JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)

AGRICULTURAL LAND REFORM OFFICE(ALRO), MOAC
THE KINGDOM OF THAILAND

THE FEASIBILITY STUDY
ON
THE INTEGRATED AGRICULTURE DEVELOPMENT
IN
THE AGRICULTURAL LAND REFORM AREAS
IN
THE UPPER NORTHEASTERN REGION
THE KINGDOM OF THAILAND

FINAL REPORT

APPENDIX (I)

JULY, 1988

SANYU CONSULTANTS INC.

JAPAN INTERNATIONAL COOPERATION AGENCY(JICA)
AGRICULTURAL LAND REFORM OFFICE(ALRO), MOAC
THE KINGDOM OF THAILAND

THE FEASIBILITY STUDY
ON
THE INTEGRATED AGRICULTURE DEVELOPMENT
IN
THE AGRICULTURAL LAND REFORM AREAS
IN
THE UPPER NORTHEASTERN REGION
THE KINGDOM OF THAILAND

FINAL REPORT

APPENDIX (I)

JULY, 1998

SANYU CONSULTANTS INC.

APPENDIX (I)

APPENDIX(I)

A. GENERAL
B. METEOROLOGY, HYDROLOGY AND WATER RESOURCES
C. SOCIAL CONDITIONS
D. EXISTING INFRASTRUCTURE

APPENDIX(II)

E. SOIL AND LAND USE
F. AGRICULTURE
G. ECONOMY AND RURAL FINANCE
H. ENVIRONMENT
I. INVENTORIES

A. GENERAL

APPENDIX A. GENERAL

1. Tables

Table A-1 ALRO'S DIVISIONS AND SECTIONS

Office of the Secretary	Land Reform Operation Division	Legal Affairs Division	Land Reform Financing Division
- Correspondence Section	- General Affairs Section	- General Affairs Section	- General Affairs Section
- Agricultural Land Reform Executive Committee Section	- Cadastral Survey Section	- Legal Advisory Staff	- Fund Development Section
- Assistance Managing Director and Coordination Section	- Mapping Section	- Legal and Regulations Section	- Finance and Accounting Section
- Documentation and Public Relations Section	- Photogrammetry Section	- Complaints and Investigation Section	- Land Deal Section
- Vehicle and Office Facilities Section	- Agricultural Development and Extension Section	- Contracts Section	- Credit Section
	- Occupation Promotion and Farmers' Institutions Extension Section		- Auditing and Monitoring Section

Personnel Division	Finance Division	Research and Planning Division	Engineering Division
- General Affairs Section	- General Affairs Section	- General Affairs Section	- General Affairs Section
- Recruitment and Payroll Section	- Budget Section	- Planning and Project Formulation Section	- Engineering Planning Section
- Personnel Record and Award Section	- Financial Section	- Monitoring and Evaluation Section	- Survey and Design Section
- Personnel Planning and System Analysis Section	- Accounting Section	- Statistics Section	- Construction and Maintenance Section
- Disciplinary and Social Welfare Section	- Procurement Section	- Data Processing Section	- Analysis and Testing Section
- Personnel Development Section		- Farmer Training Section	- Mechanical Section
		- Foreign Cooperation Section	- Mechanical Maintenance Section
		- Land Reform Research Staff	

Table A-2 LAND PROVISION (LAND REFORM AREAS), UP TO SEP. 30, 1995

Area	Public Lands		Private Lands		Total		
	(1,000 rai)	(1,000 ha)	(1,000 rai)	(1,000 ha)	(1,000 rai)	(1,000 ha)	%
Whole Kingdom	34,952	5,591	420	67	35,372	5,658	100.0
(1) Central	6,158	985	287	46	6,445	1,031	18.2
(2) Northern	7,953	1,272	125	20	8,078	1,292	22.8
(3) Southern	4,121	659	-	-	4,121	659	11.7
(4) Northeastern	16,720	2,675	7	1	16,727	2,676	47.3
- Khon Kaen	487	78	1	-	488	78	
- Mahasarakham	77	12	-	-	77	12	
- Sakhonnakhon	417	67	-	-	417	67	
- Mukdahan	110	18	-	-	110	18	

*Source: Selected Data on Land Reform Areas, Sep., 1996, ALRO

Table A-2 LAND PROVISION (LAND REFORM AREAS), UP TO SEP. 30, 1995

Area	Public Lands		Private Lands		Total		
	(1,000 rai)	(1,000 ha)	(1,000 rai)	(1,000 ha)	(1,000 rai)	(1,000 ha)	%
Whole Kingdom	34,952	5,591	420	67	35,372	5,658	100.0
(1) Central	6,158	985	287	46	6,445	1,031	18.2
(2) Northern	7,953	1,272	125	20	8,078	1,292	22.8
(3) Southern	4,121	659	-	-	4,121	659	11.7
(4) Northeastern	16,720	2,675	7	1	16,727	2,676	47.3
- Khon Kaen	487	78	1	-	488	78	
- Mahasarakham	77	12	-	-	77	12	
- Sakhonnakhon	417	67	-	-	417	67	
- Mukdahan	110	18	-	-	110	18	

*Source: Selected Data on Land Reform Areas, Sep., 1996, ALRO

Table A-3 Annual Budget

Unit : million Baht

Organization \ Year	1990	1991	1992	1993	1994	1995	1996
1. Government Budget	335,000	387,500	460,400	560,000	625,000	715,000	843,200
2. MOAC	26,600	31,400	35,400	44,300	54,700	65,100	74,300
3. MOAC share = 2/1 x 100	7.9%	8.1%	7.7%	7.9%	8.8%	9.1%	8.8%
4. ALRO							
- Preparation & Administration	260	324	344	458	539	543	605
- Land Distribution	263	122	374	368	812	1,054	872
- Infrastructure Development	138	116	107	400	475	842	526
- Income Generation, etc.	10	11	12	20	724	73	108
- Special Project	49	185	187	84	78	132	55
Total	720	758	1,024	1,330	2,628	2,644	2,166
5. ARD	7,750	9,468	9,892	13,244	17,681	21,504	28,140

Table A-4 Annual Budget of MOAC and Number of Ministry Employee, 1994

Organization	Budget		Number of		
	Million Baht	%	Official	Employee	Total
Office of the Under Secretary of State	3,497	6.4	983	1,095	2,078
Royal Irrigation Department (RID)	24,435	44.7	8,724	41,259	49,983
Department of Cooperative Auditing	259	0.5	1,362	276	1,638
Department of Fisheries (DOF)	2,719	5.0	3,260	2,872	6,132
Department of Livestock (DOL)	2,963	5.4	5,060	3,320	8,380
Royal Forest Department (RFD)	6,959	12.7	9,061	8,642	17,703
Department of Land Development (DLD)	1,850	3.4	2,152	1,867	4,019
Department of Agriculture (DOA)	2,468	4.5	3,474	5,027	8,501
Department of Agricultural Extension (DOAE)	4,683	8.6	12,017	2,685	14,702
Department of Cooperative Promotion (DCP)	1,988	3.6	4,095	2,701	6,796
Agricultural Land Reform Office (ALRO)	2,628	4.8	2,417	572	2,989
Office of Agricultural Economic (OAE)	245	0.4	762	287	1,049
Total (MOAC)	54,694	100.0	53,367	70,603	123,970

Table A-4 Annual Budget of MOAC and Number of Ministry Employee, 1994

Organization	Budget		Number of		
	Million Baht	%	Official	Employee	Total
Office of the Under Secretary of State	3,497	6.4	983	1,095	2,078
Royal Irrigation Department (RID)	24,435	44.7	8,724	41,259	49,983
Department of Cooperative Auditing	259	0.5	1,362	276	1,638
Department of Fisheries (DOF)	2,719	5.0	3,260	2,872	6,132
Department of Livestock (DOL)	2,963	5.4	5,060	3,320	8,380
Royal Forest Department (RFD)	6,959	12.7	9,061	8,642	17,703
Department of Land Development (DLD)	1,850	3.4	2,152	1,867	4,019
Department of Agriculture (DOA)	2,468	4.5	3,474	5,027	8,501
Department of Agricultural Extension (DOAE)	4,683	8.6	12,017	2,685	14,702
Department of Cooperative Promotion (DCP)	1,988	3.6	4,095	2,701	6,796
Agricultural Land Reform Office (ALRO)	2,628	4.8	2,417	572	2,989
Office of Agricultural Economic (OAE)	245	0.4	762	287	1,049
Total (MOAC)	54,694	100.0	53,367	70,603	123,970

Table A-5 ALRO's ACCOMPLISHMENT (1975 - 1996)

1. Land Provision (LRAs)			
- Nos. of province with LRA	68		
- Public Land	35,430,000	rai	(5,668,000 ha)
- Private Land	440,000	rai	(70,400 ha)
2. Land Distribution			
(1) Public Land			
- Cadastral survey	33,980,000	rai	(5,437,000 ha)
- Check of ownership	24,530,000	rai	(3,925,000 ha)
- "	1,310,000	household	
- Issue of land use certifiactes (ALRO 4-01)	8,320,000	rai	(1,331,000 ha)
- "	455,000	household	
(2) Private land			
- Leasehold	277,000	rai	(44,000 ha)
- Hire-purchase	138,000	rai	(22,000 ha)
3. Infrastructure Development			
(1) Main & lateral road	4,370	km	
(2) Tracks	146	km	
(3) Irrigation & drainage canal	453	km	
(4) Water resources development for agriculture			
- Reservoir	32	places	
- Weir	37	places	
- Deep well	911	wells	
- Pond	2,026	places	
(5) Water resources development for domestic water			
- Pond	428	places	
- Deep well	942	wells	
- Shallow well	2,026	wells	
(6) Farm system development	53,800	rai	(8,600 ha)
(7) Land clearing & leveling	102,000	rai	(16,000 ha)
(8) Improvement of road system	3,059	km	
(9) Repair of road system	3,654	km	
4. Income Generation & Restructure of Agricultural Production			
- Farmpond construction	19,130	places	
- Establishment of cooperatives	106	Nos.	

