continental Highland**

This region is usually subdivided into two subregions; the Western Mountains and the Northern Hills and Valleys. In study area, the Western Mountains are conformed to the some parts of Phitsanulok Province (the border is rather arbitrary), Sukhothai Province, Kamphaeng Phet Province and Tak Province.

The Western Mountains consist of part of the rugged Central cordillera along the Thai-Burma border from about 18 degree in the north to 12 degree, well into the Peninsula. Several sub-parallel ridges, divided by narrow and deep valleys are recognized. And some valley plains are found, they are flat and sedimentary plains among the small valley, and the terrace in small scale and the former river course are found. On the topographic feature, the valley plain is only stated.

(a) Slope

Slope: > 1,000 (each regional difference of slope is large)

(b) Land Utilization

Field, orchard and woodland.

(c) Soil and Ground Feature

Soil is formed by gravel, sand and silt.

## B-2 Geology

According to the geological map by Geological Survey Division of Mineral Resources of Ministry of Industry in 1981, the bedrocks (basement complex) on study area are classified into three kinds; the sedimentary rocks, metamorphic rocks and igneous rocks. And the tectonic lines are mainly found in parallel with the border line of Central Plain of the classification on topographic regions.

### B-2-1 Quaternary Sedimentary Rocks

Quaternary sedimentary rocks are basement complexes of Central Plain in the topographic regions, and classified into two kinds; Alluvium and Diluvium.

(1) Alluvium

Alluvium is the recent flood plain, and made up of alluvial sand, silt, backswamp deposits.

(2) Diluvium

Diuvium is the undulating formation in some degree, and made up of terrace gravel, sand, silt, laterite and lateritic soil.

**B-2-2 Cretaceous-Jurassic-Triassic Sedimentary Rocks**

The Cretaceous-Jurassic-Triassic sedimentary rocks are generally called as Khorat Group, mainly sandstones, shales and some conglomerates. And they are found in the Central Highlands, their colors are many different; reddish brown, yellowish brown, brown, white, pale brown, pale orange, purplish brown, purplish red, pink, and gray to black. On Khorat group, some faults and folds are found, and the tectonics is complex.

**B-2-3 Triassic Sedimentary Rocks**

The Triassic sedimentary rocks are classified into two kinds; general sedimentary rocks and Lampang Group.

(1) General Sedimentary Rocks

The general sedimentary rocks are made up of conglomerate, sandstone, intercalates of shale and limestone with fossils. And limestone is light gray to dark gray, massive to well bedded and with calcareous shale, and also sandstone and lime-conglomerate are gray to brownish gray. And the general sedimentary rocks in Triassic are found at the area along the border between Thailand and Burma in the North and West Continental Highlands (Tak Province).

(2) Lampang Group

Lampang Group is found in North and West Continental Highlands, made up of limestone, shale, sandstone, liemstone and conglomerate. The

limestone is gray to dark gray pinkish gray, massive to well bedded with fossils. The shale is greenish gray, dark gray or olive gray, laminated with fossils, and calcareous in some parts. The sandstone is gray, greenish gray, greenish brown, reddish brown, with calcareous and well stratified and fossils in some parts. The liemstone conglomerate is made up of agglomerate tuff, basal conglomerate and mudstone. On Lampang Group, some faults and folds are found, and the tectonics is complex.

#### **B-2-4 Permian-Carboniferous Sedimentary Rocks**

Permian-Carboniferous sedimentary rocks are found in Central Highlands and in North and West Highlands, made up of limestone, shale, sandstone, chert, tuff, agglomerate, rhyolite, andesite, pebbly shale and pebbly sandstone. Limestone is light to dark gray, bedded with fossils. Shale is red, gray to black, carbonaceous, calcareous, laminated to thin bedded with fossils. Chert is black, nodular or thin bedded. And the above stated sedimentary rocks had bedded in the Permian.

Pebbly shale and pebbly sandstone are gray to dark gray, greenish gray, brown, laminated to thick bedded, conglomerate and tuff. And these sedimentary rocks had bedded from the first stage in the Carboniferous to the last stage in the Permian.

#### **B-2-5 Carboniferous Sedimentary Rocks**

Carboniferous sedimentary rocks are made up of shale, chert, limestone and other rocks. Shale is gray, greenish gray, brownish gray, red and reddish brown. Chert is banded to massive. Limestone is light gray to gray, thin bedded to massive. Other rocks are sandstone, conglomerate, greywacke, sandstone agglomerate, rhyolitic agglomerate, tuff and volcanic conglomerate.

#### **B-2-6 Devonian-Silurian Metamorphic Rocks**

Devonian-Silurian metamorphic rocks made up of phyllite, phyllitic schist, phyllitic tuff, quartzite, shale with fossils, chert, greywacke and limestone.



### **B-2-7 Ordovician Sedimentary Rocks**

Ordovician sedimentary rocks are made up of limestone, shale and quartzite. Limestone is light gray, dark gray and bluish gray, massive to thin bedded, recrystallized, with argillaceous layers. Shale is greenish gray, dark gray.

### **B-2-8 Cambrian Metamorphic Rocks**

Cambrian metamorphic rocks are made up of sandstone, quartzite, phyllite, quartz-mica schist; brownish gray, brown, yellowish brown, locally red sandstone and shale.

### **B-2-9 Precambrian Metamorphic Rocks**

Precambrian metamorphic rocks are made up of metamorphic complexes of amphibolite facies, biotite-microcline gneiss, quartzite-feldspathic gneiss, biotite schist, banded quartzite, and marble, and well bedded.

### **B-2-10 Igneous Rocks**

In study area, the volcanic activity was in the era between the Paleozoic and the Mesozoic. And igneous rocks are classified into two kinds; granitic complexes and volcanic complexes.

#### **(1) Granitic Complexes**

The granitic complexes are made up of granite, granodiorite and diorite. And they widely range in the North and west Continental Highlands.

#### **(2) Volcanic Complexes**

Volcanic complexes are made up of rhyolite, andesite, tuff and agglomerate, and formed from the Jurassic to the Cretaceous. They are generally with ranging far and wide.

## **B-2-11 Province Geological Feature**

### **(1) Phitsanulok Province Geological Feature**

On Phitsanulok Province geological feature, the Khorat Group sedimentary rocks range on the eastern part (from the northeastern part to the southeastern part) and their proportion for the province area is amounted to about 60% , the rest is mainly the quaternary sedimentary rocks; Alluvium and Diluvium, the former area is less than the later, only about 30% of the area of the later. On Khorat Group, many faults and folds are found.

### **(2) Sukhothai Province Geological Feature**

On Sukhothai Province geological feature, the Quaternary sedimentary rocks are found almost in the eastern and the middle-western parts, and their area are amounted to about 60% of the province area, the area of Alluvium and Diluvium is almost equal, and the rest is made up of the Lampang Group sedimentary rocks, the Permian-Carboniferous sedimentary rocks, the Carboniferous sedimentary rocks and the Devonian-Silurian metamorphic rocks.

The Lampang Group sedimentary rocks are situated on the western part of the north mountain region, and tectonics and folds are found in the part.

The Permian-Carboniferous sedimentary rocks are mainly found in the north mountain region, their area are amounted about 20% of the province area, and tectonics and folds are almost not found in the region. The Carboniferous sedimentary rocks are only found in the south-western part. The Devonian-Silurian metamorphic rocks are mainly situated contacting with the southern border of the Lampang Group and Permian-Carboniferous sedimentary rocks.

