THE KINGDOM OF THAILAND

FEASIBILITY STUDY

ON

THE BANG NARA IRRIGATION AND DRAINAGE PROJECT

APPENDICES

DECEMBER 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

CONTENTS of APPENDICES

(Supporting Data)

APPENDIX I. TOPOGRAPHY AND GEOLOGY

I-1 Topography

Table I-1-1 Topographical Maps and Other Information

Classification	Scale	Number of Sheets	Description
Topographical Maps	1:250,000	3	Maps produced by US Army / RTSD in 1976, SERIES 1501S
	1:50,000	21	Maps produced by US Army / RTSD in 1972, SERIES L7017
	1:25,000	11	Maps produced by US Army / RTSD in 1983, SERIES L8019
	1:10,000	28	Maps produced by RID in 1976 for use on Mu No Project
	1:10,000	28	Maps produced by RID in 1975 for use on Bacho Project
	1:1,000	13	Maps produced by RID in 1982 for use on Bang Nara Project (Upper Regulator Site)
	1:1,000	9	ditto (Lower Regulator Site)
	1:4,000	17	Plan / Profile of Mae Nam Bang Nara produced by RID in 1984
	V1:100 H1:500	25	Cross Sections of Mae Nam Bang Nara produced by RID in 1984 Regulator and Canal drawings used for Nam Baeng Project Regulator and other drawings used for Pi Leng Project
	1:10,000	7	Plan of Mae Nam Ya Kang
	1:20,000	2	Profile of Mae Nam Ya Kang
	V1:100 H1:200	22	Cross Sections of Mae Nam Ya Kang produced by RID upon the Study Team's request

Classification	Scale	Number of Sheets	Description
Topographical Maps	1:4,000	5	Plan/Plofile of Khlong To Che
	V1:100 H1:200	13	Cross Sections of Khlong To Che produced by RID upon the Study Team's request
	1:2,000	6	Plan of three sample areas produced by RID upon the Study Team's request
Orthophotomaps	1:10,000	58	Orthophotomaps produced by RTSD in 1984 from photography of June 1982 for use on GRBDS
Aerial Photographs	1:15,000	54	Photographs taken by RTSD in 1984 for use on DLD Projects

Table I-1-2 Catalogue of Survey Field Books

Field Book	Contents	Page
1	Leveling BM 2778 C - RID 018	1
2	Leveling BM RID 018 - MUNO 02	5
3	Leveling BM MUNO 02 - MUNO 04	9
4	Leveling BM MUNO 04 - CH P 1781	12
5	Leveling BM CH P1781 - Intersection	16
6	Leveling BM N6 - CH P244478 (BM ▽3)	21
7	Leveling BM Intersection - BM 2 (Taba)	23
8	Leveling BM Intersection BM 3 (Nam Baeng)	30
9	Leveling BM 3 - BM 3 (Bang Nara Bridge)	35
10	Leveling BM 3 (Bang Nara Bridge) - BM ▽1	43
11	Leveling BM 3 (Bang Nara Bridge) - ARMY P722	45
12	Leveling BM ARMY P722 - BM ⑤ (Bangkok Bank)	47
13	Leveling BM 3 (Pasemas Bridge) - T.P (Pa Ye)	49
14	Leveling BM TP (Pa Ye) - TP 26	52
15	Leveling - BM 2 (Pa Ye) - HYDRO ③	55
16	Leveling BM ARMY P722 - BM ④ (Ya Kang X 73)	59
17	Leveling for Cross Section of Ya Kang at X 73	66
18	Leveling BM ④ (Ya Kang X 73) - BM P	69
19	Leveling - BM P - BM X 73A (BO NGO X 73A)	75
20	Leveling for Cross Section of Bo Ngo at X 73A	80
21	Leveling TBM 1 (Sala Mai) - ARMY CH3	83
22	Leveling BM ARMY CH3 - CH P244507 (BM ▽2)	85
23	Leveling - TP 105 - BM 4 (Upper Regulator)	88
24	Leveling BM N6 - CH P571542 (Lower Regulator)	90
25	Leveling PREMARK 004 - ARMY 21	92
26	Leveling for water Levels on Station ▽3▽1▽2⑤	94

I-2 Geology

I-2-1 Area Topography and Geology

(1) Topography

The Study area is situated at Lat. 6°30'N and Long. 120°E along the border with Malaysia on the Thai Peninsula. The topography in the area and its vicinity consists of the coastal plain, foothills, mountainous areas and monadnocks. As for rivers, there are Mae Nam Bang Nara with estuaries at Narathiwat and Tak Bai, Mae Nam Yakang with its catchment area in the mountains of Rangae which flows into Mae Nam Bang Nara near its estuary, and Mae Nam Kolok which forms the border with Malaysia.

The coastal plain is a so-called ridged beach plain and is characterized by development of the beach ridges along the coast and the swamps. The topography within the plain is classified into beach ridge (old beach ridge) and lagoon (old lagoon), delta and flood plain, and swamp (old swamp). (Refer to Figure I-2-1)

Beach ridges exhibit a flat surface of 2 - 6 m in elevation and are developed in three strips parallel to the coast with a combined width of as much as 6 km.

A lagoon is developed at Tak Bai, and old lagoons which have changed into swamps are seen between beach ridges. The elevation of these old lagoons is approximately 0 - 2 m.

Swamps are most widely distributed in this area, the most representative being the To Daeng swamp. They are approximately 2 m or so in elevation. They are almost flat but are sputtered with slightly higher spots consisting of beach-sand which are probably the traces of the old beach ridges. As development is in progress currently, the only on which shows the appearance of a swamp is the To Daeng swamp, but the distrubution of peat suggests their former state.

Deltas are seen along Mae Nam Kolok, and flood plains in the watershed of Mae Nam Yakang. The delta between Sg. Kolok and Tak Bai indicates an elevation of 1 - 3 m. Slightly higher places, presumably natural levees, can be observed here and there.

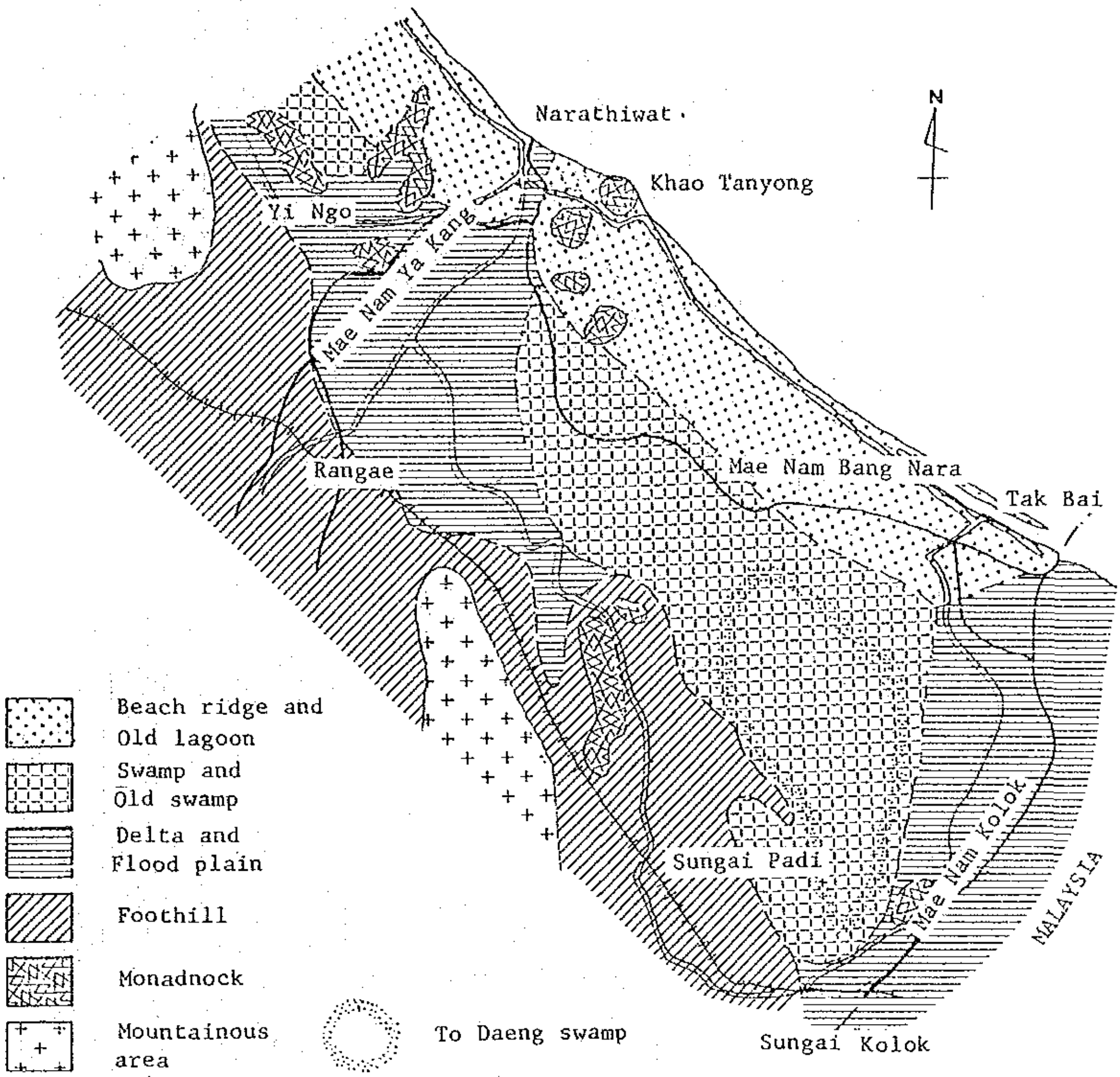
The flood plains indicate an elevation of around 13 m near Mae Nam Ya Kang bridge and become lower in elevation toward Narathiwat, being around 9 m in the vicinity of the intersection of National Highways 4055 and 4056, and about 3 m in the neighborhood of Wat Khao Kong. In terms of microtopography, valleys of very minor scale are generally developed in the direction of the watercourse of Mae Nam Ya Kang an also toward the old swamp.

As for monadnocks, there are conically shaped ones represented by Khao Tanyong (EL 294 m), and hilly shaped ones mainly seen in the north of Narathiwat. The former is presumed to consist mainly of relatively fresh granite, and the latter of colluvium or residual soil.

Foothills consist of colluvium and residual soil. Dissections are fairly well - deveoloped, but in general, these foothills are gently inclined toward the coastal plain. Major distributions are seen in the environs of Rangae and Sg. Padi. They are 20 - 30 m in elevation in the town of Rangae and around 20 m in the town of Sg. Padi.

The mountainous area consists of mountains such as Khao Ni Beng (705 m), etc., located west of Bacho, mountains located west of Rangae of which Kao Ko Lubi (916 m) is the principal peak, and mountains located west of Sg. Padi of which Khao Ta We (1,182 m) is the highest. Every one of these is steep in appearance and has waterfalls.

Figure I-2-I Outline of Topography



(2) Geology

The geology of the Study area has been inferred from the field survey, the GRBDS geology report and preliminary DMR report. Geology Map is shown in Figure I-2-2.

I-2-2 Subsurface Geology

The geological profile of the Study area has been inferred from the boring logs of existing wells and other data.

Geological cross-sections are shown in Figure I-2-3.

Figure I-2-2 Geology Map

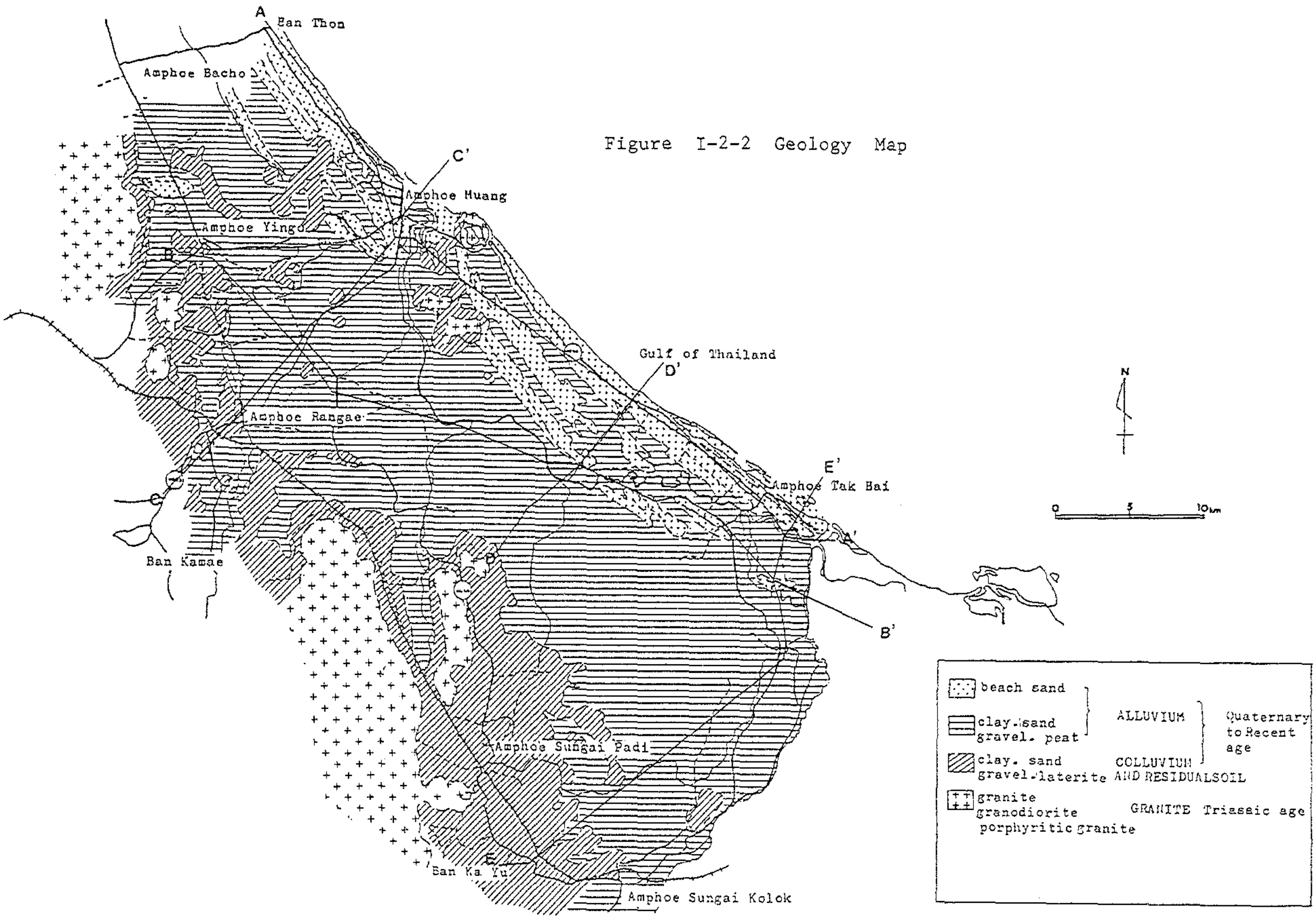
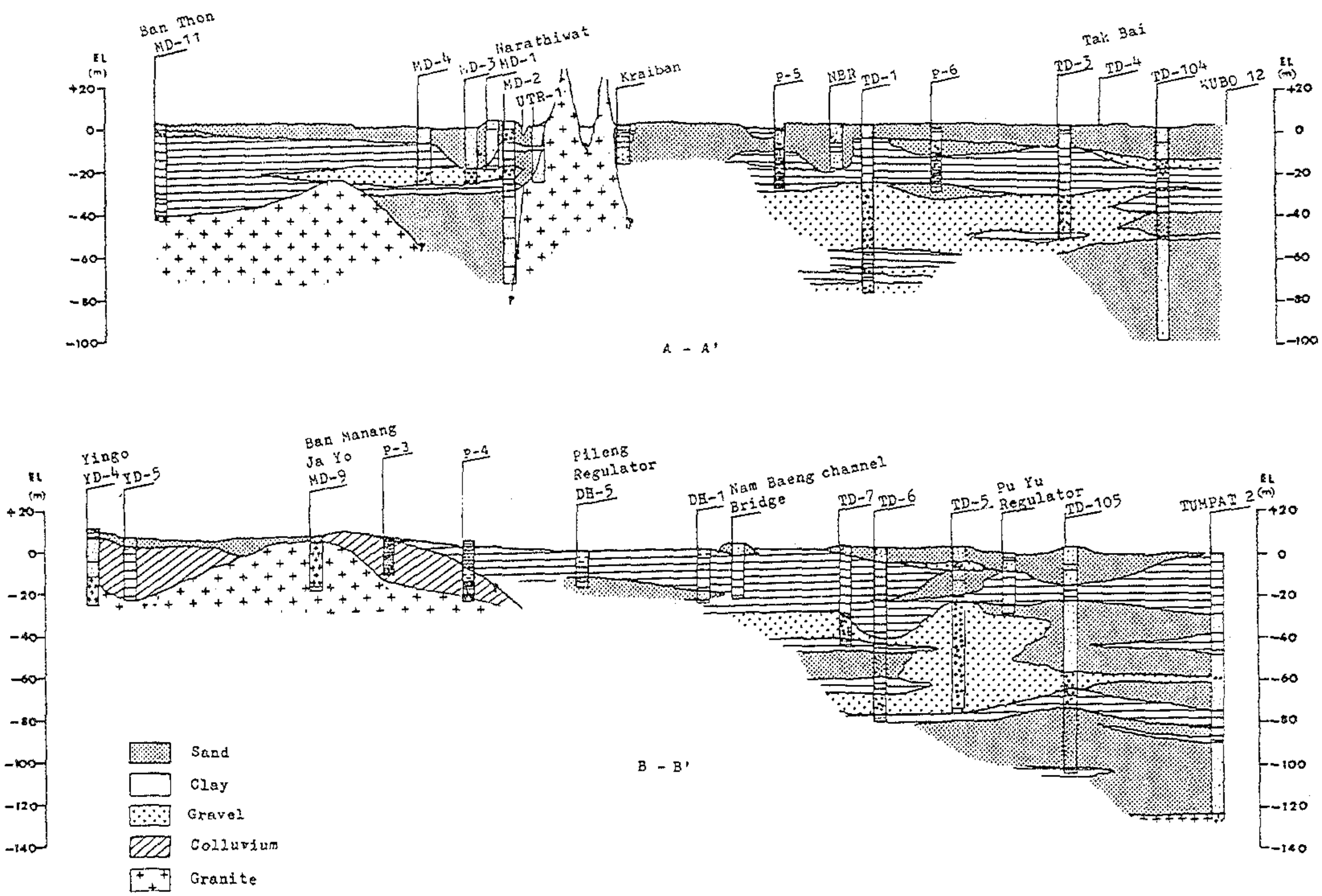
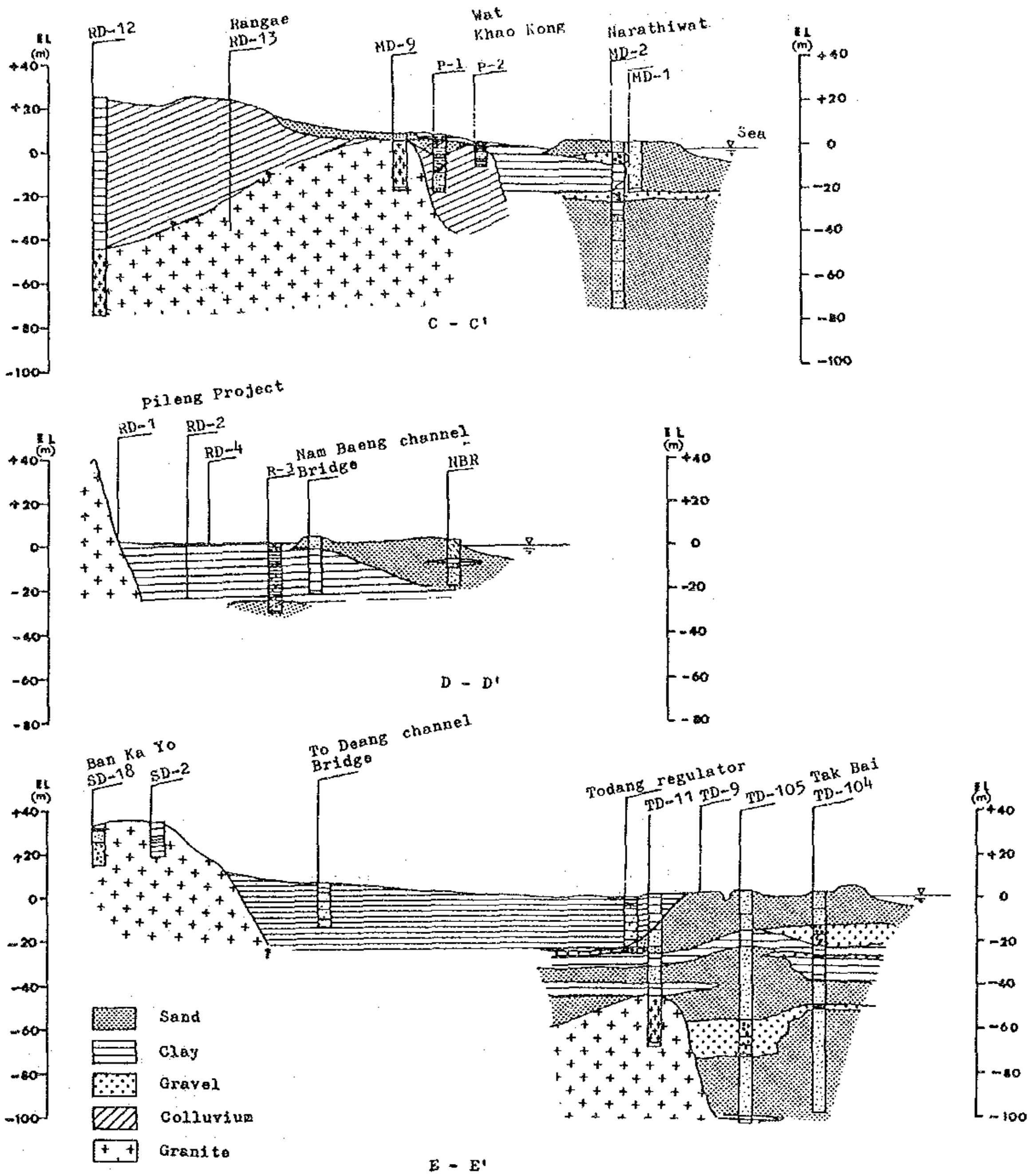


Figure I-2-3 Geological Cross-Section




EL (m)
RD-12
Rangae
RD-13
MD-9
Wat
Khao Kong
P-1
P-2
Narathiwat
MD-2
MD-1
Sea
C - C'
Pileng Project
RD-1
RD-2
RD-4
R-3
Nam Baeng channel
Bridge
NBR
D - D'
Ban Ka Yo
SD-18
SD-2
To Deang channel
Bridge
Todang regulator
TD-11
TD-9
TD-105
Tak Bai
TD-104
Sand
Clay
Gravel
Colluvium
Granite
E - E'

APPENDIX II. METEOROLOGY, HYDROLOGY AND OCEANOGRAPHY

II-1. Meteorology

II-2. Hydrology

Page

Figure II-1-1 LOCATION MAP OF SOUTHERN THAILAND

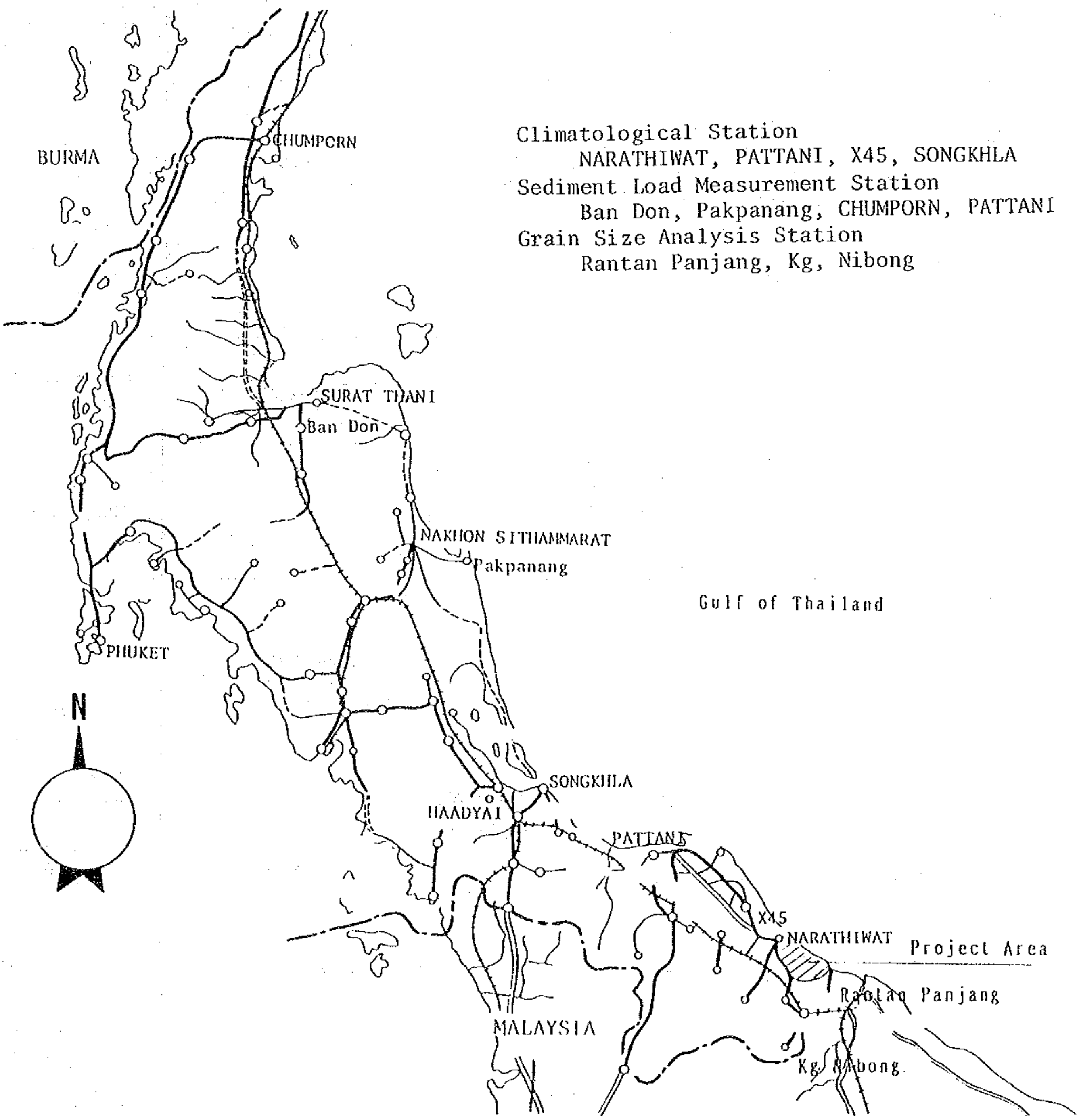


Figure II-1-2 CLIMATOLOGICAL CONDITIONS AT THE NARATHIWAT STATION (1)
(PATTANI, SONGKHLA, X45)
(Source; Climatological Data of Thailand, 30-Year Period, Meteorological Department)

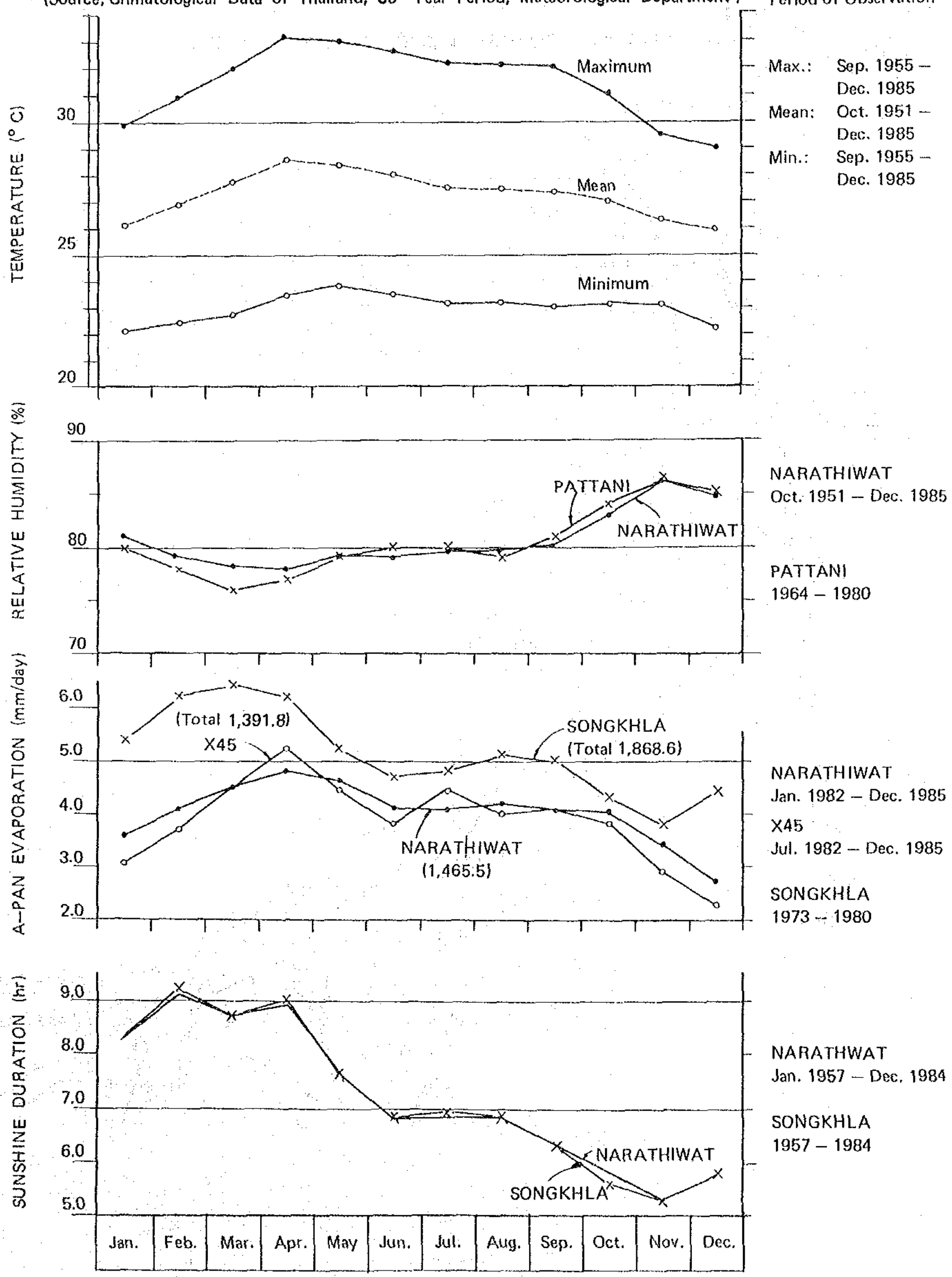


Figure II–1–3 CLIMATOLOGICAL CONDITIONS AT THE NARATHIWAT STATION (2)

(Source.; Climatological Data of Thailand, 30 - Year Period, Meteorological Department)

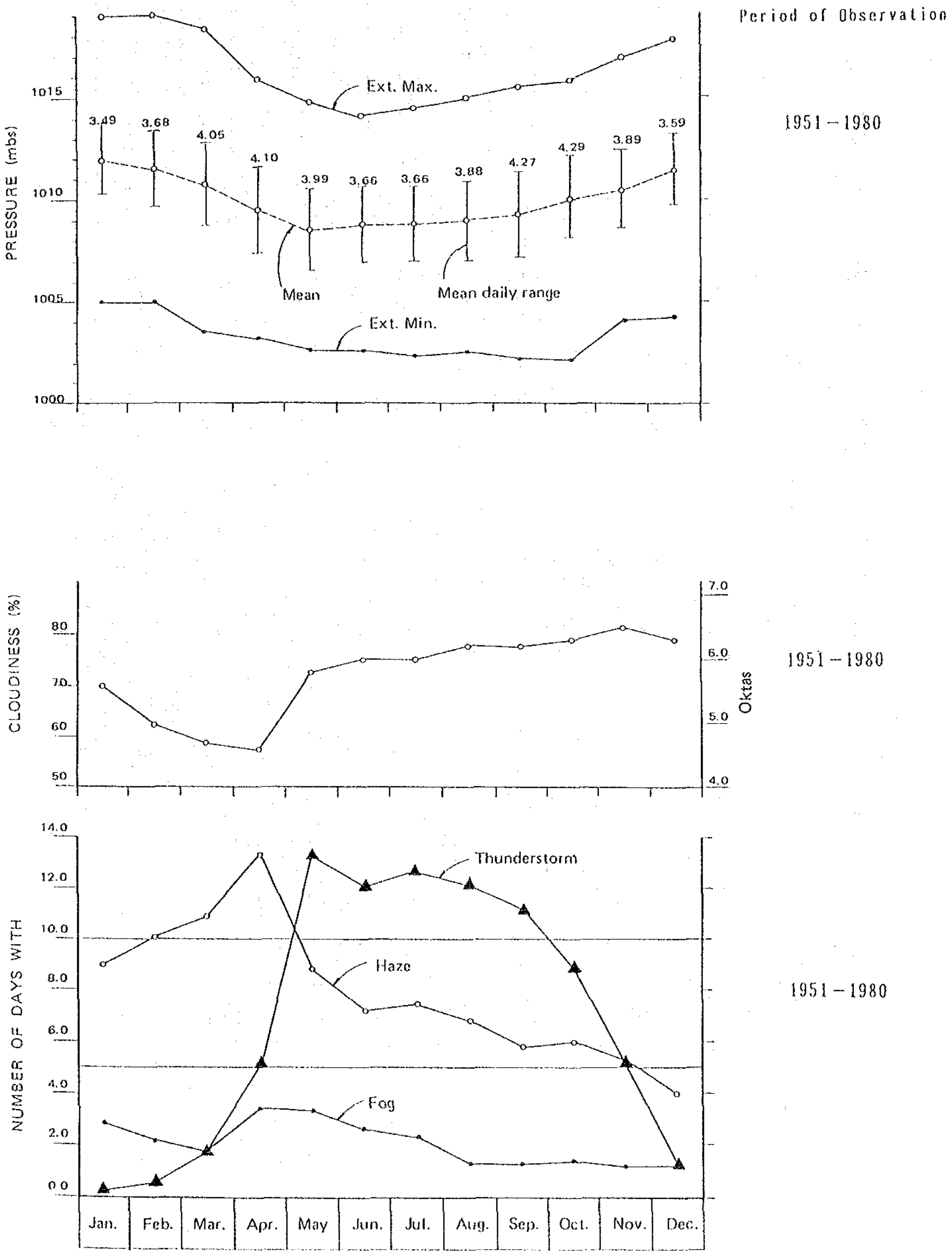


Figure II-1-4 TRACKS OF TROPICAL CYCLONES OVER SOUTH THAILAND (1)

(DURING 33 YEARS, PERIOD FROM 1951 – 1983)

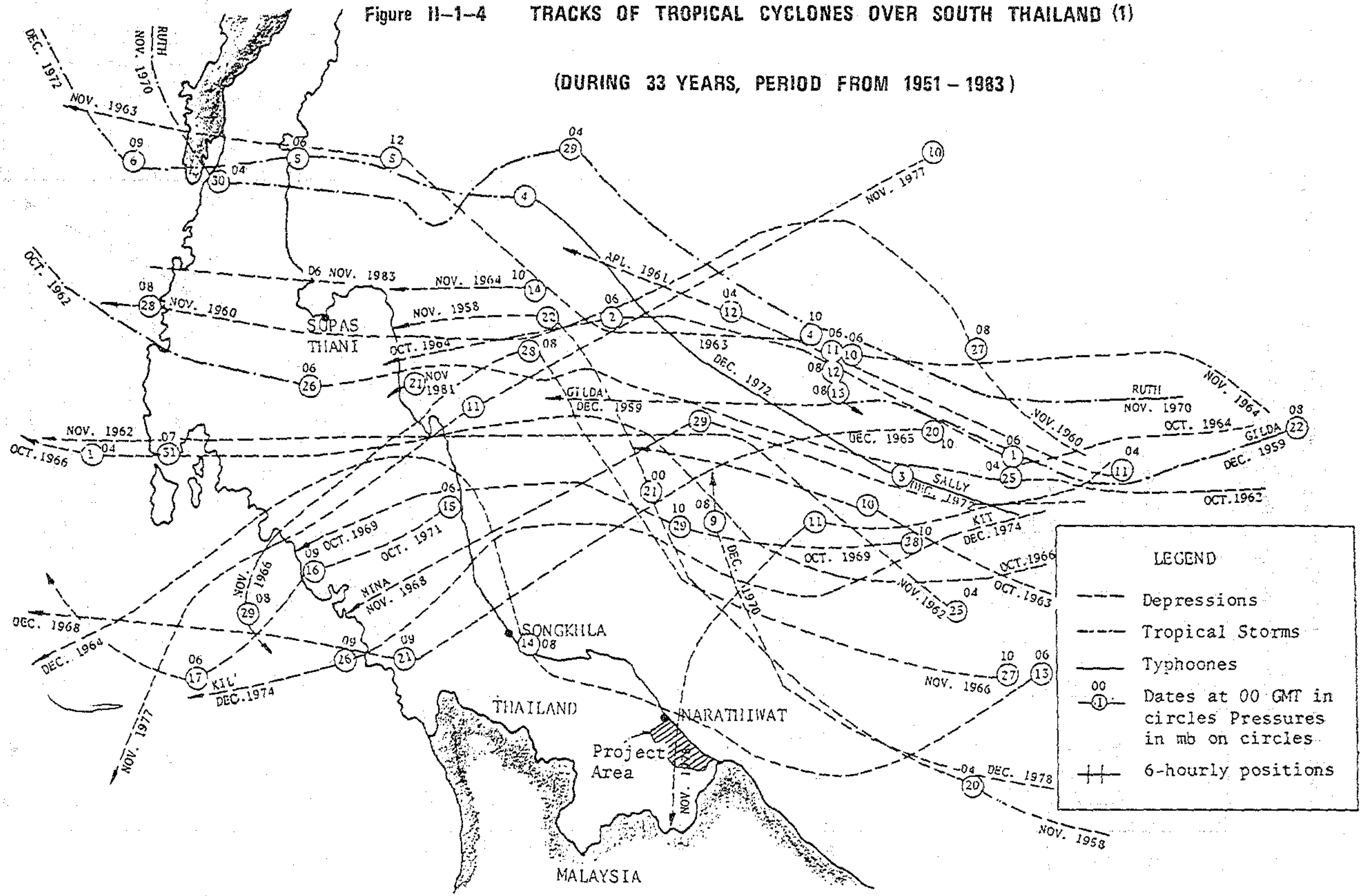
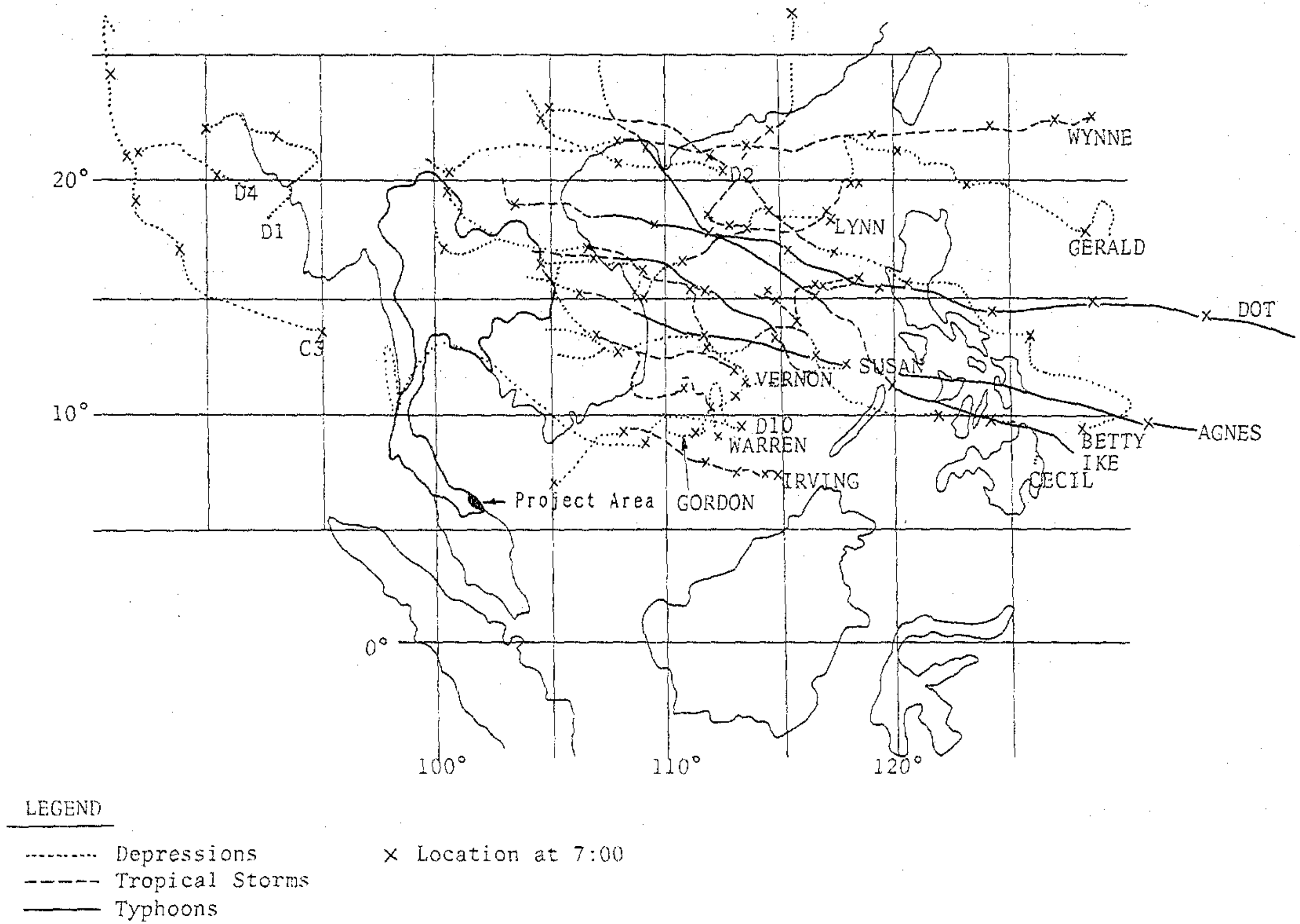


Figure II-1-5 **TRACKS OF TROPICAL CYCLONES OVER SOUTH THAILAND (2)**

(DURING 2 YEARS, PERIOD FROM 1984 – 1985)

Source : Meteorological Dept.