Table A-6 ARD's ACCOMPLISHMENT (1965 - 1994)

1. Construction of Rural Roads		
- Laterite surface	21,784	km.
- Asphalt surface	10,481	km.
- Concrete surface	1,322	km.
- Reinforced concrete bridge	105,769	m.
2. Construction of Rural Water Resources		
(1) Surface Water Resources	910	places
- Reservoir/weir	4,490	places
- Rehabilitation of natural resources/pond	236	systems
- Distribution system		
(2) Underground Water Resources		
- Deep well	28,021	wells
- Shallow well	12,970	wells
(3) Clean Water Container		
- Segmental tank 3200 litres	78,638	tanks
- RC. water container 20 cu.m.	8,590	tanks
(4) Village Water Supply System	1,000	places
3. Promotion and Development of Occupation and Youth Groups	9,573	groups

B. METEOROLOGY, HYDROLOGY AND WATER RESOURCES

APPENDIX B. METEOROLOGY, HYDROLOGY AND WATER RESOURCES

List of Figures

List of Tables

Chapter 1 Tables and Figures supporting Main Report

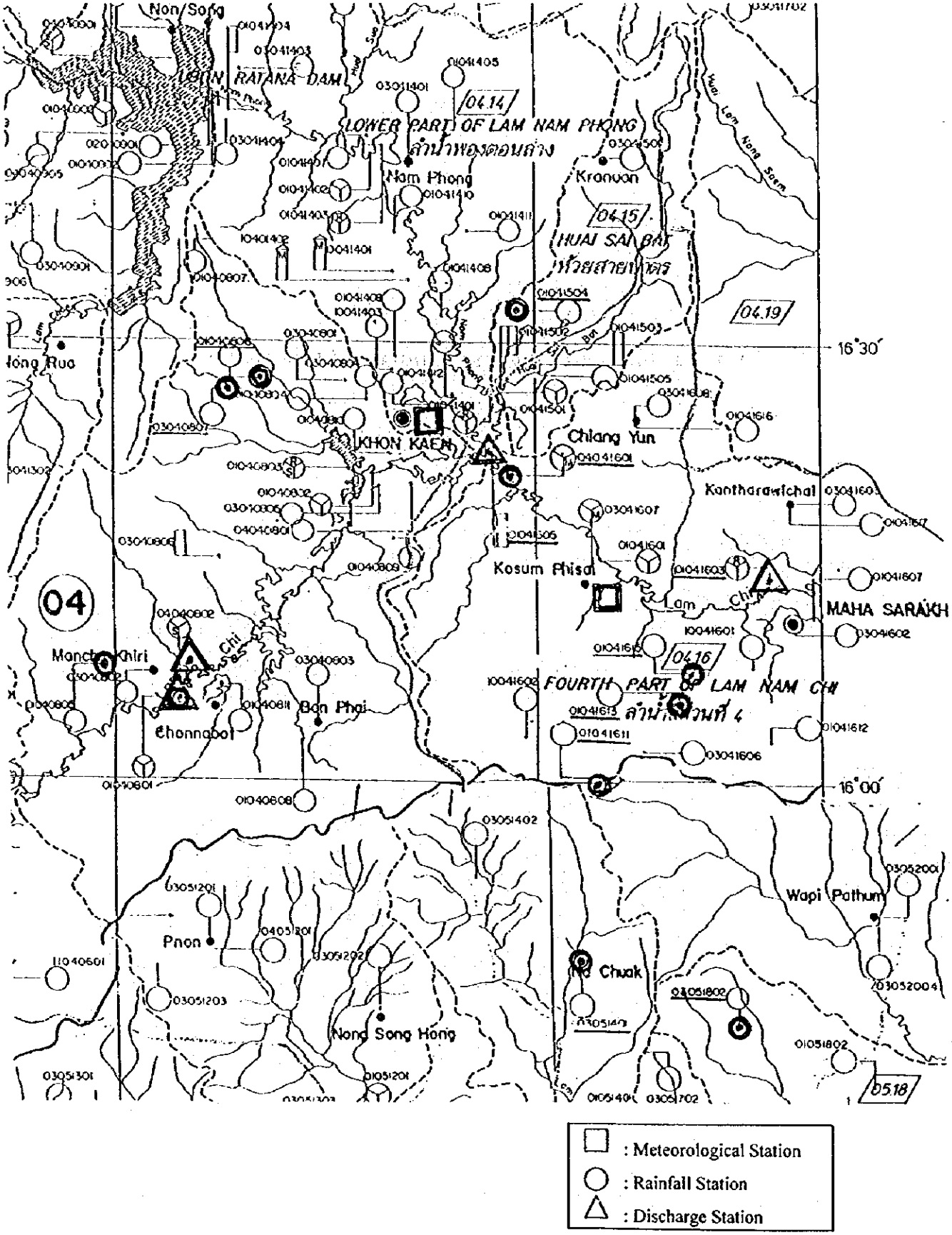


Figure B-1 Location of Meteorological and Hydrological Stations in KK, MHS

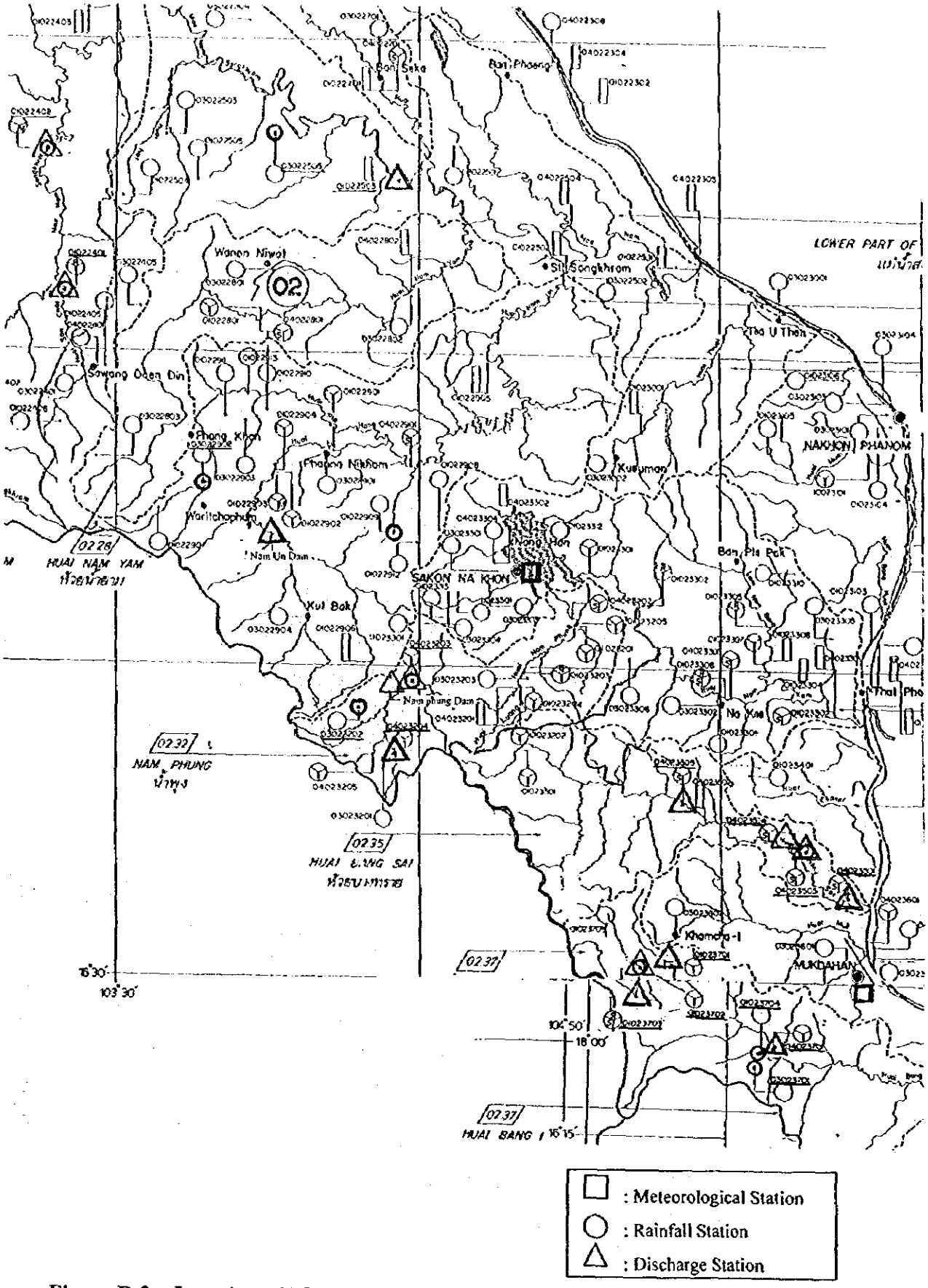


Figure B-2 Location of Meteorological and Hydrological Station in SKN, MKD

ANNUAL RAINFALL

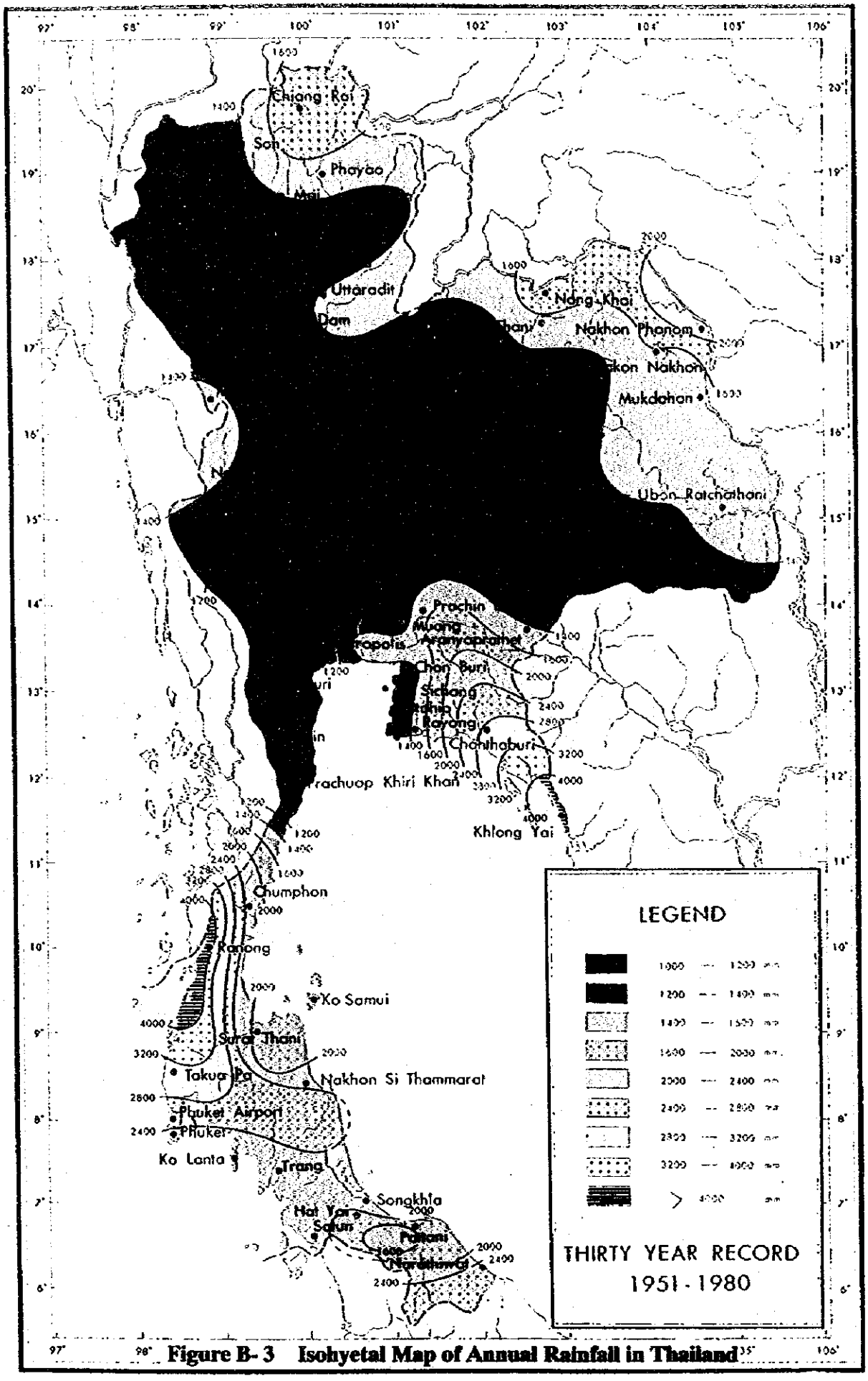


Figure B- 3 Isohyetal Map of Annual Rainfall in Thailand

ANNUAL RAINFALL

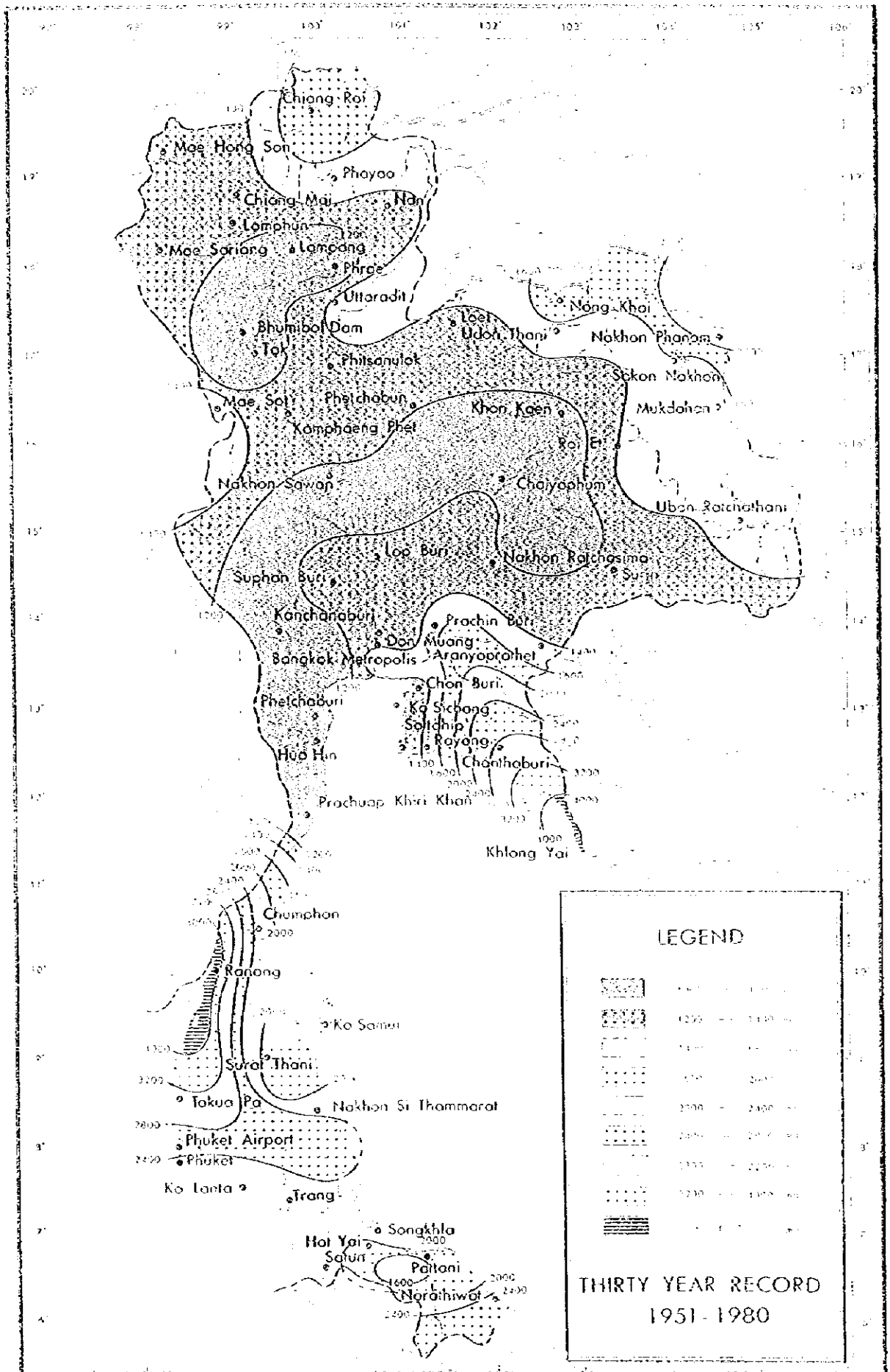


Figure B- 3 Isohyetal Map of Annual Rainfall in Thailand

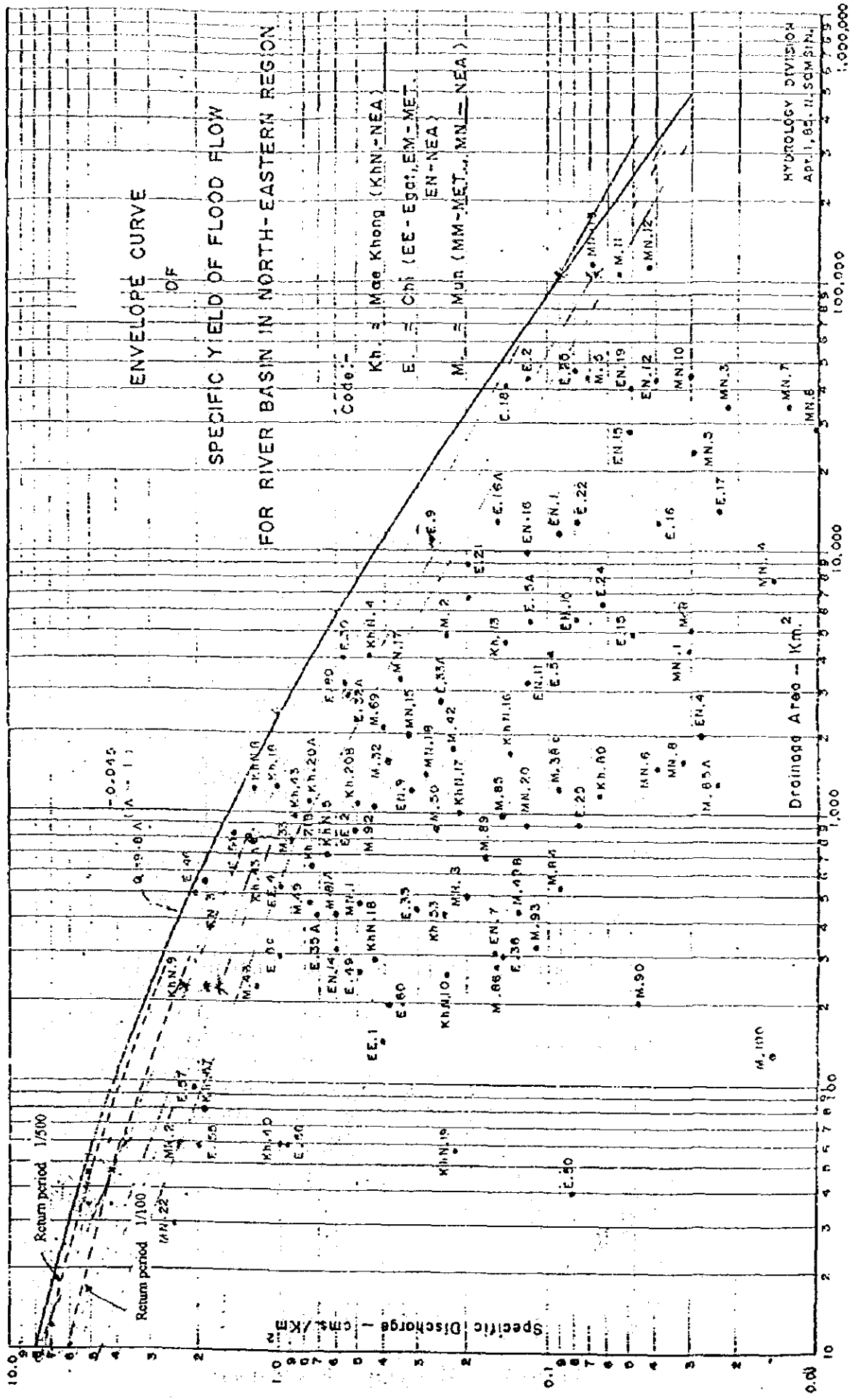


Figure B-4 Envelope Curve of Specific Discharge of Flood Peaks (Data Source: RID)