### **(3) Kamphaeng Phet Province Geological Feature**

On Kamphaeng Phet geological feature, the Quaternary sedimentary rocks are in the proportion of about 70% for the province area, almost the Diluvium sedimentary rocks, and the rest is made up of the various rocks; sedimentary rocks and metamorphic rocks in the Triassic, the Carboniferous,

the Devonian-Silurian, the Precambrian, and igneous rocks (the granite complexes and the volcanic complexes).

The Triassic sedimentary rocks are found in the south-west part along the great tectonic line, their area are not so much wide and long, and are slender. The Carboniferous sedimentary rocks are only found in a part of the north area. The Devonian-Silurian metamorphic rocks lie scattered all but the eastern area. The Ordovician sedimentary rocks and the Cambrian metamorphic rocks are limited to the west side area Cambrian metamorphic rocks are limited to the west side area of the great tectonic line, and the Ordovician sedimentary metamorphic rocks. The Precambrian metamorphic rocks are situated at the west side of the great tectonic line, abound with many tectonic lines, and their area are amounted over 20% for the province area. The igneous rocks (the granite complexes and the volcanic complexes) lie scattered in the parts from the north region to the west region.

#### **(4) Tak Province Geological Feature**

On the Tak Province geological feature, the rocks are mainly made up of the Quaternary, the Triassic, the Permian-Carboniferous, the Carboniferous, the Devonian, the Ordovician, the Cambrian, the Precambrian and the igneous.

On the north side of the great tectonic line, the Ordovician sedimentary rocks and granitic rocks (complexes) are mainly found, and the other sedimentary rocks or metamorphic rocks are only dotted. And the Quaternary sedimentary rocks are found only along the Mae Nam Ping River in a narrow range (their area are in a small scale). The granitic complexes are ranged in the proportion of about 70% for the north side area of the great tectonic line, and the Ordovician sedimentary rocks are ranged in the proportion of about 20%. The other rocks are only found among the above-state rocks in a small scale area.

On the south side of the great tectonic line, the rocks are mainly the Quaternary, the Triassic, the Permian Carboniferous, the Devonian-Silurian and the Cambrian; their proportion is about 60% for the south side area. The Quaternary sedimentary rocks are found at the two parts; the first place is along the border line between Thailand and Burma near by Mae Sot city, the second place is at the valley plain near by the middle point of the great tectonic

line, their area are range in the proportion of about 10%. The other rocks are dotted.

### **B-3 Groundwater**

According to the hydrogeological map by Geological Survey Division of Mineral Resources Department of Mineral of Industry in 1982, the groundwater is found in three kinds of the aquifers; the porous rock aquifers, the jointed massive rock aquifers, an the metamorphic aquifers and igneous rock aquifers.

#### **B-3-1 Porous Rocks Aquifers**

Porous rocks aquifers are mainly situated at the Central plain in Topographic Regions of Thailand, made up of three kinds of aquifers; Chao Phraya aquifers, Chiang Mai aquifers and Chiang Rai aquifers. Chao Phraya aquifers were formed in Holocene (alluvial epoch), Chiang Mai aquifers were formed in Upper Tertiary to Pleistocene and Chiang Rai aquifers were formed in Pleistocene (diluvial epoch). And then these aquifers are classified into three classes according to the extent of the region area. On the study area, the 8 kinds of aquifers are applicable.

##### **(1) Extensive and Productive Aquifers**

###### **(a) Chao Phraya Aquifers (Holocene)**

The aquifers are alluviums on flood plain and meander belts. Thickness rarely exceed 50 meters in the river valley but reach 100 meters or more than in the Upper Central Plain; Successive layers of sands and gravel form major aquifers; yielding from 200 to 500 gpm of good quality water.

###### **(b) Chiang Mai Aquifers (Upper Tertiary to Pleistocene)**

The aquifers are consisted of unconsolidated to semi-consolidated sand-gravel and clay beds. Thicknesses are generally in excess of 300 meters. Yields range from 500 to 1,000 gpm of good quality water.

## **(2) Extensive but Moderate Productive Aquifers**

### **(a) Chao Phraya Aquifers (Holocene)**

The aquifers are consisted of alluviums of same origins as those mentioned above but yield less quantity of water, principally due to thin productive zones. Yield ranges are generally 100 to 200 gpm of water of relatively good quality.

### **(b) Chiang Rai Aquifers (Pleistocene)**

The aquifers are consisted of thick sequence of clays with minor or local sand and gravel beds. Generally form low relatively flat-surfaced terraces. Thicknesses are generally over 100 meters but rarely exceeding 30 meters in western part of Upper Central Plain. Yield is normally less than 200 gpm.

### **(c) Chiang Mai Aquifers (Upper Tertiary to Pleistocene)**

The aquifers are consisted of terrace deposits of the same characteristics as those mentioned above but yield less quality of water, principally due to smaller grain sizes and poorer assortment. Yields are normally about 200 to 500 gpm of potable water.

## **(3) Local and Less Productive Aquifers**

### **(a) Chiang Rai Aquifers (Pleistocene)**

The aquifers are consisted of thick sequence of clays, with minor sand and gravel beds as those mentioned above but yield less quantity of water from localized sand or gravel lenses. Yield are only few to about 50 gpm of good quality water.

## **(4) Local and Unimportant Aquifers**

### **(a) Chiang Rai Aquifers (Pleistocene)**

The aquifers are consisted of thick sequence of clays layers, with occasional sand lenses, exposed along edges of basin or narrow valley.

Thicknesses are commonly not significant. Yield only small quantity of groundwater.

(b) Chiang Mai Aquifers (Upper Tertiary to Pleistocene)

The aquifers are include older terrace deposits of limited thickness, and colluvium on bed rock terranes. Both types of sediments are usually located along the peripheries of basins or along foot hills, and in many areas are above water table. After rainy season the sediments retain some sub-soil water which is important sources for shallow dug wells. Under favorable condition small quantity of groundwater can be developed for domestic uses.

**B-3-2 Jointed Massive Rock Aquifers**

The jointed massive aquifers are situated at the Central Highlands and the North and West Continental Highlands in Topographic Regions of Thailand, classified into two classes; extensive and productive aquifers and extensive but less productive aquifers.

The extensive and productive aquifers are classified into two classes; Lower Khorat aquifers (Upper Triassic to Jurassic) and Carbonate aquifers (Ordovician and Permian). Lower Khorat aquifers are mainly found in the Central Highlands, and Carbonate aquifers are only in the western parts of the North and west Continental Highlands.

The extensive but less productive aquifers are classified into four classes; Mae Sot aquifers (Tertiary), Middle Khorat aquifers (Jurassic), Lampang aquifers (Triassic) and metamorphism sediment aquifers (Permian to Carboniferous). Mae Sot aquifers are only found centering around Mae Sot city, along the boundary between Thailand and Burma. Middle Khorat aquifers are only found in the Central Highlands. Lampang aquifers and metamorphism sediment aquifers are mainly found in the North and West Continental Highlands (but metamorphism sediment aquifers are found in the southern part of the Central Highlands).

## **(1) Extensive and Productive Aquifers**

### **(a) Lower Khorat Aquifers (Upper Triassic to Jurassic)**

The aquifers are consisted of variegated shales, sandstones of Phu Kradung formation, siltstones, sandstones and some conglomerates of Nam Phong formation. Yield ranges of 20 to 100 gpm. Water quality is generally good for domestic purpose. Depth is not over 200 feet.