D1 : 31 MAY-2 JUN '84
VERNON: 8-12 "
WYNNE : 19-26 "
D2 : 20-22 "
BETTY : 4-10 JULY '84
GERALD: 11-12 AUG.
IKE : 27 AUG- 7 SEP.
LYNN : 24-29 SEP.
SUSAN : 10-14 OCT.
WARREN: 22 OCT- 3 NOV.
D4 : 1-3 OCT
AGNES : 1-9 NOV.

D10 : 10-12 OCT.'85
DOT : 11-12 "
CECIL : 11-17 "
C3 : 13-18 "
GORDON: 21-26 NOV.
IRVING: 16-22 DEC.

Figure II-1-6 OBSERVATION FOR THE MONTHLY WIND SPEED AND THE DIRECTION OF THE WIND AT NARATHIWAT

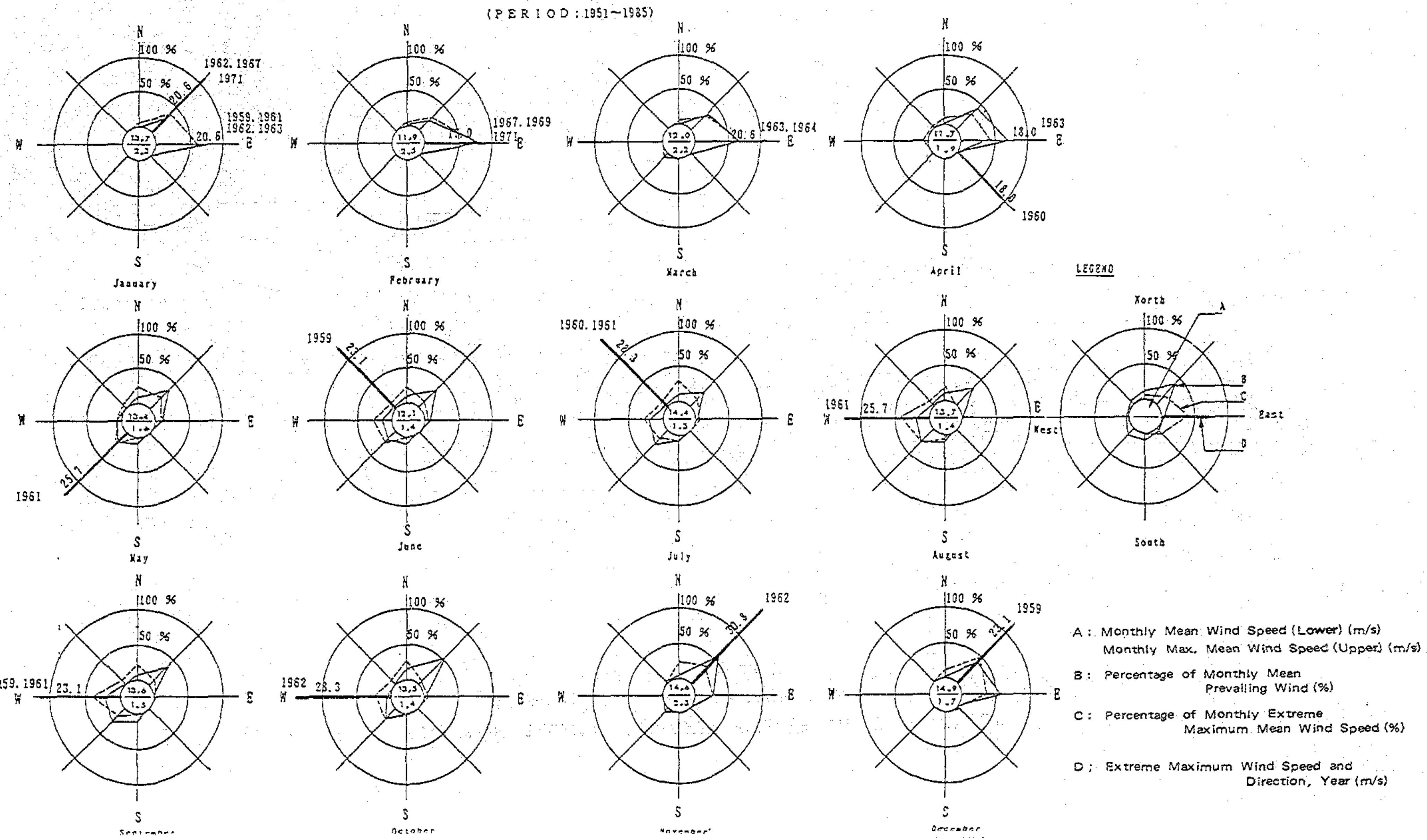


Figure II-1-7 LOCATION OF RAINFALL AND WATER LEVEL STATION

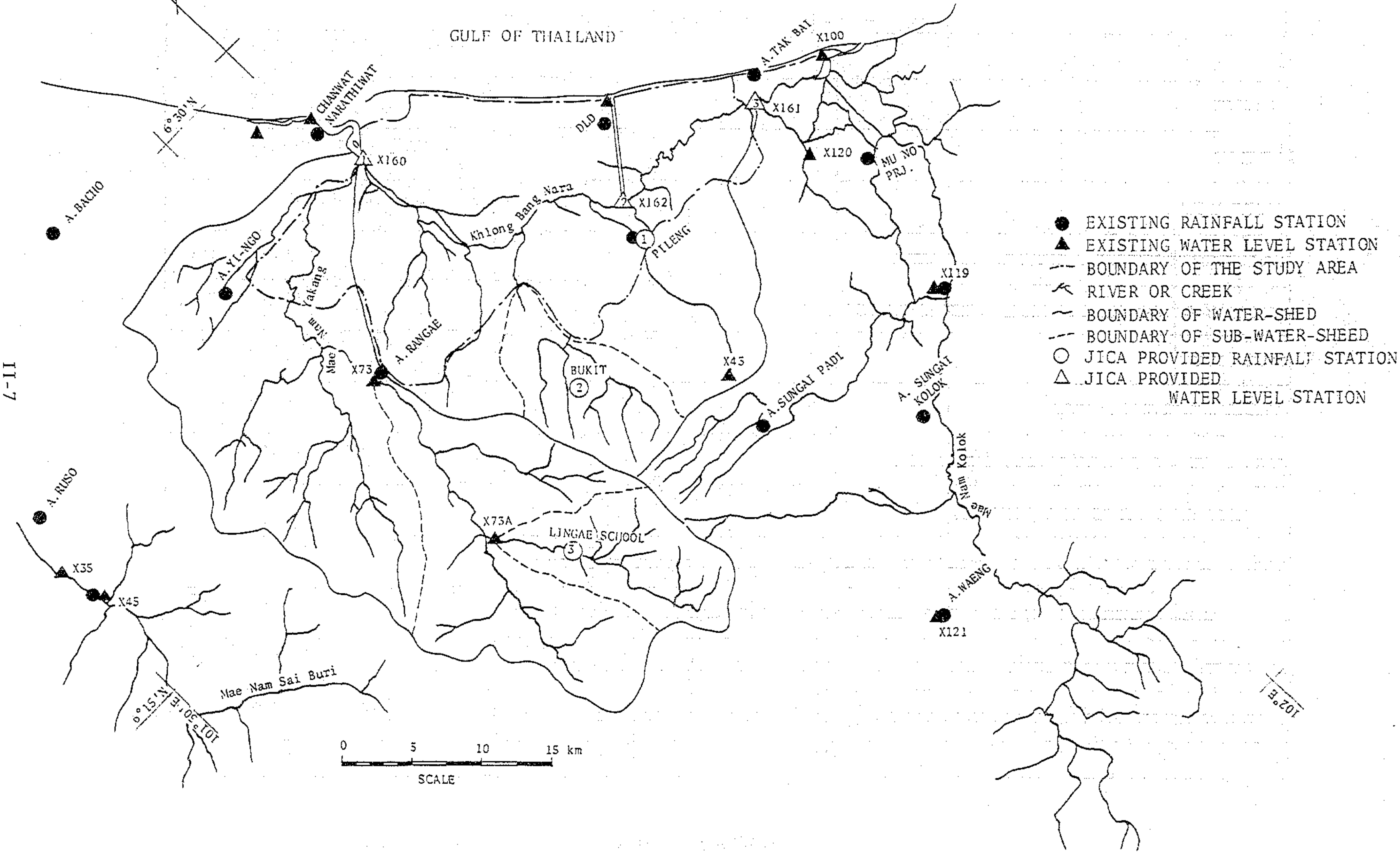
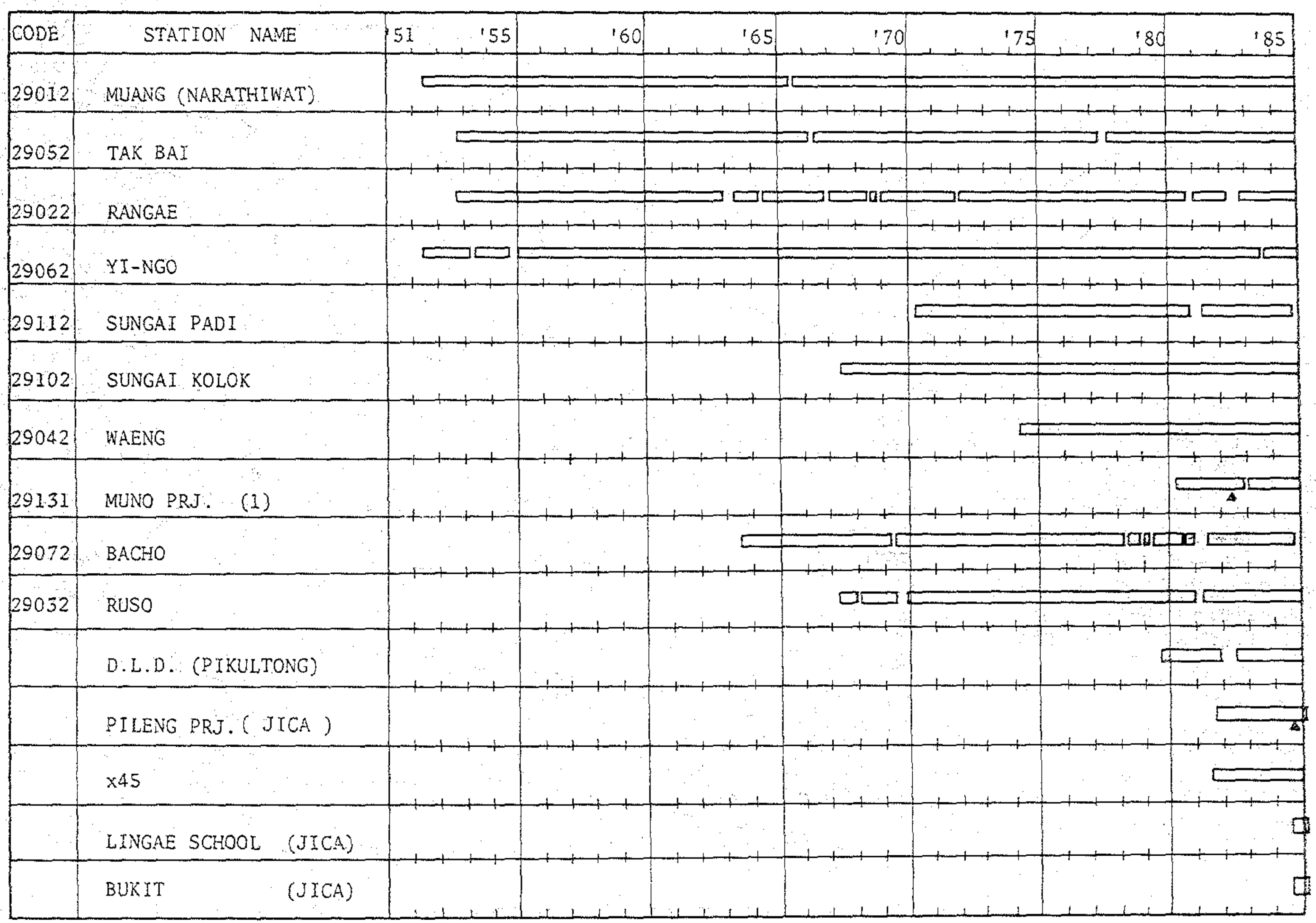
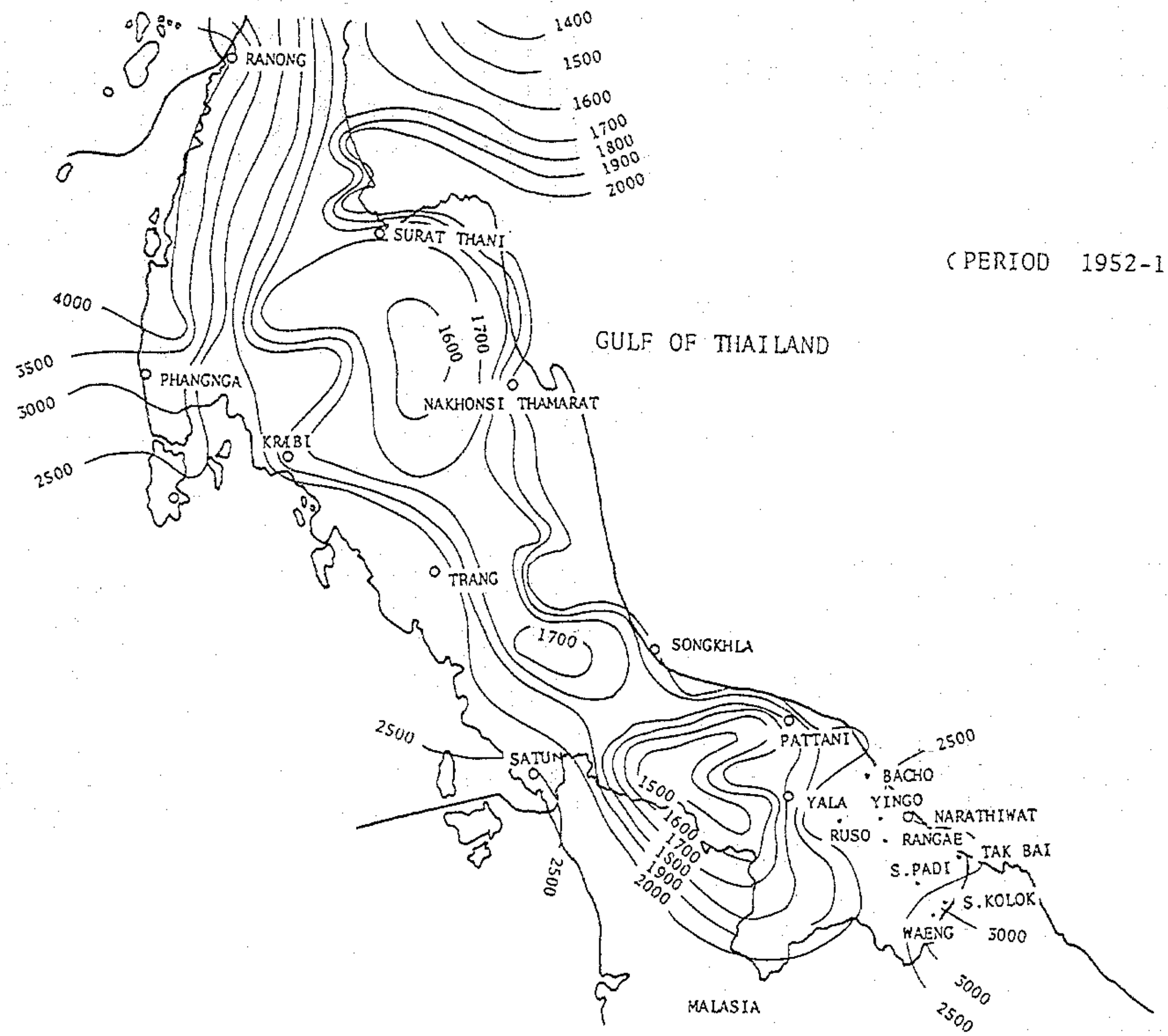


Figure II-1-8 DAILY RAINFALL RECORDS



NOTES: BLANK MEANS NO RECORDS, CODE DEPENDS ON RID,(1) RELOCATED FROM A. TAK BAI TO X119(MuNo)

Figure II-1-9 ISOHYETAL MAP OF MEAN ANNUAL RAINFALL (mm)



(PERIOD 1952-1980)

SOURCE
RID HYDROLOGY DIV.

Figure II-1-10 ANNUAL RAINFALL AND MOVING AVERAGE

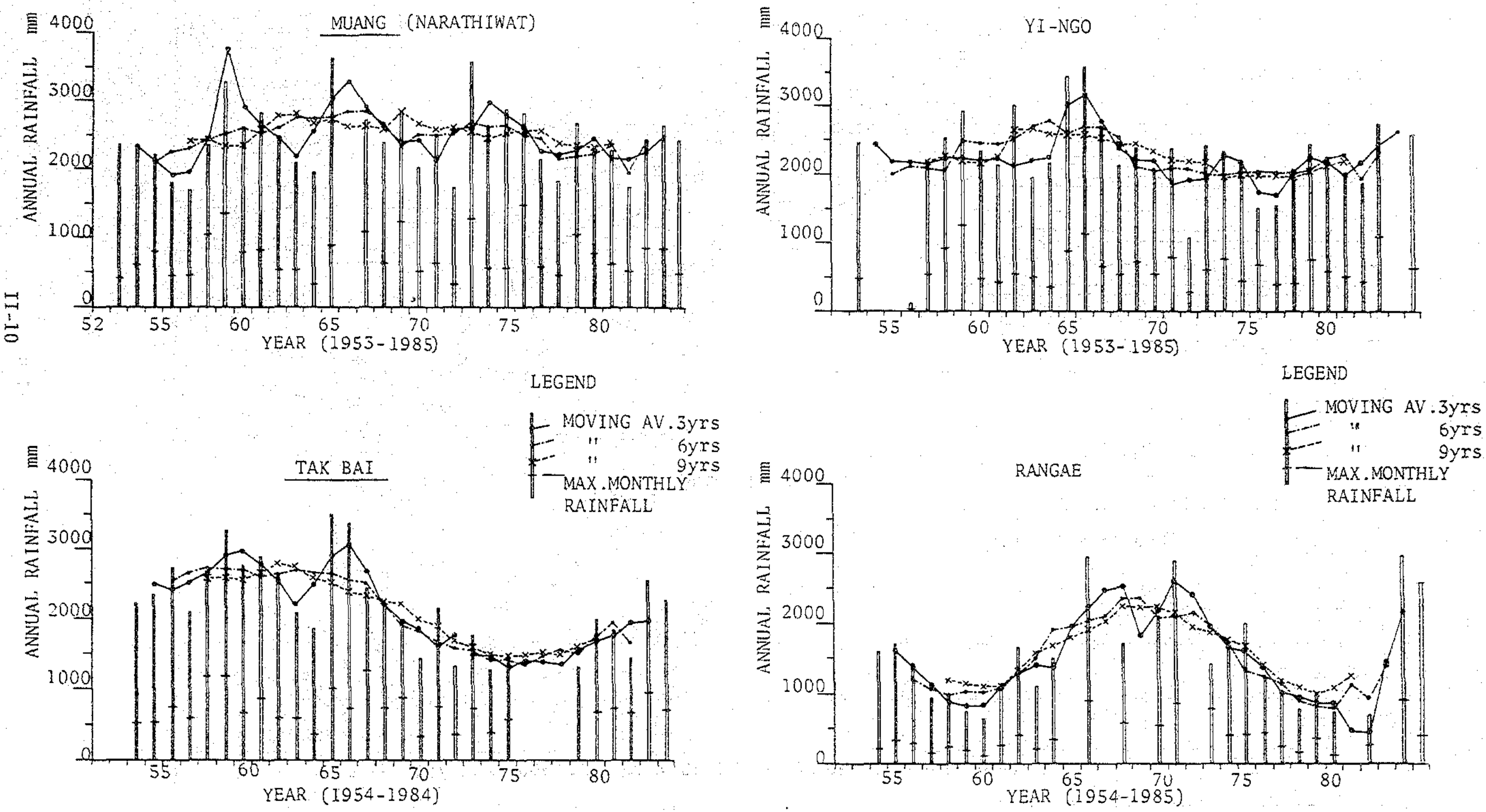


Figure II-1-11 MONTHLY DISTRIBUTION OF RAINFALL

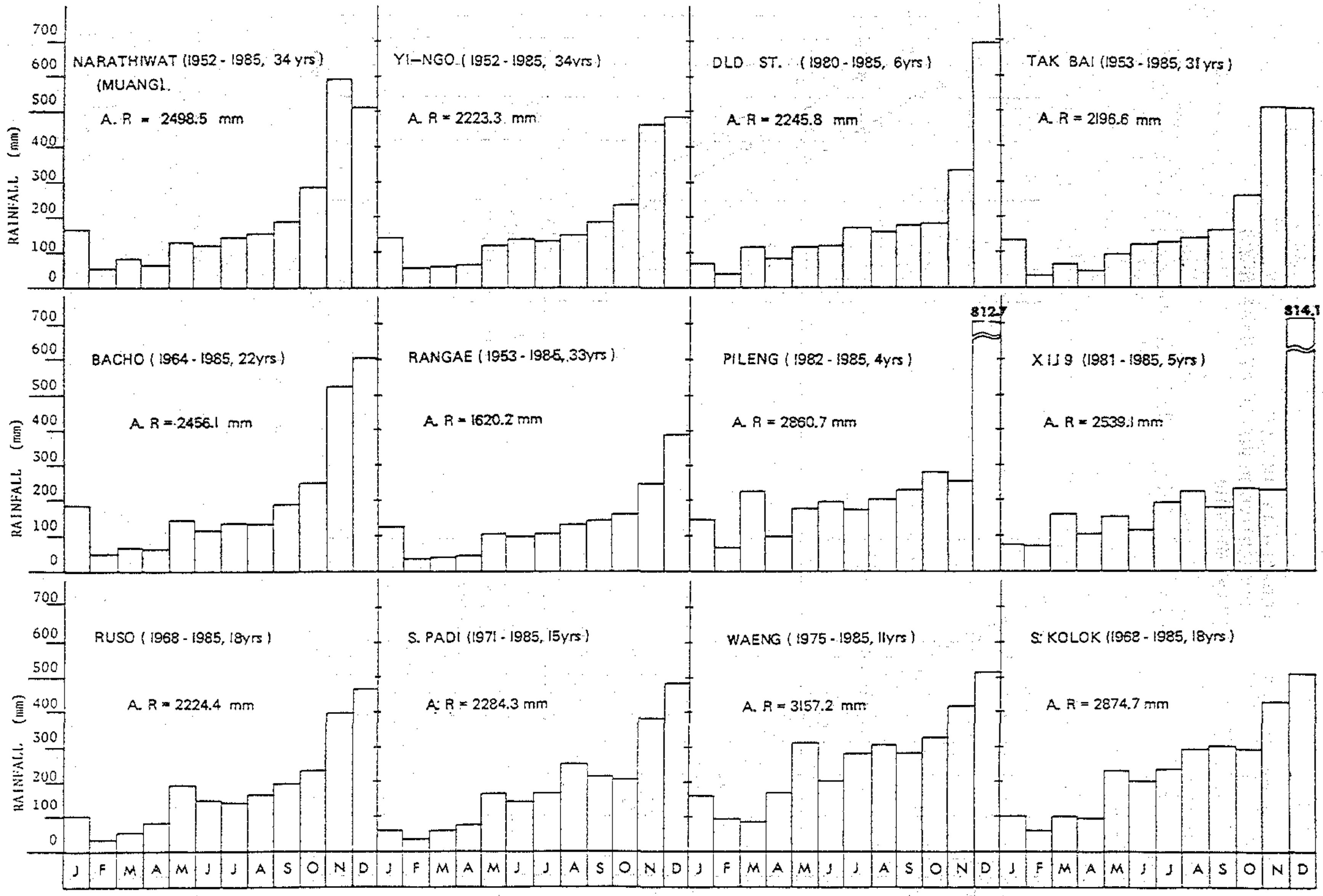


Figure II-1-12 PROBABILITY ANALYSIS
CONSECUTIVE RAINFALL AT NARATHIWAT
(IWAI METHOD)

Period ; 1955 — 1985 (Calender Year)

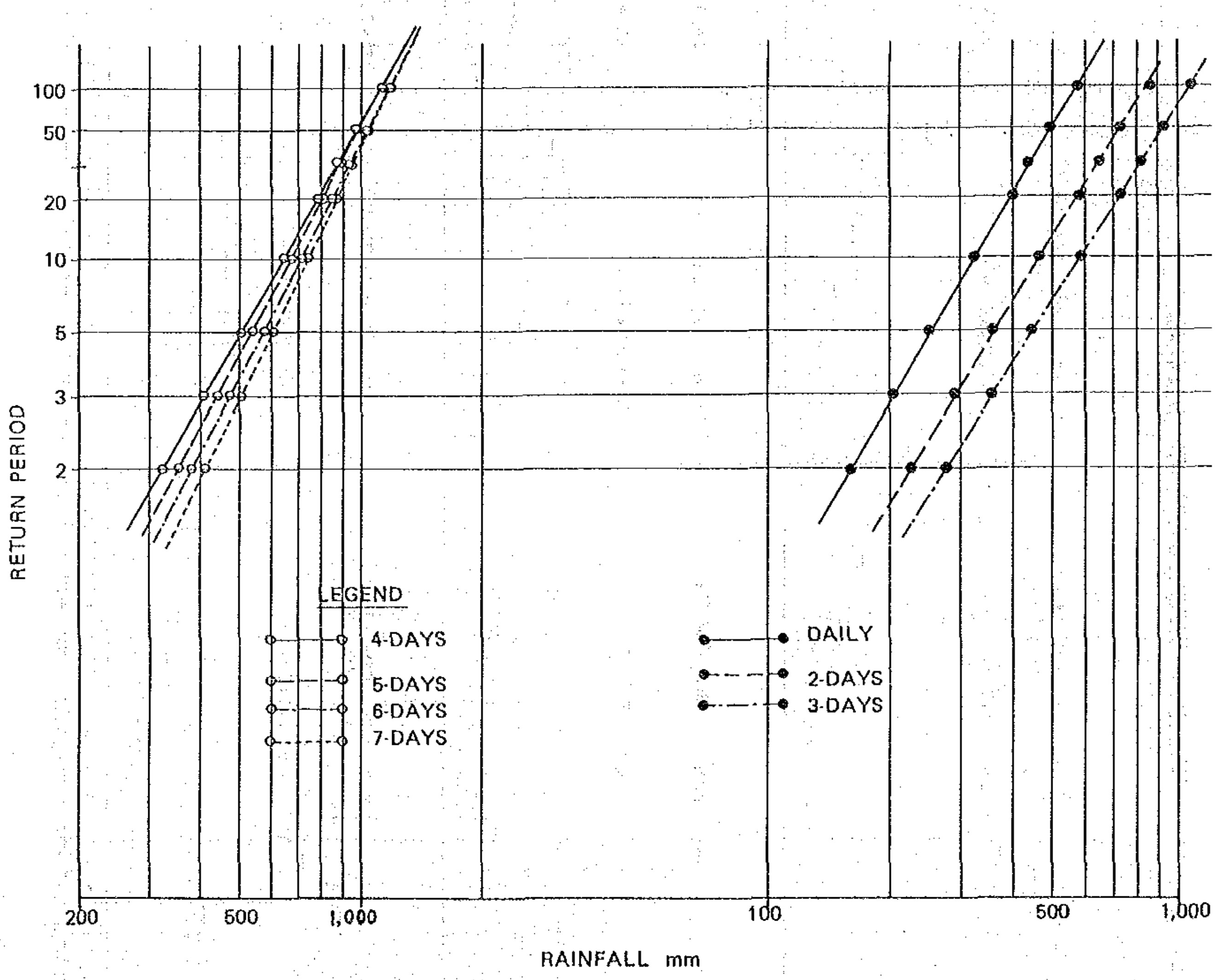


Figure II-1-13 DAILY RAIFALL DISTRIBUTION AT EACH STATION
(DURATION 19 – 25 DEC. 1984)

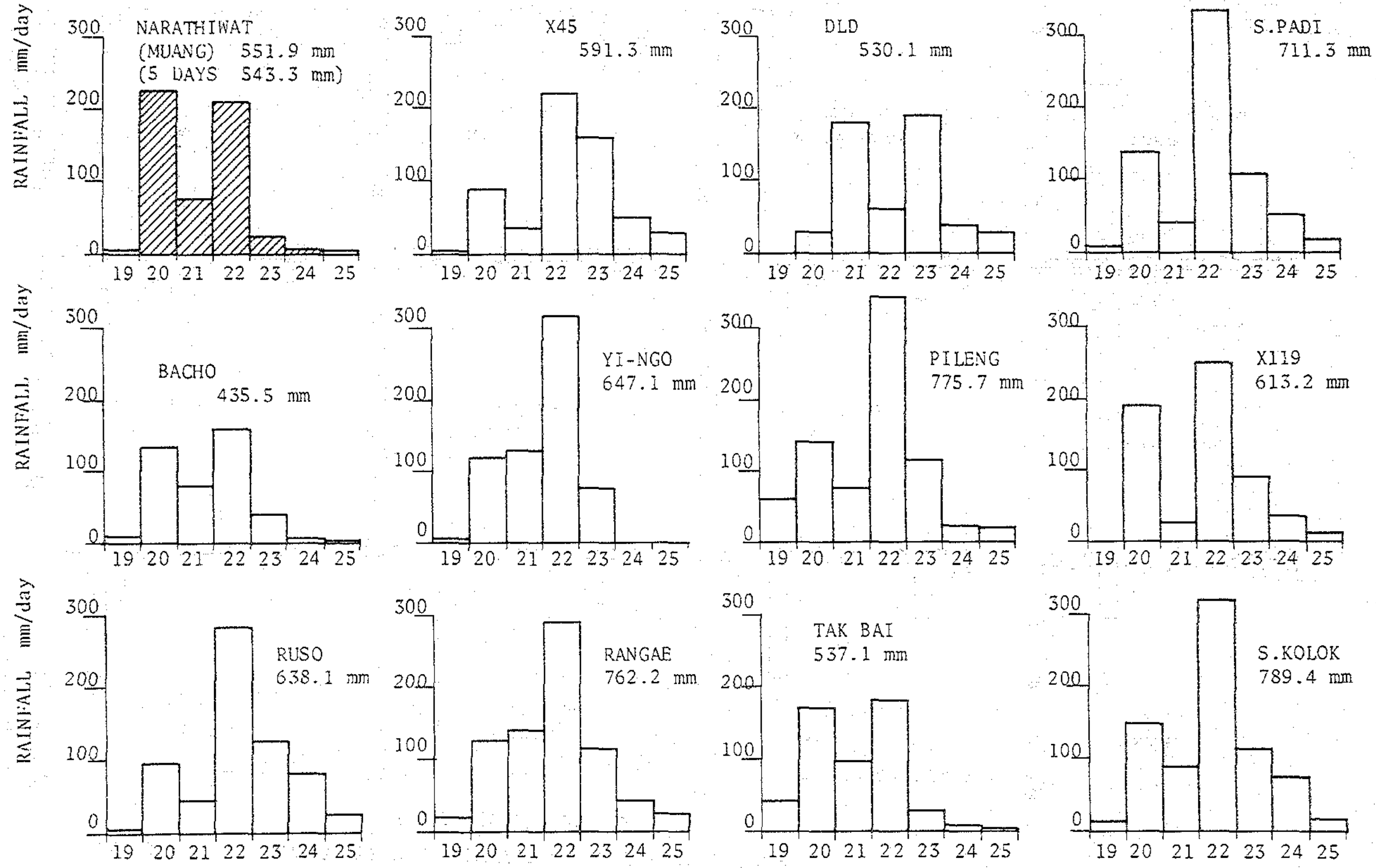


Figure II-1-14 DAILY RAINFALL DISTRIBUTION AT EACH STATION (DURATION 10-23 DEC. 1985)

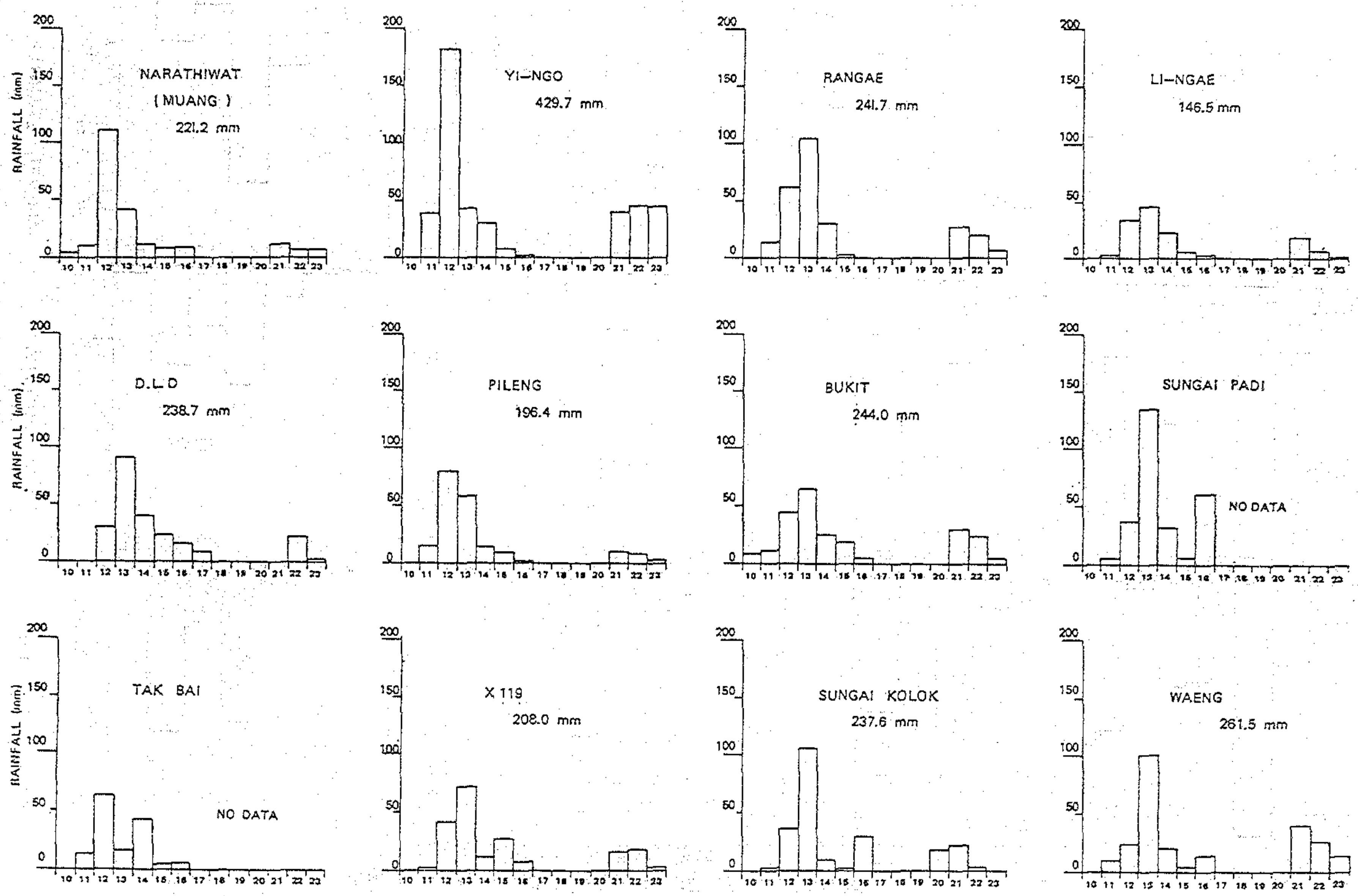


Figure II-1-15 VARIATION OF HOURLY RAINFALL

(A. MUANG NARATHIWAT)

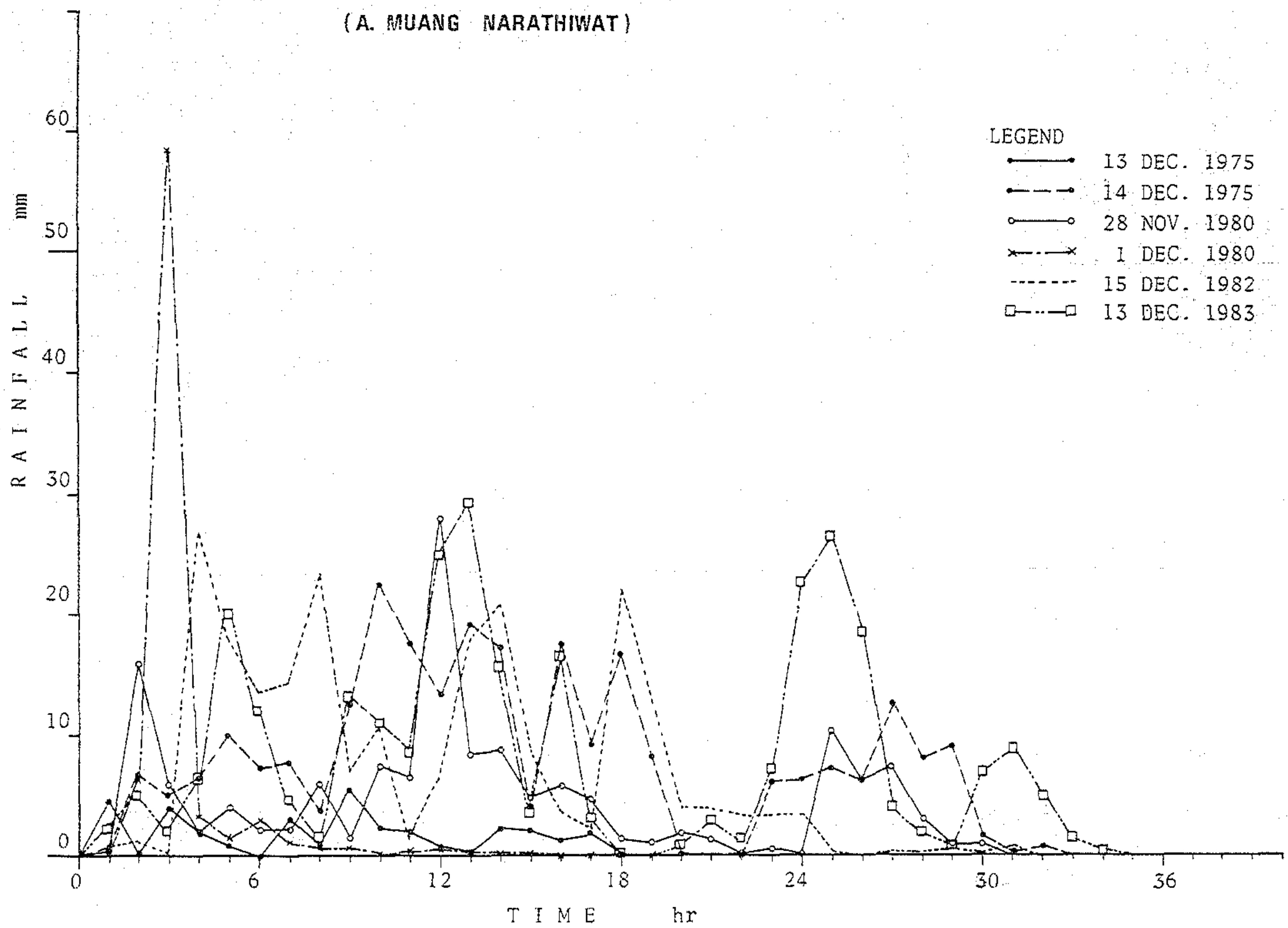


Figure II-1-16 VARIATION OF HOURLY RAINFALL (JICA Provided Station)