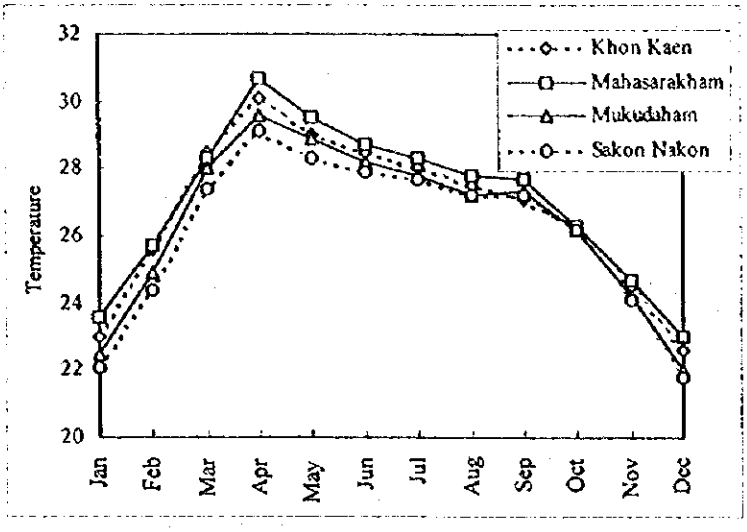


Figure B-5 Temperature at Key Stations

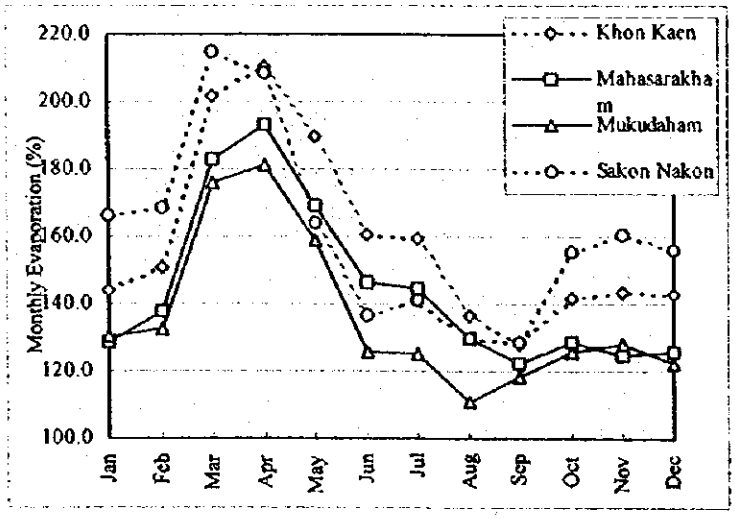


Figure B-6 Evaporation at Key Stations

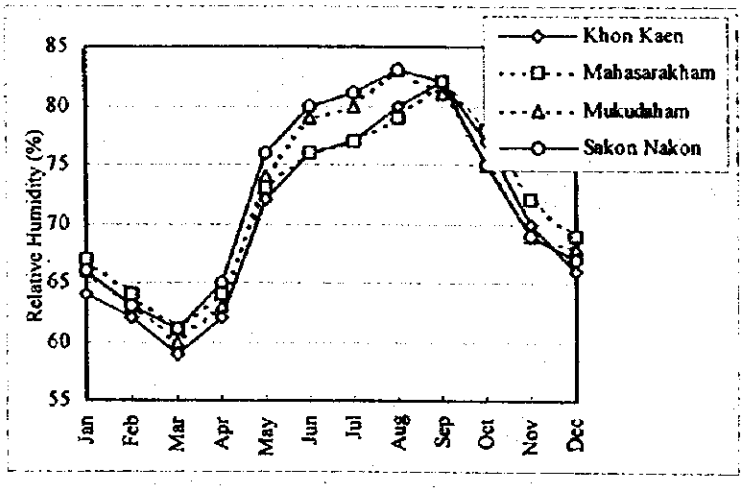


Figure B-7 Humidity at Key Stations

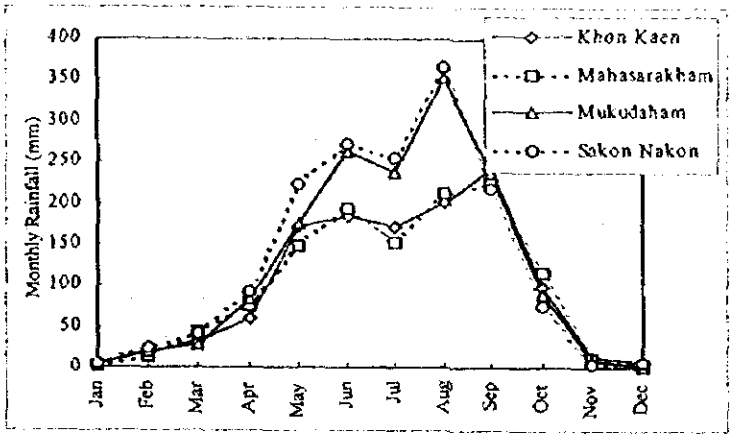


Figure B-8 Monthly Rainfall Distribution at Key Stations

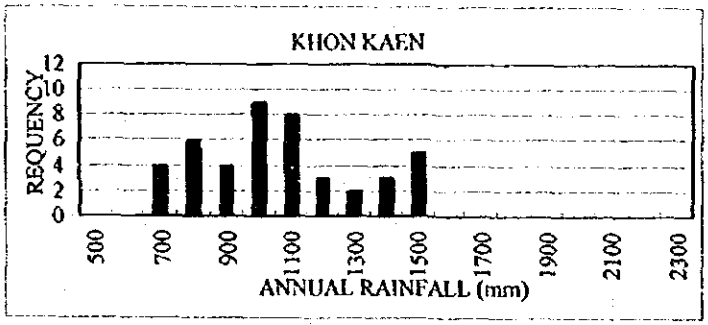


Figure B-9 Annual Rainfall Frequency at Khon Kaen

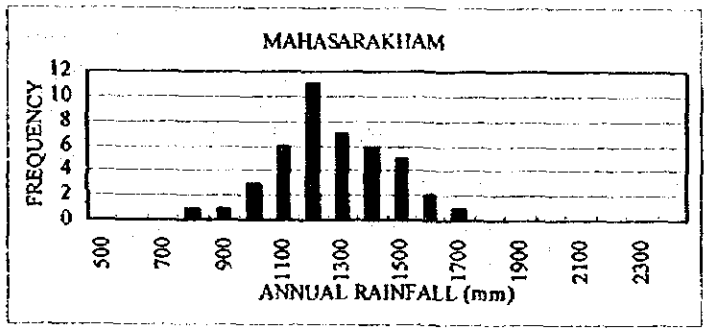


Figure B-10 Rainfall Frequency at Maha Sarakham

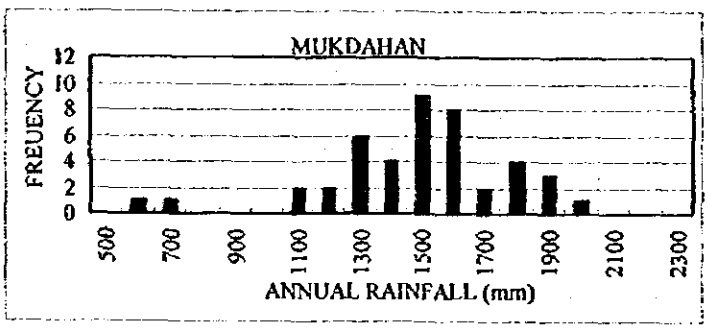


Figure B-11 Annual Rainfall Frequency at Mukdahan

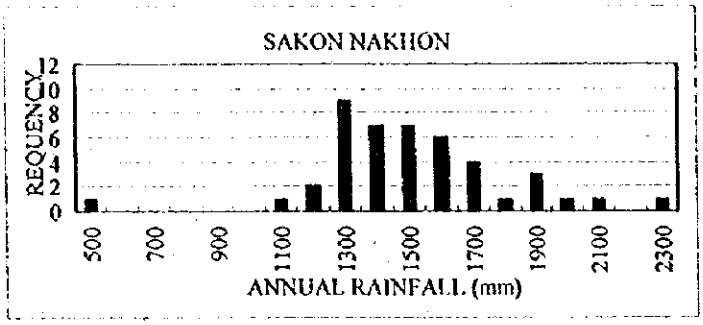


Figure B-12 Annual Rainfall Frequency at Sakon Nakhon

Table B-1 Study Area and Applied Rainfall Station

No	Station code	Period	Av. Rainfall	Applied	reference code
1	01040801	1952 -1995	1021	KK-1, 6	14022
2	01040505	1958 - 1995	1051	KK-3	14170
3	01040806	1959 - 1995	1125	KK-2	14190
4	01041504	1977 - 1979	1202	KK-5,MH-1	14390
5	03040807	1983 - 1994	1008	KK-4	14452
6	01041611	1955 - 1991	1112	MH-8	21120
7	01041613	1955 - 1995	1106	MH-3, 7	21170
8	01041615	1962 - 1994	1085	MH-4	21200
9	03051401	1971 - 1995	1135	MH-9	21252
10	03051802	1985 - 1995	1012	MH-5, 6	21292
11	04041601	1966 - 1994	1164	MH-2	42001
12	01023702	1955 - 1995	1386	MK-7	64032
13	01023704	1952 - 1995	1430	MK-1	64013
14	03023701	1959 - 1995	1545	MK-2,3,4,5,6	64042
15	04023503	1968 - 1994	1692	MK-8, 9,10,11,12	023803
16	01022401	1974 - 1995	1387	SK-2	68212
17	01022402	1970 - 1995	1636	SK-1	50252
18	01022909	1959 - 1993	1446	SK-3	50180
19	03022505	1991 - 1995	1304	SK-7	50382
20	03022902	1956 - 1995	1432	SK-6	50042
21	03023202	1967 - 1995	1356	SK-4	50102
22	04023203	1962 - 1968	1434	SK-5	023403

Table B-2 List of Discharge Station

Stream	Station Name	Station Code	Drainage Area (Km2)	Period of Record	Available data	ref. Code	Agency
Songkham	Ban tha Huai Lua, Ban Mang Sakon Nakon	1022402	2145	1984 - 1994	daily	KH.74	RID
Song Khram	Dong Yan, Ban Dung Udon Thani	1022401	1177	1985	daily	KH.60	RID
Huai Nam Phung	Ban Tao Ngoi,Muang Sakon Nakon	4023203	641	1978 - 1989	daily	KH.21B	RID
Huai Nam Man	Ban Pong Bia, Loei	1022503	79	1978 - 1986	daily	KH.57	RID
Chi	Wat Tai Kosm,Cosum Phisai,Maha Sarakham	4041605	29788	1978 - 1994	daily	E. 1	RID
Chi	Ban Tha Khon Yang, Kantharawio Maha Sarakham	1041603	29788	1978 - 1994	daily	E. 8A	RID
Chi	Ban Tha Nang Luan,Chonnabot,Khon Kaen	104801	11020	1978 - 1994	daily	E. 9	RID
Huai Sai	Ban Nong-lan, Kham Chai,Mukdahan	1023701	48	1987 - 1994	daily	KH.84	RID
Huai Bang-I	Ban Nom Yang, K.A. Nong Sung Mukdahan	1023703	110	1984 - 1994	daily	KH.79	RID
Huai Khan Thae Yai	Ban Khan Chai, Kham Chai,Mukdaham	1023702	28	1987 - 1993	daily	KH.85	RID
Chi	Nam Chi at Ban Chod	4040802	10200	1975 - 1994	Monthly	41002	DEDP
Huai Nam Phung	Huai Khae near Ban Sang Kho	4023204	58	1965 - 1966	Monthly	23404	DEDP
Huai Bang-I	Huai Bang-I near Ban Khan Soi	4023701	702	1964 - 1979	Monthly	24001	DEDP
Huai Bang Sai	Huai Bang Sai at Ban Na Lak	4023505	925	1985 - 1994	Monthly	23805	DEDP
Huai Bang Sai	Huai Bang Sai at Ban Nong Aek Bridge	4023501	1340	1968 - 1994	Monthly	23801	DEDP
Huai Bang Sai	Huai Bang Sai at Ban Kham Pa Lai	4023503	1240	1962 - 1967	Monthly	23803	DEDP
Huai Bang Sai	Huai Bang Sai at Ban Na Kham Noi	4023504	1220	1985 - 1994	Monthly	23804	DEDP
Nam Un	Nam Un Dam (inflow,outflow)		1100	1969 - 1995	Monthly		RID
Nam Phung	Nam Phung Dam (inflow,outfow)		269	1984 - 1994	daily		EGAT

(Data Source : RID,DEDP,EGAT)

Table B -3-1 Weekly Crop coefficient (Kc)

Week	Irrigated field				Upland		
	W.S Rice(*1)	Soybean (*1)	Sweet corn(*2)	Water melon(*2)	Vegetable (*1)	Maize (*1)	Tomato (*2)
1	0.92	0.58	0.55	0.67	1.03	0.52	0.59
2	0.92	0.63	0.58	0.67	1.09	0.59	0.66
3	0.94	0.63	0.71	0.86	1.14	0.70	0.74
4	1.00	0.74	0.71	0.86	1.17	0.91	0.74
5	1.13	0.92	0.84	1.21	1.18	1.14	0.82
6	1.29	1.14	0.96	1.44	1.16	1.28	0.91
7	1.23	1.23	1.01	1.44	1.14	1.35	0.98
8	1.23	1.24	1.00	1.59		1.36	1.05
9	1.29	1.26	0.95	1.48		1.37	1.10
10	1.32	1.24	0.78	1.35		1.32	1.12
11	1.30	1.17	0.59	1.12		1.22	1.12
12	1.30	1.01	0.59	1.12		1.02	1.09
13	1.20	0.79	0.50	0.80		0.79	1.04
14	1.20	0.69		0.60		0.60	0.96
15	1.21	0.69		0.60			0.85
16	1.11	0.65		0.52			0.85
17	0.95	0.63		0.52			0.72
18	0.95			0.41			
19	0.75						
20							
Av	1.12	0.90	0.75	0.96	1.13	1.01	0.90

(Note) modifying to local conditions, (*1): source from TIA(study of potential development of water resources in the Mae Khong Basin), (*2) : source from Irrigation Agriculture Branch RID.