### **(b) Carbonate Aquifers (Ordovician and Permian)**

The Carbonate aquifers are classified into two classes; Rat Buri Group and Thung Song Group.

Rat Buri Group (Pc) is made up of the Permian limestone. In the Rat Buri limestones, groundwater occur mainly in solution cavities, and occasionally the faults zones. The average yield is about 100 gpm but yield up to 200 gpm can be expected.

Thung Song Group (Oc) limestones yield 20 to 50 gpm of water from small solution cavities and fractures. Water quality is generally moderately hard to hard.

## **(2) Extensive but Less productive Aquifers**

### **(a) Mae Sot Aquifers (Tertiary)**

The aquifers are generally not very productive due to semi-consolidated of properties and the poorly developed fissure system. Yielding from meager to about 20 to 30 gpm is common.

### **(b) Middle Khorat Aquifers (Jurassic)**

The aquifers are consisted of yellowish gray to grayish pink massive sandstones and conglomerates of Phu Phan formation. Yield ranges of very few to 20 gpm is common. Water quality is generally excellent.

(c) Lampang Aquifers (Triassic)

The aquifers are consisted of thick sequence of dark gray friable marine shales and thin bedded fine grained sandstones with limestone intercalation. Layer of tuffs and agglomerates are present at the lower parts. Yield range from very few to about 50 gpm of portable water from the poorly inter-connected jointing system. Water quality is generally good.

(d) Metamorphism Sediment Aquifers (Carboniferous)

The aquifers are consisted of clastic sedimentary rocks belonging to Rat Buri and Kaeng Krachan Groups of which quartzitic sandstones, feldspathic sandstones, phyllite to shales, and graywackes are predominated interbedding tuffs and agglomerates occur in places. Groundwater occur, only in joints and fractures which are generally complex but not well inter-connected. Yield range from meager to about to 20 gpm.

**B-3-3 Metamorphic Aquifers and Igenous Rock Aquifers**

On those aquifers, the local groundwater is generally found in joints and fractures which are generally complex but not well inter-connected. But groundwater is commonly devoid in many places, although some wells penetrating the relatively recent fissures may yield sufficient amount of water for domestic purposes.

(1) Metamorphic Aquifers (Cambrian to Devonian)

The aquifers are consisted of metamorphic rocks in ages from Cambrian to Devonian. Slates, phyllites, quartzites and schist are dominant. Marbles and phyllitic tuffs are also present. The rocks are complexly folded, contorted or crumpled and subject to various degrees of faulting and fracturing, but the fissure system is not well interconnected. Groundwater is devoid in many places although some wells penetrating the relatively recent fissures may yield sufficient amount of water for domestic purposes.



## (2) Volcanic Aquifers

The aquifers are consisted of andesite, tuff, agglomerate and pyroclastic rocks of many age and the Tertiary basalt. The rocks are generally massive and poorly bedded. Small amount of groundwater can be obtained from fractures or bedding planes. Drilled wells are generally pumped dry or may yield few of potable water.

## (3) Granitic Aquifers

The aquifers are a combination of granites, and associated intrusive rocks and gneisses. Small quantity of groundwater can be mainly obtained from jointing system or decomposed zones at a rate meager to about 10 gpm, although yield of up to 30 gpm has been obtained.

### **B-3-4 Aquifer Features of the Provinces (Phitsanulok, Sukhothai, Kamphaeng Phet and Tak)**

#### (1) Aquifer of Phitsanulok Province

The aquifers of Phitsanulok Province are made up of 11 aquifers. The productive aquifers are only 2 aquifers but their yields range from 200 to 1,000 gpm, their areas are about 15% in the proportion for the province area. The moderate productive aquifers are 3 aquifers, their yields range from 200 to 500 gpm and their areas are about 10% in the proportion for province area. The less productive aquifers are Chiang Rai aquifers, yielding only few to about 50 gpm, but their areas are 10% in the proportion for the province area. And the above mentioned aquifers belong to the Central Plain. On the aquifers in the Central Highlands, Lower Khorat aquifers and Carbonate aquifers are productive aquifers, both yields range from 20 to 100 gpm and both areas are about 10% in the proportion for the province area. 3 aquifers belong to the Central Highlands, the less productive aquifers, are Middle Khorat aquifers, yielding from very few to 20 gpm but their area are about 65% in the proportion for the province area.

## (2) Aquifers of Sukhothai Province

The aquifers are made up of 10 aquifers. The productive aquifers are Chao Phraya aquifers, yielding from 200 to 500 gpm. The moderate aquifers are 3 aquifers, yielding from 100 to 500. The less productive aquifers are Chiang Rai aquifers, yielding from only few to 50 gpm, the above mentioned aquifers are about 50% in the proportion for the province area. Local unimportant aquifers are Chiang Rai aquifers, under favorable condition small quantity of groundwater can be developed, and their area are about 20% in the proportion for province area. The other 4 aquifers belong to the highland regions, yielding from very few to 50 gpm, and their area are about 30% in the proportion for the province area.

## (3) Aquifers of Kamphaeng Phet Province

The aquifers of Kamphaeng Phet Province are made up of 9 aquifers. The productive aquifers are 3 aquifers, yielding from 100 to 500 gpm, and their area are about 40% in the proportion for the province area. Local unimportant aquifers are Chiang Mai aquifers, and their area are about 40% in the proportion for the province area. The other 5 aquifers belong to the highland regions, yielding from very few to about 50 gpm.

## (4) Aquifers of Tak Province

The aquifers of Tak Province are made up of 13 aquifers, 3 aquifers (metamorphism sediment aquifers, metamorphic aquifers and granitic aquifers) are about 80% in the proportion for the province area, yielding from meager to 20 gpm. As the productive aquifers (in consideration of the jointed massive and metamorphic aquifers), 3 aquifers (the Rat Buri Group, the Thung Song Group and Mae Sot aquifers) are found, yielding from 20 to 100 gpm, and their area are about 15% in the proportion for the province area.

## B-4 WATER QUALITY TEST FOR DRINKING WATER ON WELLS

In study area, the water quality test for drinking water on well or rain water (including stream water) was carried out with 29 water samples collected at 25 villages on four provinces; Phitsanulok, Sukhothai, Kamphaeng Phet and

Tak. And on 29 water samples, the provinces and villages concerned with the collecting of water samples are as follows:

- (1) Phitsanulok : 3 samples (inc. one Mt. stream samples)  
3 villages
- (2) Sukhothai : 13 samples (inc. two rain water samples)  
10 villages
- (3) Kamphaeng Phet : 13 samples (inc. two rain water samples)  
9 villages
- (4) Tak : 6 samples (inc. two rain water samples)  
3 villages

The water quality test on the field was carried out, dating from Aug. 14 to Aug. 30 in 1990.

#### B-4-1 Test Items

- |                                    |                           |
|------------------------------------|---------------------------|
| (1) water temperature              | (2) turbidity             |
| (3) color                          | (4) electric conductivity |
| (5) chemical oxyegen demand        | (6) calcium               |
| (7) pH                             | (8) bacterium coli        |
| (9) bacteria total                 | (10) chloride             |
| (11) hardness (CaCO <sub>3</sub> ) | (12) iron total           |
| (13) manganese                     | (14) ammonia              |
| (15) chromium hex                  | (16) zinc total           |
| (17) nickel                        | (18) copper               |

#### B-4-2 Test Result

On the test result, the items concerned with the value of Thailand Standard Rule for drinking water are mainly explained, and others are referred to the table of Water Quality Test.