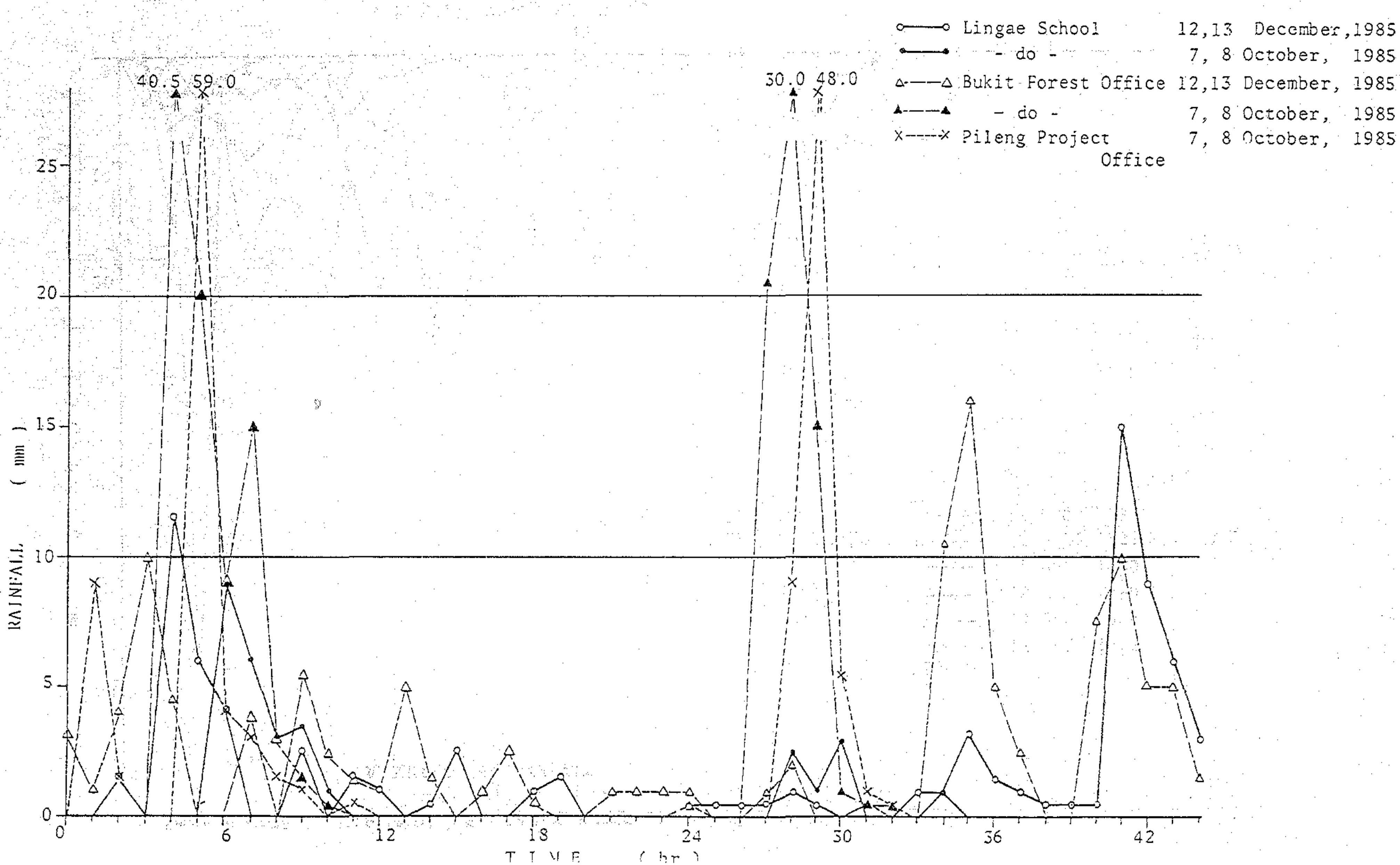
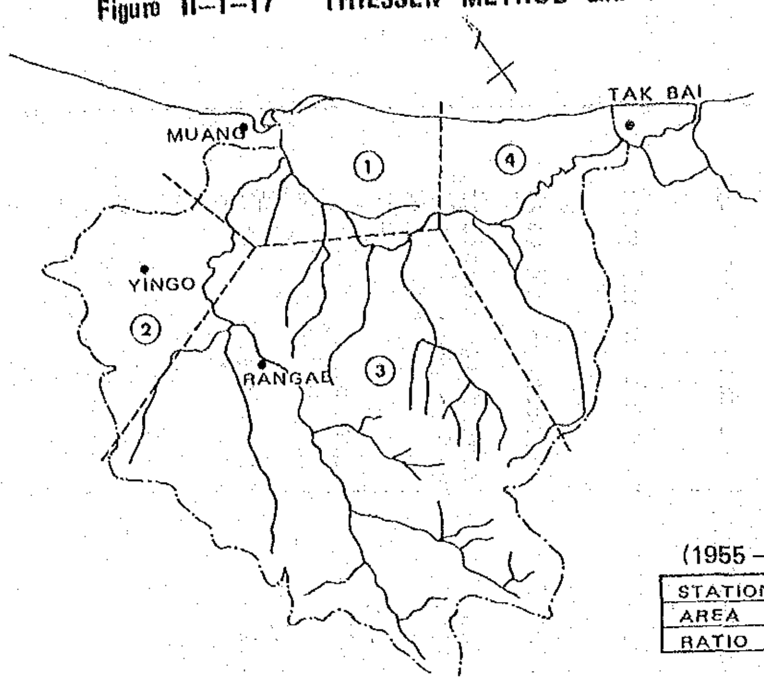
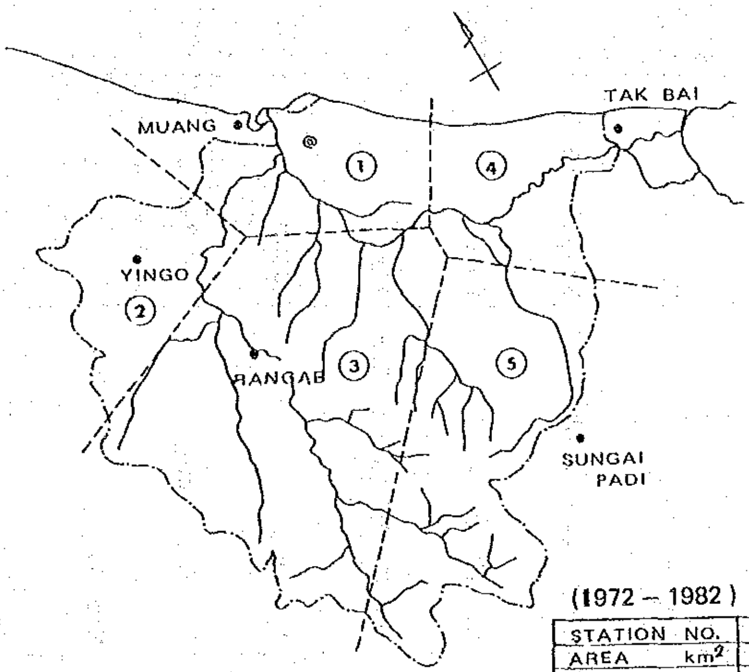


Figure II-1-17 THIESSEN METHOD and NETWORK



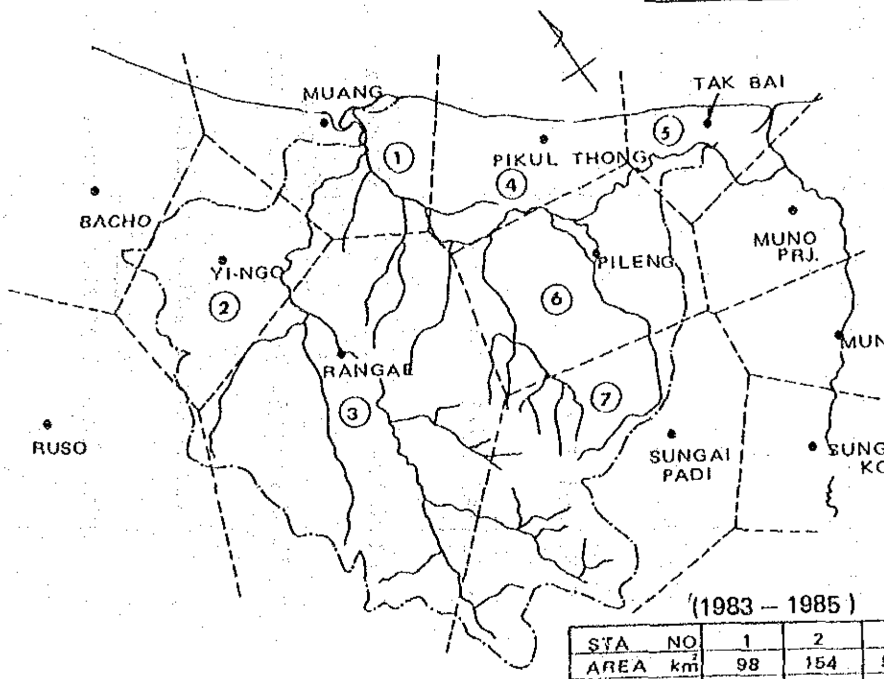
(1955 – 1971)

STATION NO.	1	2	3	4
AREA km²	182	154	813	252
RATIO %	13	11	58	18



(1972 – 1982)

STATION NO.	1	2	3	4	5
AREA km²	168	154	561	168	350
RATIO %	12	11	40	12	25



(1983 – 1985)

STA NO	1	2	3	4	5	6	7
AREA km²	98	154	543	126	4	224	252
RATIO %	7	11	36	9	3	16	18

Table II-2-1 STREAM GAGING STATIONS

Changwat Narathiwat

Code	River	Stream	At or Near	Amphoe	Approx Lat. °N Long. °E	Type of gage
X 43	Khlong Sungai Padi	--	A. Sungai Padi	Sungai Padi	6°-08'-50" 101°-54'-52"	Vertical Staff gage
X 73	Khlong Bang Nara	Khlong Tan Yong Mat	Highway Bridge	Rangae	6°-17'-44" 101°-44'-04"	Vertical Staff gage
X73A	Khlong Tan Yong Mat	Khlong Bo Ngo	Ban Bo Ngo	Bangae	6°-10'-10" 101°-42'-59"	Recorder, Float gage
X100	Kolok	--	Ban Che He	Tak Bai	6°-13'-55" 102°-05'-28"	Recorder, Float gage
X119	Kolok	--	A. Sungai Kolok	Sungai Kolok	6°-04'-09" 102°-02'-22"	Vertical Staff gage
X 35	Sai Buri	--	Tha Kham	Ruso	6°-21'-02" 101°-29'-50"	Vertical Staff gage
X 45	Sai Buri	--	Wat Na On Ban Ba Kong	Ruso	6°-19'-25" 101°-30'-31"	Vertical & Recorder, Bubble gage
X121	Kolok	Khlong Waeng	A. Waeng	Waeng	5°-55'-26" 101°-53'-14"	Vertical
X120	Khlong Pu Yu	Khlong Khok Yong	Ban Khok Yong	Tak Bai	6°-11'-54" 102°-02'-22"	Vertical
	Nam Baeng Regulator (A. Muang)	Canal	Nam Baeng			
	Bai Chao Regulator	Canal	Bai Chao	Muang		
*	A. Muang (Narathiwat)		A. Muang	Muang		

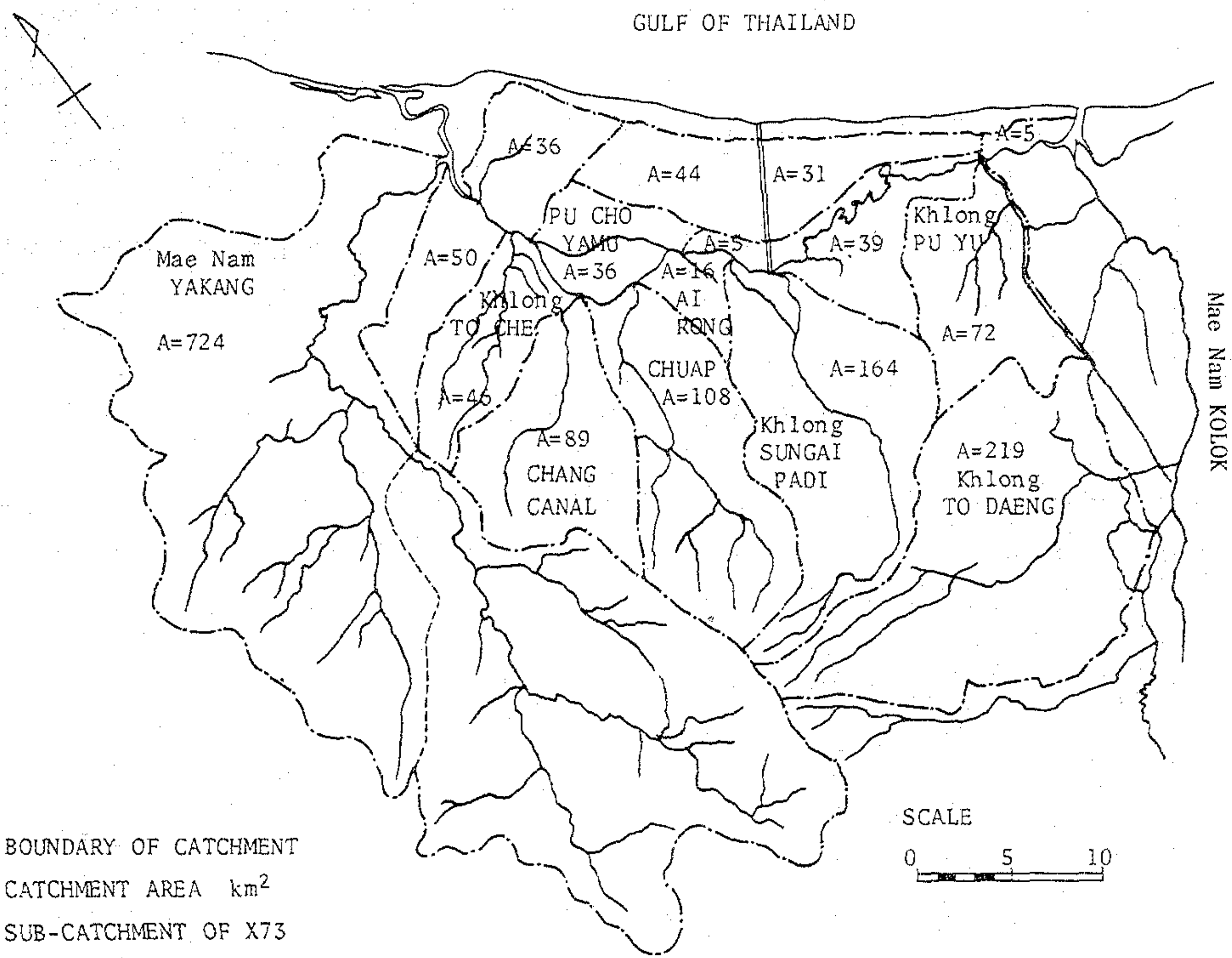
Note * Belongs to Harbor Department Source: RID Hydrology Division

Table II-2-2 CATCHMENT AREA AND RIVER LENGTH OF MAE NAM BANG NARA

	River Name	Simbol */	River Length (km)	Catchment Area (sq. km)
1.	Mae Nam Yakang	A+B	75.5	724
2.	(X73)	(B)		(336)
3.		C	15.5	50 (96)
4.	Khlong To Che	D		46
5.	Chang Canal	E	16.0	89
6.	Khlong Chuap	F	23.0	108
7.	Khlong Ai Rong	G	5.0	16
8.	Khlong Sungai Padi	H	10.0	164
9.		I	5.0	39 (52)
10.		L	5.0	36 (77)
11.		M	10.0	44
12.	Khlong Pu Cho Ya Mu	N		36
13.		O	10.0	31
14.		P		13
15.		R		5
	Total			1,401
16.		Q		5
17.	Khlong Pu Yu	J	10.0	72
18.	Khlong To Daeng	K		219
	Total			1,697

*/------ Refer to Figure II-2-7.

Figure II-2-1 CATCHMENT AREA AND BOUNDARY



LEGEND

—·— BOUNDARY OF CATCHMENT

A = CATCHMENT AREA km^2

---- SUB-CATCHMENT OF X73

Figure II-2-2 LONGITUDINAL PROFILE OF STREAM

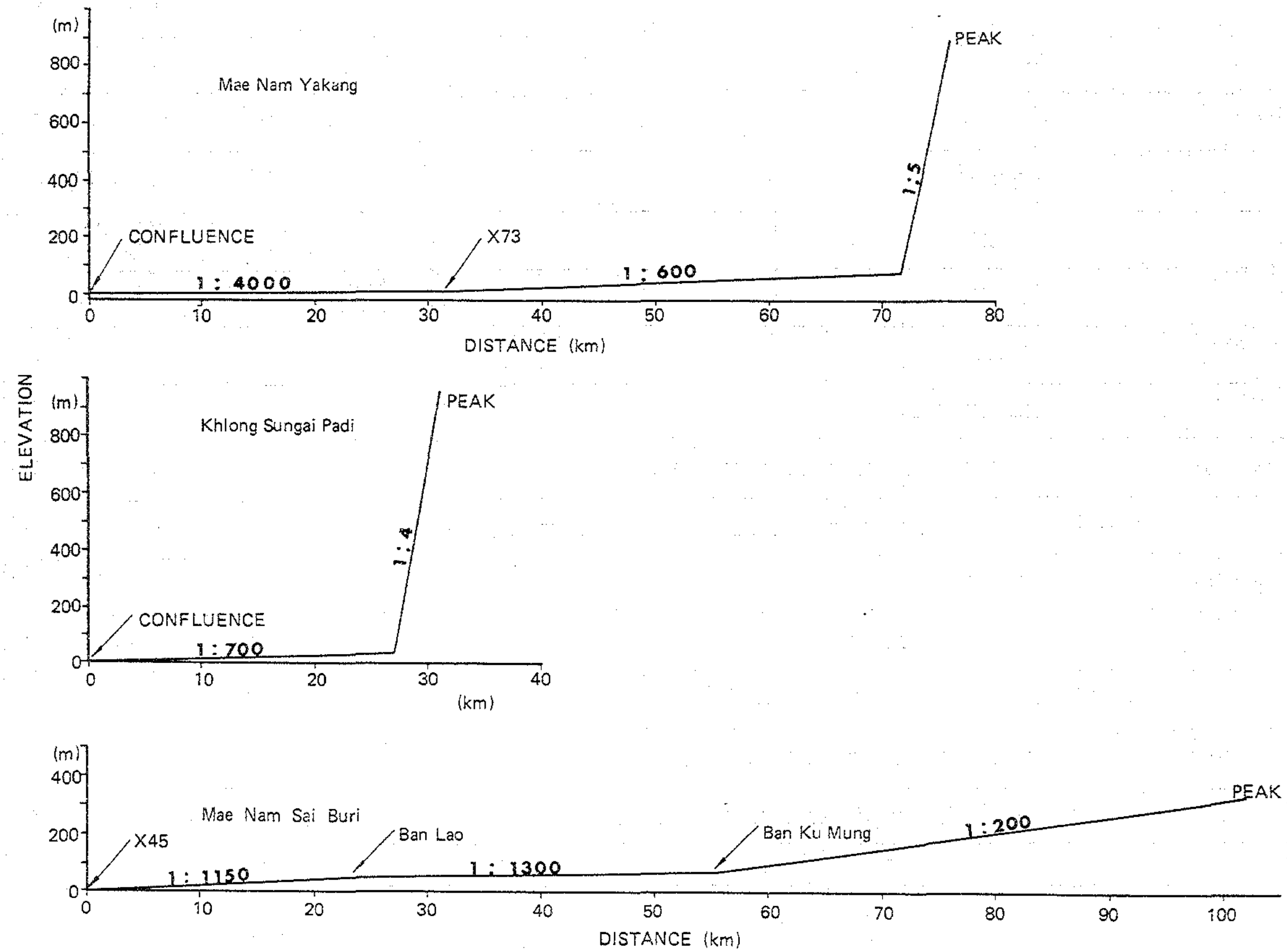


Figure II-2-3 WATER LEVEL RECORDS

CODE	RIVER NAME	61 '65 ''70 '75 '80 '85		Rating Curve
X43	KHLONG SUNGAI PADI		STOP	1982
X73	KHLONG BANG NARA			1985
X73A	KHLONG TAN YONG MAT		STOP	
X100	KOLOK			
X119	KOLOK			1983,84
X35	SAI BURI		STOP	
X45	SAI BURI			1983,84
X121	KOLOK			1983,84
X120	KHLONG PU YU			
	NAM BAENG REGULATOR (upper / Lower)			
	(A. MUANG) BAI CHAO REGULATOR			
	MUANG (NARATHIWAT)			
X160	JICA PROVIDED STATION			
X161	- do -			
X162	- do -			

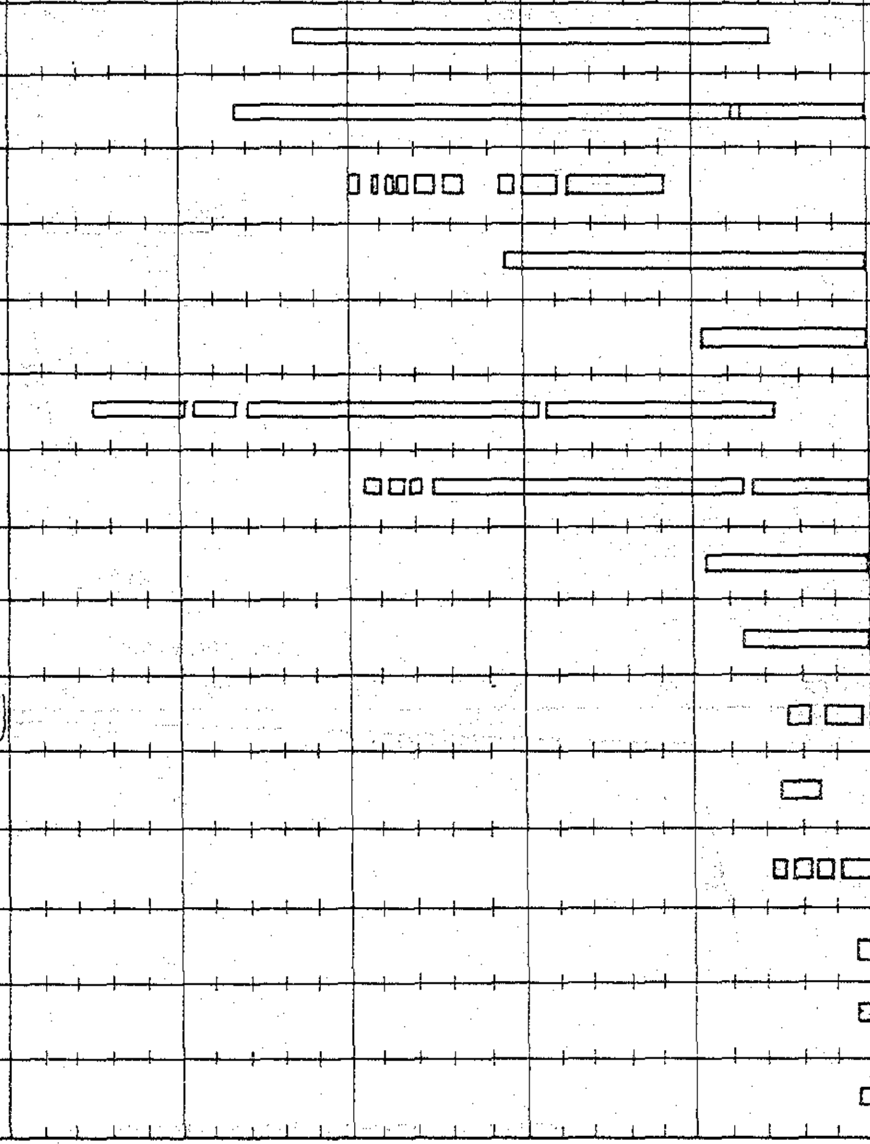
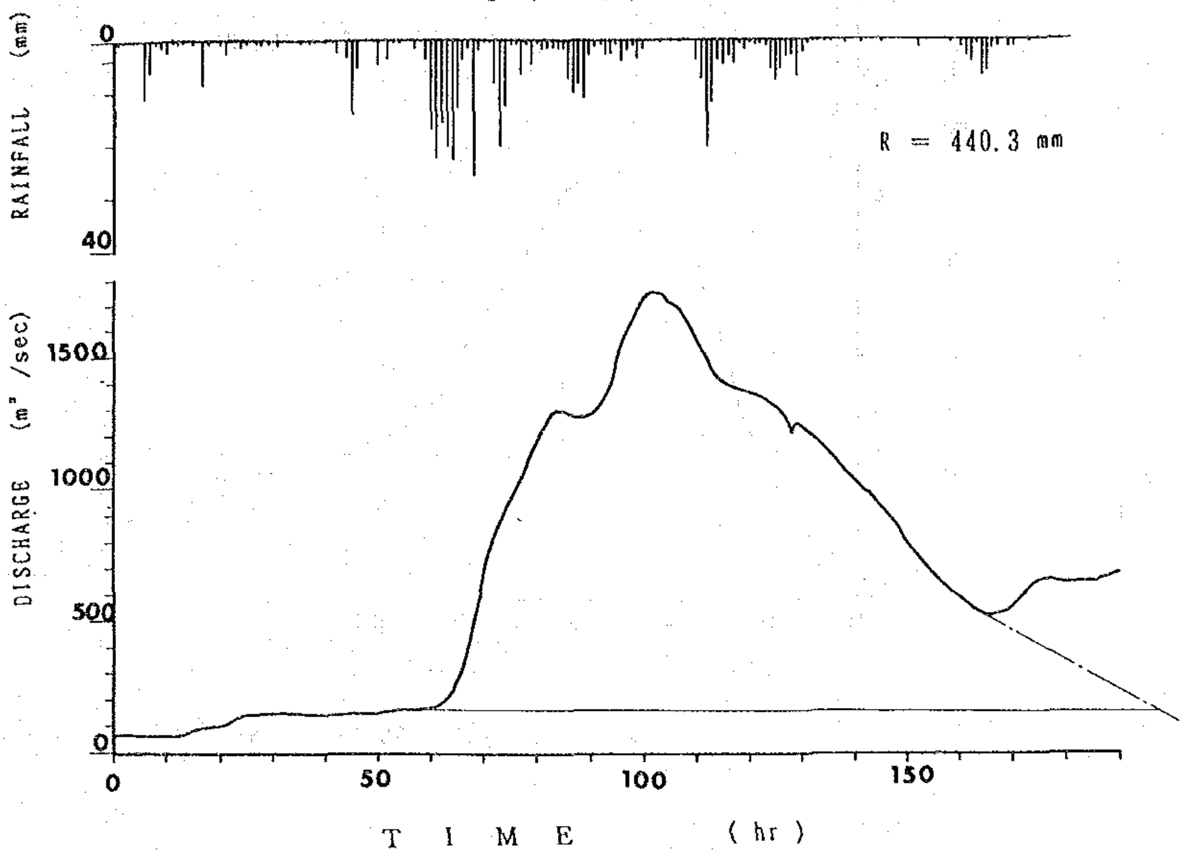


Figure II-2-4 HYDROGRAPH (X 45)

1-7 DEC. 1983 (1)



11-14 DEC. 1983 (2)

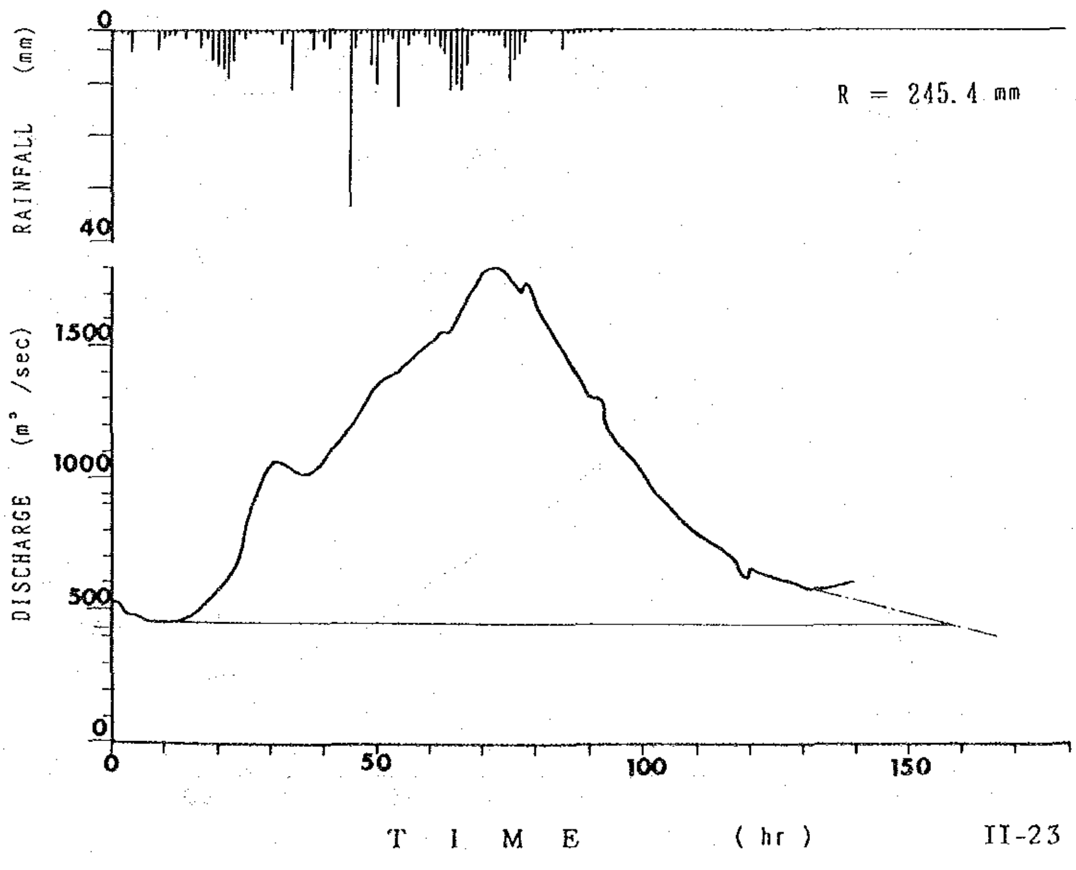


Figure II-2-5 HYDROGRAPH (X45)

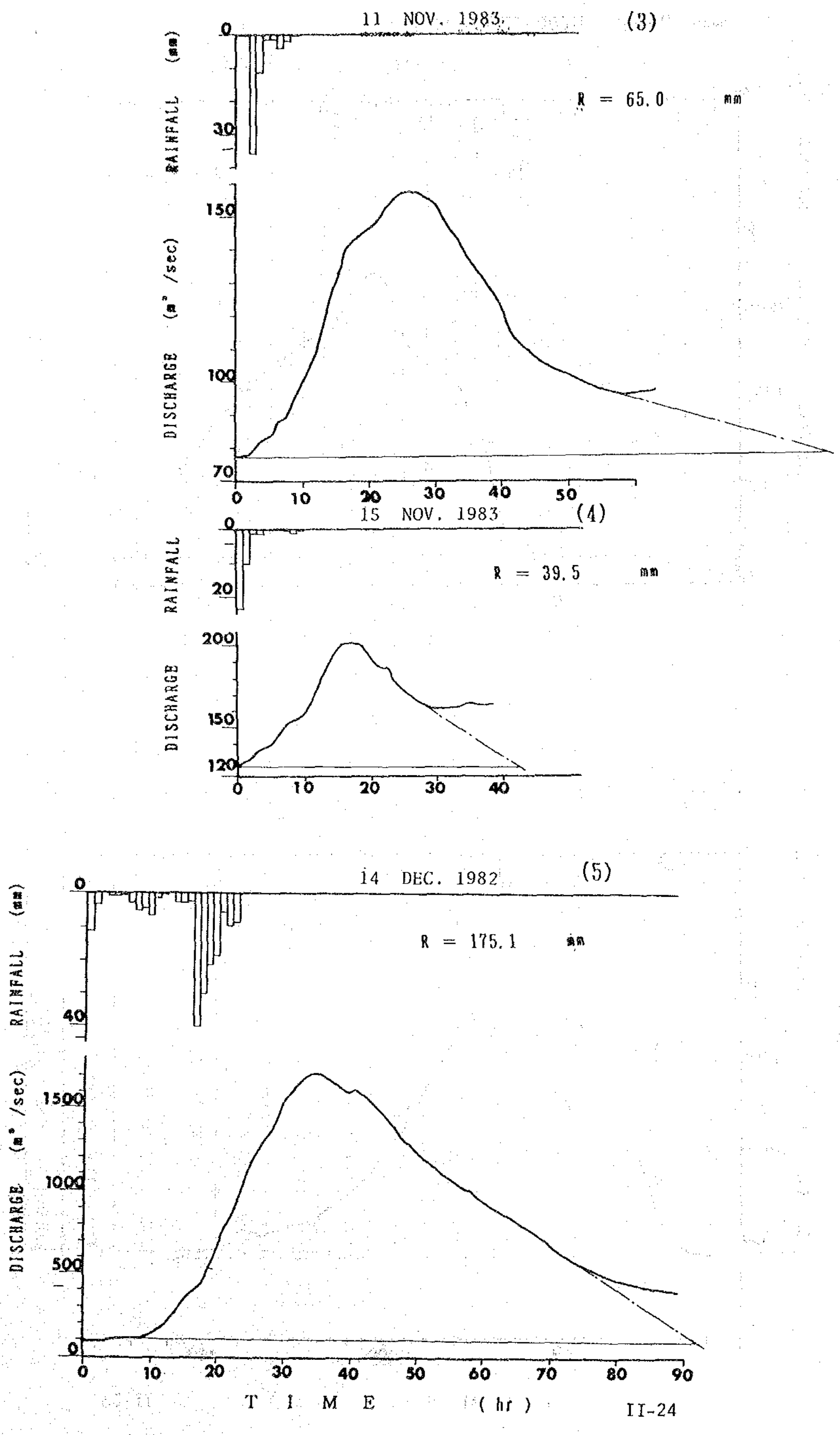


Figure II-2-6 RELATION OF RAINFALL AND DIRECT RUN-OFF(X45)

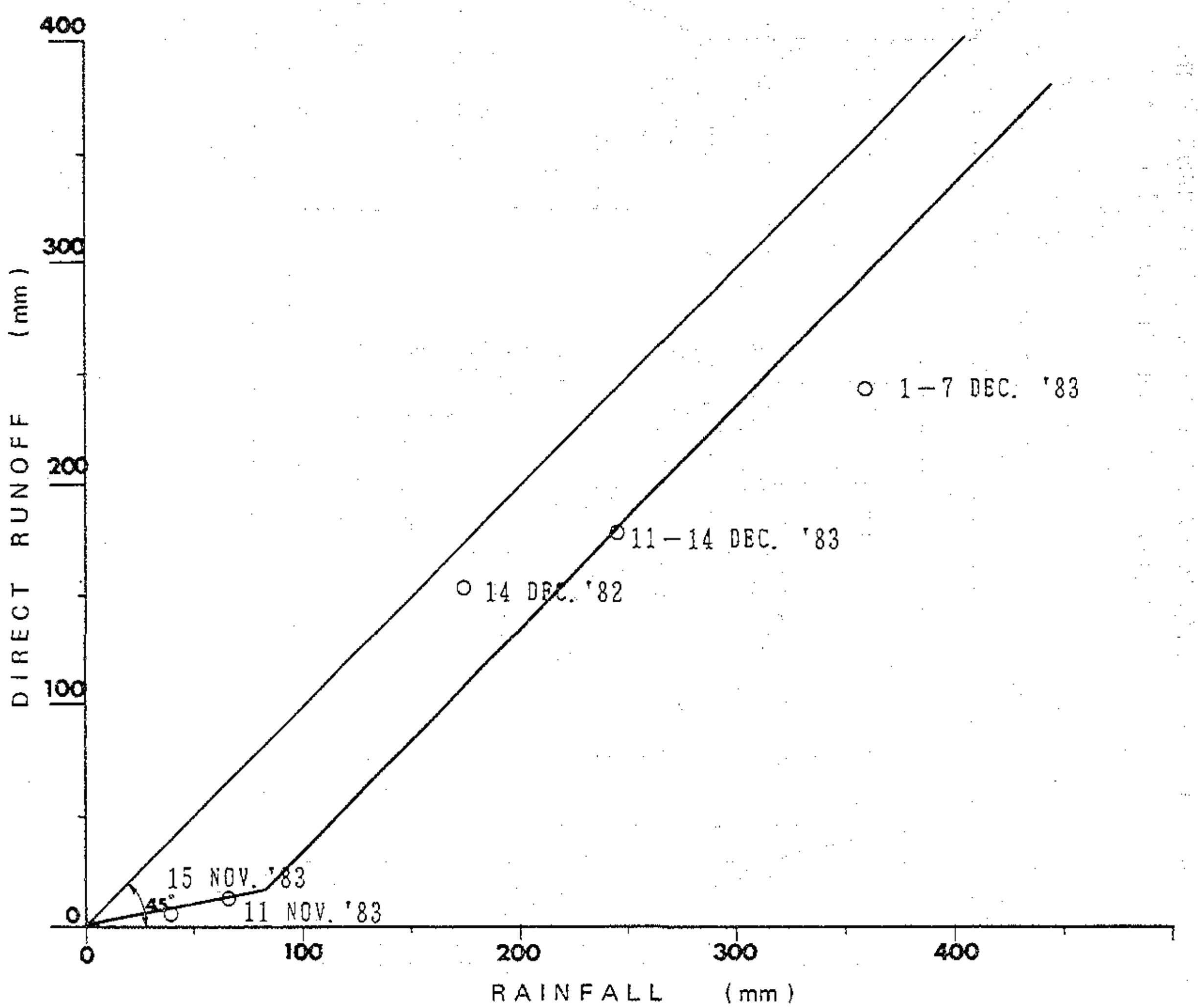
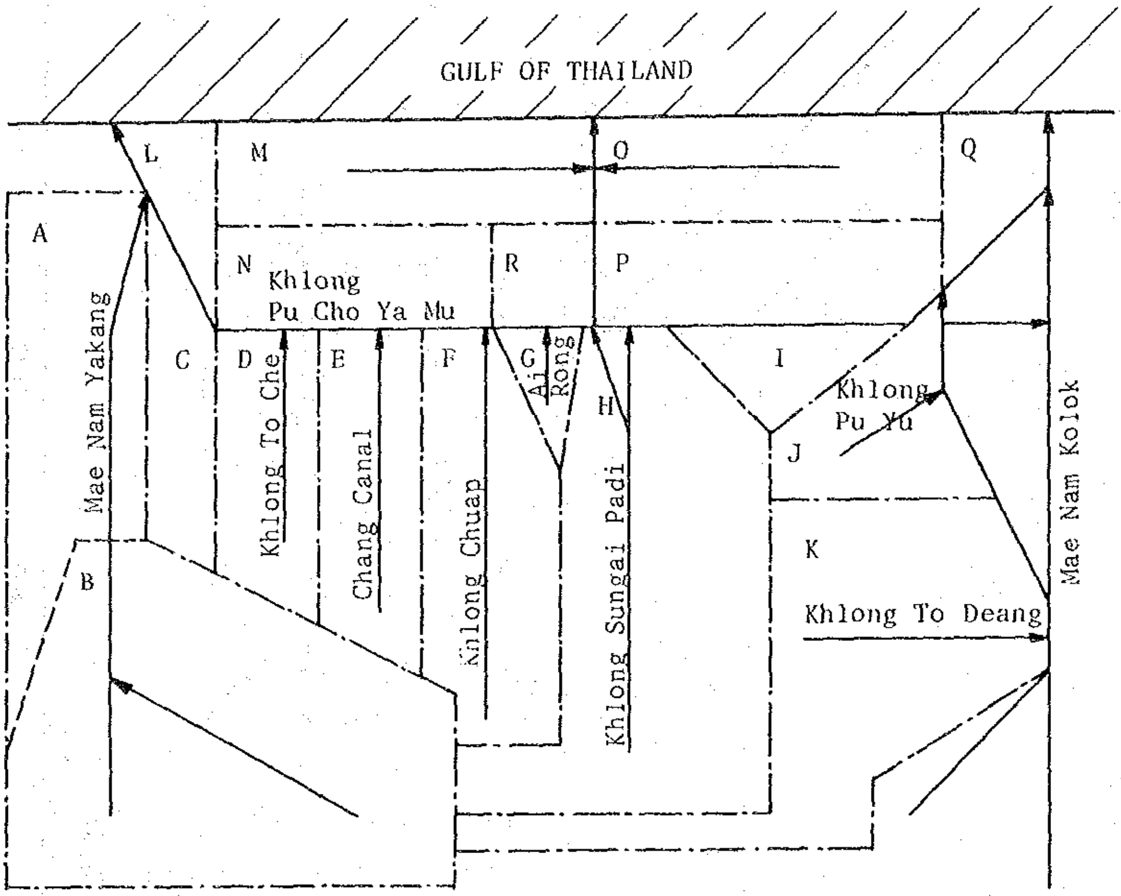


Figure II-2-7 CATCHMENT AREA OF MAE NAM BANG NARA
(TYPICAL MAP FOR RUNOFF ANALYSIS)



LEGEND

- - - - BOUNDARY OF CATCHMENT

- - - - SUB BOUNDARY

←—— RIVER OR CANAL

Figure II-2-8 **FLOOD RUN-OFF (1) (20 – 24 DEC. 1984)**

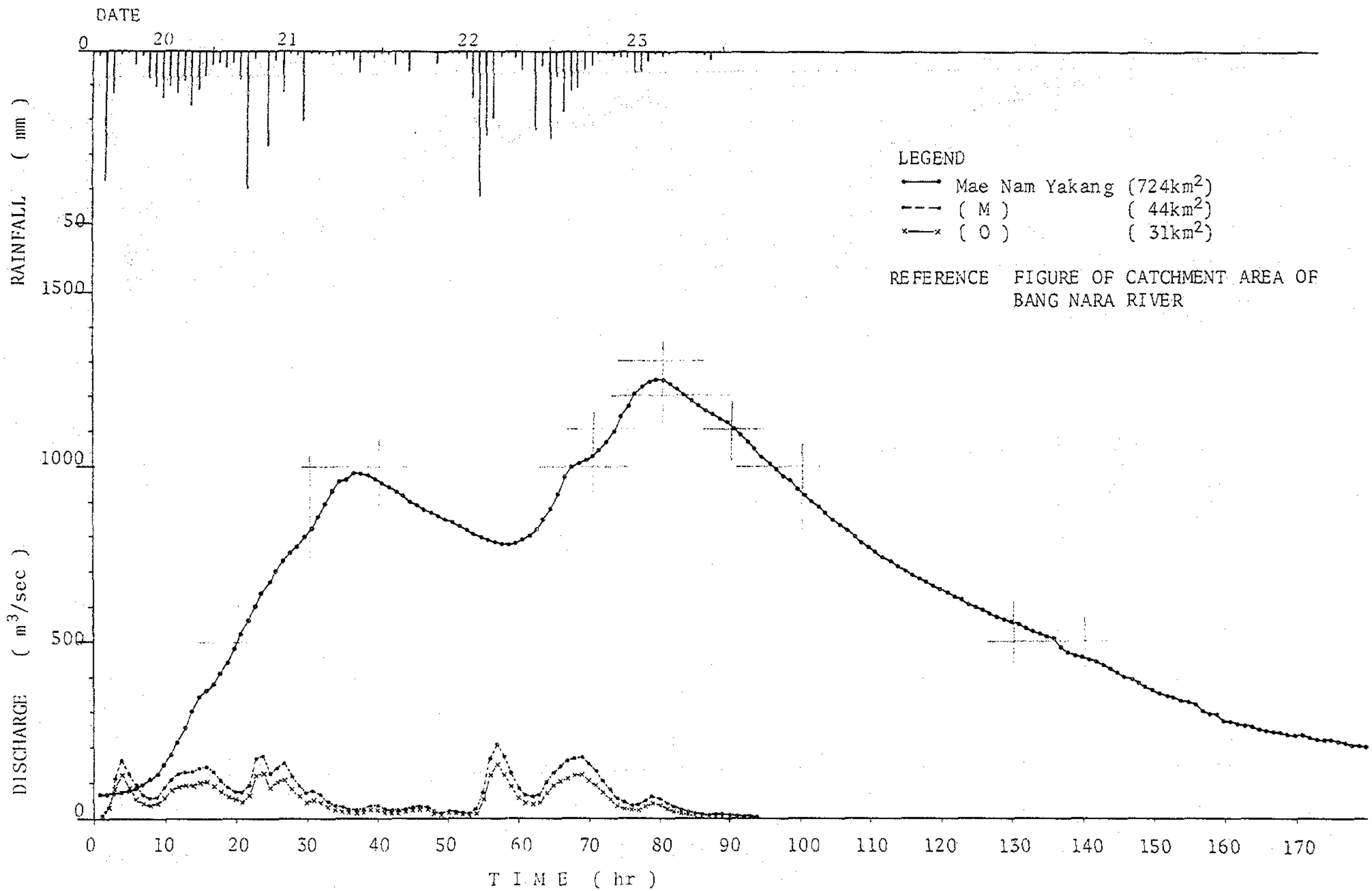


Figure II-2-9 FLOOD RUN-OFF (2) (20 - 24 DEC. 1984)