Table B -3-2 Monthly Crop coefficient (Kc)

Month	Irrigatin Field				Upland				Pond
	W.S Rice (*1)	Soybean	Sweet corn	Water melon	Vegetable (*1)	Maize (*4)	Tomato	Fruit tree (*2)	Farm pond (*3)
1	1.10	0.50	0.50	0.50	1.11	0.71	0.80	0.9	1.10
2	1.10	1.00	1.05	0.95	1.16	1.30	1.05	0.9	1.10
3	1.05	1.00	0.95	0.95		1.13	1.05	0.9	1.10
4	1.05	0.50		0.95		0.62		0.9	1.10
5	0.95			0.65	1.11			0.9	1.10
6					1.16			0.9	1.10
7								0.9	1.10
8								0.9	1.10
9					1.11			0.9	1.10
10					1.16			0.9	1.10
11								0.9	1.10
12								0.9	1.10
Av.	1.05	0.75	0.83	0.80	1.14	0.94	0.97	0.90	1.10

(Note)
1)referring to Crop Water Requirement (FAO Irrigation and Drainage Paper 24,1984) p35-54 and modifying to meet local conditions.
2)estimated under light to moderate wind (0-5 m/s), and humid min.>70%.
3)(*1):averaged into monthly value from weekly Kc value of vegetables used in RID.
4)(*2):estimated as matured citrus with no weed control in Table 25, FAO Crop Water Requirement.
5)(*3):assumed as open water in Table 30, FAO Water Requirement.
6)(*4):arranged into monthly value from weekly Kc value of maize used in RID.

Table B-4 Monthly Discharge Record of Huai Bang-I at 24001 Station

(Unit: cms)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1964	9.3	3.3	3.5	3.8	92.9	238.0	117.6	276.9	1650.5	587.6	101.2	27.7	3112.1
1965	7.9	5.7	6.2	6.0	258.9	1126.2	632.2	442.7	1176.2	118.1	45.7	24.7	3850.3
1966	22.2	13.4	14.9	35.6	267.3	147.0	381.4	1035.4	1483.7	120.4	59.7	29.9	3610.8
1967	16.2	9.0	9.4	15.7	59.4	39.5	63.2	187.0	773.9	114.8	25.2	6.1	1319.4
1968	4.8	32.0	2.6	1.3	17.0	197.8	88.1	393.8	1178.3	122.5	31.8	16.6	2086.5
1969	6.3	3.2	3.0	14.4	48.6	201.7	597.2	456.3	1378.6	213.4	72.0	21.2	3016.1
1970	10.0	3.6	1.6	5.4	77.7	495.7	701.3	2027.5	1045.3	200.2	62.3	27.5	4658.0
1971	14.6	23.0	14.8	12.6	179.7	618.5	1716.7	1150.3	609.5	901.3	87.5	37.4	5365.8
1972	19.4	17.5	8.4	7.2	5.5	214.6	859.4	1444.6	610.4	1442.2	151.6	68.4	4849.1
1973	35.0	18.6	14.3	24.9	122.1	260.4	777.0	487.4	599.3	264.4	59.9	28.7	2692.0
1974	21.9	17.0	13.7	6.9	28.0	81.5	132.1	1626.0	1063.2	262.6	73.7	33.8	3360.1
1975	20.6	21.9	9.4	6.5	42.0	378.5	382.1	1340.0	1530.4	361.5	89.8	43.9	4226.7
1976	31.6	25.4	21.7	53.0	63.7	32.9	691.4	804.3	527.2	219.9	54.8	29.3	2555.0
1977	18.5	8.9	6.0	32.4	27.9	14.3	95.2	435.8	2165.6	74.6	21.2	5.6	2905.8
1978	3.0	0.6	0.6	0.3	19.1	181.1	778.8	2687.0	2269.0	475.2	179.0	106.9	6700.4
1979	86.3	59.2	49.9	53.0	300.8	982.5	661.8	1189.4	1410.5	347.5	102.2	52.5	5295.5

River : Huai Bang-I, Station code 24001 (Discharge Area = 702 sq.km) (Data Source: RID)

Table B- 5 Monthly Discharge Record of Huai Bang Sai at 23805 Station

(Unit: cms)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1985	20.0	10.3	4.4	5.0	49.1	210.8	316.1	1705.0	662.7	422.7	63.4	21.2	3490.6
1986	11.0	3.7	3.1	35.0	512.5	548.8	121.5	945.4	104.2	183.1	79.3	13.4	2560.8
1987	9.9	9.1	5.5	2.1	39.0	471.8	482.7	2974.2	2927.3	397.1	124.3	72.9	7515.8
1988	47.8	33.5	34.8	20.0	232.1	416.7	128.1	1745.7	341.3	431.9	111.7	55.7	3599.1
1989	15.7	4.2	17.0	9.1	196.8	220.8	333.8	1586.1	1593.8	389.3	117.5	55.5	4539.5
1990	16.3	23.1	82.7	6.5	105.7	479.3	711.9	5532.3	2653.5	437.5	138.2	56.4	10243.3
1991	25.9	13.5	16.9	7.0	25.9	251.8	526.2	1989.8	2096.9	555.8	104.6	55.5	5669.5
1992	43.0	21.0	15.3	8.0	144.2	464.9	291.5	1157.7	886.2	128.4	42.5	22.4	3225.1
1993	15.1	8.6	3.7	40.5	226.3	133.4	285.8	791.6	1069.3	228.9	70.9	32.4	2906.6
1994	17.7	17.6	26.2	12.3	199.3	950.7	610.5	2614.5	1207.4	385.0	77.1	28.7	6147.0

River : Huai Bang Sai, Station code 23805 (Discharge Area = 925 sq. km) (Data Source: DEDP)

Table B- 6 Monthly Discharge Record of Huai Bang Sai at 23804 Station

(Unit: cms)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1985	33.2	18.7	11.1	10.5	77.0	278.6	363.2	2476.7	925.9	459.4	118.2	38.0	4810.4
1986	23.3	10.9	8.8	40.3	482.7	376.9	210.0	971.1	1258.3	264.2	116.0	55.4	3817.9
1987	20.4	10.8	12.0	10.6	121.8	422.5	486.5	2902.6	2601.3	471.6	127.8	44.3	7231.9
1988	18.3	9.2	6.9	3.3	116.1	469.4	143.3	2134.4	448.1	532.6	100.4	42.0	4024.0
1989	25.1	15.0	17.3	11.2	114.1	281.0	457.0	1901.8	1718.5	416.6	107.2	46.3	5141.0
1990	25.5	33.0	59.6	8.4	103.7	625.5	943.7	4527.0	3518.5	997.3	306.2	63.4	11211.7
1991	37.1	22.3	21.1	10.4	41.3	165.3	625.3	2954.9	3854.8	605.6	148.1	70.4	8556.6
1992	57.6	31.1	19.1	10.4	156.9	317.5	332.1	1545.2	776.5	194.7	63.5	28.8	3533.5
19.93	22.0	11.9	7.5	20.1	233.9	200.3	344.2	1147.4	1477.3	267.0	84.9	47.1	3863.5
1994	29.4	49.8	35.6	23.3	126.7	1061.4	791.0	2833.8	1649.8	474.1	127.5	50.7	7253.1

River : Huai Bang Sai Station code 23804 (Discharge Area = 1,220 sq.km) (Data Source: DEDP)

Table B-7 Groundwater Development Potential of Aquifers summarized by GREP

Aquifer Class	Formation	Safe Yield L/sec./Km^2	Tubwell Av.Depth(m)	Tubwell Av.Yield(L/s)	Water Quality mg/L(TDS)	Potential Uses / Development
Class 1	Gravel / Sand Deposits	13 Khon Kaen University	50	2.5	<500.	Domestic & village water supply, Small scale irrigation
		13 N.E sector	30	2.5	<500	Tubewell,Dugwell
	Phu Tok	20	100	40 discharge zone	<500	Domestic & village water supply, Small & large scale irrigation, industry
		8	100	2	<500.	Tubewell
	Khok Kruat	N/A	40	2	<500to<1500	Village water supply, Small scale irrigation Tubewell
Class 2	Phu Phan Sao Khua Pra Wihan Pru Kradung	N/A	40	2	<500to<1500	Village water supply, Small scale irrigation Tubewell,Sping capture
	Flood Alluvium	N/A	10	2	<1000.	Village water supply,Dugwell,Tubewell
Class 3	Mahasarakham	N/A	40	2	localized area <1000 localized area	Village water supply, Tubewell

(Data Source : GREP)

(Note)

N/A: not assessed

Class 1 Aquifers providing large yield of high quality water suitable for most uses. These belong to the Tertiary Phu Tok Formation and the Quatemary gravel/sand deposits.

Class 2 Aquifers providing low to medium yields of good to moderate quality groundwater suitable possibly for village water supply and for small scale irrigation. The aquifers in this class belong to the Khok Kruat and older formation.

Class 3 Aquifers containing essentially brackish to saline groundwater with varying yields. Aquifers within the plain alluvium and Maha Sarakham Formation belong to this group.

Chapter 2. Groundwater

Groundwater potential indicated as expected well yield in each priority area are distributed from the range of less than 2 cu.m/hr to 10-20 cu.m/hr from the indication of the Groundwater Map. The groundwater map is compiled from information so as soil layer, soil texture, aquifer, groundwater level and also yield of existing wells, and it is useful to grasp the ground idea or basic plan regarding groundwater. When particle data is necessary regarding groundwater potential, detail investigations should be carried out as the contents and area of expected well yield shown on the groundwater map is not enough accurate to apply for practical planing or project

Table B-8 Expected Well Yield in the Priority Area

Study Area	A (ha)	Proportion of Acreage by Expected Well Yield			
		<2 m^3/hr	2 - 10 m^3/hr	10 -20 m^3/hr	>20 m^3/hr
KK-6	23,967	70%	20%	10%	0%
MH-5	2,085	50%	40%	10%	0%
SK-3-1	2,970	20%	50%	30%	0%
MK-8-2	5,080	40%	60%	0%	0%

Chapter 3. Water loss from farm pond

Water loss from a farm pond is composed of evaporation from surface and percolation from bed and side of pond. Field investigation was carried out to find out the actual situation of water loss from farm pond in the priority area from 15 to 19th December 1997 in Khon Kaen, from 23 to 25th December in Maha Sarakham, and from 6 to 12th January 1998 in Sakon Nakhon and Mukdahan.

3.1 Selection of pond

Under following considerations, existing farm ponds were selected for investigation:

- Farm ponds should locate within the priority area.
- Size of pond should be small as a size of individual farm pond.
- Farm ponds should not be located in the depressed area like as in valley.
- Farm ponds should have a certain depth of water for measuring.