##### (1) Water Temperature

The water temperature is not indicated in Thailand Standard Rule for drinking water, because the water temperature is an important item from a point of view on the water quality test, the 29 water samples were carried out

on the water temperature measurement, ranging from 26.7 deg. to 31.2 deg. On the water temperature, the difference between the shallow well and the deep well could not make out, but the water temperature of Mt. stream is low as a rule; about 27 degree.

## (2) Water Turbidity

The 22 water samples in the 29 samples were carried out on the water turbidity test, the any samples over the allowable value of Thailand Standard Rule are not found, and then the water quality is good in the water turbidity, ranging from 1 to 20 degree.

And the difference between the shallow well and the deep well could not make out.

## (3) Water Color

The water color is much the same as the water turbidity, and then the water quality is good in the water color, ranging from 4 to 50 degree. And also the difference between the shallow well and the deep well could not make out.

## (4) Electric Conductivity

The electric conductivity is much the same as the water temperature, the 29 samples were carried out on the electric conductivity measurement, ranging from 42 micro mho to 1,050 micro mho. And also the difference between the shallow well and the deep well could not make out, but the electric conductivity on Mt. stream and rain water is low; ranging from about 80 micro mho to 100 micro mho.

## (5) Calcium

On Thailand Standard Rule for drinking water quality, calcium content in drinking water is indicated but calcium content in groundwater for drinking purpose is not indicated, however calcium content in drinking water is an important item from a point of view on water quality test. And then the 22 water samples were carried out on water quality test. In study area, the 22

water samples are abound with calcium, ranging from 50 ppm to 1,100 ppm (50 ppm water samples are only two samples).

On calcium content, the differences among Phitsaulok Province, Sukhothai Province, Kamphaeng Phet Province and Tak Province are found. The differences are from that the sedimentary rocks (limestones as typical rocks) are different from their geological time. Now, quoting Thailand Standard Rule for drinking water, the arrangement on water quality test is as follows:

- (a) 2 water samples, on Phitsanulok Province, were carried out on the calcium content test. 3 water samples are less than 200 ppm, ranging from 110 ppm to 150 ppm, the geological time on the sedimentary rocks in Phitsanulok ranges from Triassic to Quaternary-Recent, dating from 230 million years ago to the present time.
- (b) 10 water samples, on Sukhothai Province, were carried out on the calcium content test. 8 water samples are over 200 ppm or equal to 200 ppm, 2 water sample are over 200 ppm, ranging from 260 ppm to 450 ppm, the geological time on the sedimentary rocks in Sukhothai Province ranges from Carboniferous-Permian to Quaternary-Recent, dating from 280 million years ago to the present time.
- (c) 5 water samples, on Kamphaeng Phet Province, were carried out on the calcium content test. 1 water sample is 150 ppm, less than 200 ppm. And 4 water samples are over 200 ppm, ranging from 300 ppm to 1,000 ppm, the geological time on sedimentary rocks in Kamphaeng Phet Province ranges from Precambrian to Quaternary-Recent, dating from 4,000 million years ago to present time. (Cambrian, dating from about 570 million years ago to 500 million years ago)
- (d) 4 water samples, on Tak Province, were carried out on the calcium content test, ranging from 50 ppm. (2 water samples) to 850 ppm, the geological time on sedimentary rocks in Tak Province is as stated above (the Kamphaeng Phet Province geological time).

## **(6) pH**

On the pH measurement, 29 water samples (all water samples) were carried out, test results are as follows:

- (a) 3 water samples, on Phitsanulok Province, ranging from 5.8 to 7.5.
- (b) 13 water samples, on Sukhothai Province, ranging from 6.2 to 8.5.
- (c) 7 water samples, on Kamphaeng Phet Phet Province, ranging 6.1 to 7.1.
- (d) 6 water samples, on Tak Province, ranging from 6.7 to 8.6.

On the pH measurement results, the difference among Phitsanulok Province, Sukhothai Province, Kamphaeng Phet Province and Tak Province is particularly not found.

## **(7) Bacterium Coli**

The bacterium coli content tests for water samples were carried out by Test Paper Method (TRA-CG) on 22 water samples, and on the test results, the coliform bacteria are generally found in the open shallow wells; 10 shallow wells in 14 shallow wells, ranging from 2 per 100 ml to 35 per 100 ml on the bacterium coli content test. And the coliform bacteria in 9 shallow wells are over 2.2 per 100 ml (Thailand Standard Rule for drinking water quality), ranging from 5 per 100 ml to 35 per 100 ml. But on the closed shallow wells with manual pumps, the coliform bacteria are not found.

On the deep wells (2 deep wells), the coliform bacteria are not found.

### **B-4-3 The Rest Items on Water Quality Test**

About on the water quality test of the rest items (chloride content, hardness ( $\text{CaCO}_3$ ), iron total content, manganese content, zinc total content and copper content) excepting from the zinc total and the copper, 22 water samples were carried out. 10 water samples are less than the value of Thailand Standard Rule for drinking water quality on the rest items, because we didn't keep all quantities of Test Paper for all the rest items on water quality test.

On the rest items, including the other items, it hopes that the water quality test will be carried out by the different facilities in Thailand.

## **B-5 WATER QUALITY, SOIL INVESTIGATIONS AND GEOLOGICAL SURVEY**

### **B-5-1 Water Quality**

On the water quality of groundwater in study area, according to the Inspection of Groundwater Quality for Drinking Purpose caused by JICA's Project, 12 water samples was carried out in laboratory by Water Quality Control Division Provincial Waterworks Authority from January 21 to February 11 in 1991.

#### **1) Sampling Locations and Type of Samples**

Sampling Locations and Type of Samples are as follows.

##### **Phitsanulok Province**

- (1) Sampling Location : Ban Kaeng Wa-Hi School, Nakornthai  
Type of Sample: Shallow well water (5 meters in depth)
- (2) Sampling Location: Ban Laeng Moo 11, Nakornthai  
Type of Sample: Shallow well water (3 meters in depth)

##### **Sukhothai Province**

- (1) Sampling Location: Ban Kok Kwai Yai Long, Ban Dan Lan Hoi  
Type of Sample: Shallow well water (5 meters in depth)
- (2) Sampling Location: 170/1 Moo 8 Ban Wang Pthong, Ban Dan Lan Hoi  
Type of Sample: Shallow well water (5 meters in depth)

##### **Kamphaengphet Province**

- (1) Sampling Location: 14 Ban Nam Dib Maphrao, Prankratai

**Type of Sample: Shallow well water (3 meters in depth)**

- (2) **Sampling Location: Opposite of Village Leader's House Ban Samokhon**  
**Type of Sample: Shallow well water (5 meters in depth)**

#### **Tak Province**

- (1) **Sampling Location: Ban Wang Tamlung School, Muang Tak**

**Type of Sample: Shallow well water (>10 meters in depth)**

- (2) **Sampling Location: 236 Ban Na Bot, Muang Tak**

**Type of Sample: Shallow well water (4.5 meters in depth)**

#### **2) Analyses Items**

**Analysis items are as follows.**

##### **(1) Physical Property**

(a) **Color**

(b) **Turbidity**

(c) **pH**

##### **(2) Chemical Property**

(a) **Iron**

(b) **Manganese**

(c) **Copper**

(d) **Zinc**

(e) **Sulfate**

(f) **Chloride**

(g) **Fluoride**

(h) **Nitrate as N**

(i) **Total Hardness as CaCO<sub>3</sub>**

(j) **Non-Carbonate Hardness as CaCO<sub>3</sub>**

(k) **Total Solids**



**(3) Bacteria Properties**

- (a) Standard Plate Count
- (b) Coliform Bacteria
- (c) E. Coli

**3) Results of Water Analysis**

**(1) Physical Property**

On physical property, it is various of every project area.