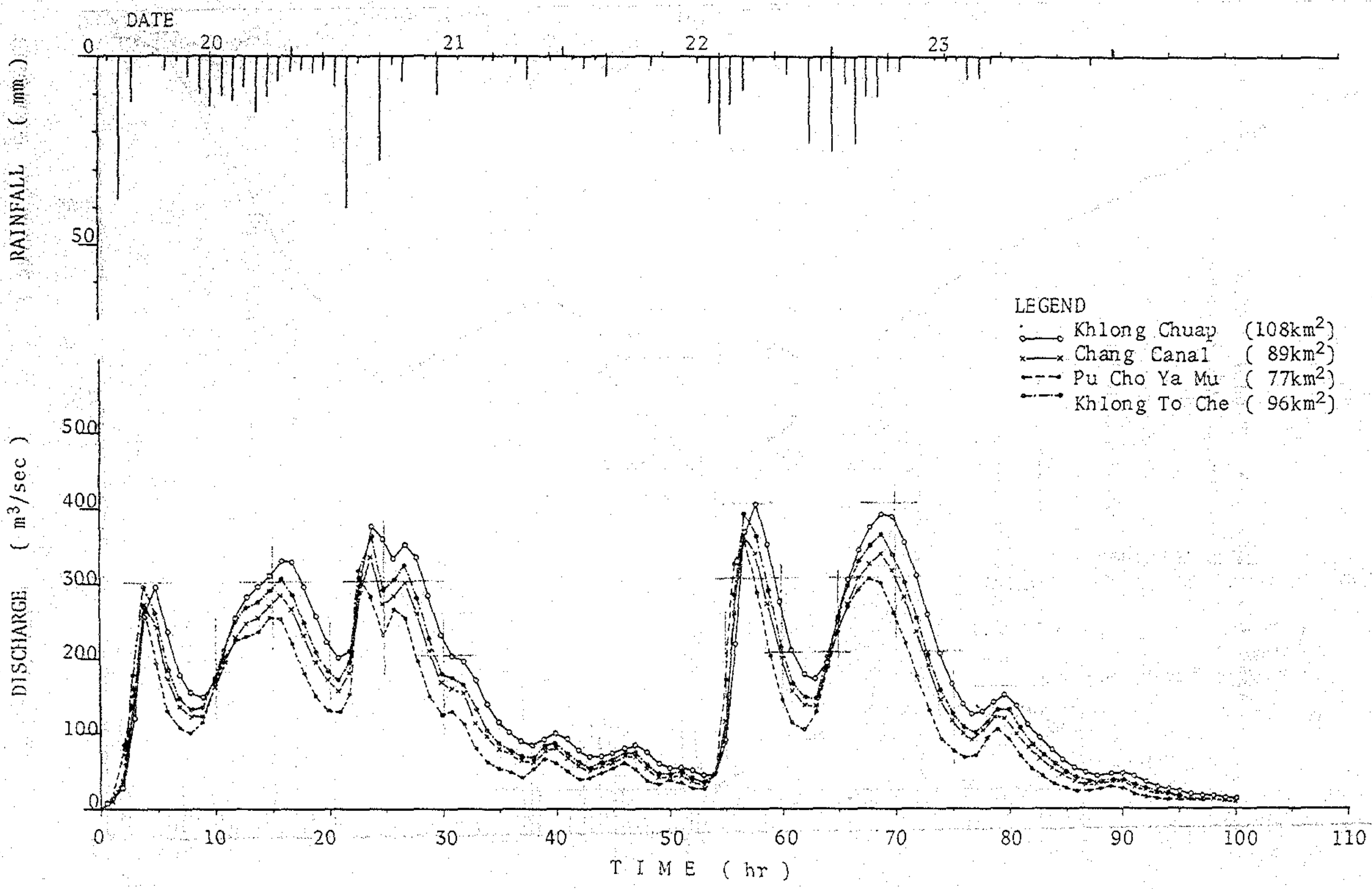


Figure II-2-10 FLOOD RUN-OFF (3) (20 - 24 DEC. 1984)

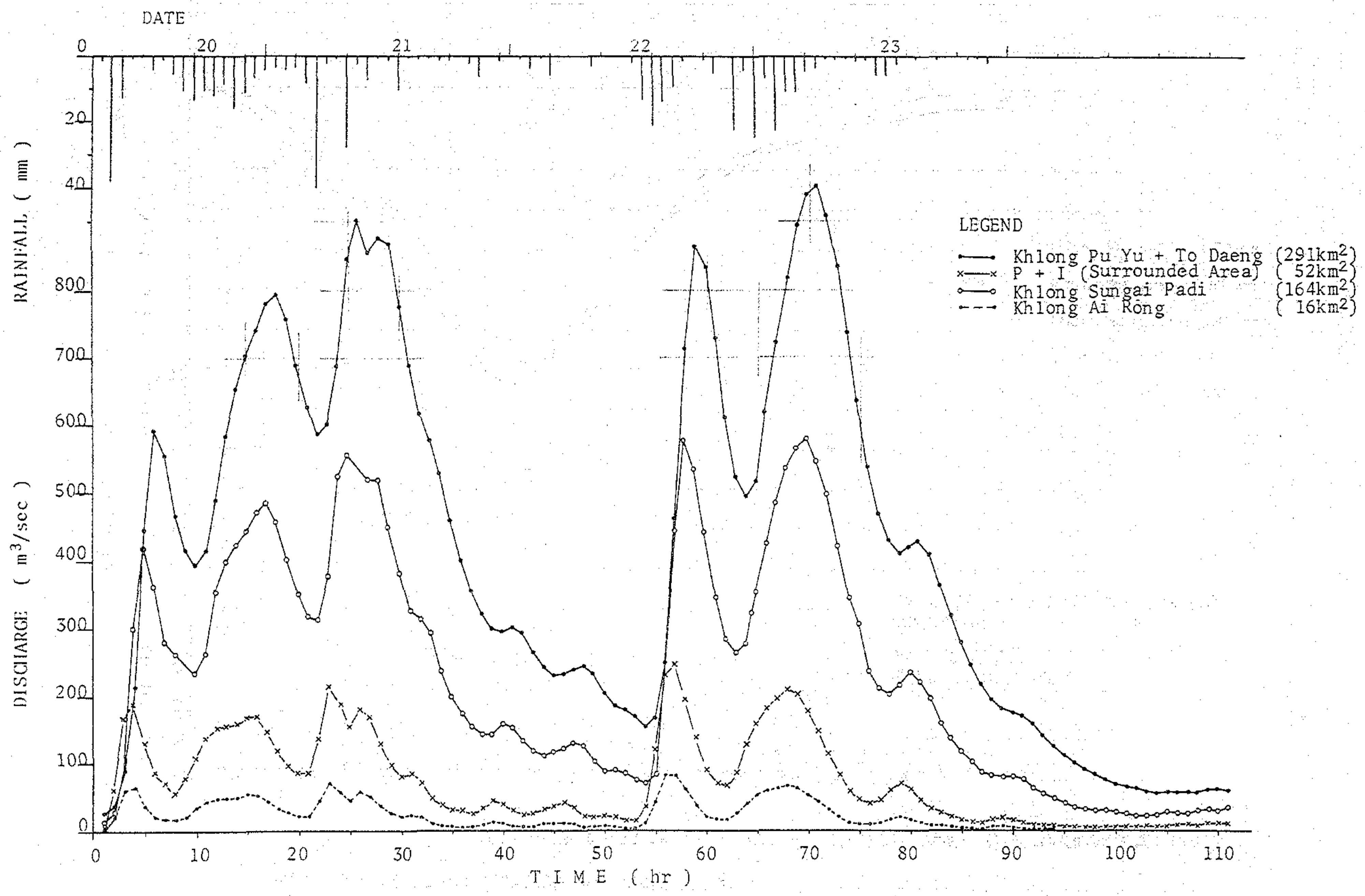


Figure II-2-11 VERIFICATION OF PARAMETERS

RUN-OFF ANALYSIS BY NAKAYASU METHOD (MAE NAM YAKANG, X73)

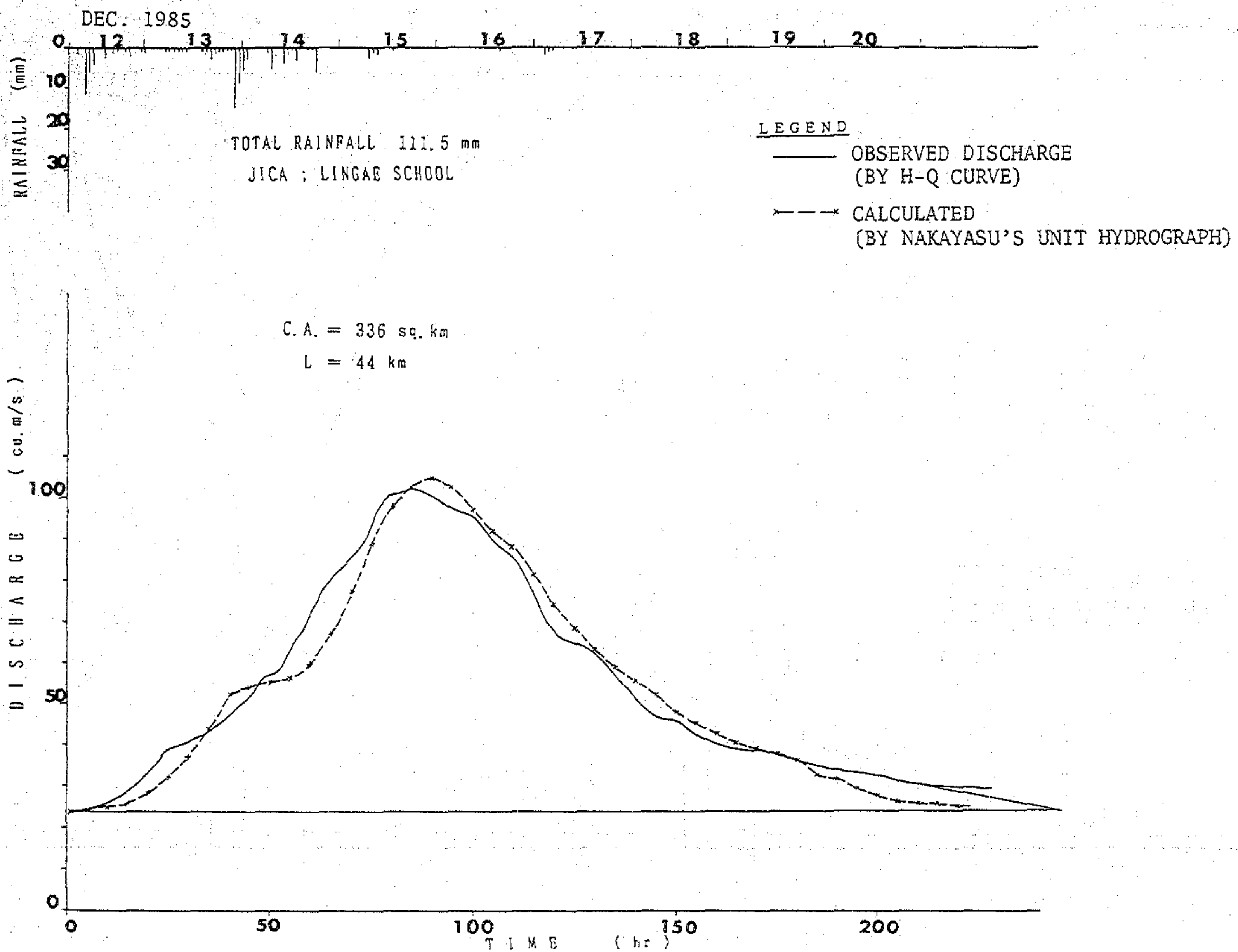


Figure II-2-12 FLOOD RUN-OFF (1) (10-19 DEC. 1985)

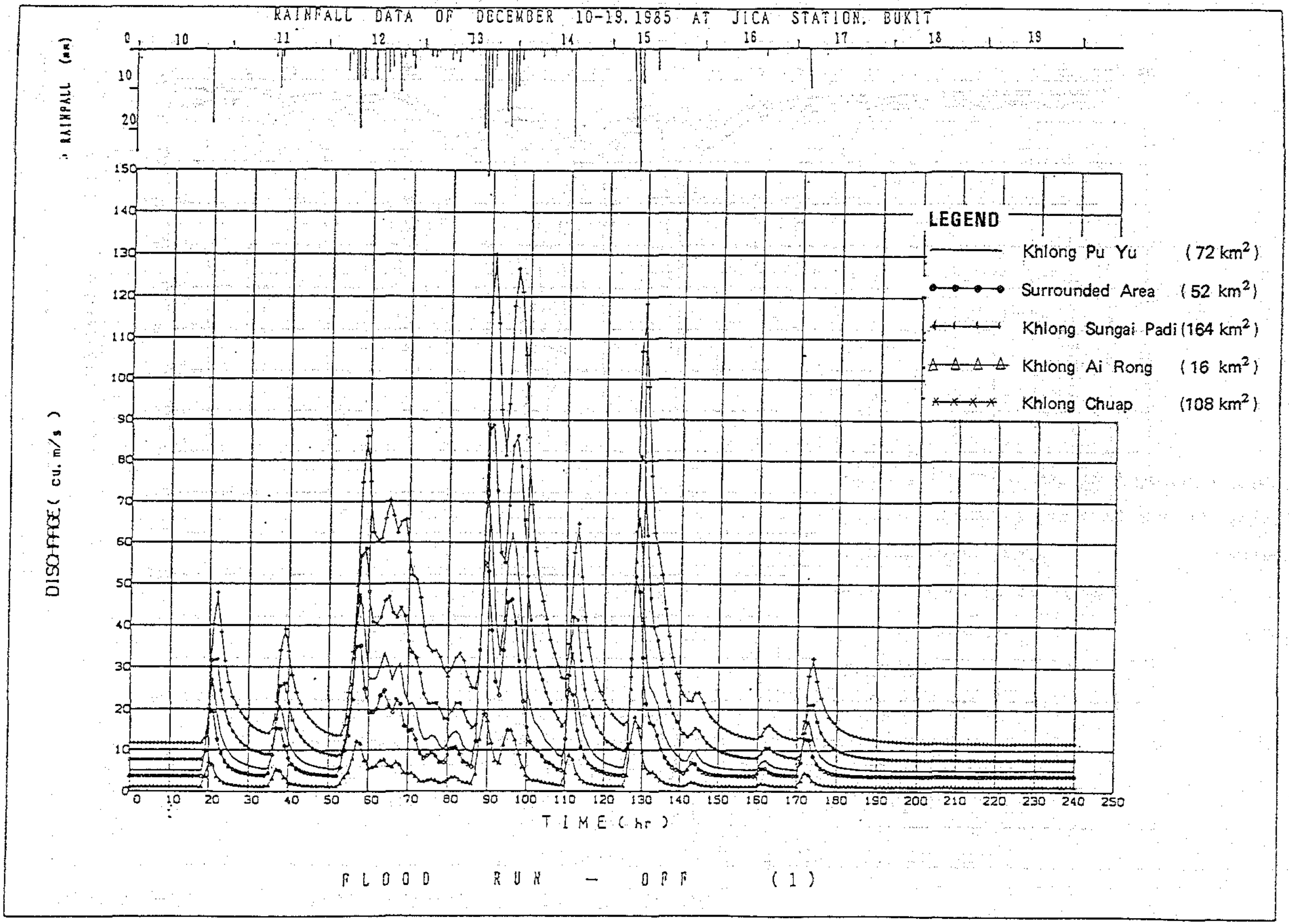


Figure II–2–13 FLOOD RUN – OFF (2) (10 – 19 DEC. 1985)

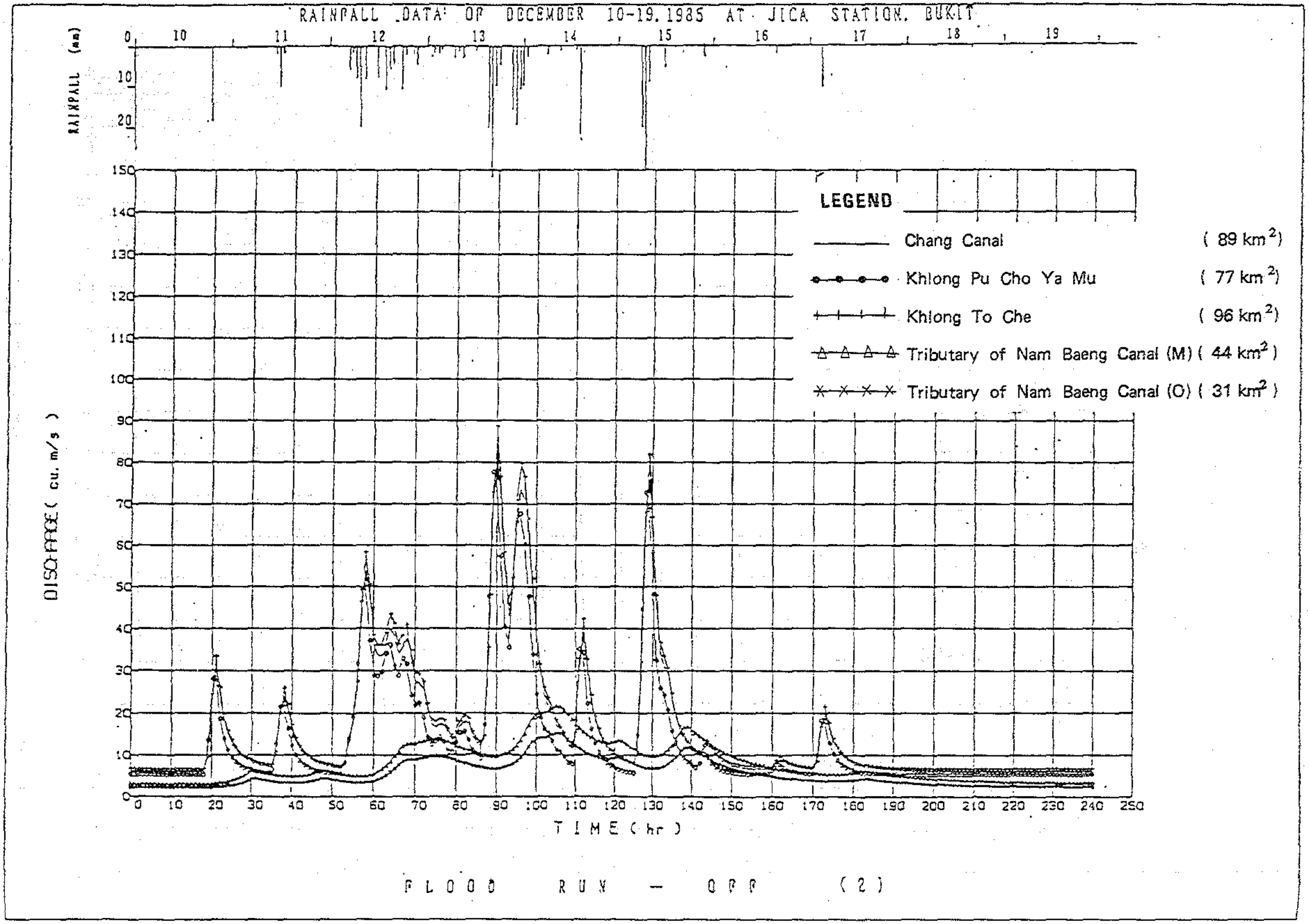


Figure II-2-14 **FLOOD RUN-OFF (3) (10 - 19 DEC. 1985)**

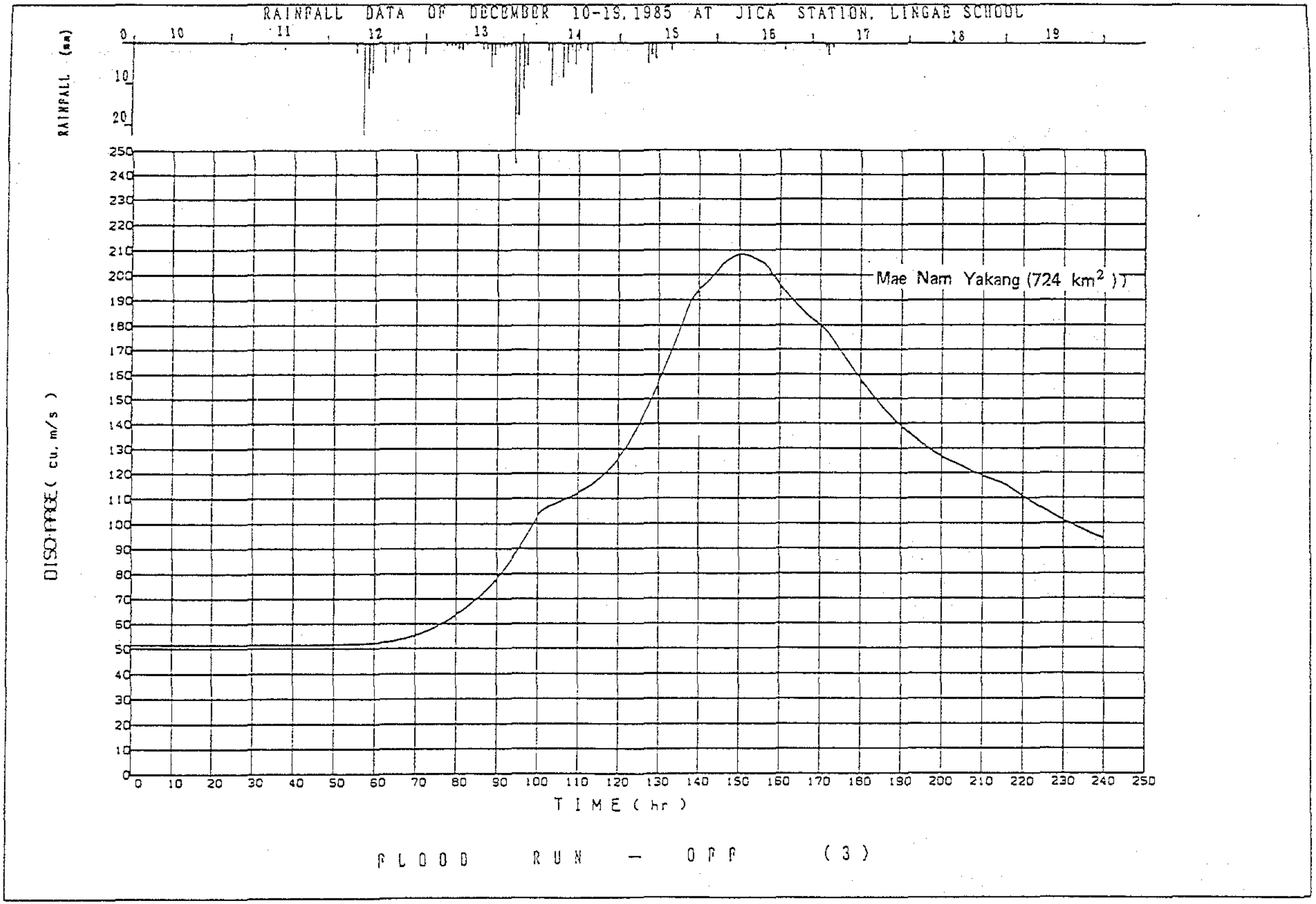


Figure II-2-15 ACCUMULATED DISCHARGE CURVE BY NAKAYASU METHOD
(10 – 19 DEC. 1985)

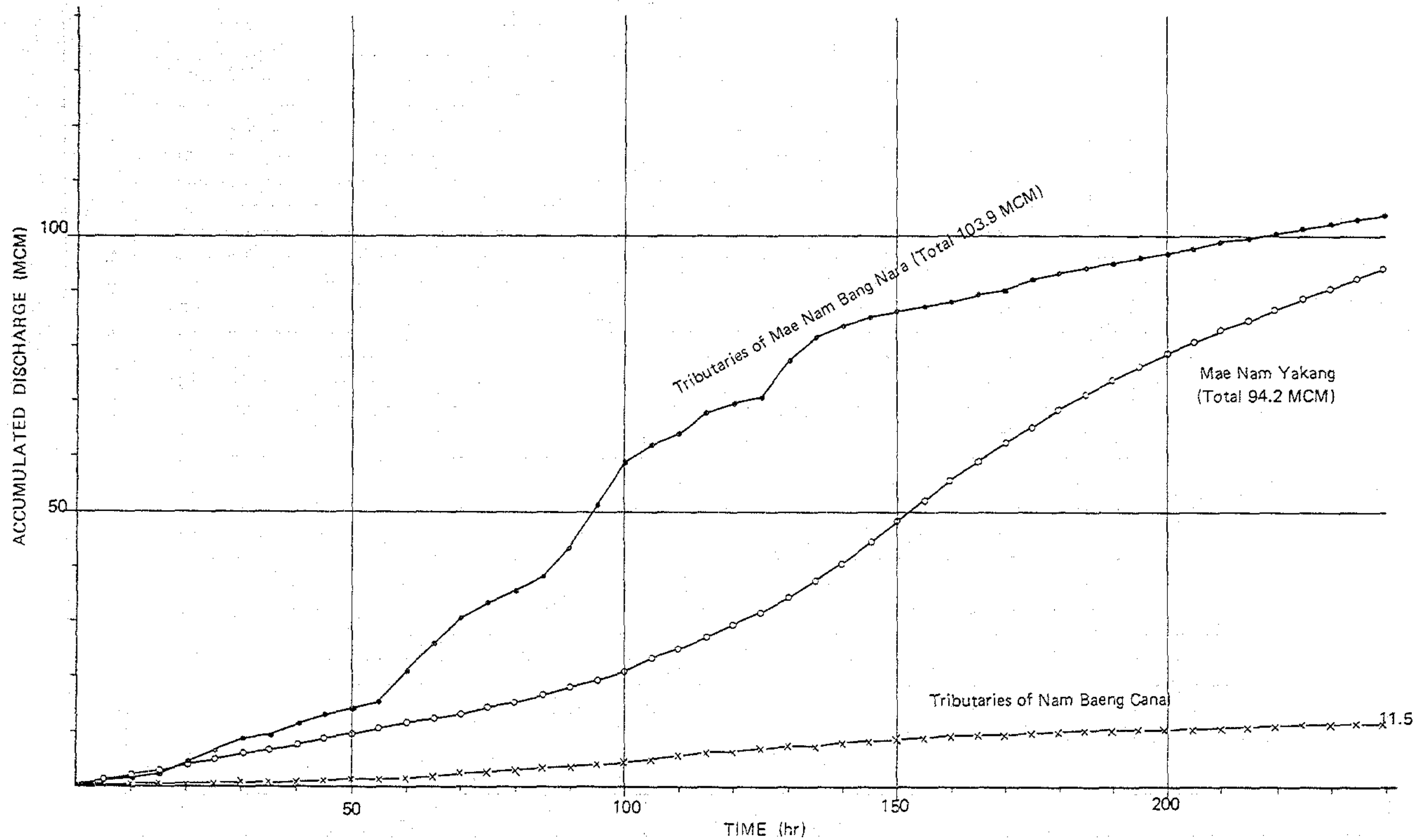
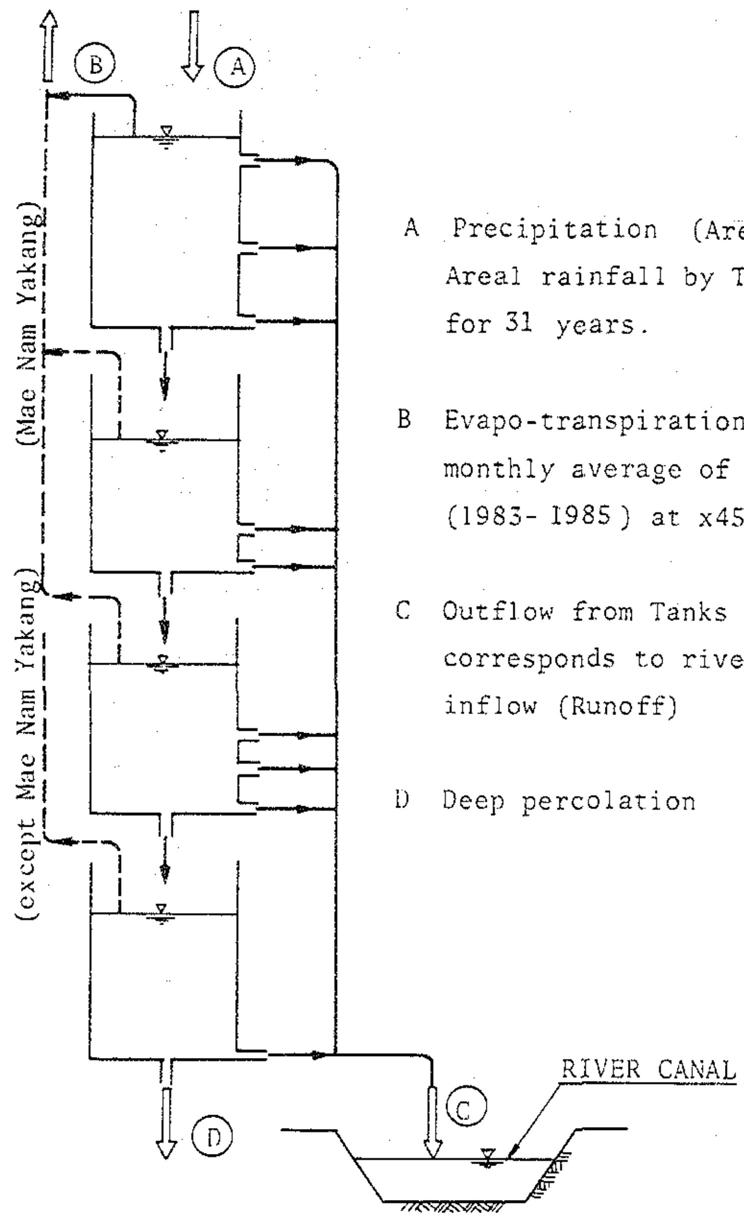


Figure II-2-16 LOW FLOW ANALYSIS

SERIES TANK MODEL FOR RUNOFF ANALYSIS



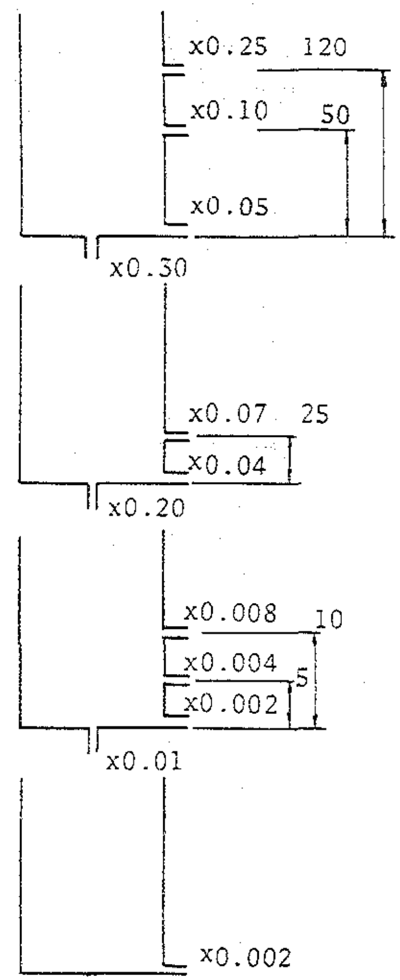
A Precipitation (Areal Rainfall)
Areal rainfall by Thiessen Method for 31 years.

B Evapo-transpiration
monthly average of 3 years (1983- 1985) at x45

C Outflow from Tanks which corresponds to river canal inflow (Runoff)

D Deep percolation

DIMENSION OF TANKS



NOTE ; Evapo-transpiration (mm)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
3.1	3.7	4.5	5.2	4.4	3.8	4.4	4.0	4.1	3.8	2.9	2.3

In case of a rainy day ; multiplied by 0.5

Figure II–2–17 VERIFICATION OF TANK MODEL (1983, 1984)

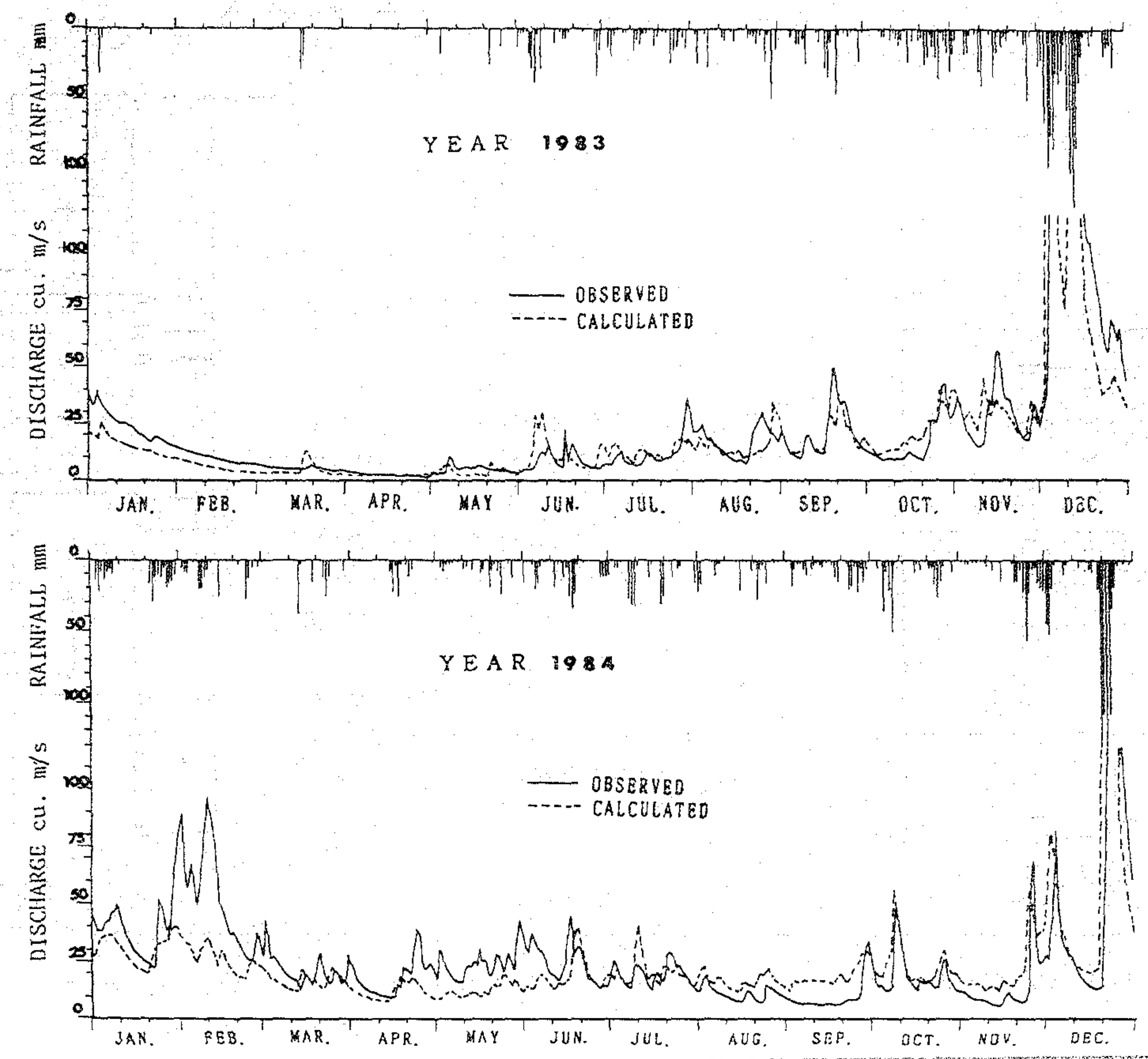
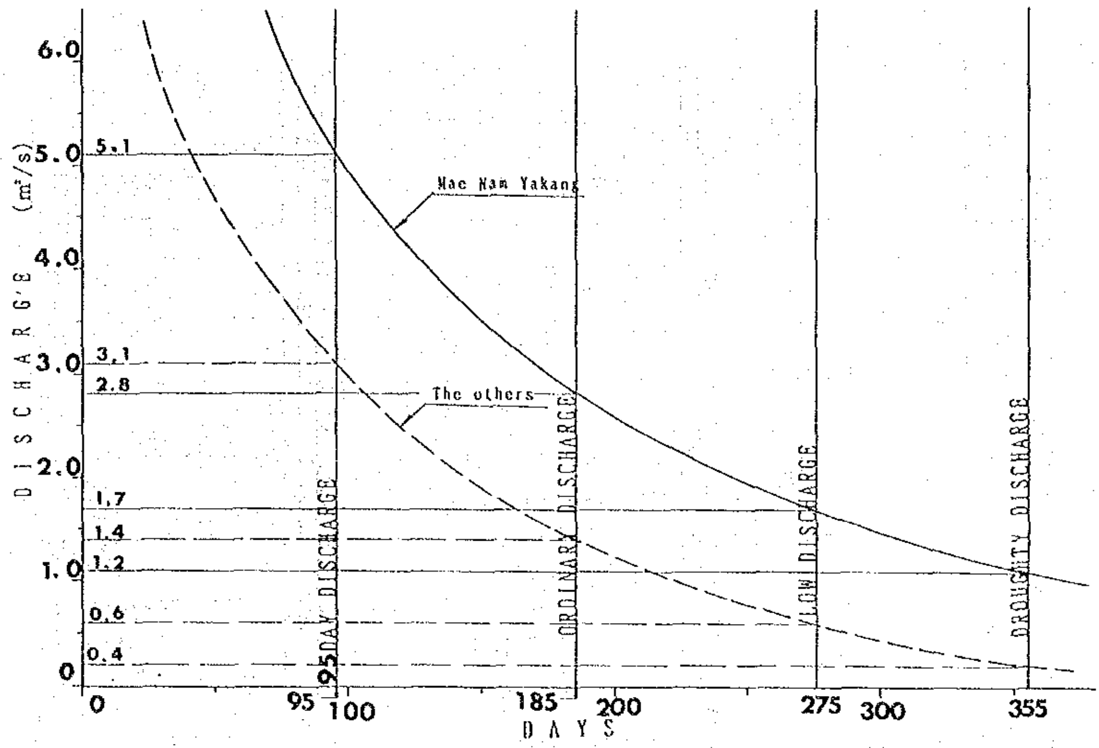


Figure II–2–18 **DISCHARGE – DURATION CURVE**

(MAE NAM YAKANG, MAE NAM BANG NARA)

(CATCHMENT AREA 100 sq. km)



(CATCHMENT AREA; Mae Nam Yakayang 724 sq.km
The others 677 sq.km)

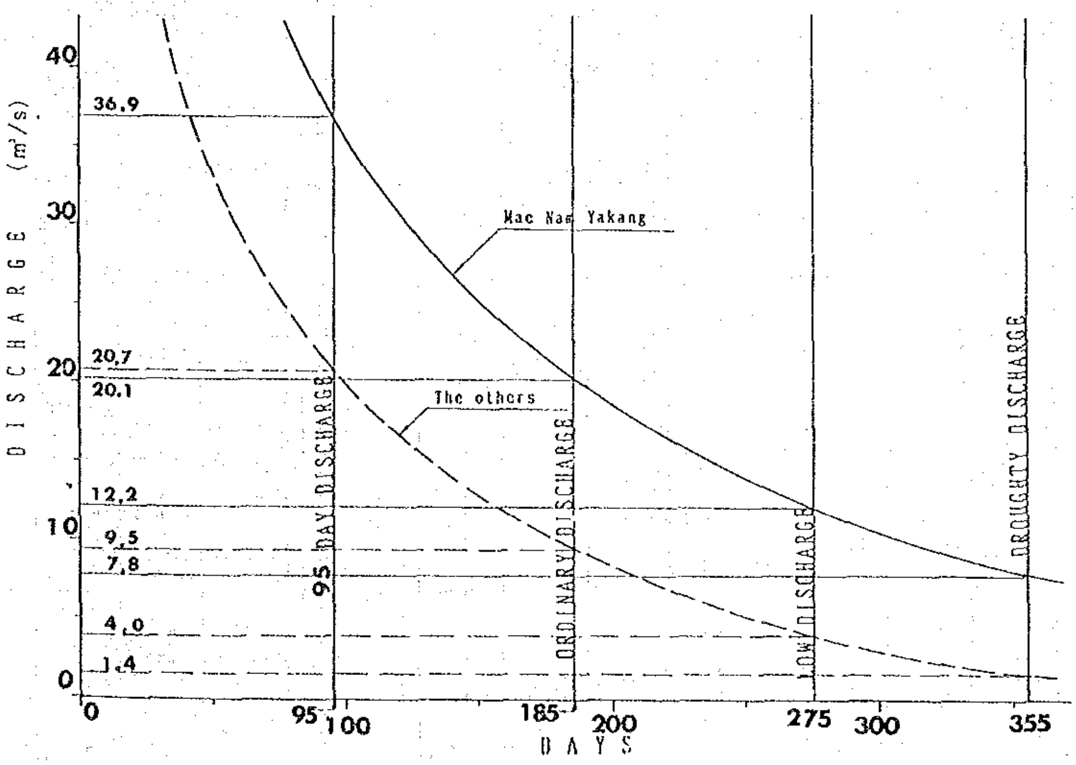


Figure II-2-19 DISCHARGE OF MAE NAM YAKANG FOR 30 YEARS

(BY TANK MODEL, From 1956 To 1985)