18 ponds were selected on the map, and measurement was carried out at 15 ponds in Khon Kaen, because some of selected ponds were empty or insufficient in water depth.. 12 ponds were selected and measurement at 11 pond in Maha Sarakham. 11 and 5 ponds were measured in Sakon Nakhon and Mukdahan respectively.

3.2 Method of Measurement

As a method of measurement, direct and indirect measurement are adopted. Rapid seepage meter is applied for direct seepage measurement. And measuring the descending of water level of pond using gauge staff is adopted as indirect method. The period of measurement were 3 to 4 days in Khon Kaen, 2 to 3 days in Maha Sarakham, 2 to 3days in Sakon Nakhon and 4 days in Mukdahan.

3.3 Result of Measurement

Descending of water level are as follows.

Table B-9 Frequency of Water Level Descending in Farm Ponds in the Priority Area

(cm/day)	KK	MHS	SKN	MKH
0.1				1
0.2		1		
0.3	2	1		
0.4	1	3	1	
0.5	4	2		
0.6	3	2	1	2
0.7	3	1		1
0.8	1	1	1	
0.9	1		2	1
1.0				
1.1				
1.2				
1.3			1	
Av.	0.6	0.5	0.8	0.6

3.4 Findings

Measurement of descending water level is considered more reliable as measuring the water level itself directly than the rapid seepage meter, because the figures from rapid seepage meter are fluctuated widely and there's difficulty to assume representative value of seepage through the measured figures. In this study, result from descending water level are used for the estimation of water loss form farm pond.

Water loss measured in the field are scattered from 0.3 cm/day to 0.9 cm/day in Khon Kaen and from 0.2 to 0.8 cm/day in Maha Sarakham, 0.4 to 1.3 cm/day in Sakon Nakhon, 0.1 to 0.9 cm/day in Mukdahan. Regarding to proportion of occurrence ,water loss from 0.5 to 0.7 cm/day occupies 67 % of whole measurements in Khon Kaen and 0.4 to 0.6 cm/day occupies 64 % in Maha Sarakham 0.6 to 0.9 cm/day occupies57% in Sakon Nakhon. 0.6 to 0.7 cm/day occupies 60% in Mukdahan respectively.

The seepage loss from pond is estimated to describe the evaporation from descending of water level. The evaporation from pond is assumed 0.36 cm/day in Sakon Nakhon and

Mukdahan and 0.43 cm/day in Sakon Nakhon. and Mukdahan as same value as estimated potential evapotranspiration in December and January in these region.

Consequently, the seepage loss from farm pond is estimated 0.2 to 0.4 cm/day in Khon Kaen, 0.1 to 0.3 cm/day in Maha Sarakham, 0.1 to 0.4 cm/day in Sakon Nakhon, 0.2 to 0.3 cm/day in Mukdahan as dominant value.

Table B-10 Frequency of Seepage from Farm Ponds in the Priority Area

(cm/day)	KK	MHS	SKN	MKH
< 0	2	2	1	1
0.1	1	3	1	0
0.2	4	2	1	2
0.3	3	2	0	1
0.4	3	1	1	0
0.5	1	1	2	1
0.6	1	0	0	0
0.7	0	0	0	0
0.8	0	0	0	0
0.9	0	0	1	0
Average	0.3	0.2	0.4	0.2

3.5 Conclusions

In generally, soil profile shows sandy loam or loamy sand at top and sandy loam or sandy clay loam at lower in priority areas. When the pond is constructed digging deeply than surround ground level, clayey soil prevents seepage from pond. In this field study during end of December 1997 to beginning of January 1998, shallow pond in depth or pond located on ridge or high position comparing to surround land had been dried up. High values of seepage are measured at the ponds mentioned above.

The values of seepage from pond based on the water level descending measurement are breakup from 0 to 0.6 cm/day and dominant values are concentrated from 0.1 to 0.4 cm/day. In this study, 0.2 cm/day is adopted as seepage from farm pond excepting isolated height and low values.

Chapter 4. Evaluation of the rainfall in 1997

The amount and distribution of rainfall in 1997 has examined to prove the rainfall in 1997. Rainfall data of 1997 are collected and compared to that of average rainfall as monthly basis from April to possible month as data available.

In generally, estimated annual rainfall in 1997 is smaller than average year and the differences between 1997 and average year are fairly breakup from half of average to almost same as average depending upon each station. Regarding the monthly distribution, generally, it rained less in August and September during 1997 rainy season Rainfall in September is remarkably small compare to average year as about half or less than half of it at many stations.

Supplemental irrigation for paddy by using farm pond was accreted being affected with small rainfall in half end of rainy season, consequently, it is suggested that less water remained in farm pond or it was dried up after irrigation in 1997

Table B-11 Analysis of Rainfall in 1997

Station code	province	data period	rainfall of data period	estimated annual rainfall	Average annual rainfall	97/Av.(%) Annual	97/Av.(%) September	Return period (equivalent)
14452	Khon Kaen	Apr - Dec	953	988	1,008	98	78	2
14190	Khon Kaen	Apr - Nov	505	536	1,008	49	41	>500
14170	Khon Kaen	Apr - Dec	723	774	1,051	74	59	10
21252	Maha Sarakham	Apr - Nov	743	778	1,135	69	52	25
21200	Maha Sarakham	Apr - Oct	616	657	1,081	61	49	50
21170	Maha Sarakham	Apr - Oct	607	653	1,106	59	47	>500
21120	Maha Sarakham	Apr - Oct	703	747	1,112	67	59	20 - 25
21292	Maha Sarakham	Apr - Nov	933	1,002	1,002	100	99	2
64042	Mukdahan	Apr - Dec	1,136	1,172	1,500	78	39	7 - 8
64013	Mukdahan	Apr - Dec	1,052	1,090	1,432	76	42	3 - 4
64032	Mukdahan	Apr - Nov	1,134	1,174	1,388	85	41	5
23803	Mukdahan	Apr - Dec	1,197	1,249	1,436	87	23	3 - 4
50180	Sakon Nakhon	Apr - Dec	1,232	1,262	1,426	89	0	3
50102	Sakon Nakhon	Apr - Oct	1,174	1,244	1,356	92	38	2
23403	Sakon Nakhon	Apr - Dec	1,453	1,453	1,434	101	117	*
50042	Sakon Nakhon	Apr - Dec	1,009	1,077	1,432	75	41	8

[Note]
data period : data period applied for comparison
estimated annual rainfall : converted annual rainfall by monthly proportion of average rainfall
97/Av.(%) : proportion of 97's value to that of annual
*rainfall in 1997 is more than average

Chapter 5 Perennial Rivers in the Study Areas

If river water flows through out the year, utilization of it is most easy and convenient both from quantitative and economical aspects. As most of the base flow is normally occupied by the vested water users and water for environment control is becoming more important, river water use should be carefully studied so as to examine present flow at various points and also water use downstream.

Flow regime of the Chi river and the Nam Phung river have been examined at measuring station E 9 and Nam Phung Dam site (release water) based on daily basis. A year as much close to the average discharge or release has been selected to examine the flow regime. Low water-discharge, that is defined as a discharge which river flow exceeds for 275 days in a year, is 2.4 cms, and droughty discharge, that is defined as a discharge which river flow exceeds for 355 days in a year, is 0.2 cms at E 9 station in the Chi river in 1983. While, low water-discharge and droughty discharge are recorded as 1.1 cms and 0.7 cms respectively at the downstream of Nam Phung Dam site in 1975.

Table B-12 Low Water Flow in Chi River and Nam Phung River

Station	Low water-discharge	Droughty discharge
Chi river at E9 (cms)	2.4	0.2
Nam Phung Dam Release (cms)	1.1	0.7

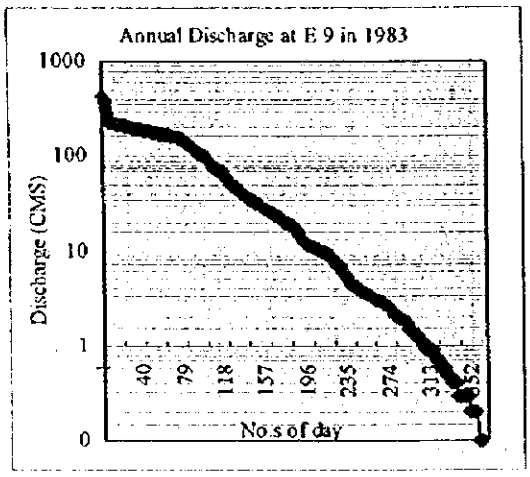


Figure B-13 Flow Regime of Chi River at E 9 in 1983

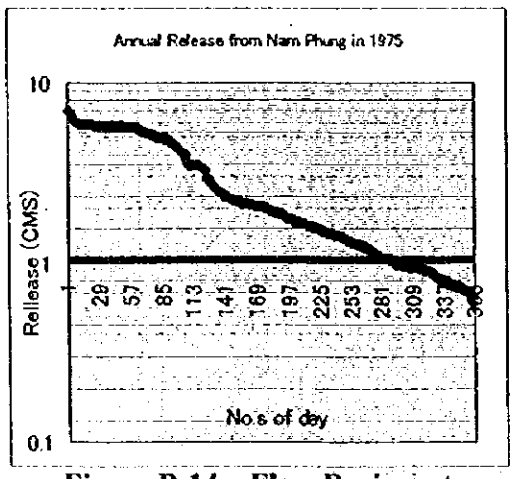


Figure B-14 Flow Regime at Downstream of Nam Phung Dam in 1975

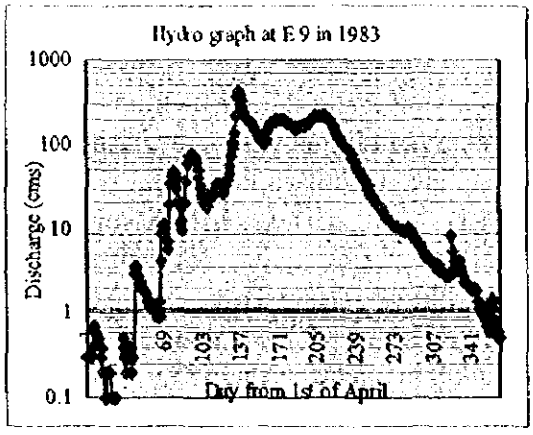


Figure B-15 Hydrograph of Chi River at E 9 in 1983

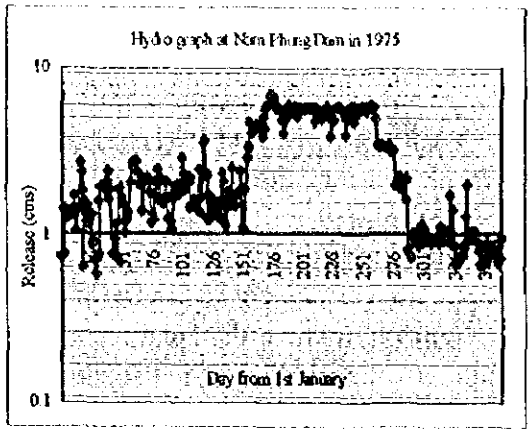


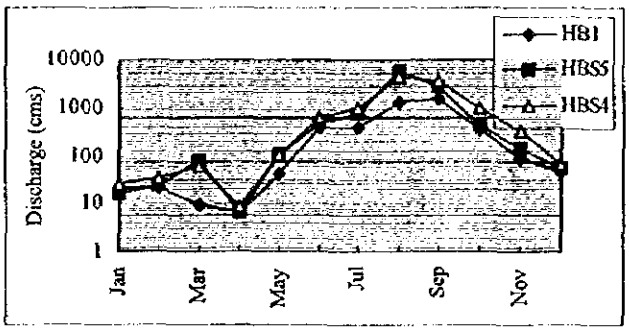
Figure B-16 Hydrograph at Downstream of Nam Phung Dam in 1975

Low water flow of the Huai Bang-I and the Huai Bang Sai rivers has been examined on monthly basis at the measuring stations 24001, 23804, and 23805 (location to be referred to Table B-2). Low water flow appears generally in the period from January to April. Probability analysis has been carried to clarify the probable drought flow of both rivers in return periods of 2-year, 5-year and 10-year.