**Huai Sam Ru Project Area (Phitsanulok Province)**

On Color, it is in conformity with the Groundwater Quality Standard. But on Turbidity, ranging from 15 to 18, it exceeds suitable allowance of the Groundwater Quality Standard, and on pH, ranging from 5.7 to 6.06, it exceeds max. allowance of the Groundwater Quality standard.

**Huai Nong Kho Project Area (Sukhothai Province)**

On Color, it is in conformity with the Groundwater Standard. But on Turbidity, ranging from 6.26 to 1.3, is various, and the value of the former exceeds suitable allowance of the Groundwater Quality Standard. And on pH, ranging from 6.26 to 6.96, it is various, and the value of the former exceeds max. allowance of the Groundwater Quality Standard.

**Khlong Samo Khon Project Area (Kamphaengphet Province)**

On Color it is in conformity with the Groundwater Quality Standard. But on the Turbidity, ranging from 180 to 0.85, it is various, and the value of the former exceeds max. allowance of Groundwater Quality Standard. And on pH, ranging from 5.93 to 6.78, it is various, and the value of the former exceeds max. allowance, the latter value exceeds suitable allowance of the Groundwater Quality Standard.

#### **Khlong Sai Project Area (Tak Province)**

On physical properties, they are about in conformity with the Groundwater Quality Standard.

#### **(2) Chemical Property**

On chemical properties, they are in various values every project area.

#### **Huai Sam Ru Project Area (Phitsanulok Province)**

On chemical properties, they are about in conformity with the Groundwater Quality standard. But on Iron, ranging from 0.38 to 1.0, it is various and the value of the latter exceeds suitable allowance of Groundwater Quality Standard.

#### **Huai Nang Kho Project Area (Sukhothai Province)**

On chemical properties, they are in conformity with the Groundwater Quality Standard.

#### **Khlong Samo Khon Project Area (Kamphaengphet Province)**

On Iron, ranging from 3.3 to 0, it is various and the value of the former exceeds max. allowance of the Groundwater Quality Standard. On Chloride, ranging from 23 to 272, it is various and the value of the latter exceeds suitable allowance of the Groundwater Quality Standard.

#### **And on Total**

Hardness, ranging 16 to 936, Non-Carbonate Hardness, ranging from 6 to 390, and Total Solids, ranging from 360 to 1510, are various. And the values of the latter exceed max. allowance of the Groundwater Quality Standard.

#### **Khlong Sai Project Area (Tak Province)**

On Floride, ranging from 3.7 to 0.68, it is various and the value of the former exceeds max. allowance of the Groundwater Quality Standard. And on Total Hardness, ranging 428 to 178, Total Solids, ranging from 1180 to 240, they are various, the values of the former exceed suitable allowance of the Groundwater Quality Standard.

### (3) Bacteria Property

On bacterial property, it is different of every project area.

#### Huai Samo Ru Project Area (Phitsanulok Province)

On E. coli, it is in conformity with standard Value. But on Standard Plate Count, ranging from 34000 to 0, and Coliform Bacteria, ranging from 3000 to 0, they are various. Both values of the former exceed suitable allowance of the Groundwater Quality Standard.

#### Huai Nong Kho Project Area (Sukhothai Province)

On Standard Plate, ranging from 0 to 200000, Coliform Bacteria, ranging from 0 to 5000, and E. coli, ranging from 0 to present, they are various. And the values of latter exceed suitable allowance of the Groundwater Quality Standard.

#### Khlog Samo Khon Project Area (Kampaengphet Province)

On Standard Plate, ranging from 0 to 5600, Coliform Bacteria, ranging from 0 30,000, and E. coli, ranging from 0 to present, they are various. And the values of the latter exceed suitable allowance of the Groundwater Standard.

#### Khlong Sai Project Area (Tak Province)

On Standard Plate Count, ranging from 36500 to 0, Coliform Bacteria, ranging from 8 to 0, they are various. And the values of the former exceed suitable allowance of the Groundwater Quality Standard.

## B-5-2 Soil Investigations

On the soil for dam embankment, according to the Inspection caused by JICA's Project, 40 soil samples was carried out in soil investigations by K. Engineering Consultants Co., Ltd. from February 5 to February 22 in 1991.

### 1) Items on Soil Investigation (in Laboratory)

- |  |   |            |
|--|---|------------|
| (1) Water content                      | : | 40 samples |
| (2) Specific gravity                   | : | 20 samples |
| (3) Wet and dry density                | : | 40 samples |
| (4) Sieve analysis                     | : | 12 samples |
| (5) Hydrometer test                    | : | 12 samples |
| (6) Liquid and plastic limits          | : | 12 samples |
| (7) Unconfined compression test        | : | 12 samples |
| (8) Direct shear test (CU test)        | : | 12 samples |
| (9) Compaction test (Standard Proctor) | : | 12 samples |

### 2) Soil Sampling

#### (1)

- (1) Sampling location
- (1) Huai Sam Ru dams site (Phitsanulok Province)
  - (2) Huai Nong Kho dams site (Sukhothai Province)
  - (3) Khlong Samo Khon dams site (Kamphaengphet Province)
  - (4) Khlong Sai dams site (Tak Province)

### 3) Sampling Type

- |                         |   |  |
|-------------------------|---|--|
| (1) Undisturbed Samples | : | 40 samples                             |
|                         |   | (sampling case: D=3.5 cm, L = 10.0 cm) |
| (2) Disturb Samples     | : | 12 samples                             |
|                         |   | (24 bags: gross weight = 540 kg)       |

### 4) Results of Soil Investigations

Summary of test results is as follows;

### Huai Sam Ru, Phitsanulok

- (1) Soil group : CL (cohesive soil)
- (2) Specific gravity,  $G_s$  : ranging from 2.74 to 2.72
- (3) Wet density ( $t/m^3$ ) : ranging from 1.65 to 1.93
- (4) Dry density ( $t/m^3$ ) : ranging from 1.45 to 1.70
- (5) Compaction test
  - (a) Maximum dry density, MDD, ( $t/m^3$ ) : ranging from 1.682 to 1.796
  - (b) Optimum moisture content, OMC (%) : ranging from 14.52 to 19.10
- (6) Direct shear test (UU)  
95%\*MDD,  $W = OMC * (1.00 + 0.02)$ 
  - (a) Cohesion,  $C$  ( $t/m^2$ ) : ranging from 1.62 to 2.00
  - (b) Angle of internal friction, PHI, (deg) : ranging from 22.0 to 32.5

### Huai Nong Kho, Sukhothai

- (1) Soil group : CL
- (2)  $G_s$  : ranging from 2.74 to 2.76
- (3) Wet density ( $t/m^3$ ) : ranging from 1.75 to 2.24
- (4) Dry density ( $t/m^3$ ) : ranging from 1.56 to 2.05
- (5) Compaction test
  - (a) MDD ( $t/m^3$ ) : ranging from 1.725 to 1.802
  - (b) OMC (%) : ranging from 13.10 to 14.31
- (6) Direct shear test (UU)
  - (a)  $C$  ( $t/m^2$ ) : ranging from 2.50 to 3.00
  - (b) PHI (deg) : ranging from 23.0 to 30.0