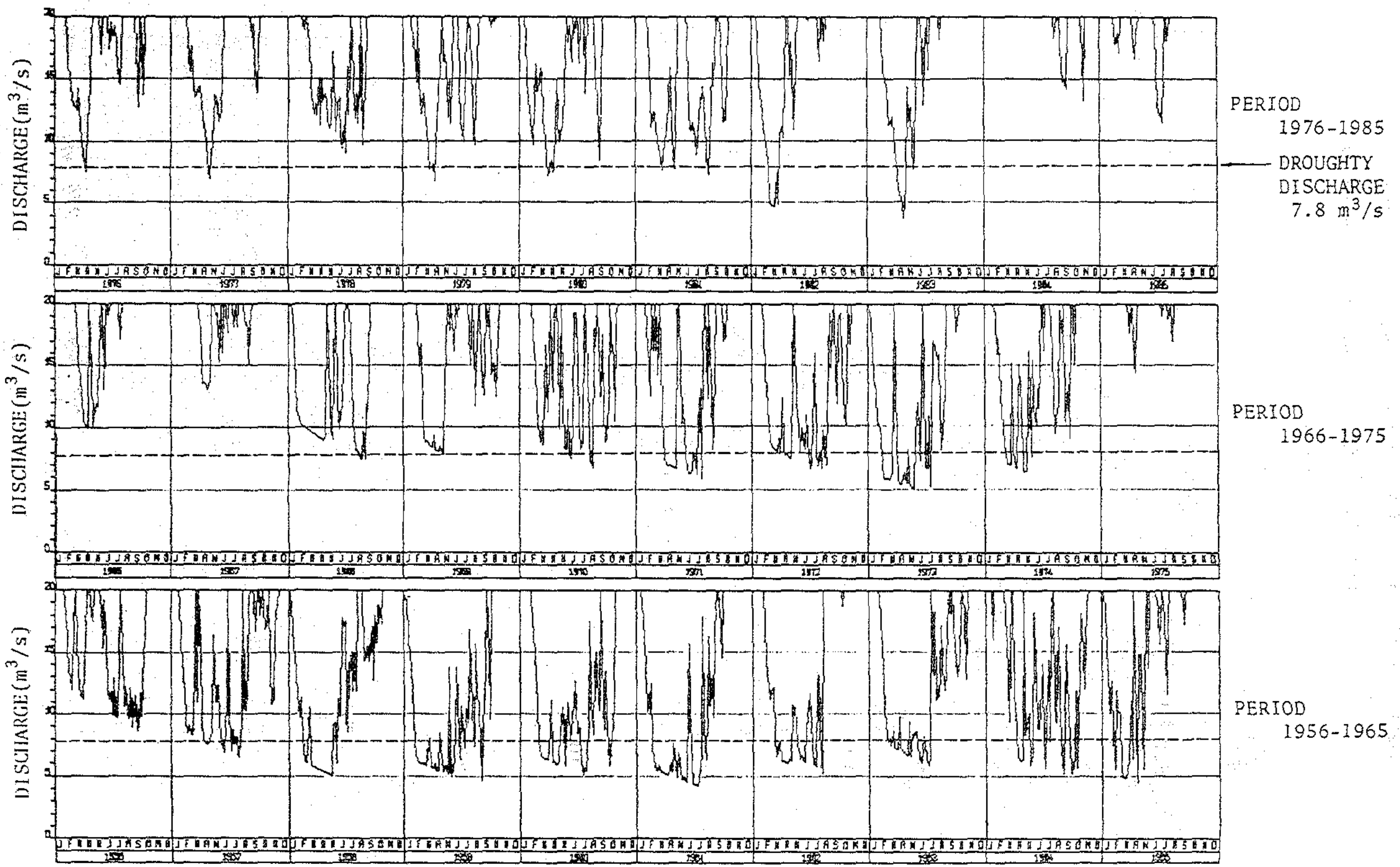


Figure II-2-20 DISCHARGE OF MAE NAM BANGNARA'S TRIBUTARIES FOR 30 YEARS

(BY TANK MODEL)

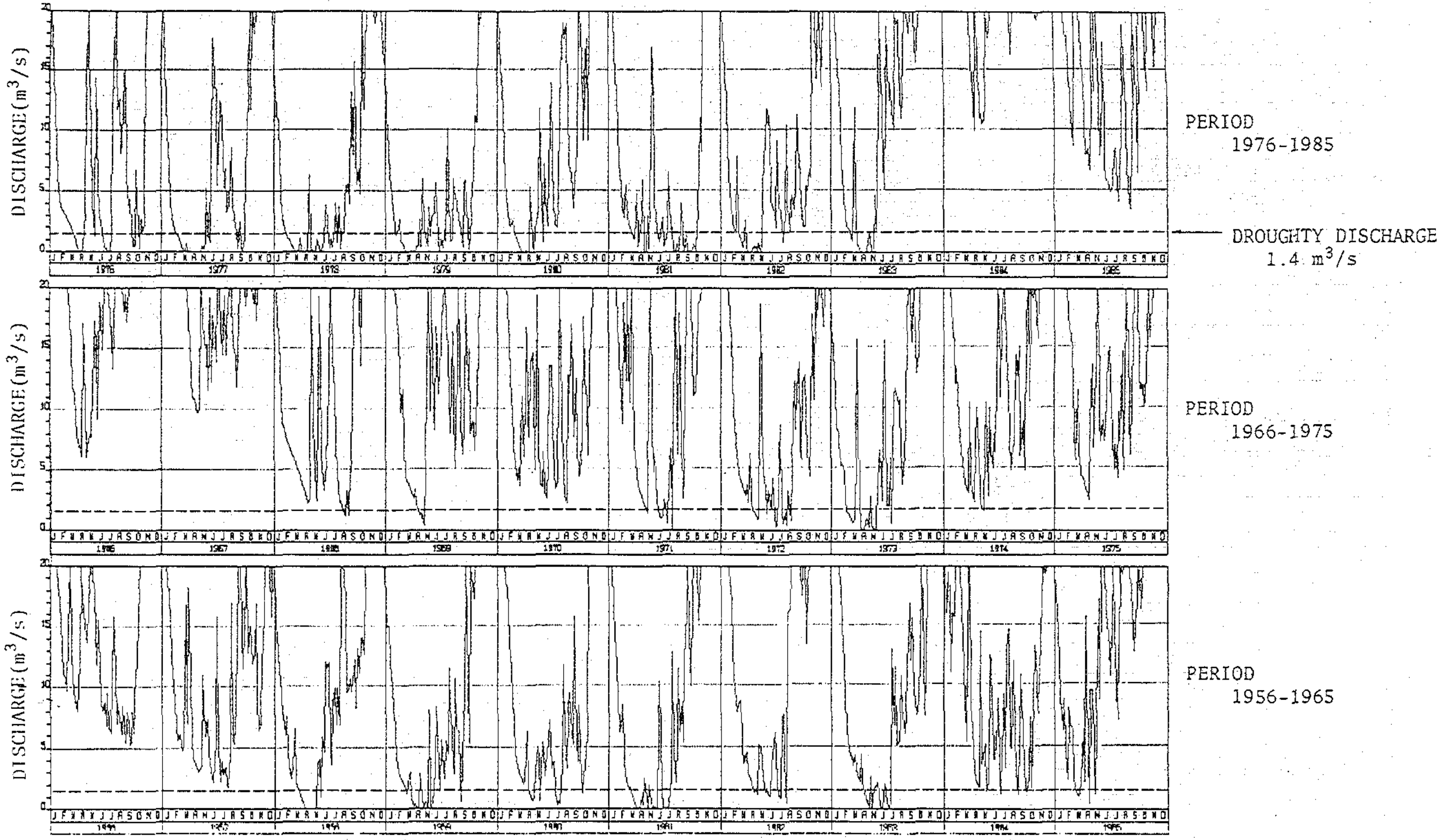


Figure II-2-21 SUSPENDED SEDIMENT RATING CURVE OF KOLOK RIVER

(AT A SUNGAI KOLOK CHANGWAT NARATHIWAT PERIOD WATER YEAR 1981 - 1982)

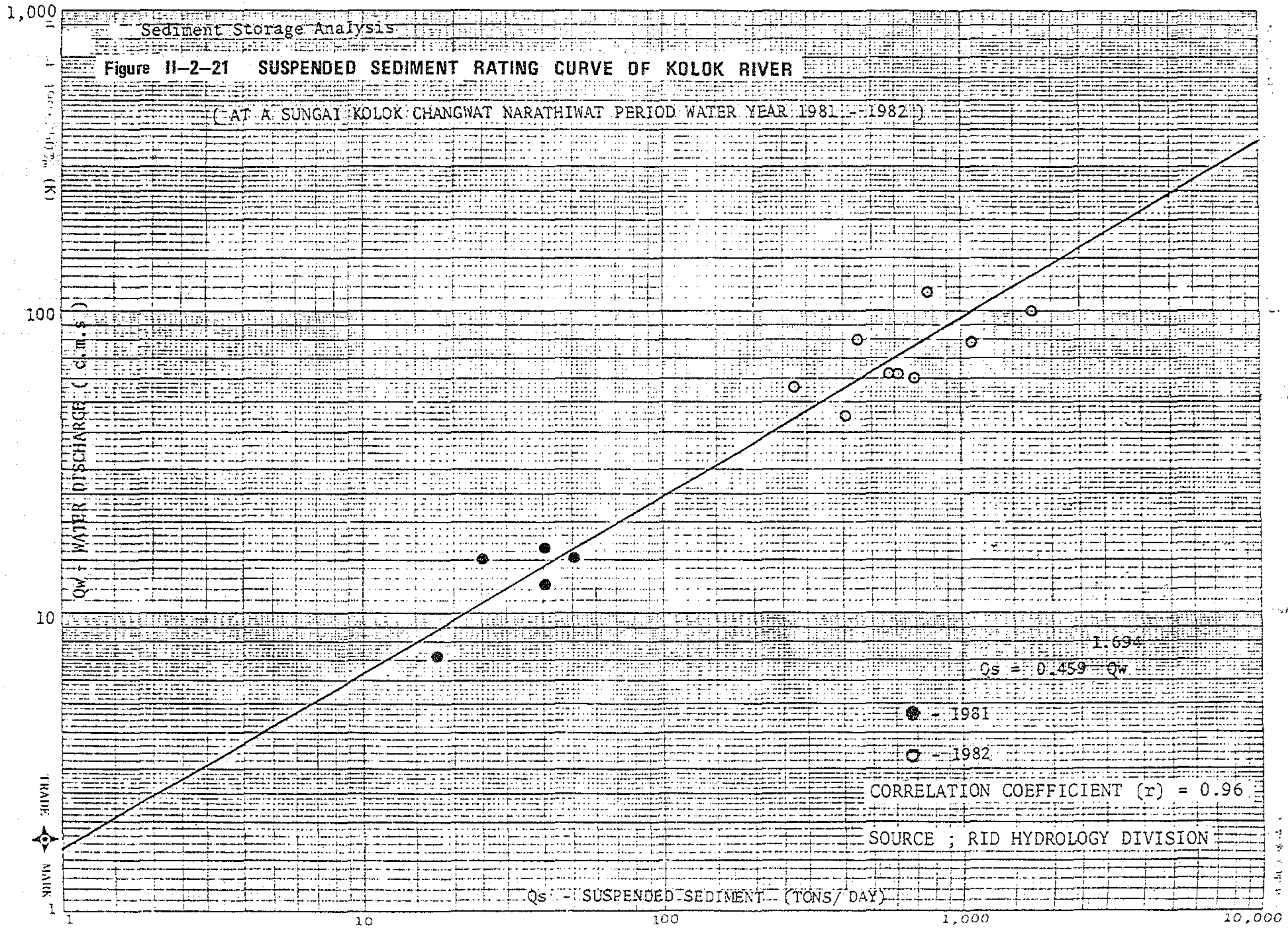


Figure II–2–22

SUSPENDED SEDIMENT LOAD OF MAE NAM YAKANG

*** AMOUNT OF THE SUSPENDED SEDIMENT (UNIT TON) ***

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1955	36494.	6981.	2518.	1976.	1886.	2782.	3977.	5145.	2926.	5685.	17633.	12090.	100092.
1956	4998.	1431.	2195.	2463.	3666.	1268.	1175.	943.	710.	3880.	7653.	12502.	42883.
1957	5238.	859.	1419.	637.	945.	866.	493.	1126.	3279.	2236.	1494.	8145.	26738.
1958	2042.	553.	383.	244.	383.	1200.	1067.	2668.	1384.	2287.	36949.	7166.	56326.
1959	1771.	352.	362.	335.	412.	532.	839.	881.	1272.	4439.	61102.	22498.	94795.
1960	6102.	1715.	357.	402.	604.	706.	387.	1122.	1108.	2335.	12160.	7073.	34070.
1961	3498.	708.	257.	276.	261.	589.	568.	888.	2021.	3798.	14265.	23826.	50952.
1962	7041.	1693.	624.	308.	560.	542.	679.	3376.	11029.	5980.	13333.	56448.	101614.
1963	13744.	1413.	459.	432.	514.	405.	1127.	1172.	2086.	1940.	7496.	13759.	44549.
1964	2959.	5499.	4132.	453.	833.	1181.	985.	1099.	641.	892.	3001.	14409.	36085.
1965	1953.	666.	261.	1181.	1397.	5005.	2086.	11053.	2913.	13822.	95087.	122039.	257463.
1966	53891.	6381.	1921.	1130.	1329.	2467.	5497.	9022.	7476.	16418.	33754.	139927.	279213.
1967	276372.	13570.	5440.	1290.	3189.	2087.	2934.	3739.	5763.	4438.	15329.	14957.	349108.
1968	2372.	709.	659.	587.	2379.	1564.	3546.	510.	4979.	10946.	8584.	40581.	77415.
1969	12750.	2225.	626.	519.	2219.	2636.	3815.	3058.	2036.	1640.	55804.	35394.	122722.
1970	9340.	2155.	939.	1850.	1294.	1164.	1702.	1091.	1417.	1392.	5063.	26917.	54323.
1971	13412.	1760.	3290.	378.	1958.	448.	626.	2256.	8372.	2534.	35839.	80750.	151622.
1972	7763.	1673.	542.	546.	1386.	579.	671.	597.	1644.	1437.	3391.	13605.	33834.
1973	1998.	485.	1030.	315.	286.	1107.	943.	1195.	3074.	3597.	9924.	89400.	113354.
1974	6354.	1588.	689.	729.	701.	1536.	3258.	1265.	1287.	3256.	73258.	41134.	135055.
1975	95755.	8443.	4314.	1895.	6911.	3308.	4339.	3136.	14370.	9496.	52277.	68127.	272373.
1976	9631.	1828.	994.	894.	7241.	3806.	1725.	9997.	2870.	9171.	76933.	51036.	176128.
1977	38675.	3680.	1403.	871.	869.	2864.	8476.	9293.	2074.	11708.	9952.	49554.	139419.
1978	12665.	2737.	1507.	1142.	1109.	856.	1513.	1231.	7711.	5509.	27416.	44300.	107696.
1979	3966.	1509.	861.	860.	1803.	3888.	2839.	1370.	12186.	2840.	87855.	29332.	149308.
1980	2718.	997.	1065.	610.	2448.	2309.	2577.	4451.	1929.	6821.	18692.	57986.	102603.
1981	6828.	1670.	669.	958.	9909.	2436.	898.	801.	5572.	2599.	20657.	57295.	110293.
1982	3179.	758.	249.	1385.	2129.	9282.	4231.	3742.	6228.	9669.	10706.	69095.	120653.
1983	12092.	2195.	959.	293.	799.	2259.	4019.	6803.	9972.	6693.	16371.	122243.	184698.
1984	27191.	45480.	9903.	7540.	12289.	12188.	8326.	3083.	3434.	8590.	7329.	62381.	207733.
1985	11526.	2816.	27015.	2524.	16513.	7748.	2115.	11921.	10547.	25202.	14059.	32466.	164452.
MEAN	22397.	4017.	2485.	1130.	2846.	2568.	2498.	3485.	4591.	6169.	27528.	46014.	125728.

* NOTE ; These figures are obtained from the following formula

$$Qs = 0.459\ Qw^{1.694}$$

(Refer to the figure of SUSPENDED SEDIMENT RATING CURVE.)

Where, The figures obtained from the results of Tank Model are applied to Qw.

No date on bed load is available, however, the total sediment load is assumed to be equal to the suspended sediment load.

* REFERENCE *

MONTHLY AVERAGE SUSPENDED SEDIMENT LOAD IN TONS

MAE NAM PATTANI, X40 1964-1975 (C.A = 3,295 km^2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN	89322.	11808.	7515.	5804.	11402.	8921.	7727.	8242.	11473.	23444.	44196.	123366.	353220.

MAE NAM PATTANI, X78A 1968-1973 (C.A = 2,044km^2)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
MEAN	142199.	13060.	12057.	8076.	21879.	13585.	7305.	13497.	23549	75894.	138574.	365695.	835370.

SOURCE ; RID HYDROLOGY DIVISION

Figure II-2-23 GRAIN SIZE ACCUMULATION CURVE

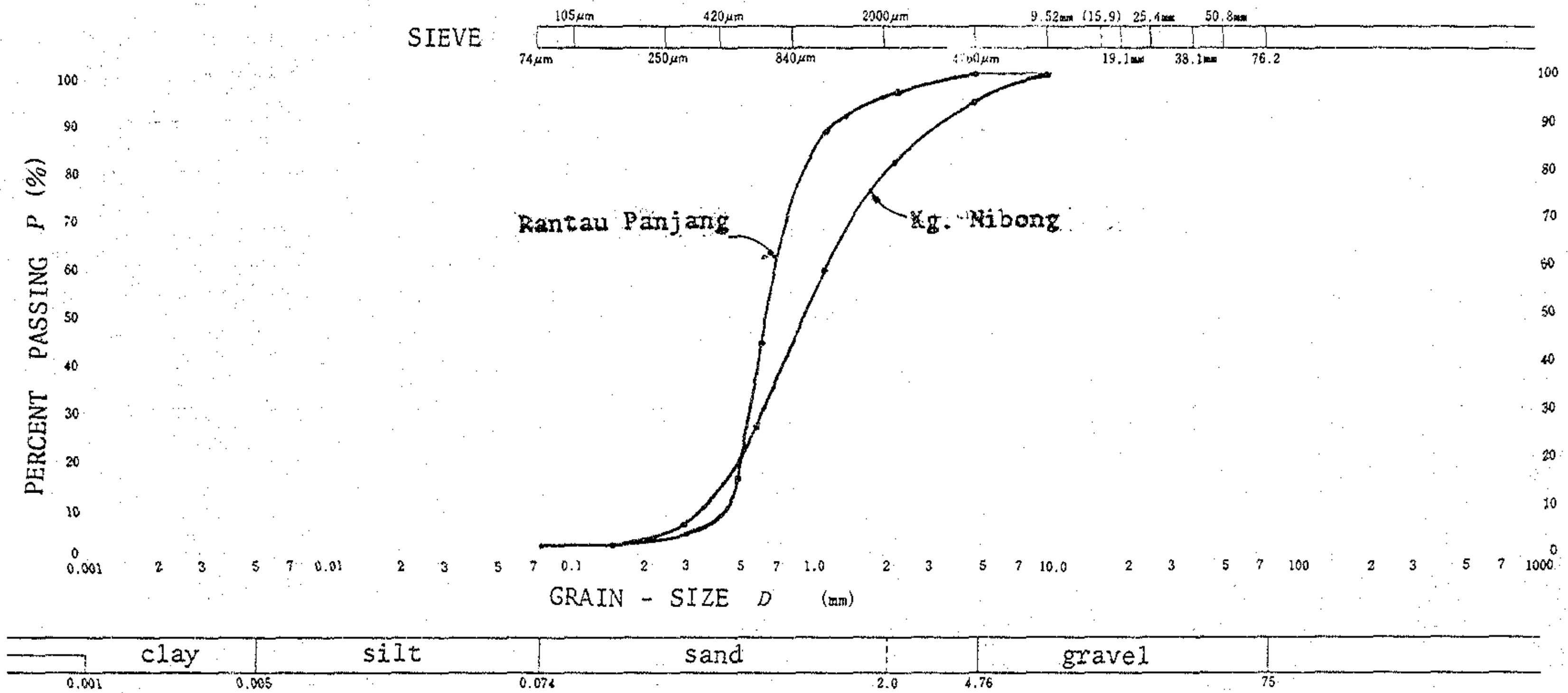
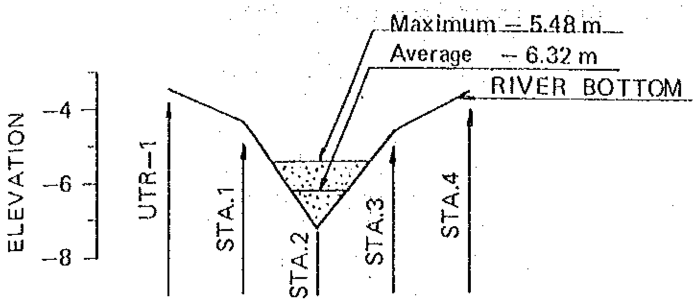
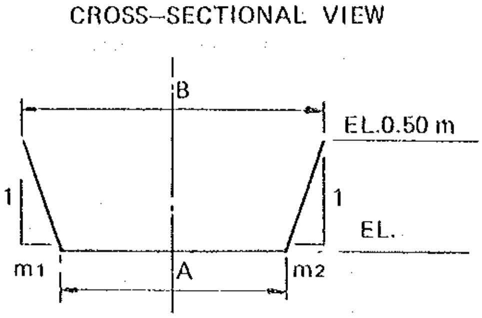


Figure II–2–24 **SEDIMENT DEPOSITION IN MAE NAM BANG NARA (UTR–1 SIDE)**





STATION (km)		A	B	m1	m2	EL
STA.0	(UTR–1)	6.0	196.0	41.98	5.64	– 3.49
STA.1		5.0	276.0	0.51	54.46	– 4.43
STA.2	(Mae Nam Yakang)	40.0	144.0	5.75	7.54	– 7.33
STA.3		70.0	278.0	7.68	32.25	– 4.71
STA.4		90.0	310.0	9.01	43.87	– 3.66

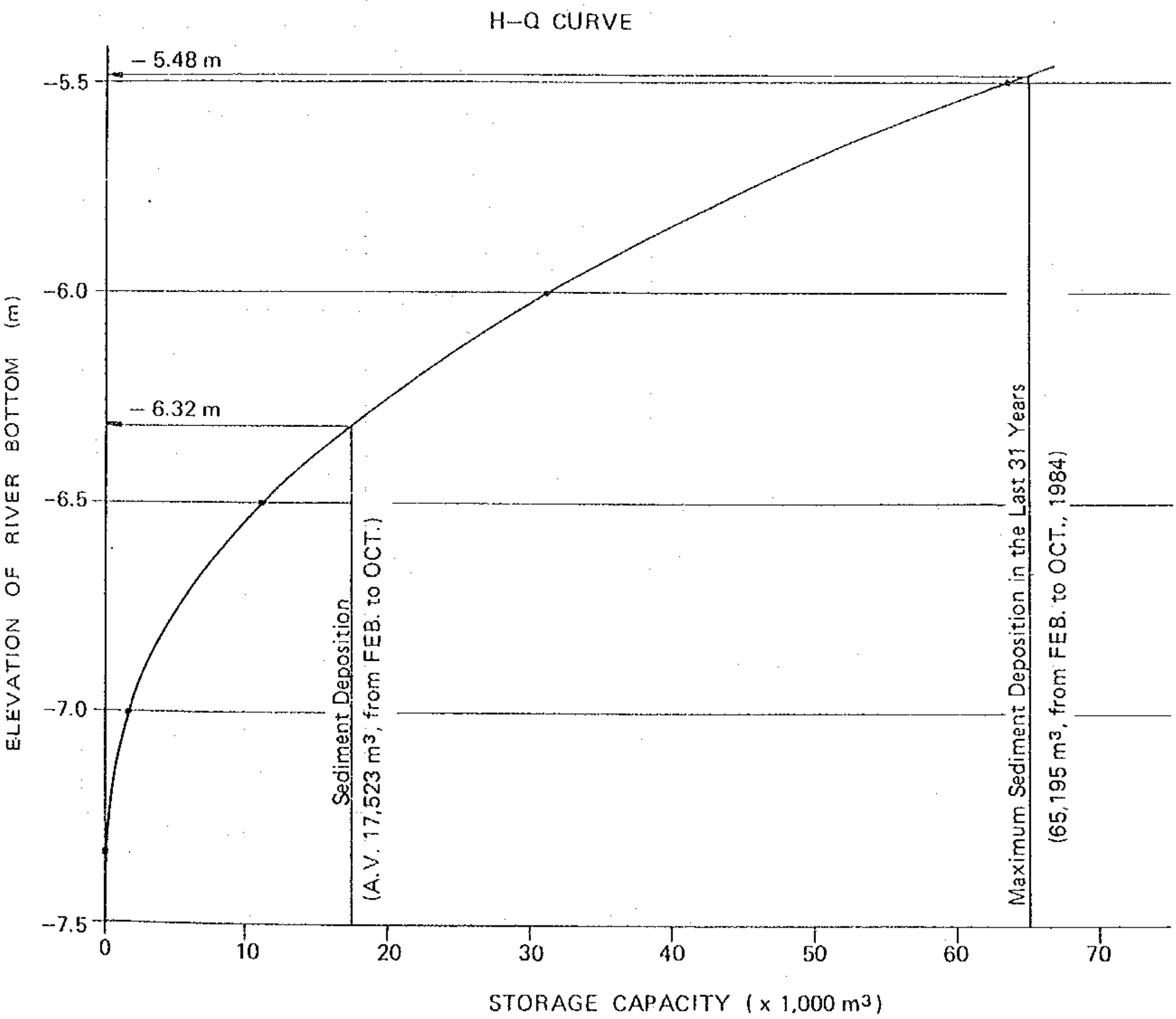
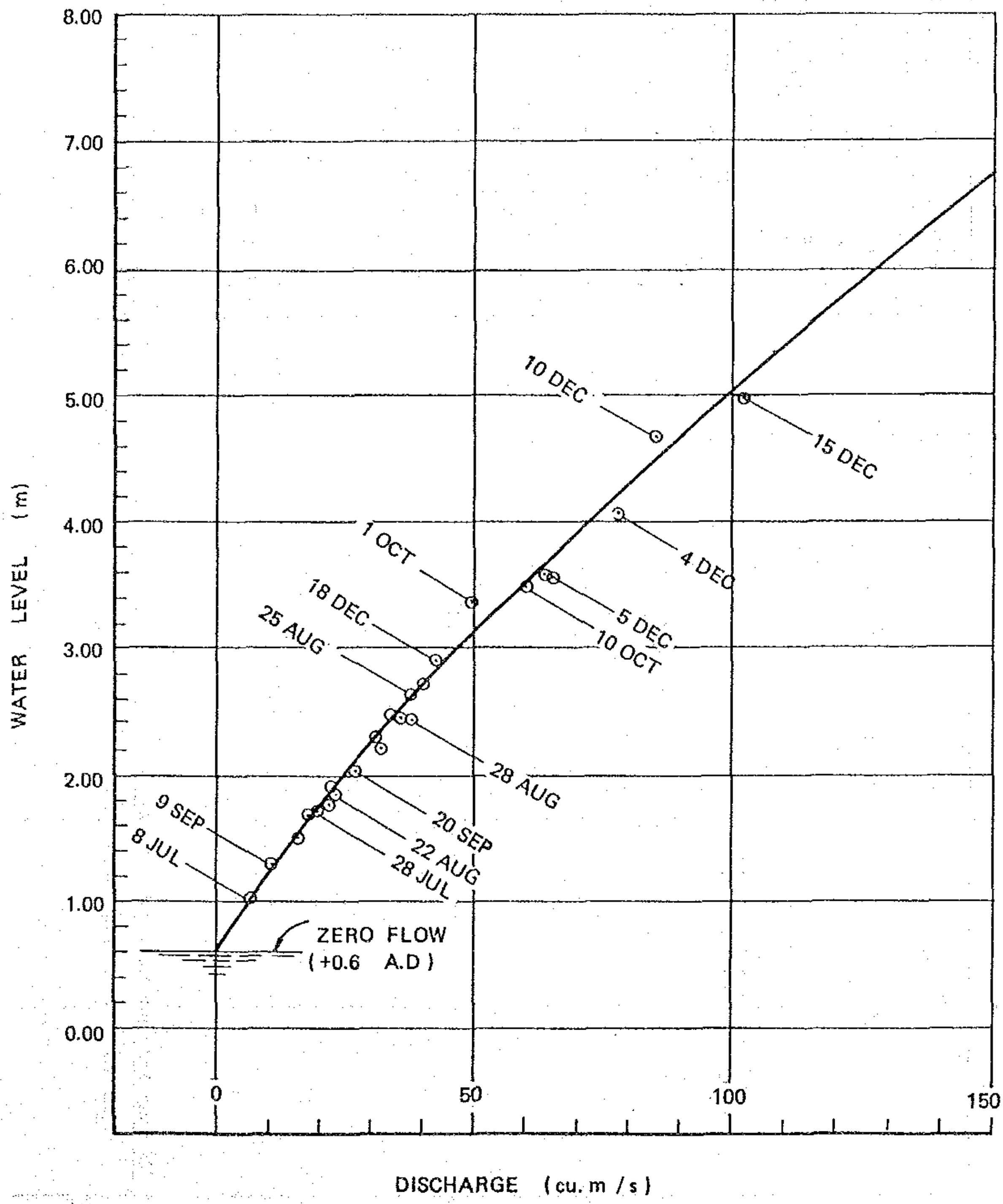


Figure II-2-25 Rating Curve at X73, Mae Nam Yakang (1985, RID)



II-3 Hydrogeology

II-3-1 Introduction

The stratum mainly consists of alluvium which belongs to the Chao Phraya aquifer according to the hydrogeological map (1:1,000,000) of DMR. A beach-sand aquifer is also seen. The possibility of developing groundwater in this area has been studied by grasping the storage condition of groundwater and the influence of the proposed Bang Nara water storage.

Shallow groundwater refers to the unconfined groundwater which can be taken by hand-dug well. Deep groundwater refers to the confined groundwater to be taken by tube well. The purpose fo groundwater investigation in this Study lies in grasping the potential of groundwater irrigation. Contents of the Study are as follows:

* Present groundwater development
* Subsurface geology
* Hydrogeology and its features
* Groundwater throughflow and total yield potential
* Groundwater quality and problems
* Effect of the proposed Bang Nara water storage
* Groundwater development potential

(1) Data collection

Data were obtained in the way such as collection and compilation of existing well data, existing reports, existing boring logs, etc.

(2) Field survey

Present conditions of existing shallow and deep wells were surveyed. The number of wells investigated are 70 shallow wells and 54 deep wells. (Refer to Figures II-3-1 and II-3-2)

(3) Water quality and water level observation

Observation points were selected at 15 wells from existing wells. Observation term was July 1985 to February 1986 (1 time/2 months), and water quality items are EC, PH, temperature, acidity, sulfate, total N, total P, total Fe and BOD. Groundwater sampling was carried out by the staff of RID Narathiwat Office, and chemical analysis was made by PSU.

Hydrogeology Map is shown in Figure II-3-3, and shallow groundwater level observed is shown in Figure II-3-4.

Figure II-3-I Location Map of Tube Wells

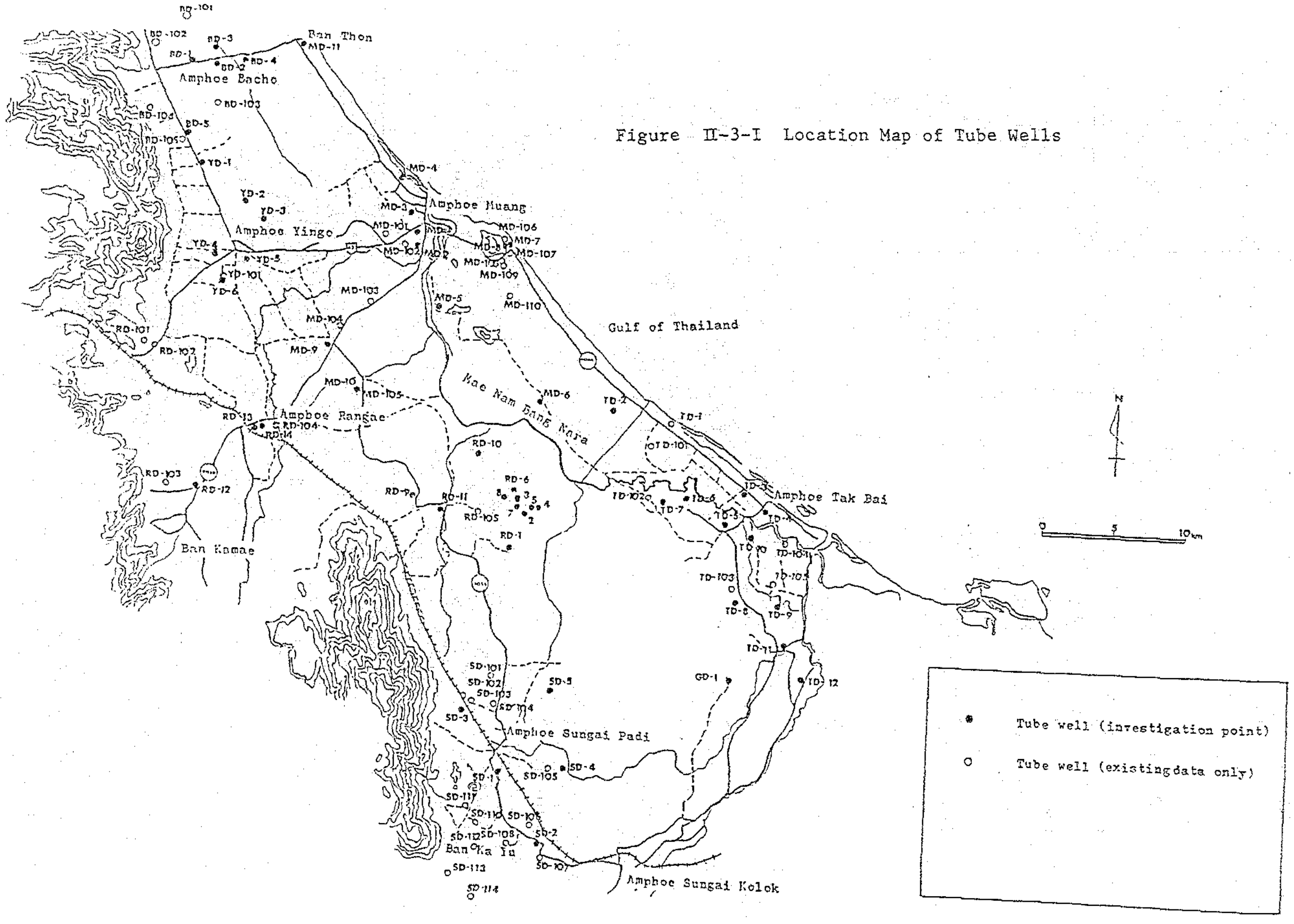


Figure II-3-2 Location Map of Investigation Hand-dug Wells

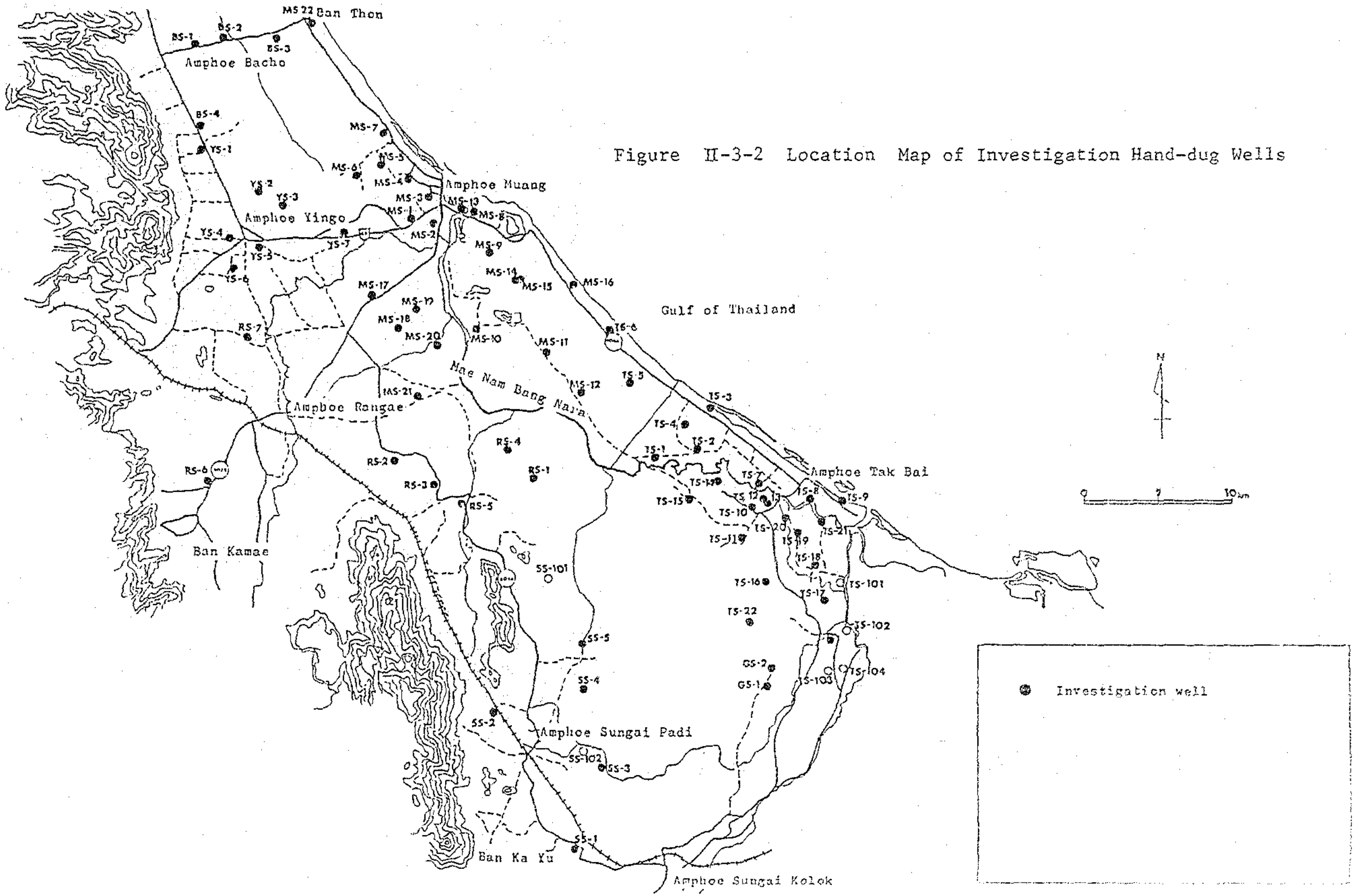


Figure Ⅱ-3-3 Hydrogeology Map

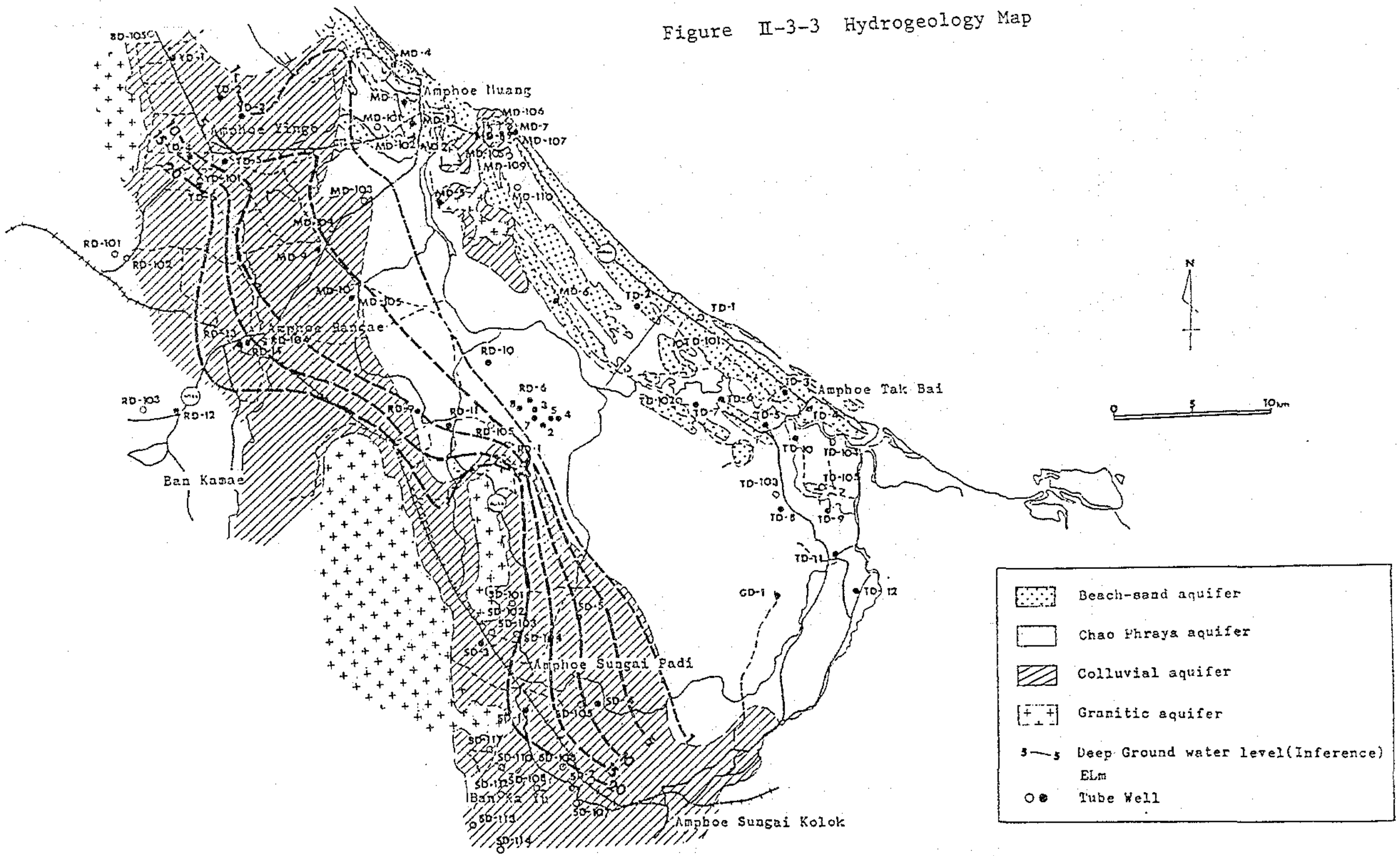
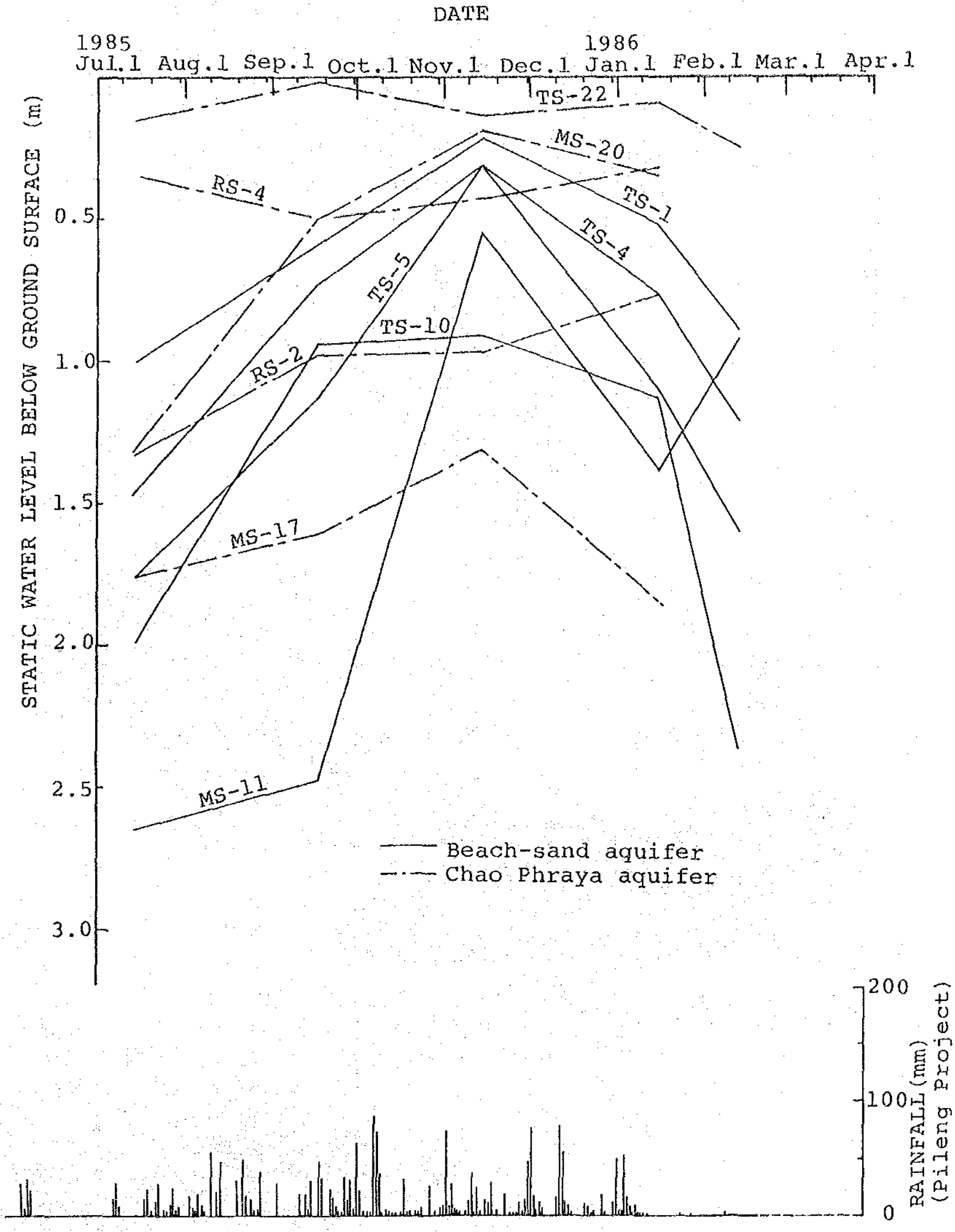


Figure II-3-4 Shallow Groundwater Level Observed



II-3-2 Groundwater resources

(1) Groundwter Quality

Groundwater quality observed is shown in Figure II-3-5, and EC of deep groundwater is in Figure II-3-6.