Generally runoff coefficient counts higher in smaller catchment area. The value of Huai Bang Sai station 23805 is advisable to adopt for the study of base flow as this value is smaller compared to that of other two stations even with larger catchment area. The results are summarized in Table B-13.

Table B-13 Probable Minimum Monthly Flow of Huai Bang I and Huai Bang Sai Rivers

River	Station	Catchment Area (km^2)	Return Period (1/2yr)		Return Period (1/5yr)		Return Period (1/10yr)	
			Low Flow (cms)	Specific Dis. (cms/100km^2)	Low Flow (cms)	Specific Dis. (cms/100km^2)	Low Flow (cms)	Specific Dis. (cms/100km^2)
Huai Bang 1	24001	702	6.38	0.909	2.87	0.409	1.9	0.271
Huai Bang Sai	23805	925	5.80	0.627	3.23	0.349	2.45	0.265
	23804	1220	9.98	0.818	6.55	0.537	5.15	0.422



(Note): HBI=Huai Bang-I at 24001,
HBS5=Huai Bang Sai at 23805,
HBS4=Huai Bang Sai at 23804

Figure B-17 Hydrograph of Huai Bang I and Huai Bang Sai Rivers

Chapter 6. Flood Analysis

Normally, there will be a high volume of flowing water during the rainy season while in summer, especially, when there is a high volume of rainfall within the basin, there will be an overflow of great volume because the basin are steeply sloping. But when the volume of rainfall is low, the volume of water will be low. There is a high volume of flowing water between June and October.

In the study of the Huai Krachoe Reservoir Project which has a 44.5 sq.km basin area, flood volume is calculated at about 75.0 cub.m/sec. in average year, 187.0 cub.m/sec. in a 100 year return period and 230.0 cub.m /sec in a 500 year return period. At the moment, the specific yield of a flood is estimated to be 1.68 cub.m/sec/sq.km in an average year, 4.20 cub.m/sec./sq.km in a 100 year return period and 5.15 cub.m/sec./sq.km in a 500 year return period respectively. The application of a 100 year return period or a 500 year return period on specific yield of flood is decided according the situation of down stream area so as number of population, social and private properties. The envelope curve of specific yield of flood which is compiled from momentum peak flood for river basin in North-Eastern region is accumulated and utilized to estimate the specific yield in RID (Figure B-4).

Chapter 7. Effective Rainfall

It is proposed several empirical method for the calculation of effective rainfall in Thailand. Out of these methods, the empirical method recommended for North-Eastern part of Thailand is applied in this study. Calculation is divided into two ways, one is for period of October effecting 100 % up to 50 mm, effecting some proportion in excess of 50 mm by up to 200 mm and maximum as 100 mm when it more than 200 mm. Another is for period for April to September and November to March effecting 100 % up to 100 mm, effecting some proportion in excess of 100 mm by up to 400 mm and maximum as 160 mm when it more than 400 mm.

Table B-14 Rainfall and Effective Rainfall Relation

Rainfall(mm)	Effective Rainfall(mm)	
	E1	E2
0	0	0
50	50	50
100	92	100
150	95	126
200	100	135
250	100	147
300	100	156
350	100	158
400	100	160
450	100	160
500	100	160

(Note) E1:applied for Oct.
E2: applied for Apr.-Sep., Nov.-Mar.

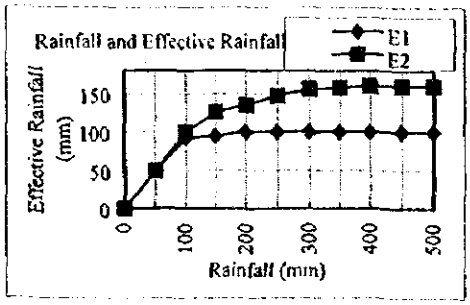


Figure B-18 Rainfall and Effective Rainfall Relation

Annual effective rainfall based on monthly rainfall is counted as 841 mm in average year and 726 mm in return period 5 year in Khon Kaen and Maha Sarakham. While, 917 mm in average year and 854 mm in return period 5 year in Mukdahan and Sakon Nakhon.

Table B-15 Annual Rainfall and Its Effective Rainfall

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Annual
Khon Kaen, Mahasarakham													
Rainfall													
Av. Year	68.2	154.9	134.8	120.5	141.7	244.4	90.3	11.8	5.4	3.7	13	32.2	1,020.9
1/5 year	54.1	122.8	106.9	95.6	112.4	193.8	71.5	9.4	4.3	3	10.3	25.5	809.6
Effective Rainfall (mm)													
Av. Year	68.2	126.9	118.1	110.7	121.7	145.7	83.9	11.8	5.4	3.7	13	32.2	841.3
1/5 year	54.1	111.9	103.6	95.6	106.4	133.9	68.1	9.4	4.3	3	10.3	25.5	726.1
Mukdahan, Sakon Nakhon													
Rainfall (mm)													
Av. Year	80.3	194.9	247.5	230.5	315.8	240.2	76.1	2.9	3.3	3.4	5.6	25	1,425.5
1/5 year	68.6	166.7	211.6	197.1	270	205.4	65.1	2.5	2.8	2.9	4.8	21.4	1,218.9
Effective Rainfall (mm)													
Av. Year	80.3	134.1	146.4	142.3	156.6	144.6	71.9	2.9	3.3	3.4	5.6	25	916.4
1/5 year	68.6	129	137.8	134.5	150.6	136.3	62.7	2.5	2.8	2.9	4.8	21.4	853.9

Chapter 8. Water Requirement of Major Irrigated Crops

1) Water Requirement of Major Irrigated Crops

In the extensive irrigation areas, the first priority of irrigation is considered to be supplementary irrigation for paddy in the rainy season to stabilize and increase rice production. On the other hand, in the integrated farming areas, irrigation priority is given to vegetables first and fruit trees second. However, supplemental irrigation is to be considered for paddy even in the integrated farming areas where paddy is planted in adjacent.

Table B-16 shows the irrigation water requirement of major crops in a drought year of 1/5 year and in an average year. Much water is necessary for fruit trees as 1,299 mm because they are perennial crops. Wet season rice also needs much water as 1,124 mm even it grows in rainy period.

Table B-16 Irrigation Water Requirement of Major Crops

(unit : mm)

Crop	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
1/5 Dry Year													
KK, MHS													
Wet S. Rice			74	463	161	126	222	78					1,124
Vegetables		86	0			0	43			210	142		481
Watermelon	158	0	0							69	239	337	803
SKN, MKD													
Wet S. Rice			19	401	85	107	247	91					950
Vegetables		63	0			0	61			241	167		532
Fruit trees	153	13	0	0	0	0	104	198	186	195	205	245	1,299
Average Year													
KK, MHS													
Wet S. Rice			51	439	137	107	197	76					1,007
Vegetables		62	0			0	18			208	138		426
Watermelon	136	0	0							67	234	330	767
SKN, MKD													
Wet S. Rice			6	368	75	94	232	91					886
Vegetables		52	0			0	46			241	166		508
Fruit trees	135	5	0	0	0	0	89	197	185	195	204	240	1,250

2) Irrigation Efficiency

To account for losses of water incurred during conveyance and application to the field, irrigation efficiency should be considered in irrigation requirement. Irrigation efficiency is normally subdivided into two stages of conveyance and field application, each of which is affected by a different set of conditions;

- Conveyance efficiency (Ec) — ratio between water received at the field inlet and that released at the project headworks.
- Field application efficiency (Ea) — ratio between water directly available to the crop and that received at the field inlet.
- Irrigation efficiency (Ei); — overall ratio between headworks and crops, or Ei = Ec * Ea

Factors affecting conveyance efficiency (Ec) are, amongst others, size of the irrigation area, period of rotational unit, types of crops for irrigation, canal lining condition, type of soil in respect of seepage losses, length of conveyance and field canals, and technical and managerial level of water control. Field application efficiency (Ea) is much affected by the irrigation skill of farmers. Irrigation efficiencies of this study are estimated mainly from the information of FAO .

Conveyance efficiency and application efficiency are estimated as follows

Conveyance (Ec)	0.90	
Application Efficiency (Ea)		
Basin	0.70	
Sprinkler	0.70	
Furrow	0.60	
Farm pond / Shallow well	0.70	

Irrigation efficiency(Ei) on this study

Rice	0.63	
Upland cop		
Vegetable	0.63	
Fruit tree	0.63	
Sugarcane	0.54	(furrow irrigation)

Recommendable irrigation system and irrigation efficiencies are summarized as shown in Table B-17

Table B-17 Recommendable Irrigation System and Efficiencies

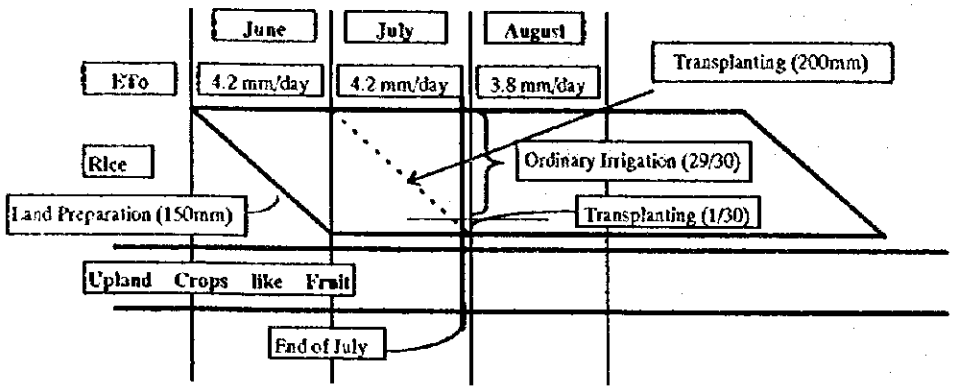
Water Resource	Irrigation crop	Irrigation hours	Method Irrigation			
			hose, bucket	micro-sprinkler	furrow	basin
Reservoir	Paddy	24				0.63
Pond	Vegetable	12	0.63	0.63		
Shallow well	fruit tree	12		0.63		0.63
	sugarcane	12			0.54	

3) Peak Irrigation Requirement

Peak irrigation requirement is an important factor governing the capacity of irrigation facilities. Peak irrigation requirement is calculated for two cases, that for the paddy dominant area and for the upland crop dominant area.

a) Peak Irrigation Requirement in Paddy Dominant Area

Peak irrigation requirement appears at the end of July that is the latest day of transplanting of paddy rice in the paddy dominant area as shown below;



<Peak Irrigation of Rice>

Net Irrigation = Ordinary Irrigation + Paddling Water = Kc×Eto x 29/30 + 200 ㎜×1/30 =
1.0×4.2 ㎜/day×29/30 + 200 ㎜×1/30 = 5.99 ㎜/day + 6.77 ㎜/day = 12.66 ㎜/day

Irrigation Water Requirement = Net Irrigation / Ei = 12.66 ㎜/day / 0.63 = 20.1 ㎜/day =
2.33 lit/sec/ha or 0.373 lit/sec/rai

<Irrigation of Upland Crops>

Irrigation Water Requirement = Kc x Eto / Ei = 0.9×4.2 ㎜/day / 0.63 = 6.00 ㎜/day =
0.70 lit/sec/ha or 0.112 lit/sec/rai (estimated as fruit tree)

b) Peak Irrigation Requirement in Upland Dominant Area

In upland dominant area, peak irrigation water requirement appears generally in March when potential evapotranspiration (ETo) reaches highest.