### Khlong Samo Khon, Kamphaeng Phet

- (1) Soil group : CL, SM-SC(sity sand-clayey sand), GM-GC(silty gravel-clayey gravel)
- (2)  $G_s$  : ranging from 2.69 to 2.74
- (3) Wet density ( $t/m^3$ ) : ranging from 1.23 to 1.89

- (4) Dry density ( $t/m^3$ ) : ranging from 1.22 to 1.88
- (5) Compaction test
  - (a) MDD ( $t/m^3$ ) : ranging from 1.864 to 2.208
  - (b) OMC (%) : ranging from 8.30 to 10.30
- (6) Direct shear test (UU)
  - (a) C ( $t/m^2$ ) : ranging from 0.62 to 2.00
  - (b) PHI (deg) : ranging from 32.5 to 38.00

**Khlong Sai, Tak**

- (1) Soil group : SM-SC, SC
- (2) Gs : ranging from 2.68 to 2.76
- (3) Wet density : ranging from 1.32 to 2.07
- (4) Dry density : ranging from 1.29 to 1.88
- (5) Compaction test
  - (a) MDD ( $t/m^3$ ) : ranging from 1.739 to 1.960
  - (b) OMC (%) : ranging from 9.25 to 12.71
- (6) Direct shear test (UU)
  - (a) C ( $t/m^2$ ) : ranging from 1.75 to 3.40
  - (b) PHI (deg) : ranging from 27.50 to 34.00

**B-5-3 Geological Survey**

Geological survey was carried out on 4 damsites in study area.

**Huai Sam Ru Damsite (Phitsanulok Province)**

Axis of dam is located on the line of N 2 degree E. (an azimuth is indicated by the angle of clinometer)

On the left side peak, it's toposoil is fairly deep, after dry excavation on hillside about 1.0 meter in depth, weathered rocks were not found, and then a cone penetrometer sounding was carried out.

The cone penetrometer index was 90 on the pit bottom of 1.0 meter in depth, and 150 on the pit bottom of 1.1 meters in depth. On fill dam, the cone penetrometer index on the dam body ranges from 130 to 150.

Riverbed is made up of reddish fine sand, and its thickness about 1.5 meters. On the right side peak, its topsoil is not so much deep, and after dry excavation about 0.5 to 1.0 in meter, weathering bed rocks will be found. And bed rocks are reddish sandstones. On the right side piedmont, the cone penetrometer index was 170 after dry excavation about 1.0 in meter.

#### Huai Nong Kho Damsite (Sukhothai Province)

Axis of dam is located on the line of N 33 degree E. (an azimuth is indicated by the angle of clinometer)

On the left side peak, the outcrop is found, its weathered phyllite, gray to dark gray. On the sidehill, pebbly shale and pebbly phyllite are found. On the piedmont, after dry excavation about 0.5 meter in depth, weathered phyllite was found.

Riverbed is made up of coarse sand, gravel and pebble, and its thickness is supposed about 2.0 in meter. On the flatland, it is thickly covered by silty and sandy loam layer. On the central point of the flatland, after dry excavation with 1.0 meter in depth, the cone penetrometer index was 130 on 0.8 meter in depth, and 170 on 1.0 meter in depth. On the right side piedmont, weathered phyllite is found.

#### Khlong Samo Khon Damsite (Kamphaengphet Province)

Axis of dam is located on the line of N 8 degree W. (an azimuth is indicated by the angle of clinometer)

On both peak, there are phyllite and shale (with chert, graywacke and limestone) according to the geological map of study area, however, small rocks are only found from weathering.

On riverbed, it is mainly covered by consolidated sand and cobble gravel, and in some places, fragments of phyllite are found. On riverbed, after dry excavation with 1.3 meters in depth, weathered phyllite was found. The depositional terrace is made up of silty loam and fragment of rocks, and its thickness is supposed to be ranging from 2 to 4 in meter.

### Khlong Sai Damsite (Tak Province)

Axis of dam is located on the line of N 12 degree E. (an azimuth is indicate by the angle of clinometer)

Khlong Sai damsite is located among both depositional terraces, formed in the Pleistocene and made up of terrace gravel, sand, silt and fragments of sedimentary rocks. On the left side terrace, after dry excavation with 1.3 meter in depth, fragments of shale with brown coarse sand were found. Indexes of cone penetrometer sounding were as follows:

<u>Depth in meter</u>	<u>Indexes</u>	<u>Description</u>
0.	110	
0.15	130	gray silt
0.20	145	dark gray silt
0.80	88	light brown clay
0.90	150	brown sandy silt
1.10	190	brown sandy silt

Riverbed is made up of coarse sand and it's thickness is supposed to be about 2 in meter.

On the right side terrace, cone penetrometer sounding was carried out on a banana plantation. On 0.15 meter in canceled, because it must be that the geological feature on the right side terrace is similar to the left side terrace from the lay of the land.

### B-5-4 Embankment Materials

#### Huai Sam Ru Dam (Phitsanulok Province)

On embankment materials, the borrow-pit is found at the westerly place on upriver from the damsite, about 0.5 to 1.0 in kilometer in a distance, ranging from about 310 to 330 in meter above the sea. It's area is supposed to be about 150,000 sq.m, and it's product may be about 400,000 cu.m including random materials.



The soil is sedentary soil, and its mother rocks almost consisted of a reddish sand stone. The surface soil belongs to CL (cohesive soil), its thickness is about 1.0 to 3.0 in meter and its percolation coefficient,  $k$ , is calculated at  $3.00 \cdot 10^{-6}$  and under by Creager's Table (see Table B-1). The surface soil is impervious materials.

The percolation coefficient,  $k$ , of random materials is calculate at  $4.00 \cdot 10^{-5}$  by Creager's Table. And random materials are mainly consisted of silty sand (SM).

Impervious materials and random materials are respectively supposed to be 70 and 30 in the proportion from the result of the surface geological survey.

#### Huai Nong Kho Dam (Sukhothai Province)

The borrow-pit is found at the north-westerly place on upriver from the damsite, about 1.0 to 1.5 in kilometer in a distance, ranging about 135 to 140 in meter above the sea. Its area is supposed to be about 400,000 sq.m, and its product may be about 1,000,000 cu.m including random materials.

The soil is residual soil in the Diluvial-age. The surface soil belongs to CL (cohesive soil), its thickness is about 2.0 to 3.0 in meter and its percolation coefficient,  $k$ , is calculated at  $3.00 \cdot 10^{-6}$  and under by Creager's Table. The surface soil is impervious materials.

Impervious materials and random materials are respectively supposed to be 60 and 40 in the proportion from the result of the surface geological survey.

#### Khlong Samo Dam (Kamphaeng Phet Province)

The borrow-pit is found at the north-easterly place on upriver from the damsite, about 0.5 in kilometer in a distance, ranging from about 135 to 120 in meter above the sea. Its area is supposed to be about 200,000 sq.m, and its product may be about 400,000 cu.m including random materials.

The soil is residual soil in the Diluvial-age. The surface soil belongs to CL (cohesive soil), it's thickness is about 0.5 to 1.0 in meter and it's percolation coefficient,  $k$ , is calculated at  $3.00 \times 10^{-6}$  and under by Creager's Table. The surface soil is impervious materials.