(2) Effects of the Proposed Water Storage

(a) Fluctuation of groundwater by water storage

In the case of the proposed maximum water level of 0.4 m above MSL in the Bang Nara water storage, it is supposed that the proposed water level would mainly affect the shallow groundwater table which is observed in the swamp and old swamp area of Chao Phraya aquifer. According to the observed records of groundwater table, however, the seasonal fluctuation is not remarkable and groundwater level is observed at 0.5 m above MSL. Therefore, the fluctuation of groundwater table would not be expected by the proposed impounding water level in the Bang Nara water storage.

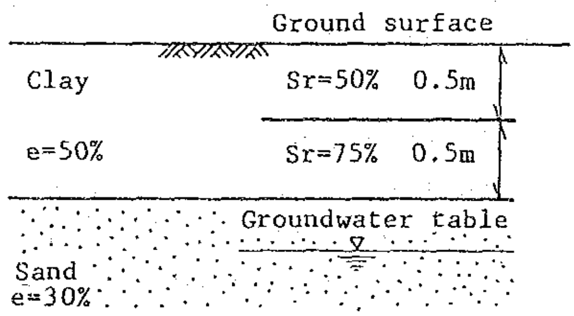
Other groundwater shows higher water level than that of the Bang Nara water storage based on the actual observed data. So, it would not affect the groundwater table.

(b) Influence of dry season irrigation on groundwater table

Groundwater table with dry season irrigation may be affected by a characteristic of an aquifer such as porosity and permeability and by an amount of irrigation water. During the dry season, the amount of irrigation water would be estimated at about 5 mm/day including various losses. When all losses of irrigation infiltrate into the soil, the percorated water would be 2 mm/day. The irrigation period of 4 months from April to July is taken and the acreage of 25 percent of the total irrigable area is planned to irrigate during the dry season.

Infiltrated water would be used to first supplement moisture of an unsaturated soil layer and the remainder of water would be through-flown as groundwater. In this section, fluctuation of groundwater table in the beach-sand aquifer which might show most remarkable movement of groundwater table, would be estimated by following estimation.

The geological profile of the aquifer, porosity(e) and saturation ratio (Sr) is assumed below:



The remaining water in the unsaturated soil layer is generally called a field capacity and is considered equal to approximately half the water which fills the voids of the soil. Therefore, in the upper 0.5 m, field capacity = layer thickness x e x (100-Sr)/2 = 500 x 0.5 x (1-0.5)/2 = 62.5 mm and in the lower 0.5 m, likewise 31.2 mm, totalling a field capacity of 93.7 mm. On the other hand, as the amount of seepage water for 4 months is considered to be 240 mm, groundwater recharge would be 240 (seepage water) - 93.7 (field capacity) = 146.3 mm/4 months. and, as e of beach-sand aquifer is 30 percent, the groundwater level would be 146.3/0.3 = 487 mm/4 months. However, as the irrigable area is 25 percent of the rainy season irrigation, the groundwater is dispersed in horizontal direction. For this reason, an actual elevation of the groundwater will be less than half the value. The average water level of the total beach-sand aquifer as of July 1985 is approximately EL - 2 m, and it could equal approximately 1.8 m (1.5 - 2.0 m) by irrigation in the dry season.

Figure II-3-5(I) Groundwater Quality Observed

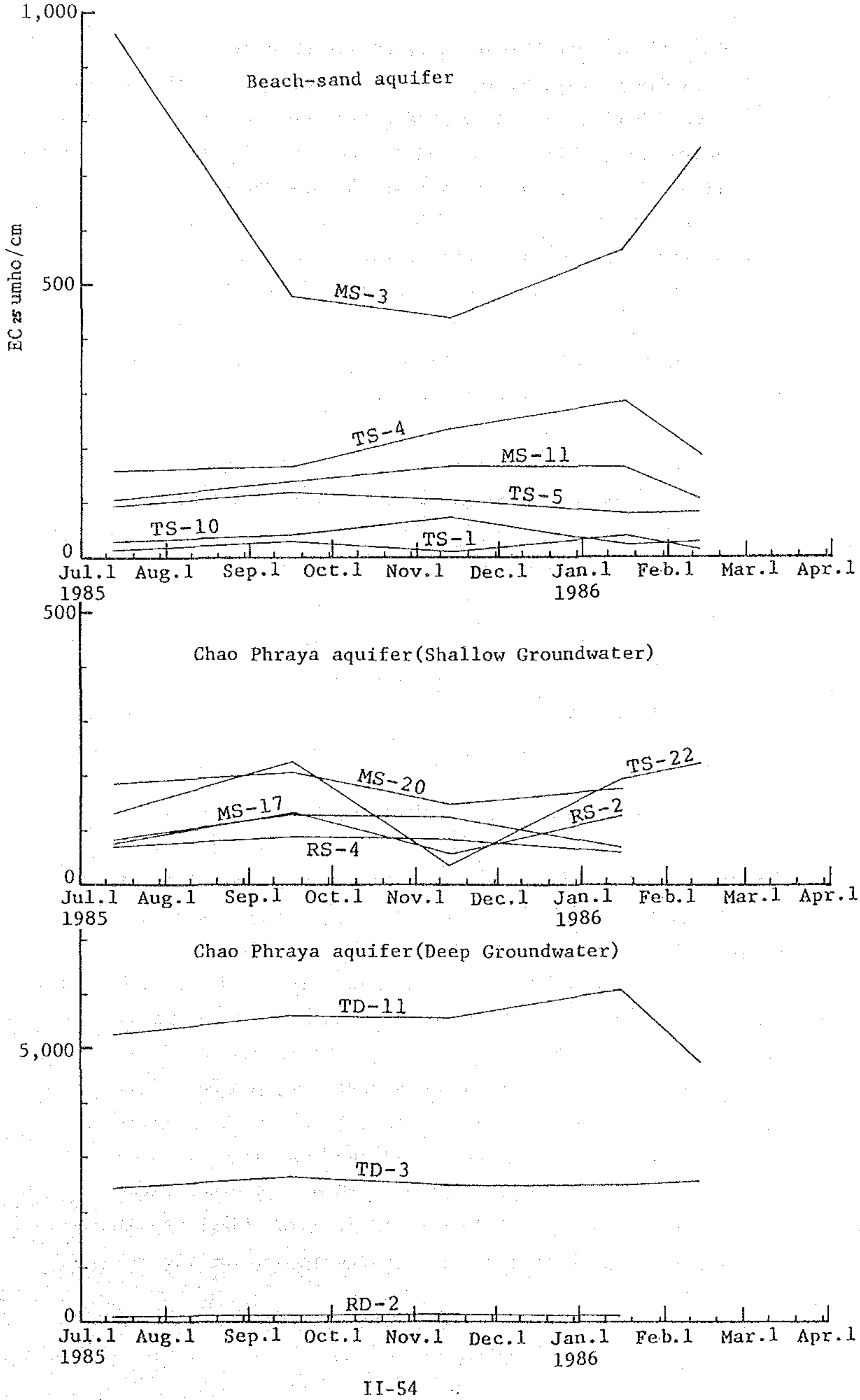
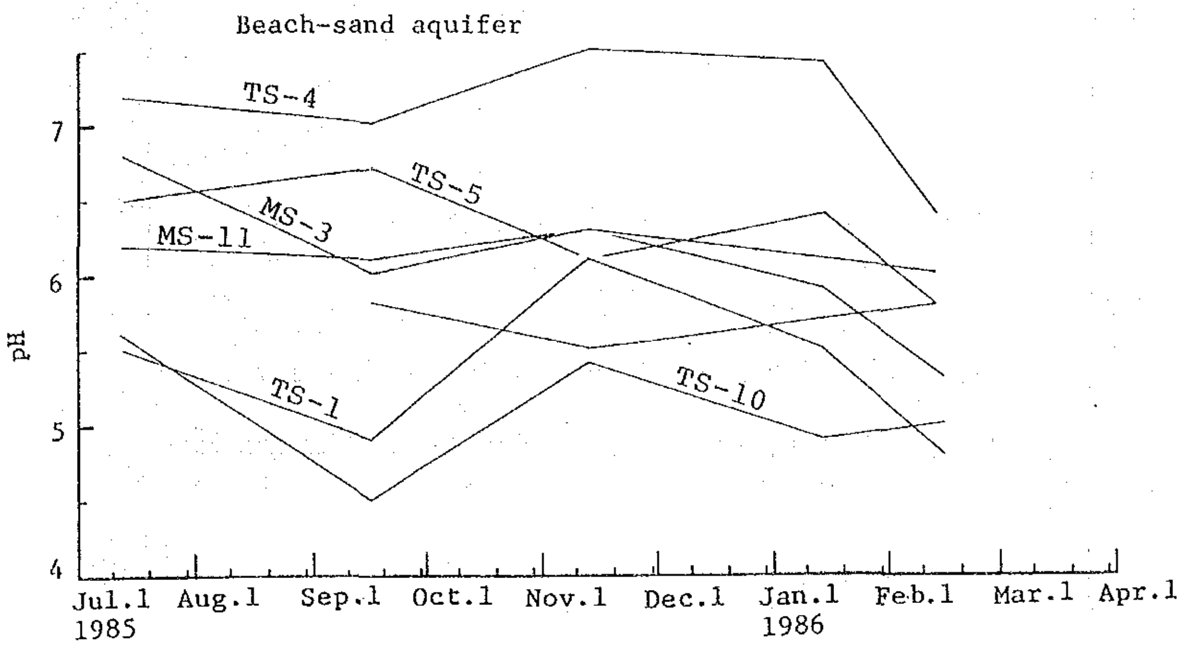
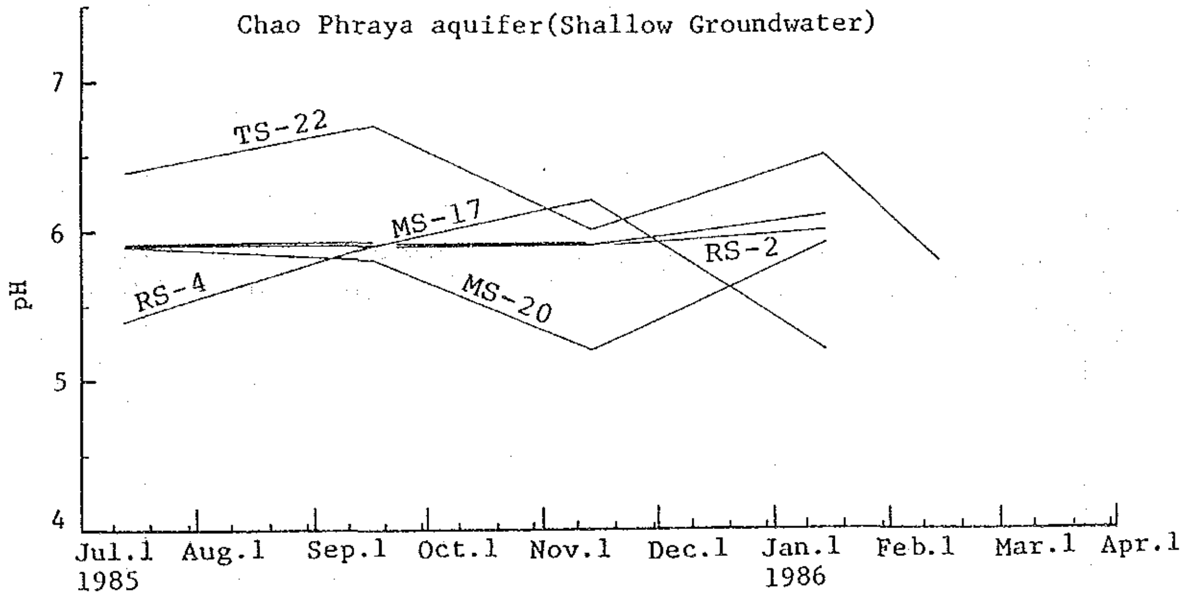


Figure II-3-5(2) Groundwater Quality Observed





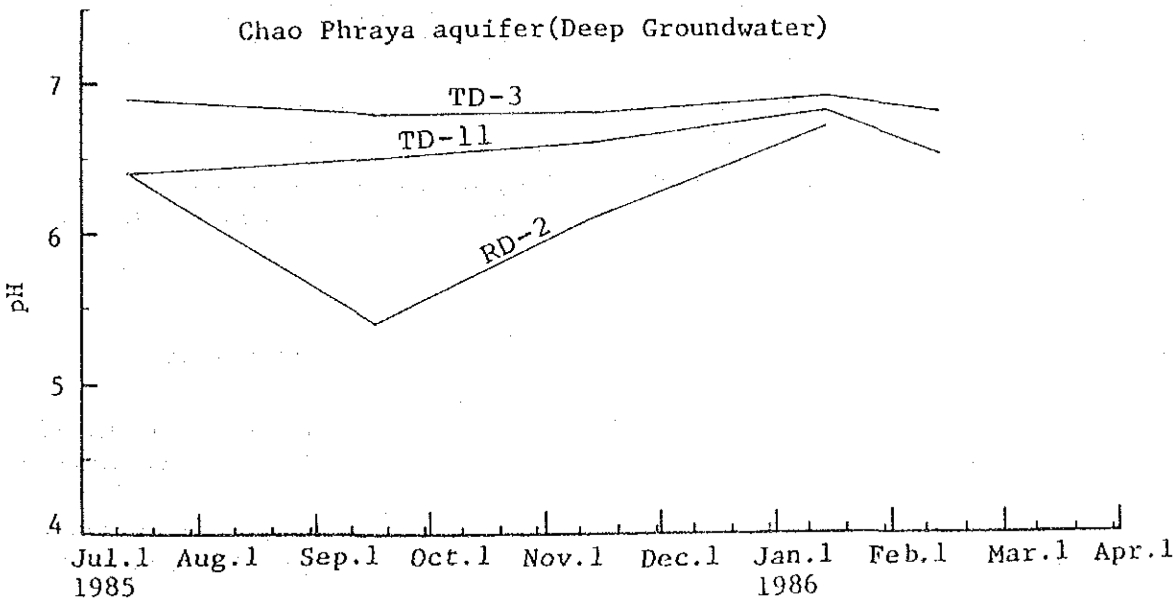
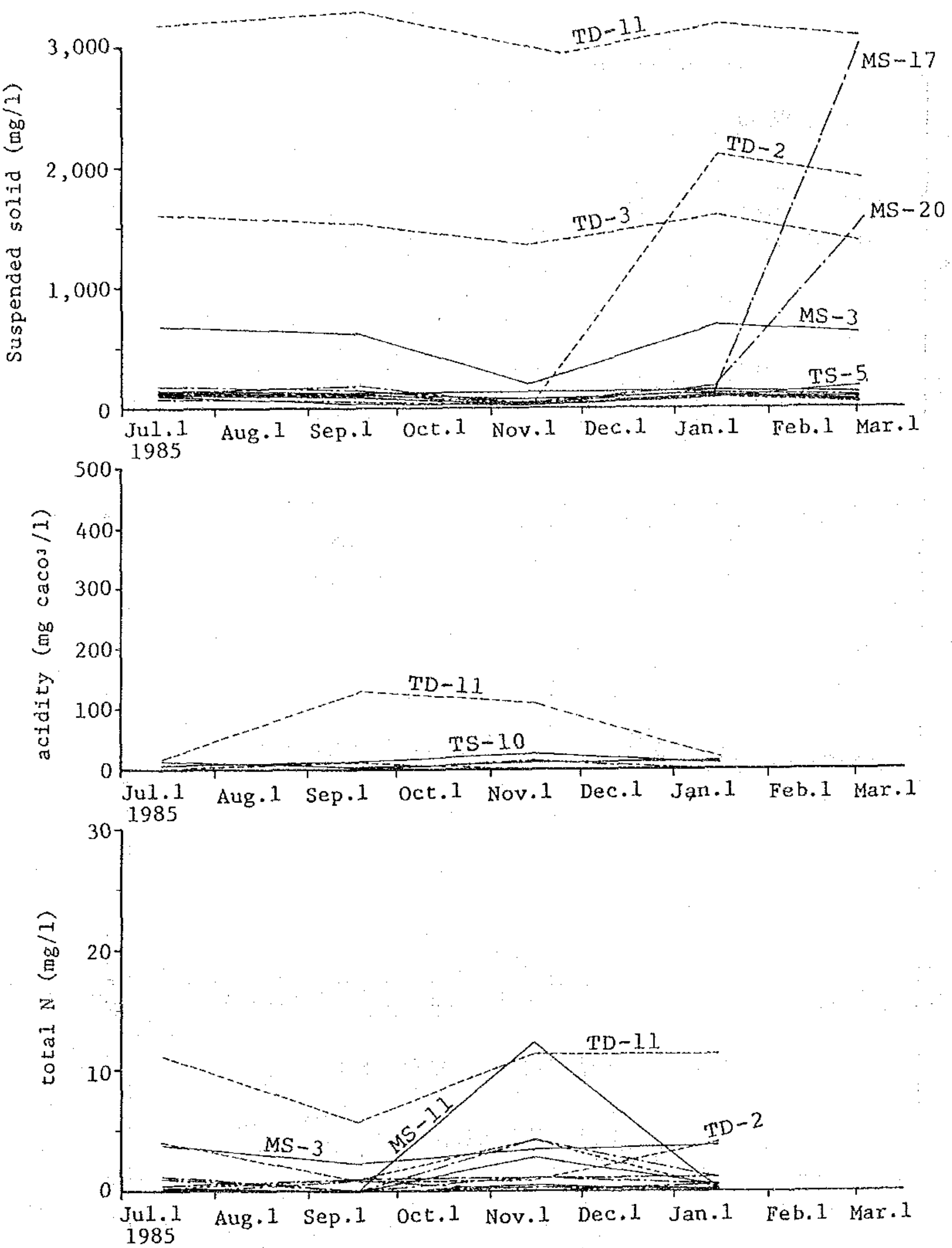


Figure II-3-5(3) Groundwater Quality Observed



——— Beach-sand aquifer

—·—·— Chao Phraya aquifer (Shallow Groundwater)

- - - - - Chao Phraya aquifer (Deep Groundwater)

Figure II-3-5(4) Groundwater Quality Observed

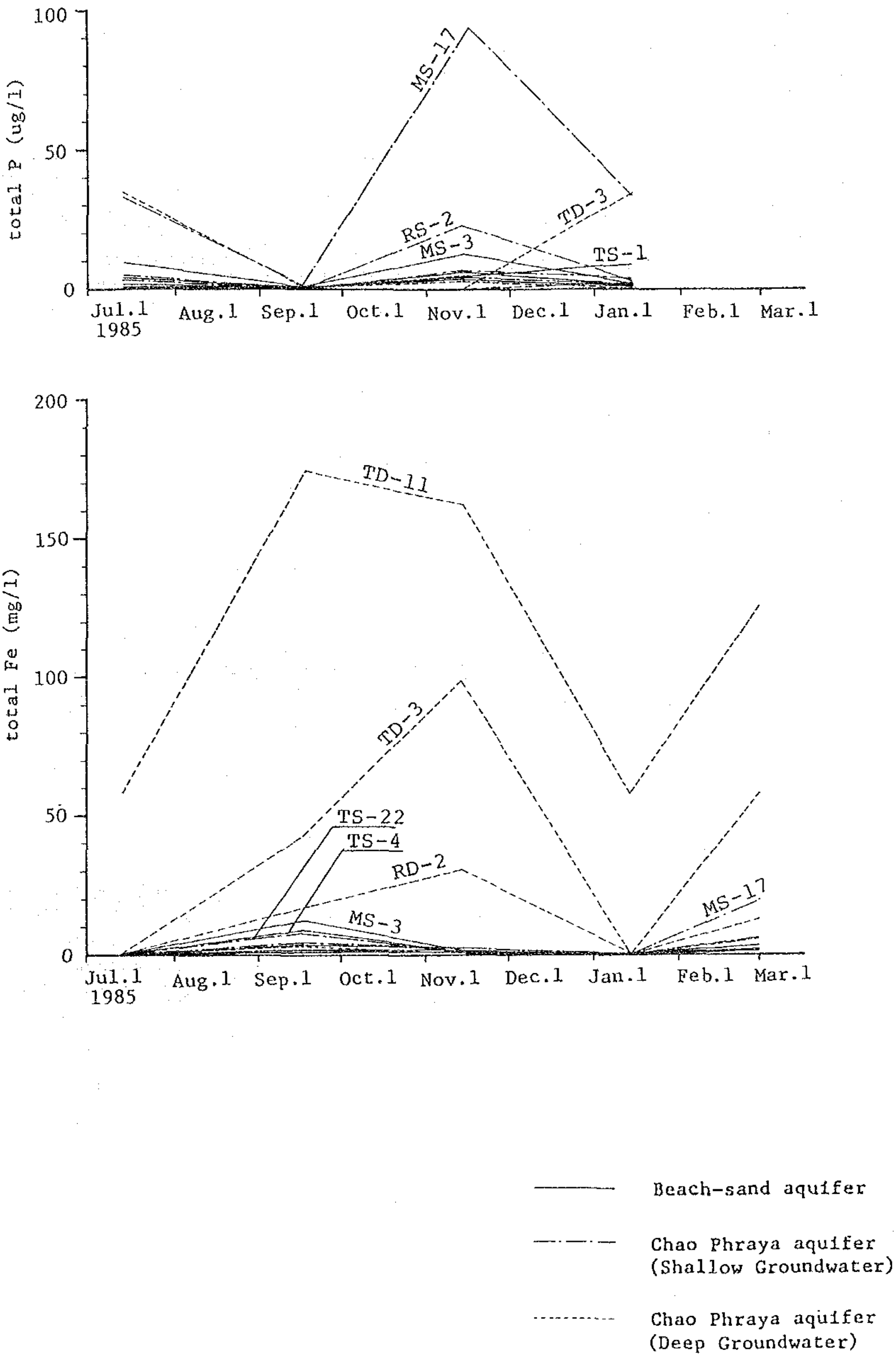
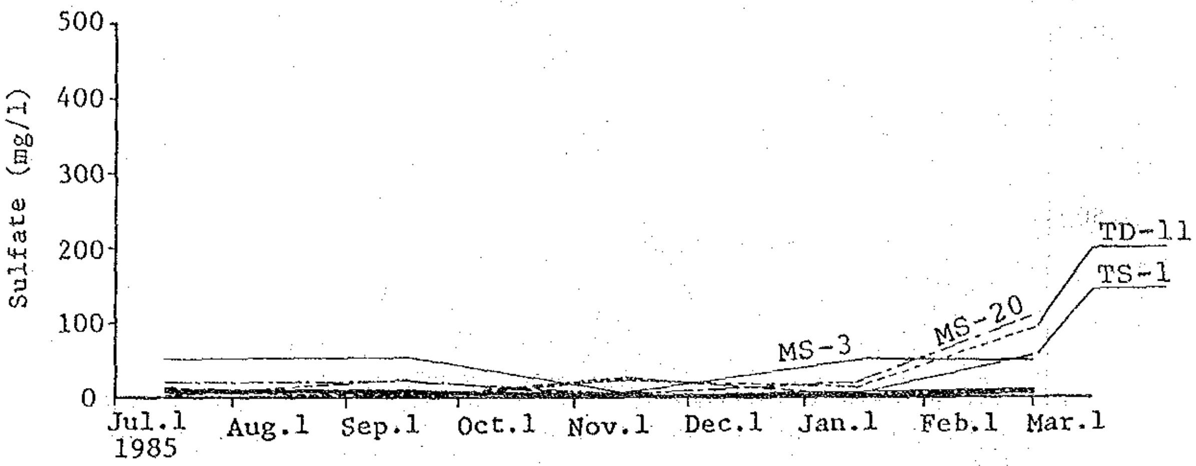
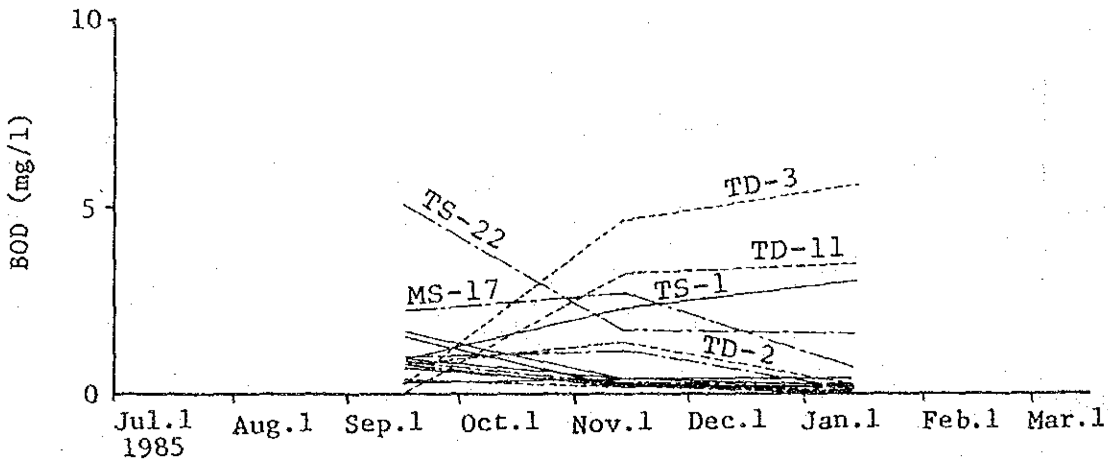


Figure II-3-5(5) Groundwater Quality Observed



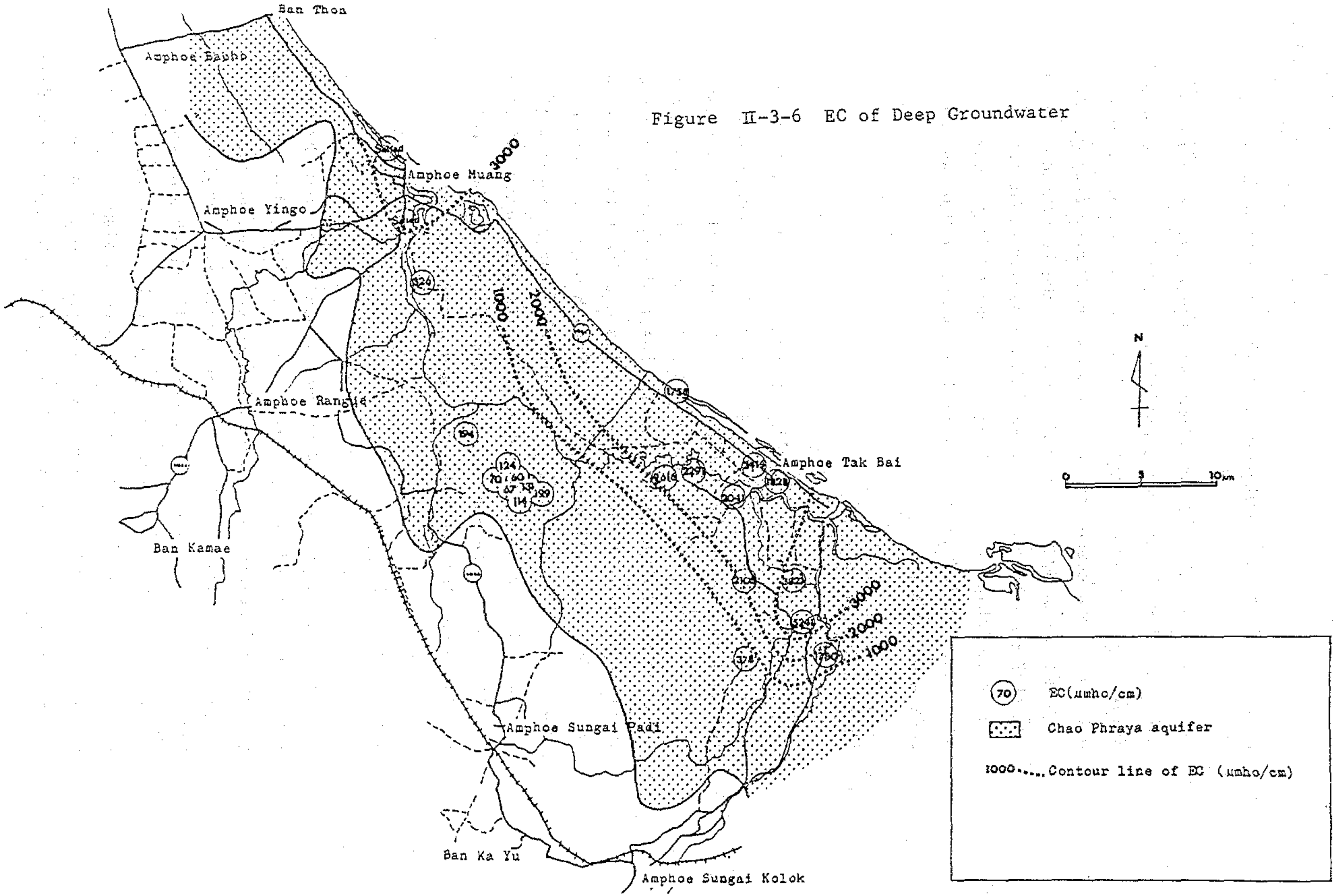


Beach-sand aquifer

Chao Phraya aquifer (Shallow Groundwater)

Chao Phraya aquifer (Deep Groundwater)

Figure II-3-6 EC of Deep Groundwater



II-3-3 Present Groundwater Development

Water resources in the Study area primarily resorts to water works, wells, rivers, ponds and rainfall. The towns of Narathiwat, Yi Ngo, and Sg. Padi have their own water works, but the others depend on shallow wells for water supply. In each Muban, an overwhelming majority of the supply sources are the shallow wells as can be seen from the survey of ARD. (Refer to Table II-3-1) Altogether about 80 deep wells have been drilled in amphoes of Narathiwat, Yi-Ngo, Rangae, Sg. Padi and Tak Bai.

(1) Shallow Groundwater

Shallow wells take shallow groundwater. In areas where water can be drawn, personal shallow wells are dug at raito of one well per one or two houses. The yield of these is presumed to be 1 m^3/day or less. Wells are hand-dug with around 1 m in diameter and 3 m in depth, and are mostly lined with concrete or bricks. Most of the personal wells are drawn by bucket and rope. Wells installed at schools, health stations, temples and mosques are slightly larger in scale than the personal wells, and some of them serve as community wells when other wells in the neighborhood become dry. In many instances, these wells are equipped with electric pumps and storage tanks.

(2) Deep Groundwater

Deep wells primarily take deep groundwater from the Chao Phraya aquifer and the colluvial aquifer. These deep wells are primarily installed at schools, health stations, hospitals, temples and mosques. Also, a number of them are drilled by the Pileng Project to serve as community wells which are not utilized for irrigation nor for large scale factories. These wells are tube wells of about 10 to 20 cm in diameter and generally equipped with hand pump, but pumps operated by windmills are also observed here and there. Most of these deep wells were constructed by DMR, ARD, RID and MOPH.

As for usage, most of the wells are not for dringking, and a few of them are totally unused because of high iron contents and coloring. At Tak Bai Hospital and other locations, water treatment by simple aeration is being practiced but it is not adequate. As above, the use of deep groundwater by means of deep well may be claimed to be extremely rare.

Table II-3-I Water Need and Water Resources in Sample Muban

AQUIFER		Colluvial aquifer					Chao Phraya aquifer			Beach-sand aquifer
LOCATION	Ampoe	Rangae		Yi Ngo	Sungai Padi		Muang	Sungai Padi	Muang	Muang
	Tambon	Kalisa	Tan Yong Mat	La Han	Pa La Ru	Pa La Ru		Pa La Ru	Bang Nak	Khok Kian
	Ban	Ka Nua	Tan Yong Mat	Pu Ta	Ta Se Tai	Khok Saya	Manang Ta Yo	Pa Yo	-	-
DESCRIPTION	POPULATION	600	8,000	800	640	950	800	1,050	2,000	1,000
	CATTLE	1,200	600	350	1,580	50	300	300	450	350
	PIG	-	300	-	-	-	-	300	-	400
	DUCK CHICKEN	1,800	4,000	1,000	2,220	1,500	1,200	1,000	500	450
TOTAL OF WATER NEED m3/yr		27,228	98,039	25,108	33,737	14,188	15,968	21,340	35,123	22,017
WATER RESOURCES	POND	-	-	-	-	-	-	-	1	1
	SHALLOW WELL	30	700	60	32	80	1	230	-	-
	DEEP WELL	-	-	-	-	-	-	-	-	-
	BARRAGE	-	-	-	-	-	-	-	-	-
TOTAL PRODUCTION m3/yr		7,238	700	2,700	4,825	-	52.3	16,200	720	720

Source: Narathiwat office, ARD, Record of well usage in Narathiwat, 1982-84

II-3-4 Groundwater Development Potential

(1) Groundwater Irrigation

In the Study area, the aquifers which can be utilized for groundwater irrigation development are considered to be the Chao Phraya aquifer (deep groundwater) and the beach-sand aquifer (shallow groundwater), on which the available volume of water and other factors are reviewed below.

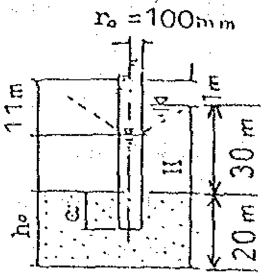
(a) Chao Phraya Aquifer

The average yield per one deep well is considered to be 170 l/min, as in para (3) of 3.3.4. "Water Resources" of Main Report. The influence radius of a well would be 500 - 700 m in the case of confined groundwater, and when it is assumed to be 600 m, one well can be drilled per every 1.44 sq.km.

Based on the foregoing conditions, the potential total yield from this aquifer becomes 3.8×10^7 m^3/yr since the area where this aquifer is distributed (Mae Nam Ya Kang - Mae Nam Kolok) is about 610 sq.km.

The groundwater throughflow, on the other hand, is estimated to be 1.75×10^8 m^3/yr for the entire watershed. As for existing yield, there are about 80 wells throughout the entire watershed and most of these are hardly used, but if al of them are assumed to be operated and the average yield per well to be 170 l/min, the total yield would come to 5.0×10^6 m^3/yr, and when subtracting this, the groundwater throughflow would be about 1.70×10^8 m^3/yr. Accordingly, the total yield is equivalent to around 22 percent of the throughflow which is a reasonable yield plan.

The geological profile of this aquifer is converted into a model as shown below. The principal geological components of the aquifer are assumed to be fine sand to coarse sand, and the yield per well is calculated according to the hydrological formula.



$$Q = \frac{2\pi Kbc'(H-ho)}{2.3\ \log\ (R/r_0)} \left(1 + 7\sqrt{\frac{r_o}{2bc'}}\ \cos\frac{\pi c'}{2}\right)$$

(Kozeny's formula)

Wherein k : Coefficient of permeability

H : Height from the bottom end of aquifer to the initial water surface

r_o: Radius of well

h_o: Height from the bottom end of aquifer to the water surface in well

b : Thickness of confined aquifer

R : Influence radius

c': c/b

c: Length of well wall penetrating into aquifer

$$Q = \frac{2 \times \pi \times 0.0005 \times 20 \times 0.3 \times (49-39)}{2.3 \times \log\ (600/0.1)} \times$$

$$\left(1 + 7 \times \sqrt{\frac{0.1}{2 \times 20 \times 0.3}}\ \cos\frac{\pi \times 0.3}{2}\right) = 3.5 \times 10^{-3}\ m^3/sec \doteqdot 213\ell/min$$

When the well efficiency is assumed to be 20 percent, the yield becomes 175 l/min.

The calculated result would be identical with the foregoing yield, so that the yield is assumed to be 170 l/min/well.

The area in which water can be drawn from these wells basically extends over the entire Chao Phraya aquifer between Mae Nam Ya Kang and Mae Nam Kolok, but since the coastal zone is salinized as shown in Figure II-3-6, there is a limit to its use in view of the relationship between salinity and crop. And, pumping of a large volume of groundwater from the area which indicates a high EC value of 1,000 μmho/cm results in promoting salinization. Because of this, irrigation of only a small scale at certain spots would be possible in this area. (Refer to Figure II-3-7)

On the other hand, since this stratum contains a lot of Fe, the relationship between Fe contents and crops must be confirmed in advance. And, although it was not confirmed during the survey, some places have produced brackish water, so that the aquifer must be selected with care and preparations made for grouting.