<Peak Irrigation of Upland Crops>

Irrigation Water Requirement = Kc×Eto / Ei = 1.1×6.3 ㎜/day / 0.63 = 11 ㎜/day =
1.27 lit/sec/ha or 0.203 lit/sec/rai (Kc is assumed at average Kc of upland crops)

(Note) Above peak irrigation requirement is corresponding to the standard water requirement of Pump Irrigation Project as below;

Irrigation Area	DEDP Pump Irrigation Project Standard	Estimation based on above peak irrigation requirement
500 rai	100 lit/sec	0.203 lit/sec/rai x 500rai =102 lit/sec/rai
1,500 rai	300 lit/sec	0.203 lit/sec/rai x 1,500rai =305 lit/sec/rai
3,000 rai	600 lit/sec	0.203 lit/sec/rai x 3,000rai =609 lit/sec/rai

Chapter 9. Water Balance of Farm Pond

To ensure the size and necessary catchment area of pond, operation of farm pond has been simulated for two cases of ponds under 1/5 drought year. It is found that necessary catchment area of farm pond is twice in Khon Kaen and Mahasarakham comparing to that in Mukdahan and Sakon Nakhon. It is a very important factor for selecting the location of farm pond to ensure necessary catchment.

1) Water Balance of Ordinary 1,200 m^3 Farm Pond

Vegetables is proposed for irrigation by a farm pond of 1,200 m^3 ordinary size, and irrigable acreage and necessary catchment area of farm pond have been investigated.

1 rai of vegetables can be irrigated collecting runoff from a catchment area of 3 rai in Khon Kaen and Mahasarakham, and 1.5 rai in Mukdahan and Sakon Nakhon.

Table B-18 Water Balance of Ordinary 1,200m^3 Farm Pond in KK, MHS

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Rainfall (mm)	54	123	107	96	112	194	72	9	4	3	10	26	810
Inflow (m^3)													
Runoff	98	223	194	174	204	352	130	17	8	5	19	46	1,470
Direct rain to pond	45	102	89	80	94	161	60	8	4	2	9	21	675
Total	143	325	283	254	298	513	190	25	12	7	28	67	2,145
Irrigation (m^3)	0	138	0	0	0	0	69	0	0	336	227	0	770
Water loss (m^3)	50	40	45	64	73	89	128	110	100	99	72	67	937
Balance (m^3)	93	240	478	668	893	1,200	1,193	1,108	1,020	592	321	321	

(Note) 1) Condition: 1/5 drought Year, Catchment area: 3.0 rai, Initial storage (end of Mar.) is at 0 m^3, Crops: Vegetable = 1.0 rai

2) *Overflow occurs in September.*

Table B-19 Water Balance of Ordinary 1,200m^3 Farm Pond in SKN, MKD

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Rainfall (mm)	68.6	166.7	211.6	197.1	270	205.4	65.1	2.5	2.8	2.9	4.8	21.4	1,218.9
Inflow (m^3)													
Runoff	49	120	152	142	194	148	47	2	2	2	3	15	876
Direct rain to pond	45	110	140	130	178	136	43	2	2	2	3	14	805
Total	94	230	292	272	372	284	90	4	4	2	6	29	1,679
Irrigation (m^3)	0	101	0	0	0	0	98	0	0	386	267	0	852
Water loss (m^3)	46	36	38	58	68	89	118	106	96	92	53	29	829
Balance (m^3)	48	141	395	609	913	1,108	982	880	788	314	0	0	

(Note) 1) Condition: 1/5 drought Year, Catchment area: 1.5 rai, Initial storage (end of Mar.) is at 0 m^3, Crops: Vegetable = 1.0 rai

2) No overflow occurs.

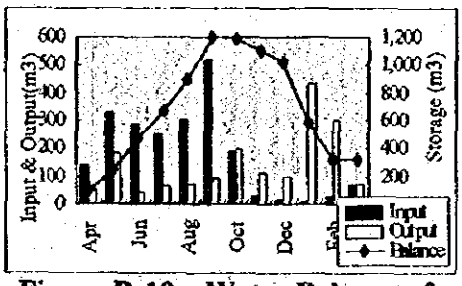


Figure B-19 Water Balance of Ordinary 1,200m^3 Farm Pond in KK,MHS

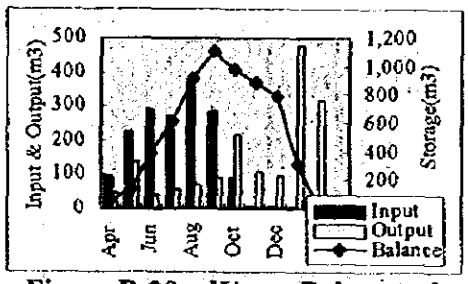


Figure B-20 Water Balance of Ordinary 1,200m^3 Farm Pond in SKN,MKD

2) Water Balance of Large 6,000 m^3 Farm Pond

For a large 6,000 m^3 farm pond, vegetables, wet season rice and dry season crops after rice have been selected in Khon Kaen and Mahasarakham, while vegetables and fruit tree in Mukdahan and Sakon Nakhon.

1 rai of vegetables, 3 rai of wet season rice and dry season crops can be irrigated in Khon Kaen and Mahasarakham, and 1 rai vegetables and 3 rai of fruit tree in Mukdahan and Sakon Nakhon. Necessary catchment areas are 30 rai in the former areas and 15 rai in the latter areas. No overflows occur from a farm pond in the former areas, but some overflows occur in the latter areas in August and September. In Mukdahan and Sakon Nakhon, therefore, some supplemental irrigation to the adjacent paddy rice should be done to utilize water efficiently and to reduce overflow.

Table B-20 Water Balance of Large 6,000m^3 Farm Pond in KK, MHS

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Rainfall (mm)	54	123	107	96	112	194	72	9	4	3	10	26	810
Inflow (m^3)													
Runoff	779	1,768	1,539	1,377	1,619	2,791	1,030	135	62	43	148	367	11,658
Direct rain to pond	122	277	241	216	253	437	161	21	10	7	23	58	1,826
Total	901	2,045	1,780	1,593	1,872	3,228	1,191	156	72	50	171	425	13,484
Irrigation (m^3)	758	138	355	2,222	773	605	1,135	374	0	667	1,374	1,618	10,019
Water loss (m^3)	211	252	204	131	185	241	160	138	143	125	108	139	2,037
Balance (m^3)	132	1,787	3,008	2,248	3,162	5,544	5,440	5,084	5,013	4,271	2,960	1,628	

(Note) 1) Condition: 1/5 drought Year, Catchment area: 30 rai, Initial storage (end of Mar.) is at 200 m^3
Crops: Vegetable (1.0 rai) and Wet Season Rice and Dry Season Crops (3 rai)
2) No overflow occurs during operation.

Table B-21 Water Balance of Large 6,000m^3 Farm Pond in SKN, MKD

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Year
Rainfall (mm)	68.6	166.7	211.6	197.1	270	205.4	65.1	2.5	2.8	2.9	4.8	21.4	1,218.8
Inflow (m^3)													
Runoff	494	1200	1,524	1,419	1,944	1,479	469	18	20	21	35	154	8,777
Direct rain to pond	155	376	477	444	609	463	147	6	6	7	11	48	2,749
Total	649	1,576	2,001	1,863	2,553	1,942	616	24	26	28	46	202	11,526
Irrigation (m^3)	734	163	0	0	0	0	597	950	893	1,322	1251	1176	7,086
Water loss (m^3)	192	234	226	228	234	213	166	125	124	110	116	158	2,126
Balance (m^3)	0	1,179	2,954	4,589	6,000	6,000	5,853	4,802	3,811	2,407	1,086	0	

(Note) 1) Condition: 1/5 drought Year, Catchment area: 15 rai, Initial storage (end of Mar.) is at 0 m^3
Crops: Vegetable (1.0 rai) and Fruit Tree (3 rai)
2) Overflow occurs in August and September. (Adjacent paddy rice should be irrigated for efficient water utilization.)

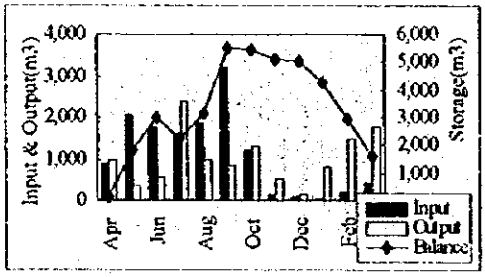


Figure B-21 Water Balance of Large 6,000m^3 Farm Pond in KK, MHS

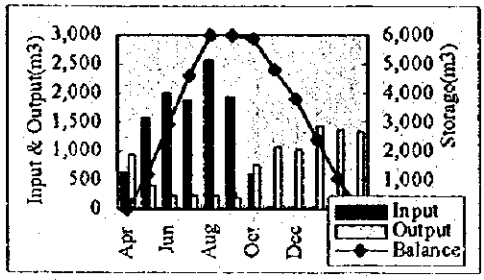


Figure B-22 Water Balance of Large 6,000m^3 Farm Pond in SKN, MKD

3) Annual Irrigation Amount from Farm Pond

Annual irrigation amount from farm pond has been estimated to clarify the operation cost of farm pond in integrated farming. Table B-22 shows annual irrigation amount of each case of farm pond.

Table B-22 Annual Irrigation Amount from Farm Pond

Area	Farm Pond (m^3)	Return Period (yr)	Irrigation Area (rai)				Irrigation Amount (mm)				Annual Irrigation (m^3)
			Vegetable	Paddy Rice	Dry S. Crops	Fruit Tree	Vegetable	Paddy Rice	Dry S. Crops	Fruit Tree	
KK, MHS	1,200	1/5	1				481				770
		1/2	1				426				682
	6,000	1/5	1	3			481	1,124	803		10,019
		1/2	1	3			426	1,007	767		9,199
MKD, SKN	1,200	1/5	1				532				852
		1/2	1				508				814
	6,000	1/5	1			3	532			1,299	7,086
		1/2	1			3	508			1,250	6,814