The percolation coefficient,  $k$ , of random materials is calculate at ranging from  $1.75 \times 10^{-3}$  to  $3.60 \times 10^{-1}$  by Creager's Table. Random materials are mainly consisted of silty sand (SM), clayey sand(SC), silty gravel (GM) and clayey gravel (GC).

Impervious materials and random materials are respectively supposed to be 30 and 70 in the proportion from the result of the surface geological survey.

#### Khlong Sai Dam (Tak Province)

The borrow-pit is found at the north-westerly place on upriver from the damsite, about 0.8 to 1.2 in kilometer in a distance, ranging from about 170 to 180 in meter above the sea. It's area is supposed to be about 200,000 sq.m, and it's product may be about 400,000 cu.m including random materials.

The soil is residual soil in the Diluvial-age. The surface soil belongs to SC (clayey sand), it's thickness is about 0.5 to 1.5 in meter and it's percolation coefficient,  $k$ , is calculated at  $3.00 \times 10^{-6}$  and under by Creager's Table. The surface soil is impervious materials.

The percolation coefficient,  $k$ , of random materials is calculate at  $2.60 \times 10^{-3}$  by Creager's Table. Random materials are mainly consisted of silty sand (SM).

Impervious materials and random materials are respectively supposed to be 50 and 50 in the proportion from the result of the surface geological survey.

**TABLE B-1 CREAGER'S TABLE**Coefficient of permeability,  $k$ , based on grain size 20%

Size 20% (mm)	$k$ (cm/sec)	Soil classification	Description
0.005	$3.00 \times 10^{-6}$	coarse clay	
0.010	$1.05 \times 10^{-5}$	fine silt	
0.020	$4.00 \times 10^{-5}$	coarse sand silt	
0.030	$8.50 \times 10^{-5}$		
0.040	$1.75 \times 10^{-4}$		
0.050	$2.80 \times 10^{-4}$		
0.060	$4.60 \times 10^{-4}$	finely particle sand	
0.070	$6.50 \times 10^{-4}$		
0.080	$9.00 \times 10^{-4}$		
0.090	$1.40 \times 10^{-3}$		
0.100	$1.75 \times 10^{-3}$		
0.120	$2.60 \times 10^{-3}$	particle sand	
0.140	$3.80 \times 10^{-3}$		
0.160	$5.10 \times 10^{-3}$		
0.180	$6.85 \times 10^{-3}$		
0.200	$8.90 \times 10^{-3}$		
0.250	$1.40 \times 10^{-2}$		
0.300	$2.20 \times 10^{-2}$	medium sand	
0.350	$3.20 \times 10^{-2}$		
0.400	$4.50 \times 10^{-2}$		
0.450	$5.80 \times 10^{-2}$		
0.500	$7.50 \times 10^{-2}$		
0.600	$1.10 \times 10^{-1}$	Coarse sand	
0.700	$1.60 \times 10^{-1}$		
0.800	$2.15 \times 10^{-1}$		
0.900	$2.80 \times 10^{-1}$		
1.000	$3.60 \times 10^{-1}$		
2.000	$1.80 \times 10^{-0}$	sandy gravel	



## **APPENDIX C. SOIL AND LAND USE**



**APPENDIX C. SOILS AND LAND USE**

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## **C-1 INTRODUCTION**

Soil information is one of the most important basic data necessary for agriculture and water resource development planning. Major characteristics of soils as well as their suitability for economic crops are not only the guide for land use planning but also needed for estimation of irrigation water demand and irrigation system design. The study on soils for this project is thus to provide such data for selection of crop types, crop diversification system and for irrigation development as well. These data will be obtained through soil survey, soil analysis and soil suitability classification.

## **C-2 STUDY METHODOLOGY**

### **C-2-1 Data Collection and Review**

Following maps and documents were collected and reviewed to obtain specific information required:

- (1) Detailed Reconnaissance Soil Maps at scale 1:100,000 of Phitsanulok, Sukhothai, Kamphaeng Phet and Tak prepared by Soil Survey and Land Classification Division, Department of Land Development (DLD), Ministry of Agriculture and Cooperatives (MOAC).
- (2) Topographic Maps of scale 1:50,000 of Royal Thai Survey Department (RTSD)
  - Sheet 5142-I      Ban Yaeng, Phitsanulok
  - Sheet 4943-III    Amphoe Ban Dan Lan Hoi, Sukhothai
  - Sheet 4842-I      Ban Nam Dip, Kamphaeng Phet and
  - Sheet 4842-III    Ban Na Bot, Tak
- (3) Topographic maps of scale 1:10,000 covering the study areas of the four provinces.

## **C-2-2 Field Survey**

Field survey was carried out during 25 January to 2 February 1991 in order to:

- (1) Make additional soil survey with particular emphasis on soil types and their major characteristics such as soil depth, texture, color, pH, occurrence of mottles and other environments. This is also to confirm the referred soil maps. If they are found serious mistake, they will be modified.
- (2) Make soil profile descriptions of the main soil types in the four model project areas. Eleven soil pits were dug and described. Nine of which are in Phitsanulok, Sukhothai and Tak. Each of these sites has three pits. The other two are in Kamphaeng Phet.

## **C-2-3 Soils Sample Analysis**

Sixty soil samples were collected from those profile pits and were analyzed for particle size, pH, EC, % Carbon, base saturation, cation exchange capacity (CEC) available P and available K.

## **C-3 HUAI SAM RU AREA**

### **C-3-1 Soils**

#### **(1) General Soil Feature**

The model project area is situated in Amphoe Nakhon Thai. Topography of proposed irrigation area is undulating highland with nearly flat land lying in between. The area tilts eastwards. Soils are derived from sandstone. The highland soils are very deep, medium-texture mainly sandy loam over sandy clay loam with well drained. Soil reaction is strongly acid with pH 5.0. Laterite may expose to the surface but in very limited coverage. Cassava is the main crop currently cultivated on these soils.

The lowland area normally used for rice growing consists of very deep, silt loam over silty clay loam soils. Drainage is moderately well to somewhat poorly drained with grayish brown to brown matrix and yellowish red mottles. Soil reaction is strongly acid to very strongly acid with pH ranging from 4.5 to 5.5.

## (2) Soil Mapping Units and Their Characteristics

Three soil units are mapped as shown in Figure 1 namely.

- AC-p : Alluvial Complex-poorly drained
- Lp : Lampang series
- Wn : Warin series

Area and soil characteristics are tabulated in Tables C-1 and C-2.

### C-3-2 Soil Suitability Classification

For effective land use planning, soil suitability for specific use is essential. In this section, the suitability of soils is identified for paddy (P), non-flooded annual crop (N) fruit tree plantation (F) and for pasture or Rangeland Livestock Farming (L).

① Soil Suitability Class: Principally, there are five classes follows:

Class I (P-I, N-I, F-I) : Soils very well suited having no significant limitations.

Class II (P-II, N-II, F-II) : Soils well suited having slight limitations.

Class III (P-III, N-III, F-III) : Soils moderately suited having moderate limitations that require special management.

Class IV (P-IV, N-IV, F-IV) : Soil poorly suited having severe limitations that require very careful management.

Class V (P-V, N-V, F-V) : Soil not suited having very severe limitations that preclude their use for crop production with ordinary method.