The cost of constructing one well is preliminarily estimated assuming a well diameter of 200 mm, depth of 40 m and the use of electric submersible pump:

Item		Quantity	Unit	Rate (฿)	Amount (฿)
Drilling	ϕ350 mm	40	m	2,300	92,000
Steel Casing	ϕ200 mm	34	m	750	25,500
Screen	Wire wounded ϕ200 mm	2	3m	15,000	30,000
Well Development					22,000
Cement grout					300
Gravel pack					400
Clay plug					100
Electric-Submersible Pump	ϕ50mm 1.5 kw				45,000
Generator	3HP				12,000
Total					227,300

Note: RID price, Aug. 1985

(b) Beach-sand Aquifer

Salinizaition is the key to determine whether or not water can be pumped from this aquifer. The model as shown below patternalizes the distribution of groundwater within this aquifer. Fresh water lies on top of saline water in lenticular form with an estimated average thickness of around 4 m.

Accordingly, taking of this fresh water in a large volume would not be possible with an ordinary tube well because of the drawdown in existing wells which ranges between 6.3 - 15.3 m.

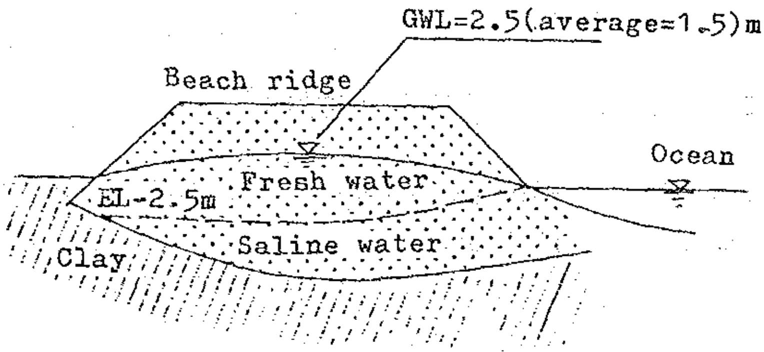


Figure II-3-7 Hydrogeology and EC

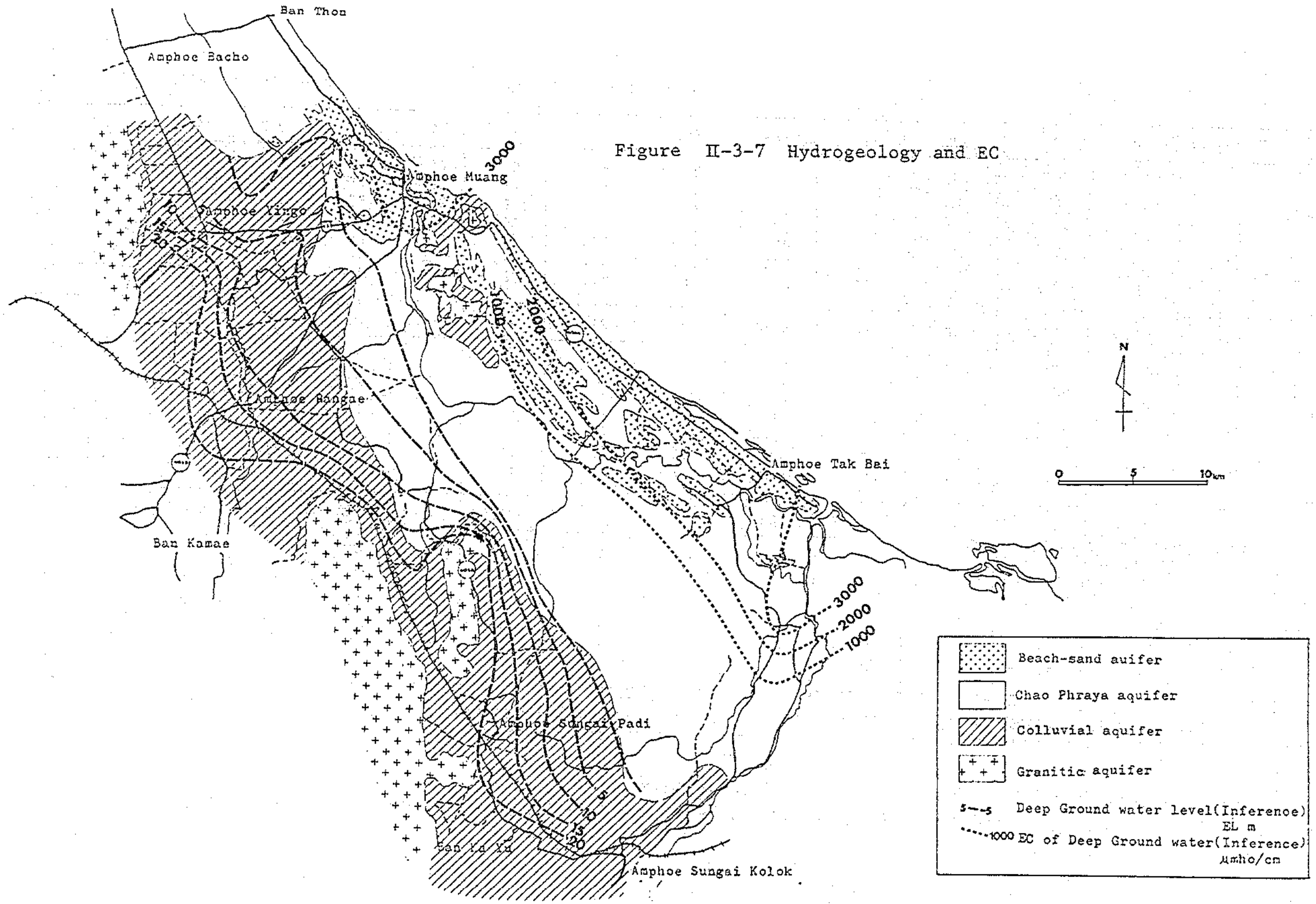


Table II-4-1 FREQUENCY OF OCEAN WAVES BY VISUAL HEIGHTS FROM SHIP OBSERVATIONS

-South China Sea; Lat 5 to 9° N & Long 101 to 106° E (1949-82)-

Season	Wave Height (m)	350to10°	20to40°	50to70°	80to100°	110to130°	140to160°	170to190°	200to220°	230to250°	260to280°	290to310°	320to340°
N-E Monsoon	<0.5	64	244	624	725	418	223	96	41	30	19	21	19
(Dec. to Mar.)	1.0	40	292	940	777	254	62	23	5	2	10	4	6
	1.5	22	259	691	450	124	27	5	5	-	2	4	2
	2.0	11	192	471	202	42	4	1	1	2	-	-	1
	2.5	3	105	250	82	13	-	1	1	2	1	-	1
	3.0	1	62	137	43	6	-	-	-	1	-	-	-
	>3.5	3	68	91	17	5	1	-	2	-	-	-	-
	Total	144	1,222	3,204	2,296	862	317	126	65	37	32	29	29
S-W Monsoon	<0.5	53	40	52	85	144	311	539	732	838	604	271	130
(Jun. to Sept.)	1.0	14	13	12	14	52	199	404	420	644	489	281	111
	1.5	7	4	2	4	10	79	182	222	270	271	128	81
	2.0	5	1	1	1	2	16	52	77	118	138	53	32
	2.5	-	-	-	1	-	1	18	15	32	28	17	11
	3.0	-	-	-	-	2	1	4	3	6	19	5	6
	>3.5	1	-	-	1	3	1	4	1	2	12	8	5
	Total	80	58	67	106	213	608	1,203	1,470	1,910	1,561	763	376
Transition	<0.5	132	270	526	726	539	526	413	306	333	235	160	135
(Apr. to May	1.0	70	176	518	367	167	138	114	101	134	154	118	71
& Oct. to Nov.)	1.5	19	142	303	167	58	31	30	30	62	58	47	20
	2.0	8	82	126	82	17	8	17	10	16	19	9	12
	2.5	5	22	45	21	2	2	3	4	8	10	1	1
	3.0	4	24	21	10	-	1	1	2	1	2	2	4
	>3.5	-	14	11	3	-	2	-	2	4	-	-	-
	Total	238	730	560	1,376	783	708	578	455	558	478	337	243

Source = Meteorological office, England through GRBDS Report.

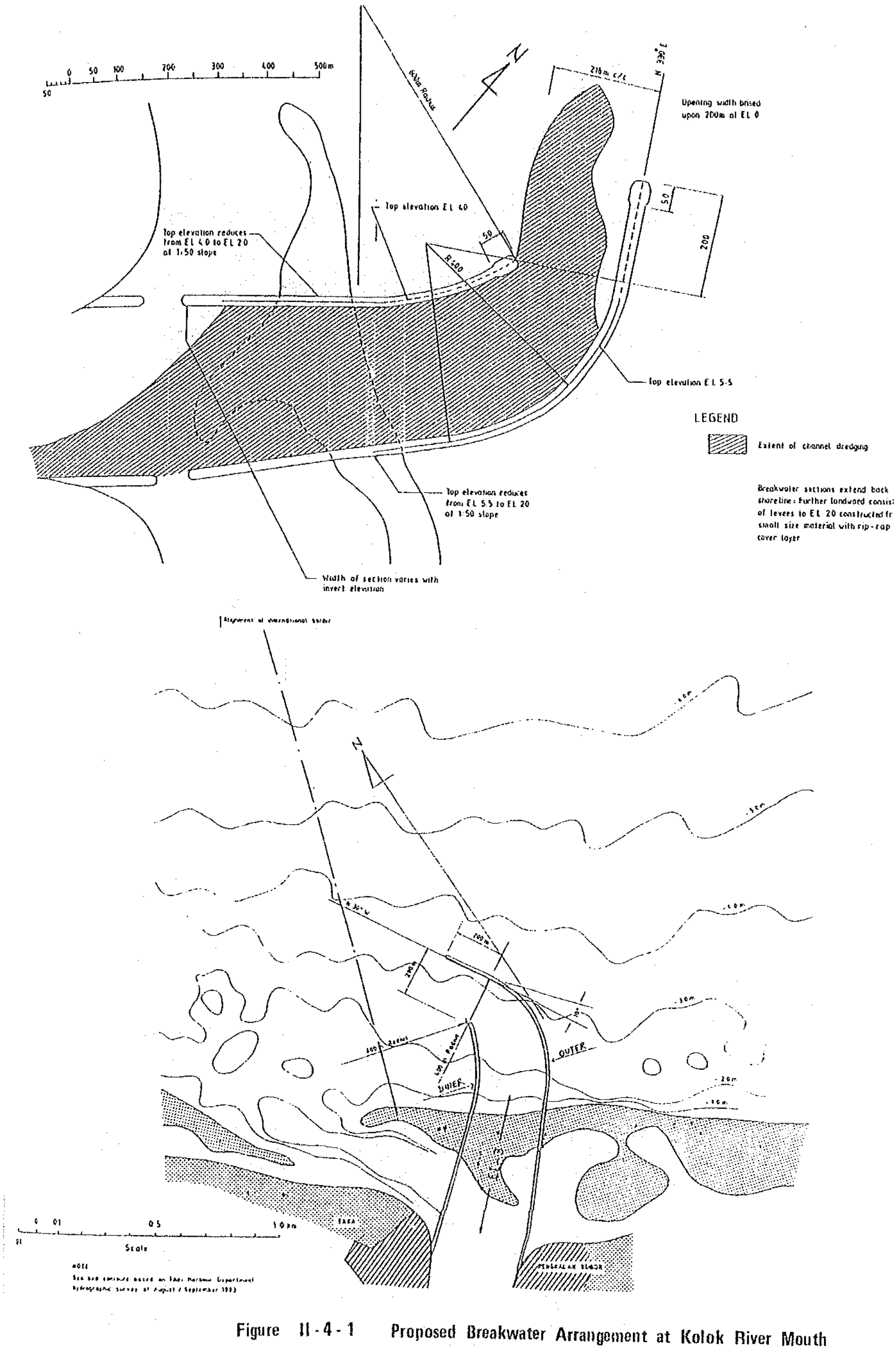


Figure II-4-1 Proposed Breakwater Arrangement at Kolok River Mouth

Source : GRBDS

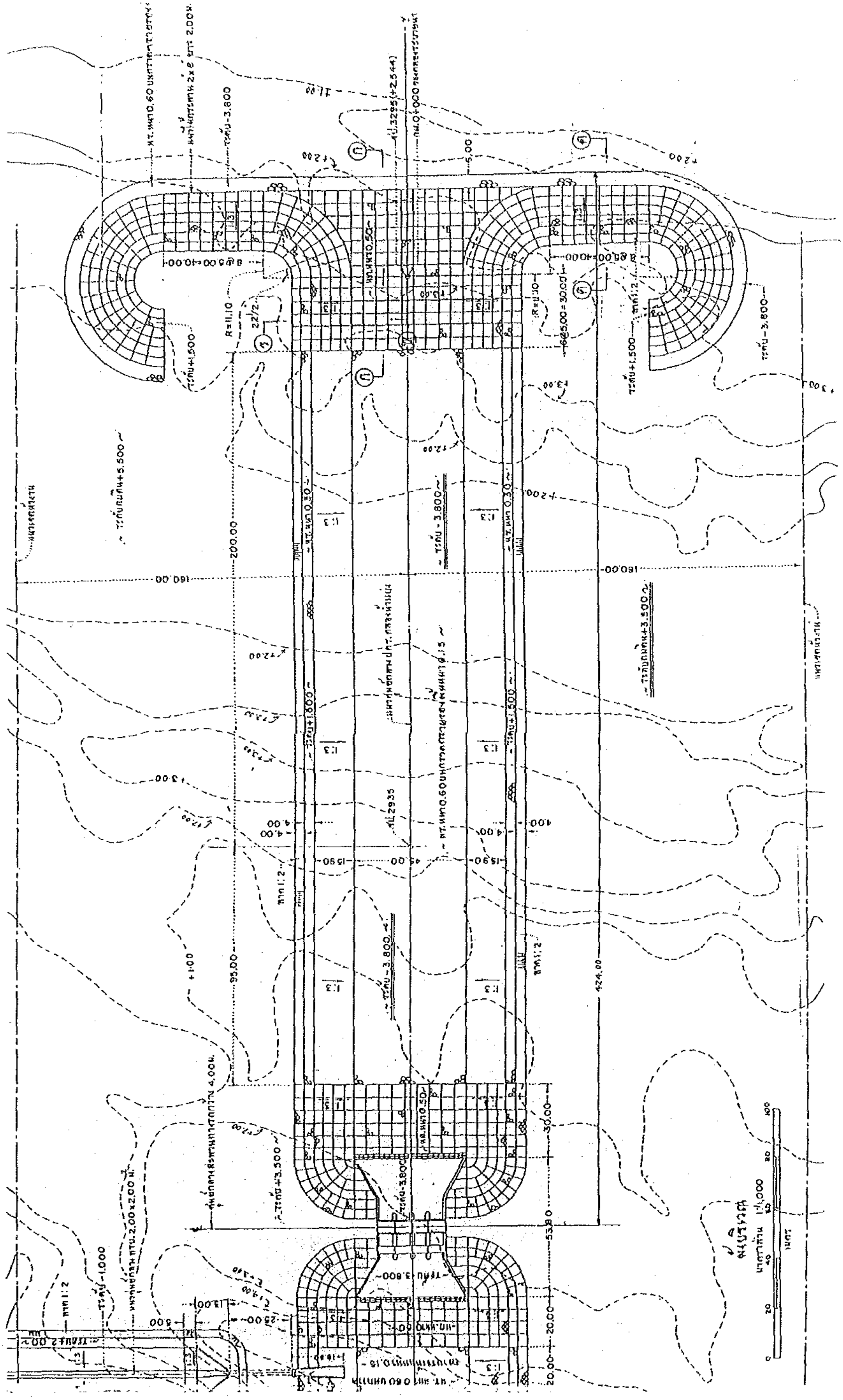
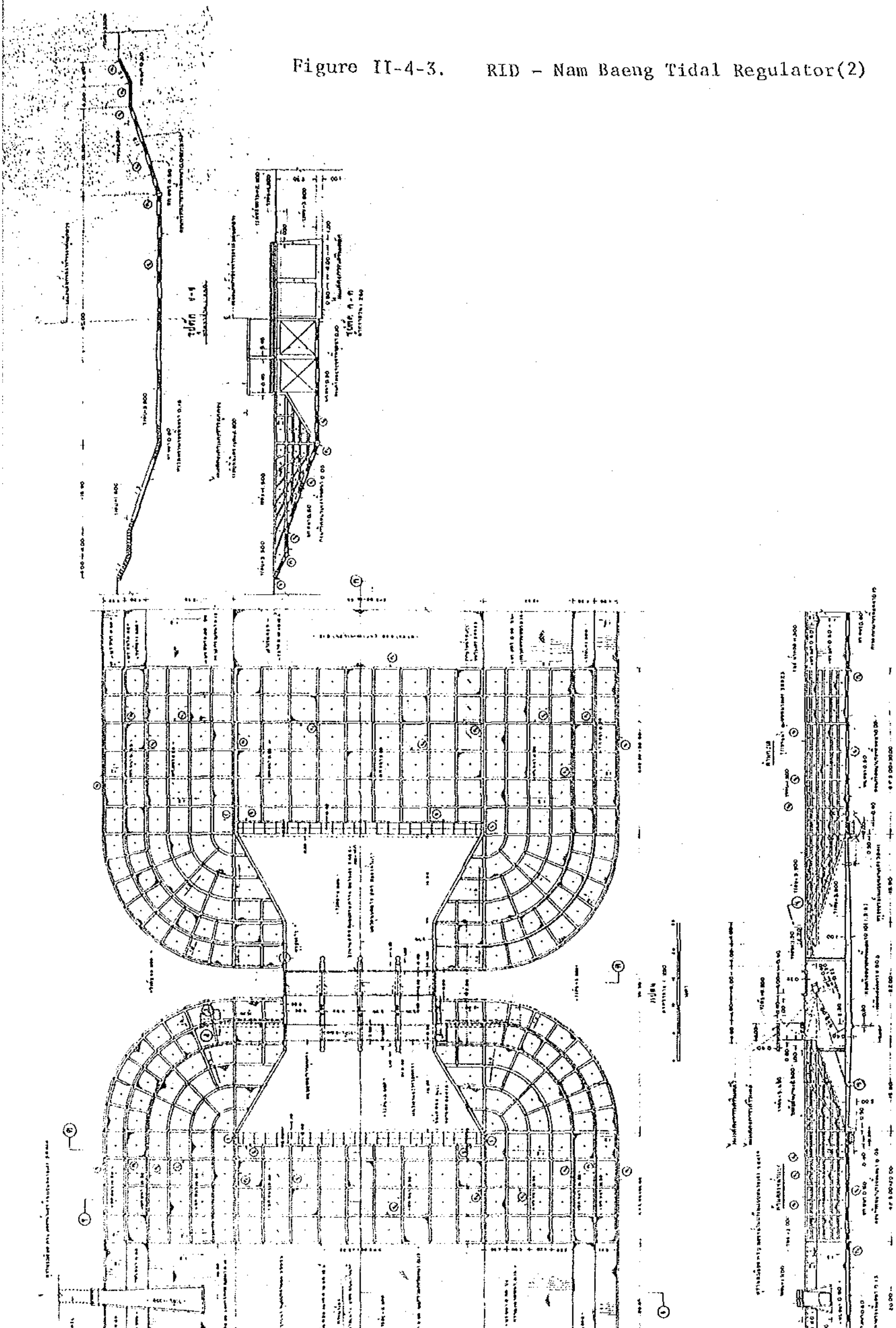


Figure II-4-2 RID-Nam Baeng Tidal Regulator (1)

Figure II-4-3. RID - Nam Baeng Tidal Regulator(2)



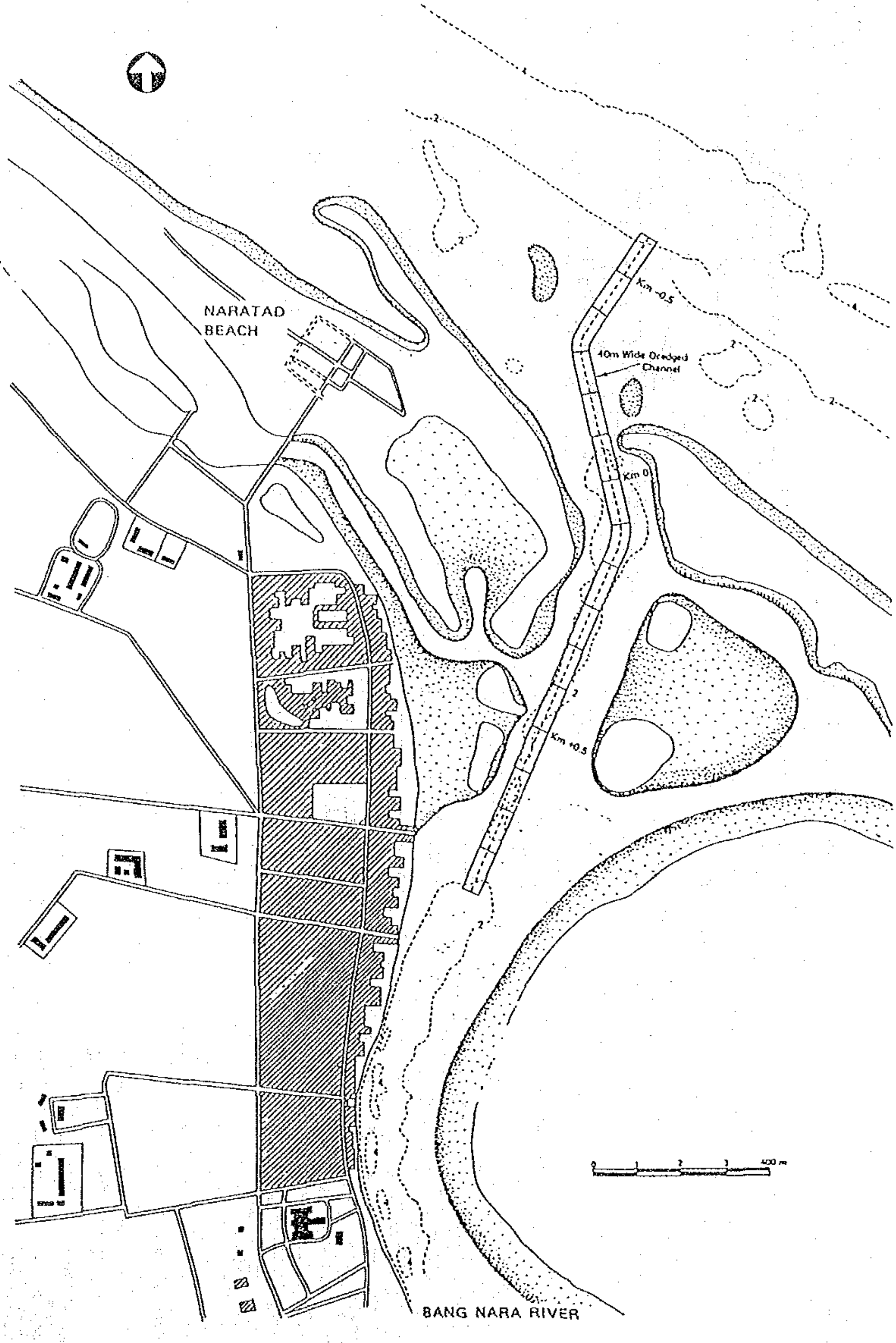
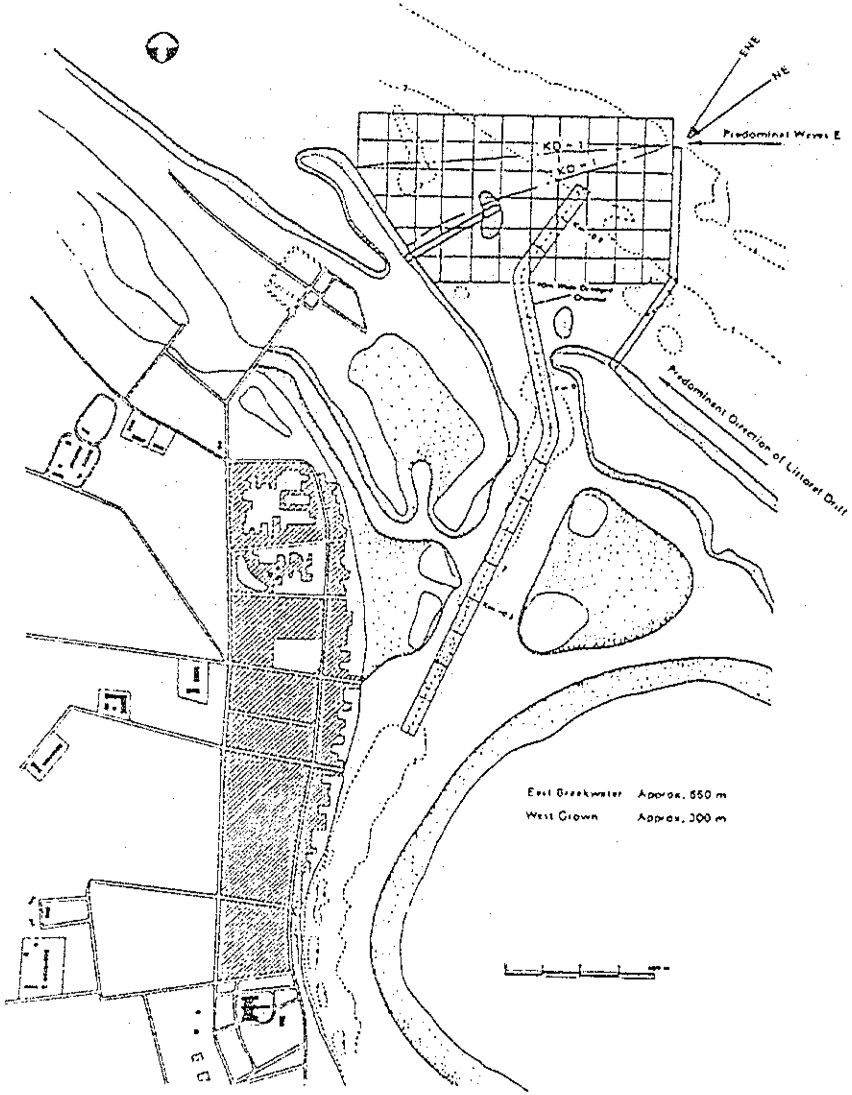
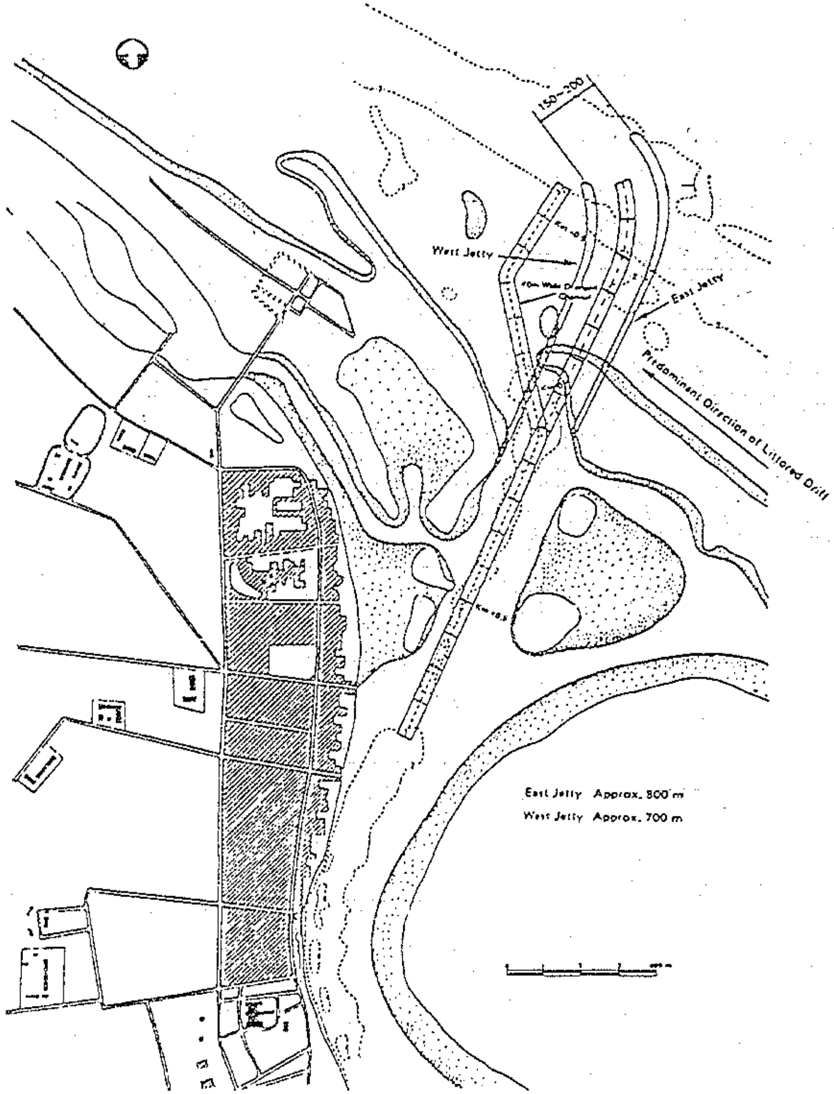


Figure II-4-4 Entrance of Mae Nam Bang Nara at Narathiwat with Target Channel Alignment for Maintenance Dredging

Source : Harbour Department



(1) Alternative : Breakwater and Groin



(2) Alternative : Training Jetties

Figure II-4-5 Proposed River Mouth Improvement at Narathiwat

Source : JICA—Assisted Dredging Plant Development Project (1986)