- ② **Soil Suitability Subclass** : At the lower level, the suitability classes are further identified into subclasses based on kinds and degree of hazard of limitations. The following are the main limitations used in identifying suitability classes into subclasses.

f : flooding-susceptibility to flash floods or prolonged dup flooding or both, which damage the crops or limit choice of corps.  
x : salinity-excessive salts which affect crop growth  
s : unfavorable surface soil texture  
n : low nutrient status or low fertility  
g : gravels in soil profile  
w : risk of water shortage-water stress in growing season  
d : impeded drainage  
t : topography of slope  
c : consolidated layer

- ③ **Soil Suitability for Pasture and Rangeland Livestock**

Farming (L)

Class L-I : Soils well suited

Class L-II : Soils poorly suited

Class L-III : Soils not suited

Limitations for subclass determination are the same as having been mentioned. Suitability subclass for paddy, non-flooded annual crop, fruit tree and pasture/rangeland of each soil unit are given in Table C-3.

**C-3-3 Land Use Plan**

According to soil types, soil characteristics, soil suitability, and etc. this site, in general, can be initially planned as following:

- Zone 1 : Paddy
- Zone 2 : Fruit Tree - Mango, Bamboo
- Zone 3 : Upland Crop - Cassava, Soybean, Mungbean, Groundnut

Details are shown in Figure C-5 and Table C-4.

### C-3-4 Soil Profile Descriptions

Three profile pits were dug as shown in soil map.

- ① Profile Code : P-1 Date 1 Feb. 1991
- Soil Name : Alluvial Complex poorly drained (AC-p)
- Location : Dam Axis, Ban Kaeng Hai
- Topography : Valley bottom
- Land Use : Paddy

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Description</u>
Ap <sub>1</sub>	0 - 20	Very dark grayish brown (10YR3/2) silt loam, weak coarse subangular blocky structure, firm sticky and plastic, many fine roots; strongly acid (pH 5.0) clear smooth boundary.
Ap <sub>2</sub>	20 - 37	Dark gray (10YR4/1) silt loam with common medium distinct dark reddish brown mottles: weak medium subangular structure, firm, sticky, plastic, many fine roots strongly acid (pH 5.5) clear smooth boundary.
B <sub>2t</sub>	37 - 65	Brown (7.5 YR5/3) and dark brown to brown (7.5 YR4/4) clay loam with soft manganese nodules, weak fine subangular blocky structure, friable, sticky, plastic, slightly acid (pH 6.5) abrupt smooth boundary.
C	65 - 120	Dark brown (7.5 YR4/2) and brown (7.5 YR5/2) sandy clay loam with common fine and medium dark brown to brown mottles, friable, sticky, plastic, slightly acid (6.5).

- ② Profile Code : P-2 Date: 1 Feb. 1991  
 Soil Name : Lampang Series (Lp)  
 Location : East of Ban Kaeng Wa.  
 Topography : Nearly flat  
 Land Use : Paddy

<u>Horizon</u>	<u>Depth (cm)</u>	<u>Description</u>
Ap	0 - 20	Grayish brown to brown (10 YR5/2-3) silt loam with many fine distinct mottles of yellowish red (5 YR 4/6) on <u>ped</u> face and along root channels, weak fine to medium subangular structure: firm, sticky, plastic; common medium and coarse interstitial pores; few fine tubular pores; many fine roots; strongly acid (pH 5.5); clear smooth boundary.
B21t	20 - 60	Yellowish brown (10 YR5/4) silty clay loam with many medium mottles of strong brown 7.5 YR5/6); weak subangular blocky structure; firm, sticky, plastic, thin patchy clay coating on ped face few fine tubular pores; few fine roots strongly to very strongly acid (pH 4.5 - 5.0); gradual smooth boundary.
B22t	60 - 120	Light brownish gray (10 YR6/2) silty clay loam with many medium prominent mottles of reddish brown (2.5 YR4/4) and few medium red (10 R4/6); weak medium subangular blocky structure; friable, very sticky, very plastic, thick continuous clay coating in pores and moderately thick patchy on ped faces; many fine tubular pores; few fine roots; strongly to very strongly acid (pH 4.5 - 5.0)

- ③ Profile Code : P-3 Date : 1 Feb. 1991  
 Soil Name : Warin series (Wn)  
 Location : Ban Kaeng Hai  
 Topography : Undulating  
 Land Use : Cassava Kapok



<u>Horizon</u>	<u>Depth (cm)</u>	<u>Description</u>
Ap	0 - 15	Dark brown (10 YR3/3) sandy loam, massive friable, non sticky, non plastic, few fine roots; few medium animal holes; strongly acid (pH 5.0); clear wavy boundary.
B <sub>1</sub>	15 - 30	Dark brown (7.5 YR4/4) sandy loam; weak fine subangular structure; firm, slightly sticky, non plastic; few fine roots; strongly acid (pH 5.0); clear smooth boundary.
B <sub>21t</sub>	30 - 60	Yellowish red (5 YR 4/6) sandy clay loam; weak medium suangular blocky structure; firm, sticky, plastic; thin clay coating in pores; common fine tubular and interstitial pores; few fine roots; strongly acid (pH 5.0); gradual smooth boundary.
B <sub>22t</sub>	60 - 90	Yellowish red (5 YR4/8) sandy clay loam; moderate medium suangular blocky structure; firm, sticky, plastic; moderately thick clay coating in pores and on ped faces; common fine tubular and interstitial pores; strongly acid (pH 5.0); gradual smooth boundary.
B <sub>3</sub>	90 - 120	Yellowish red (5 YR4/6) clay loam with discernible sand fraction with mottles of pinkish gray (7.5 YR7/2) and red (10 R4/6); moderate medium suangular blocky structure; firm, sticky, plastic; few Fe/Mn concretions; strongly acid (pH 5.0).

#### C-4 Huai Nong Kho Area

##### C-4-1 Soil

##### (1) General Soil Feature

There are two sites namely upper site and lower site. The upper site is situated in the valley of Khao Lan, Ban Wang Takian. Topography is nearly flat valley bottom bounded by foothill. Soils are derived from sandstone and alluvial deposits. The foothill area comprises rather shallow soils with sandstone fragments and gravels. These are poor for upland crops, but seem to be favorable for pasture and rangeland for cattle. The upper valley bottom

consists of well drained, medium to fine texture upland soils which are good for upland crop and orchard whereas the lower flat land devoted for paddy cultivation comprises clayey soil. Water shortage is the main limitation.

The lower site situated along Khlong Sa Ket are generally flat. Most soils are clayey suitable for paddy and irrigation development. Those along Khlong Sa Ket are well drained medium textured upland soils suited for orchard and upland crop. Generally the soils have high potential for agricultural development.

## (2) Soil Mapping Unit and Their Characteristics

Three units are recognized in the upper site namely.

Ks : Kamphaeng Saen Series  
Ms : Mae Sai Series and  
Ty : Tha Yang Series

The lower site has four mapping units including:

Bar : Ban Rai Series  
Bar/Ssr : Ban Rai/Si Samrong Association  
Cr : Chiang Rai Series  
Ks : Kampaeng Saen Series

These mapping units are shown in soil map of Figure C-2. Area coverage and their characteristics are tabulated in Table C-1 and C-2.

### C-4-2 Soil Suitability Classification

Using the same criteria as described in para C-3-2 for Huai Sam Ru area, the soil are identified for suitability of:

- Paddy (P)
- Non-Flooded Annual Crop (N) or Upland Crop
- Fruit Tree (F)
- Pasture or Rangeland Livestock Farming (L)