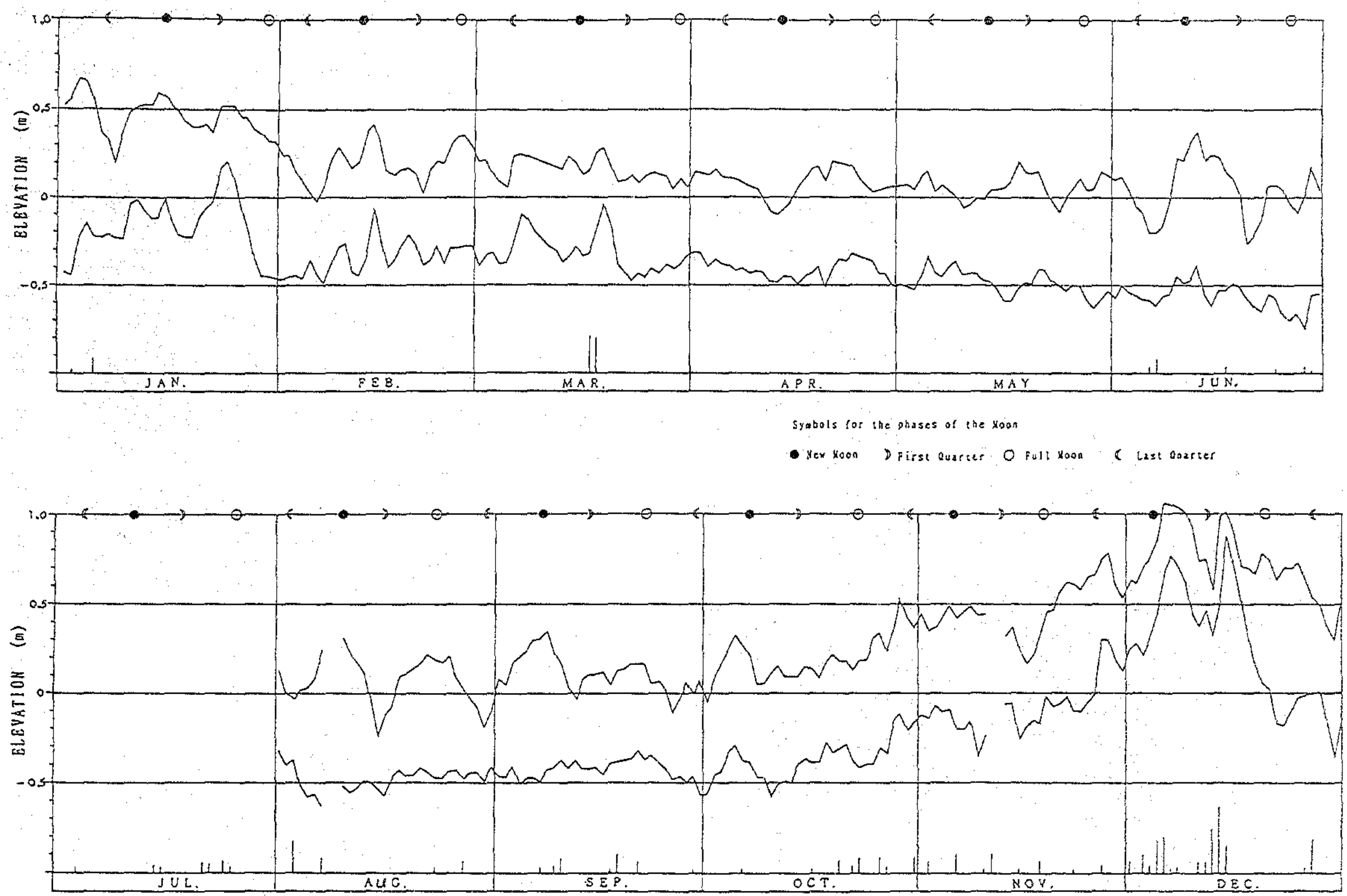


Figure II-4-6 OBSERVED DAILY HIGH AND LOWTIDE AT NARATHIWAT HORBOR AND DAILY RAINFALL AT MUANG NARATHIWAT IN 1983

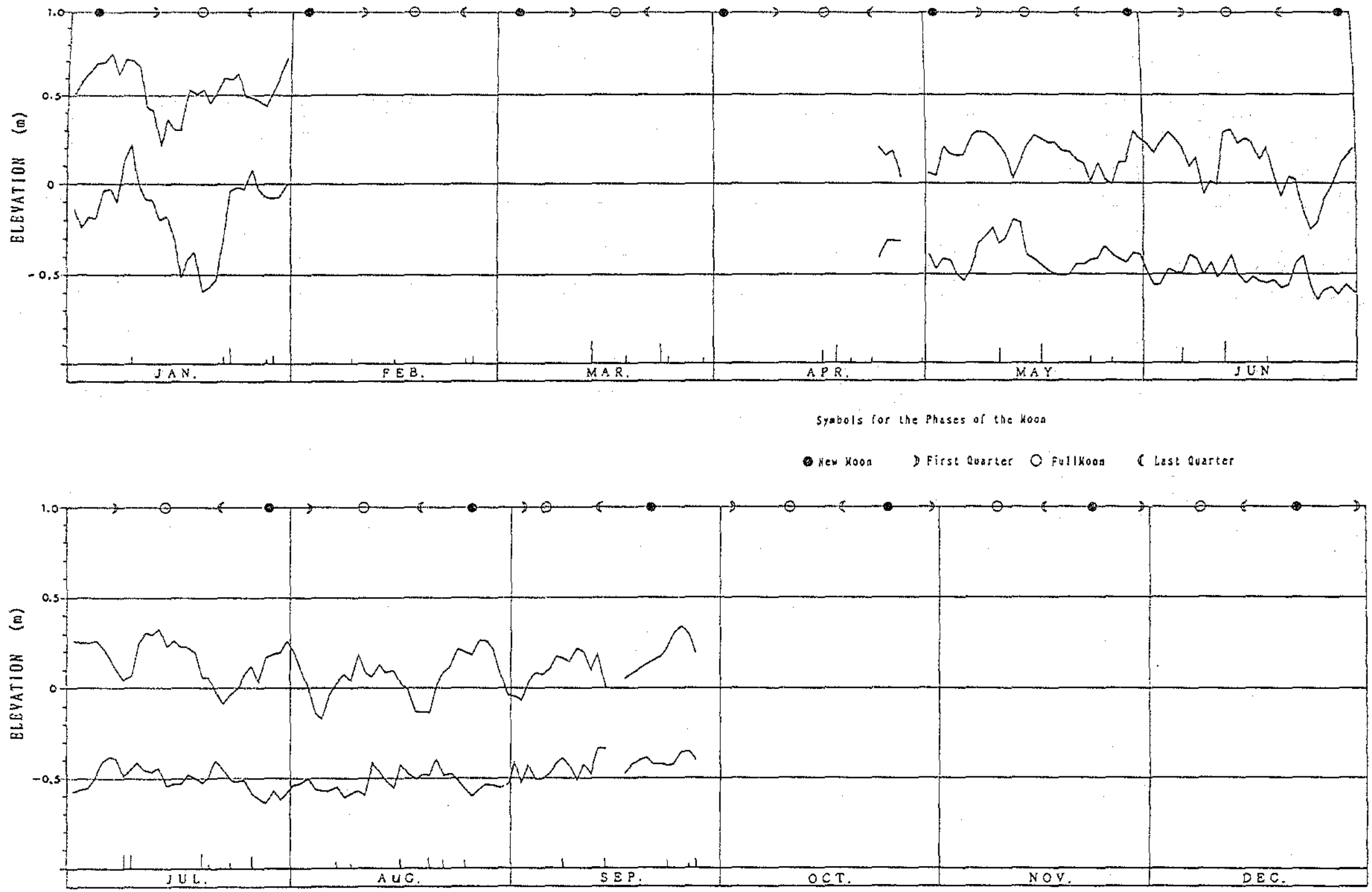


Figure II-4-7 OBSERVED DAILY HIGH AND LOWTIDE AT NARATHIWAT HORBOR AND DAILY RAINFALL AT MUANG NARATHIWAT IN 1984

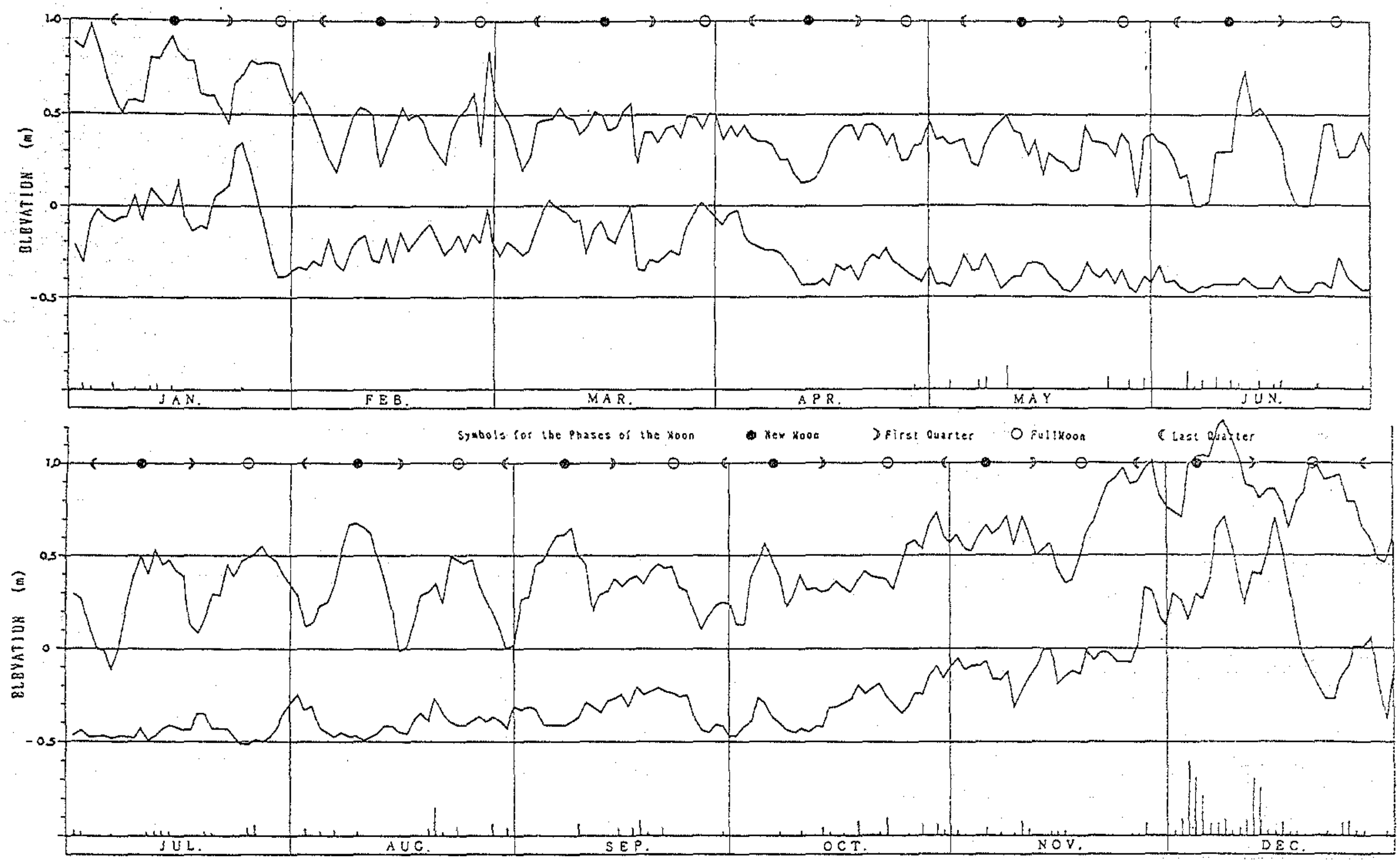


Figure II-4-8 OBSERVED DAILY HIGH AND LOWTIDE AT TABA (X100) AND DAILY RAINFALL AT WAENG IN 1983

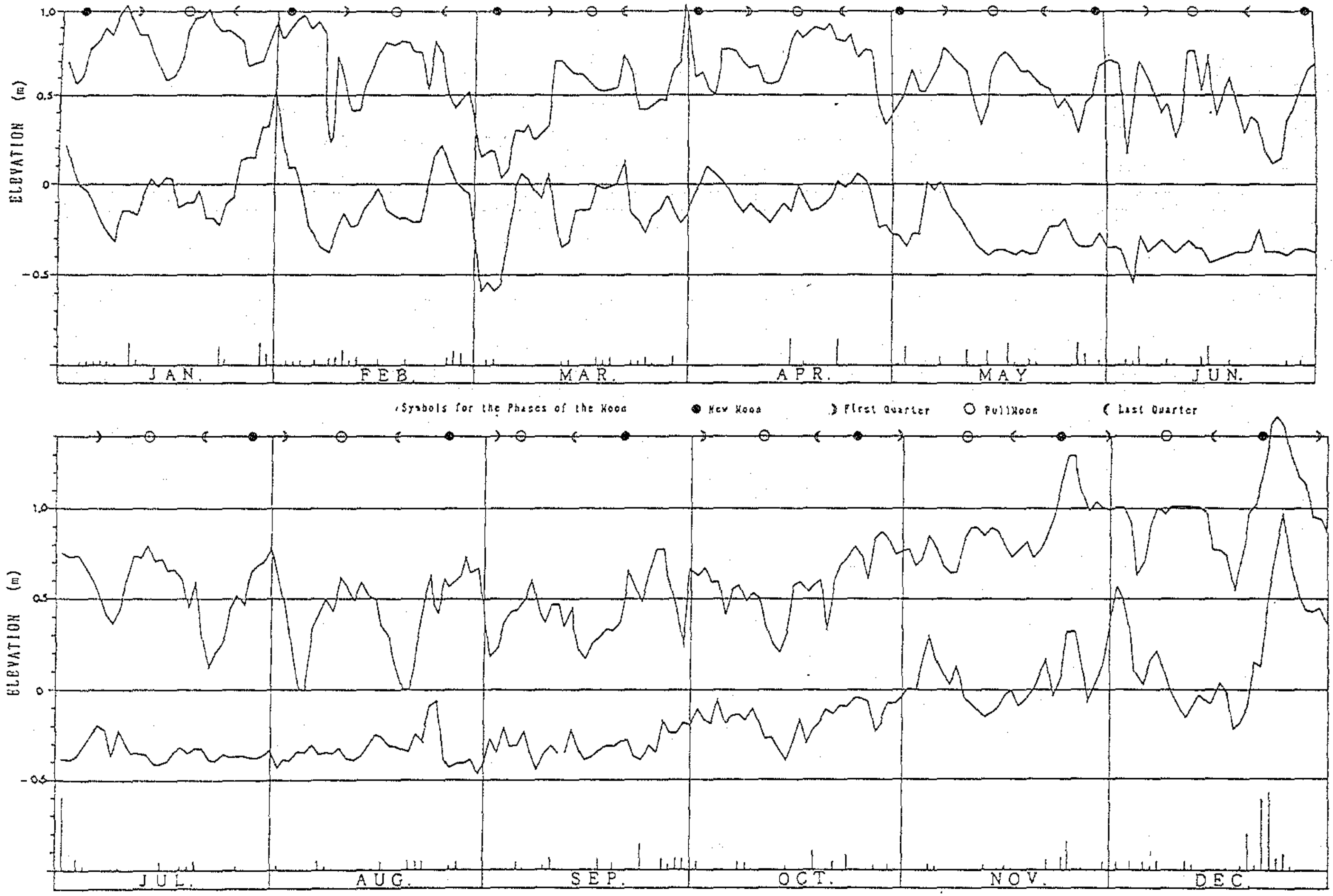


Figure II-4-9 OBSERVED DAILY HIGH AND LOWTIDE AT TABA(X100) AND DAILY RAINFALL AT WAENG IN 1984

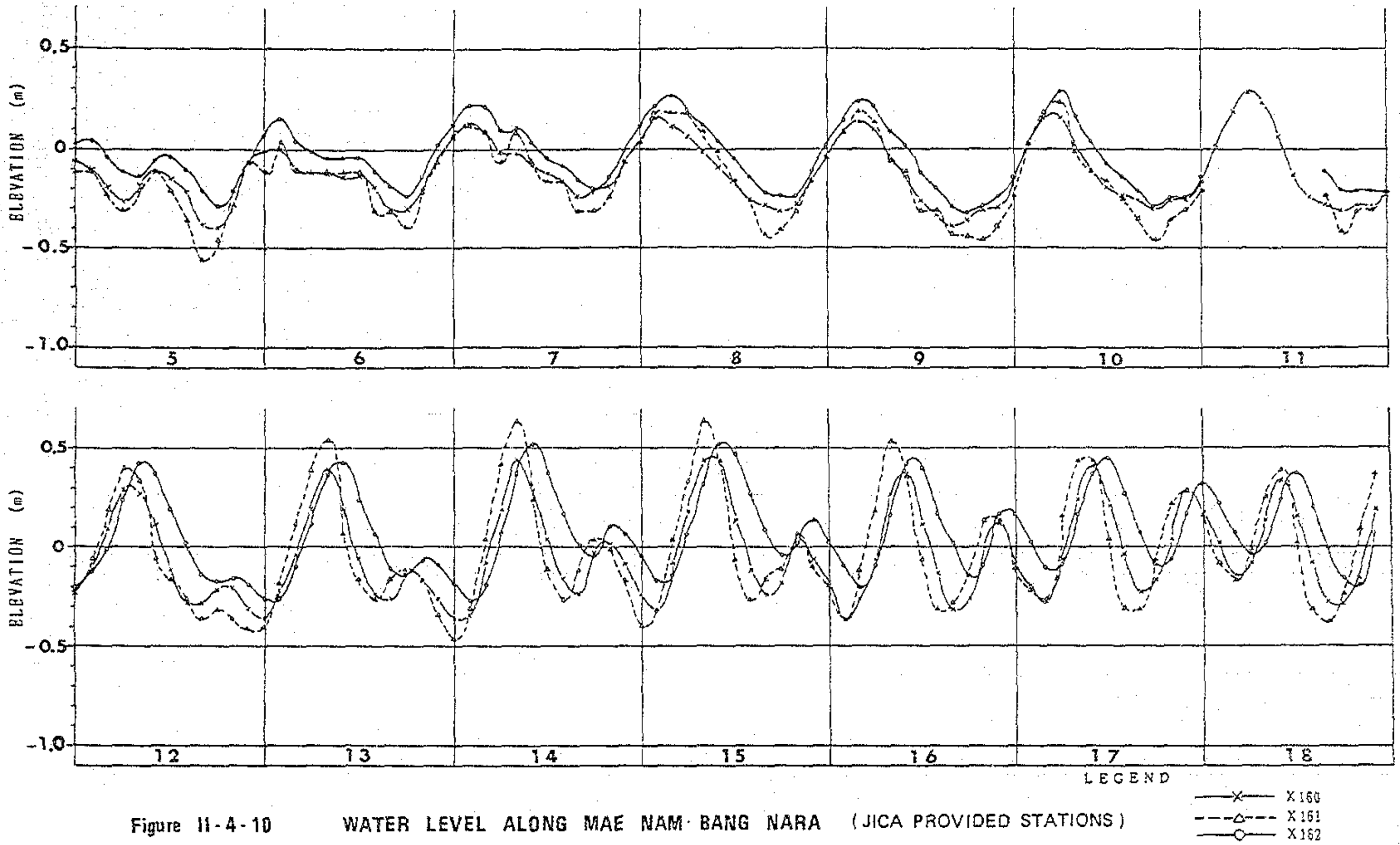


Figure II-4-10 WATER LEVEL ALONG MAE NAM BANG NARA (JICA PROVIDED STATIONS)

(PERIOD 5 — 18 September, 1985)

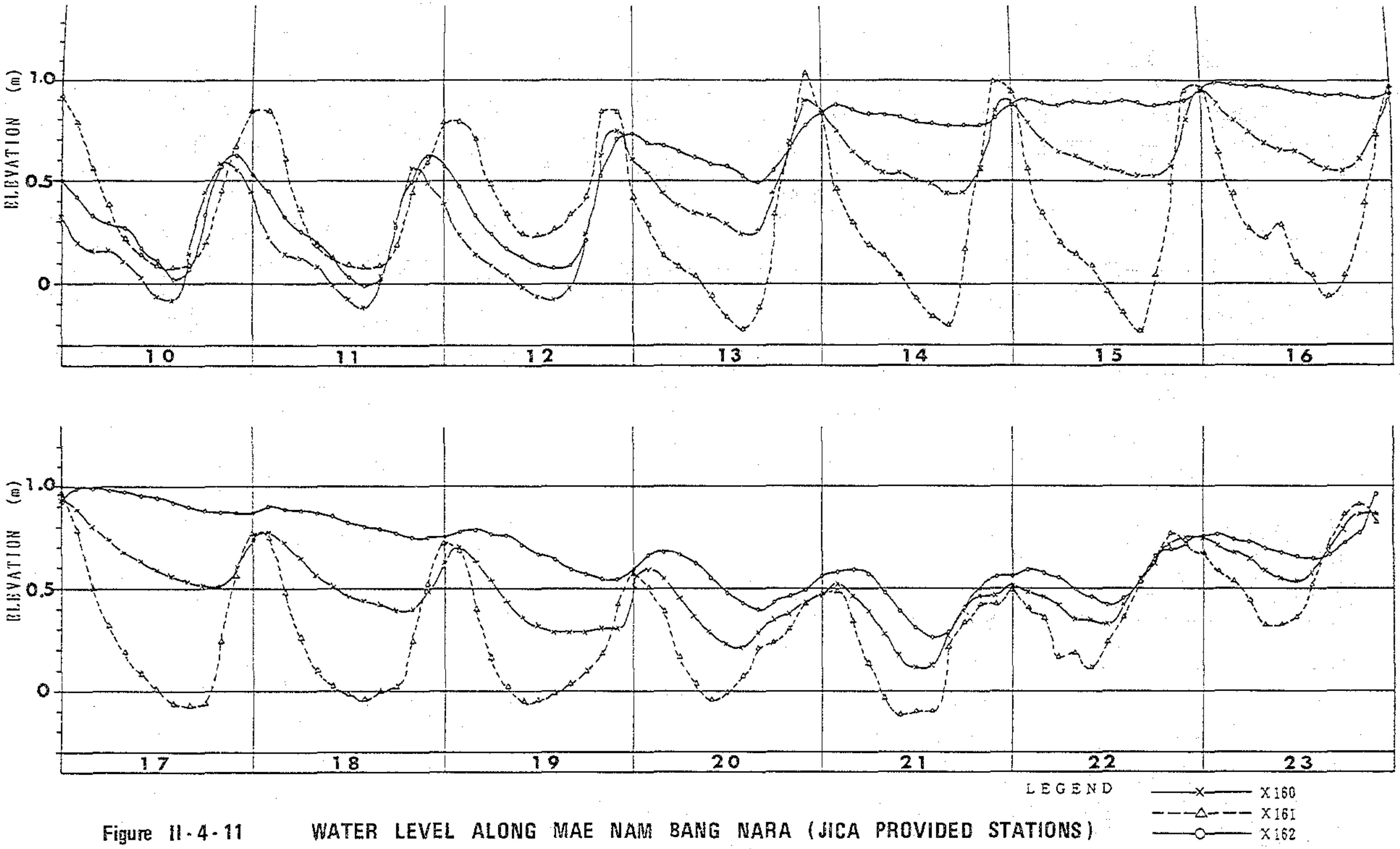
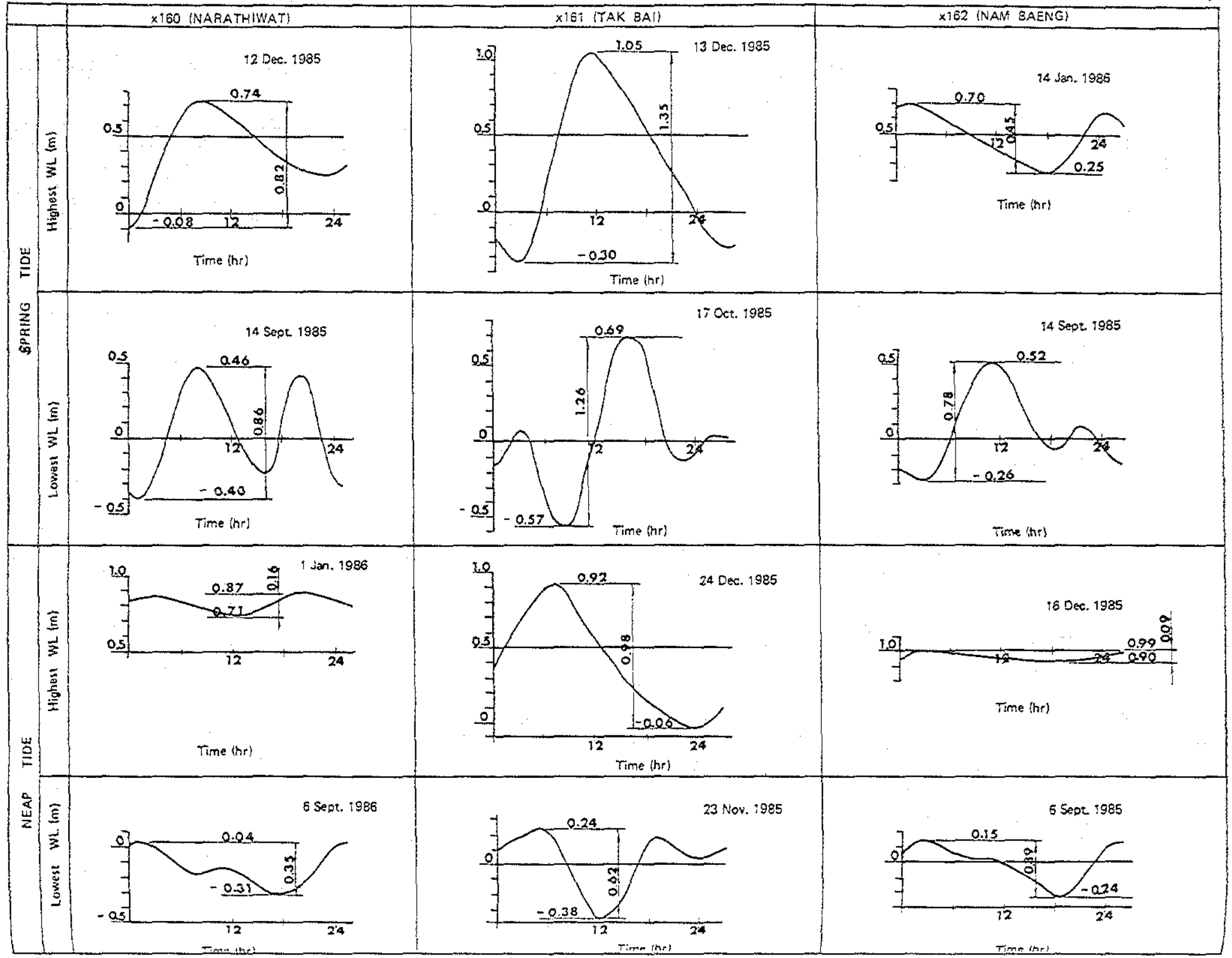


Figure II-4-11 WATER LEVEL ALONG MAE NAM BANG NARA (JICA PROVIDED STATIONS)

(PERIOD 10 — 23 December, 1985)

Figure II-4-12 WATER LEVEL ALONG MAE NAM BANG NARA IN SPRING AND NEAP TIDE

(JICA PROVIDED STATIONS)



APPENDIX III. BANG NARA WATER STORAGE: HYDRAULIC SIMULATIONS

Note: For the abbreviations used, reference is made to (4) "Hydraulic Simulation Options", para. 4.2.2. of Chapter 4.

III-1. Flood Simulation for General Cases

(5 yr-Return Period)

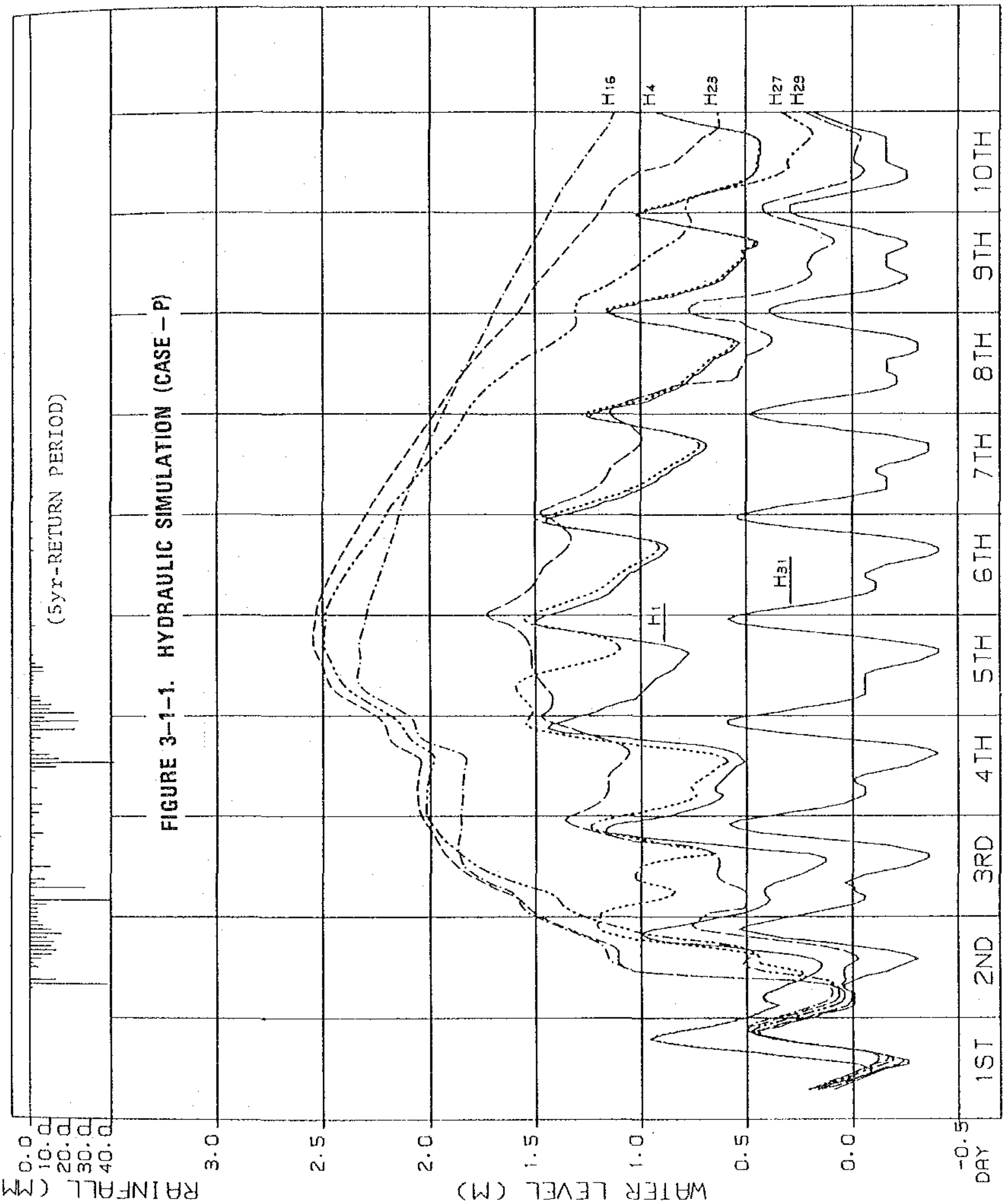
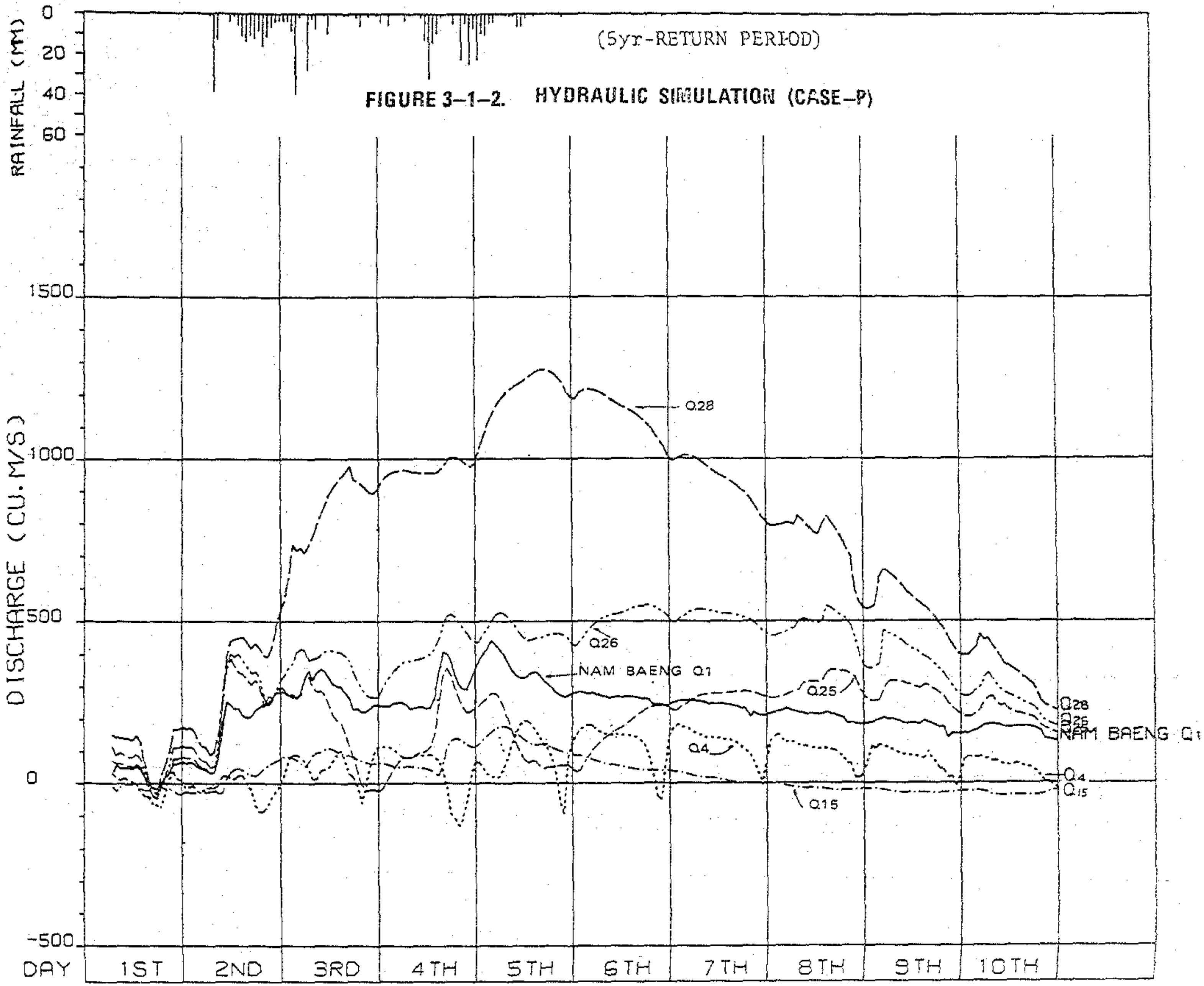


FIGURE 3-1-2. HYDRAULIC SIMULATION (CASE-P)

(5yr-RETURN PERIOD)



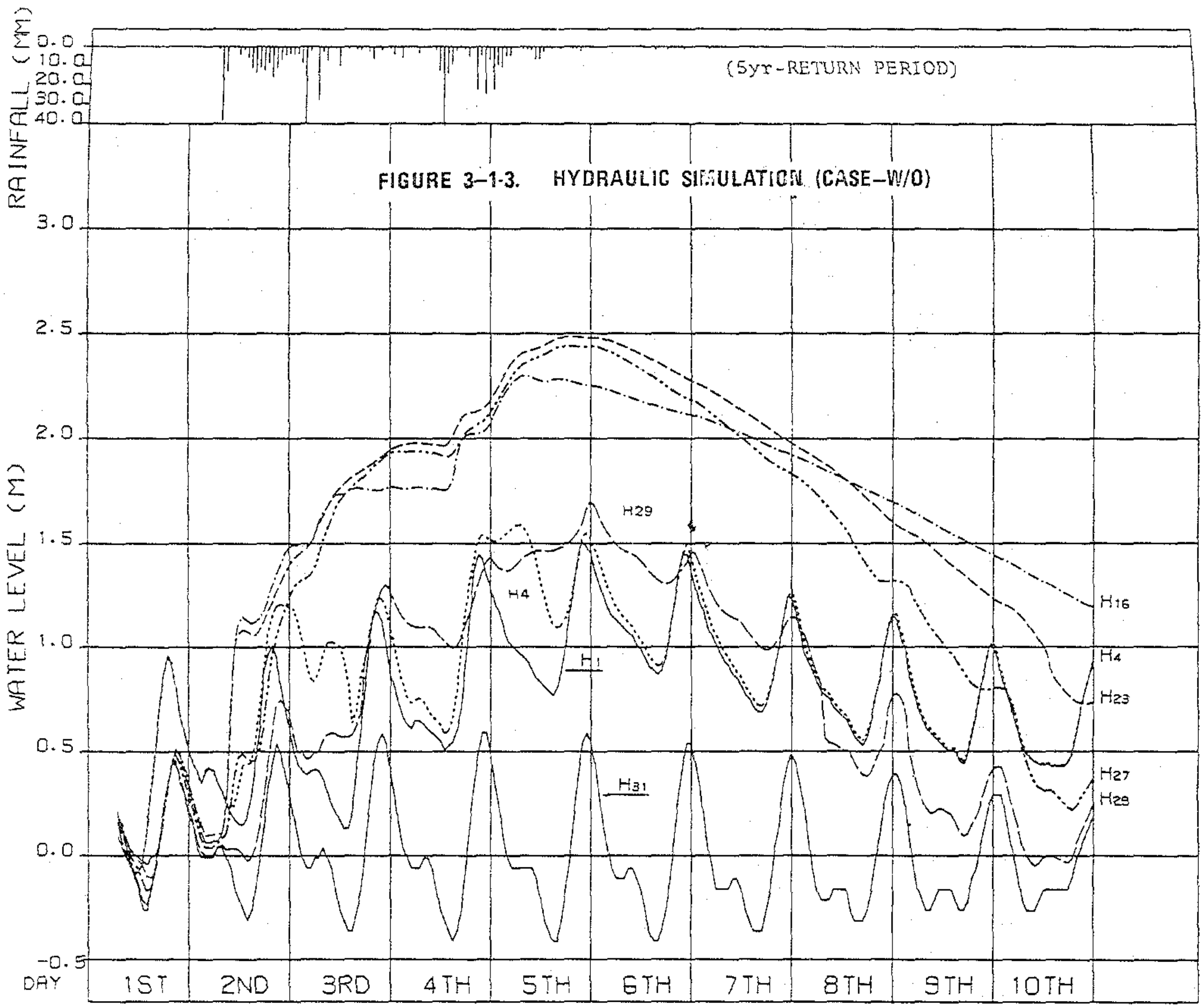


FIGURE 3-1-3. HYDRAULIC SIMULATION (CASE-W/O)

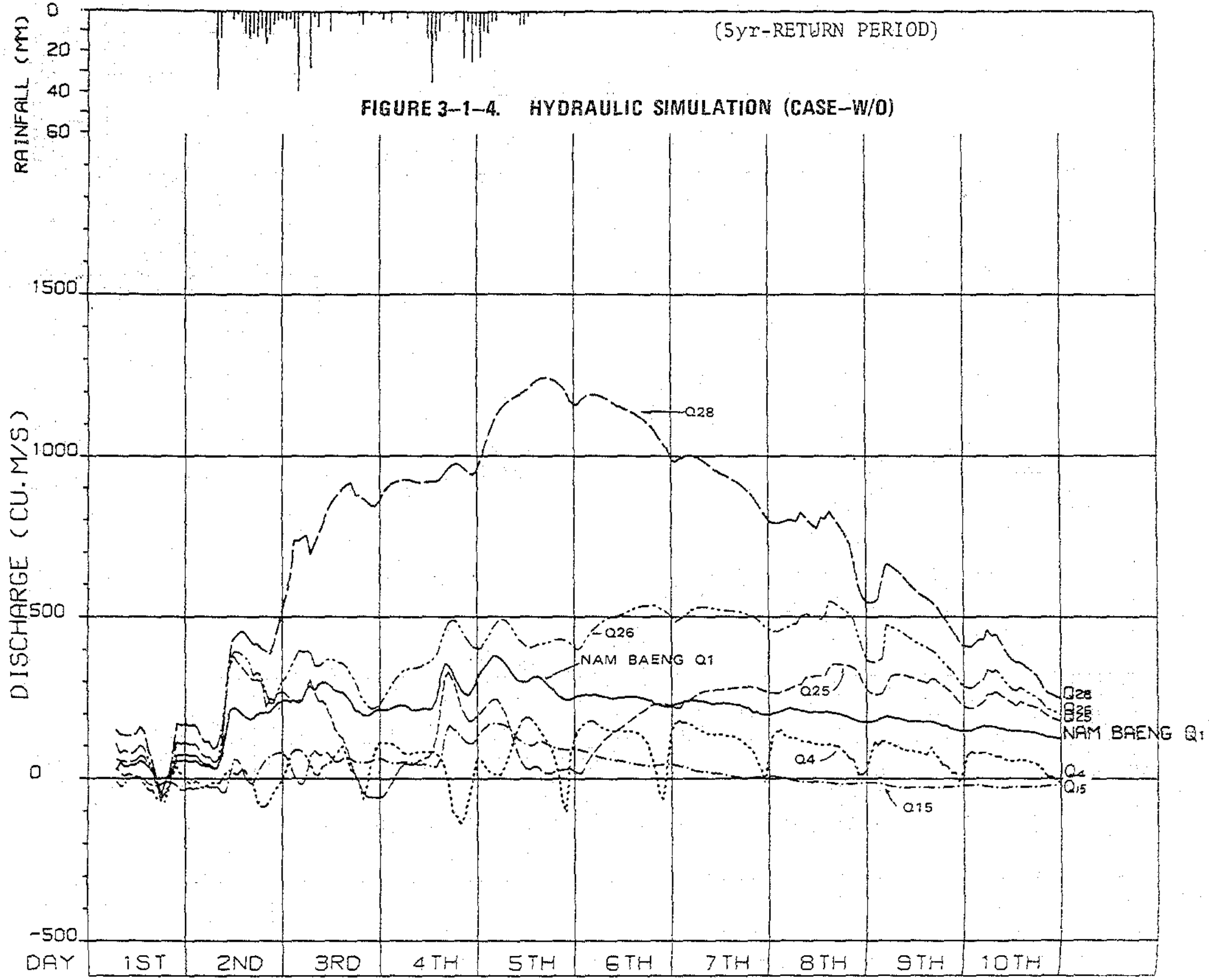


FIGURE 3-1-4. HYDRAULIC SIMULATION (CASE-W/O)

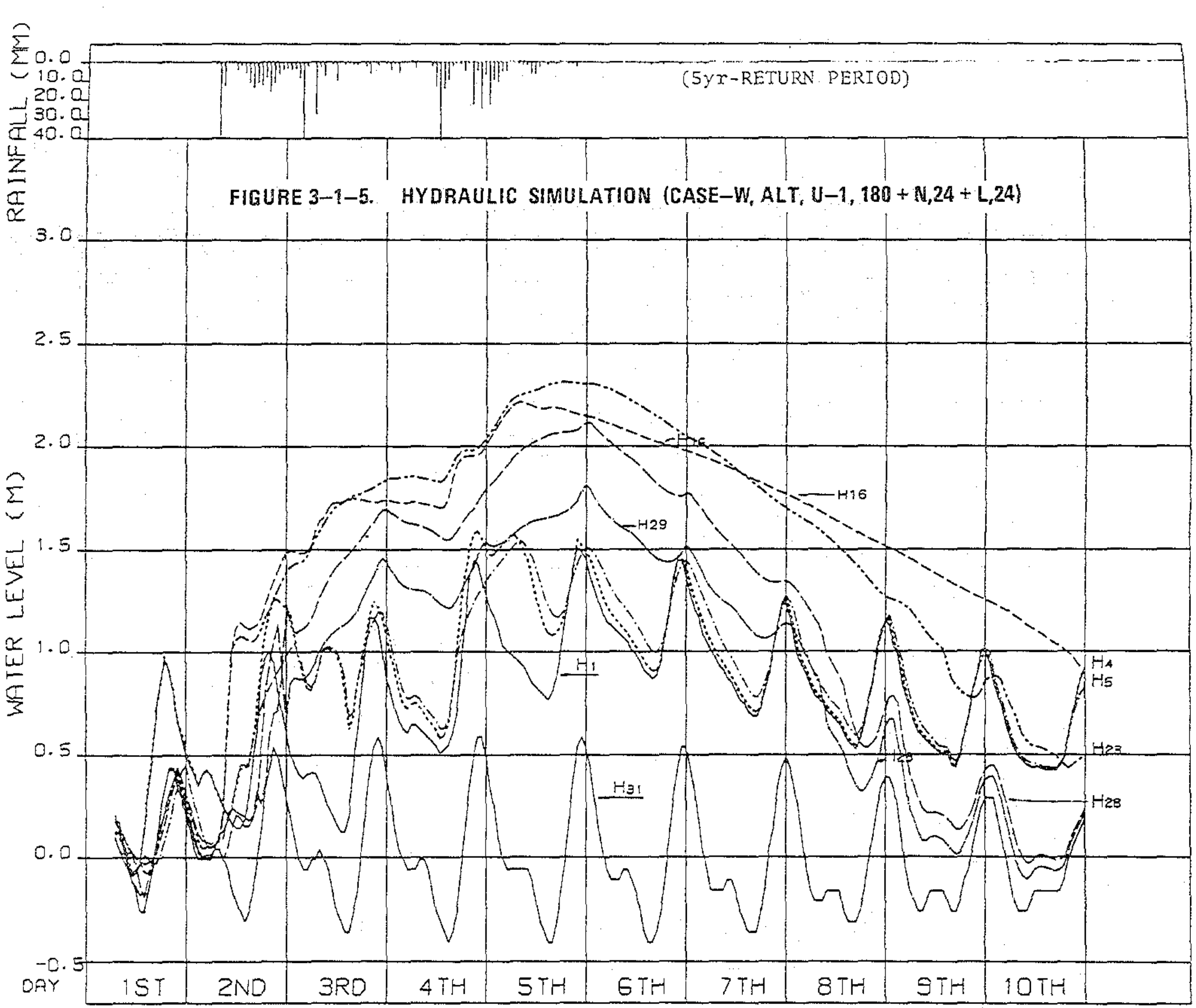
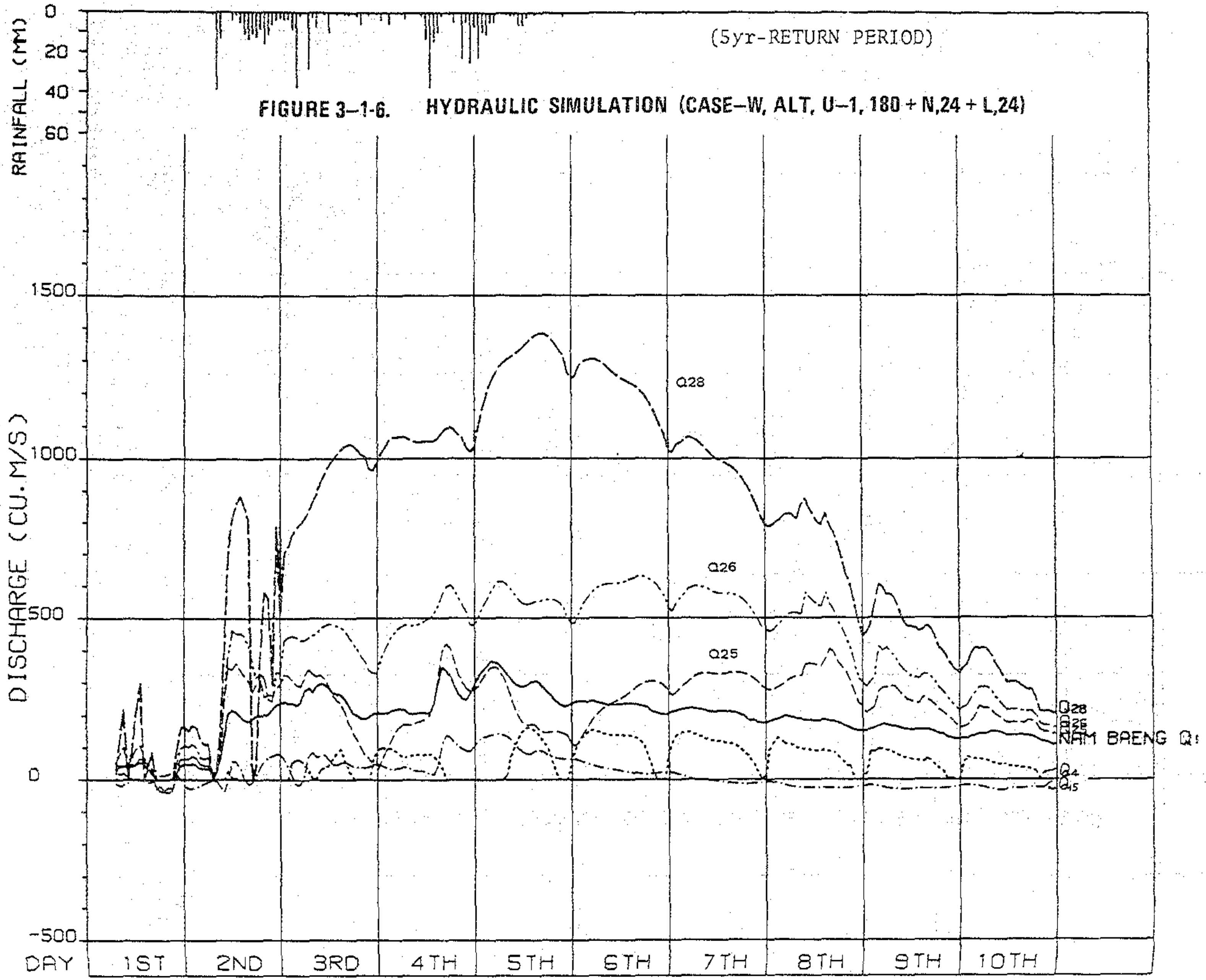


FIGURE 3-1-5. HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 180 + N,24 + L,24)

FIGURE 3-1-6. HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 180 + N,24 + L,24)

(5yr-RETURN PERIOD)



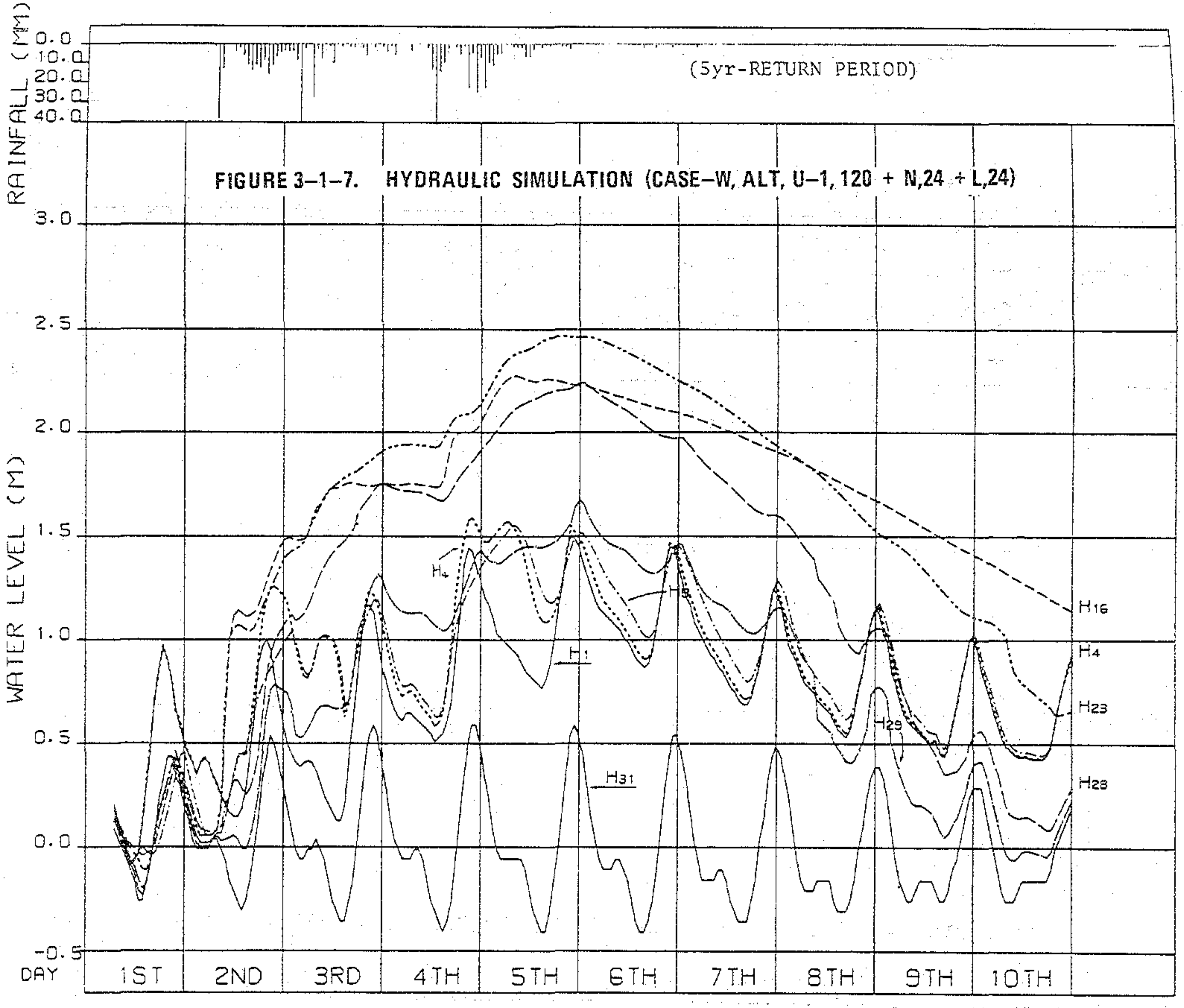


FIGURE 3-1-7. HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 120 + N,24 + L,24)

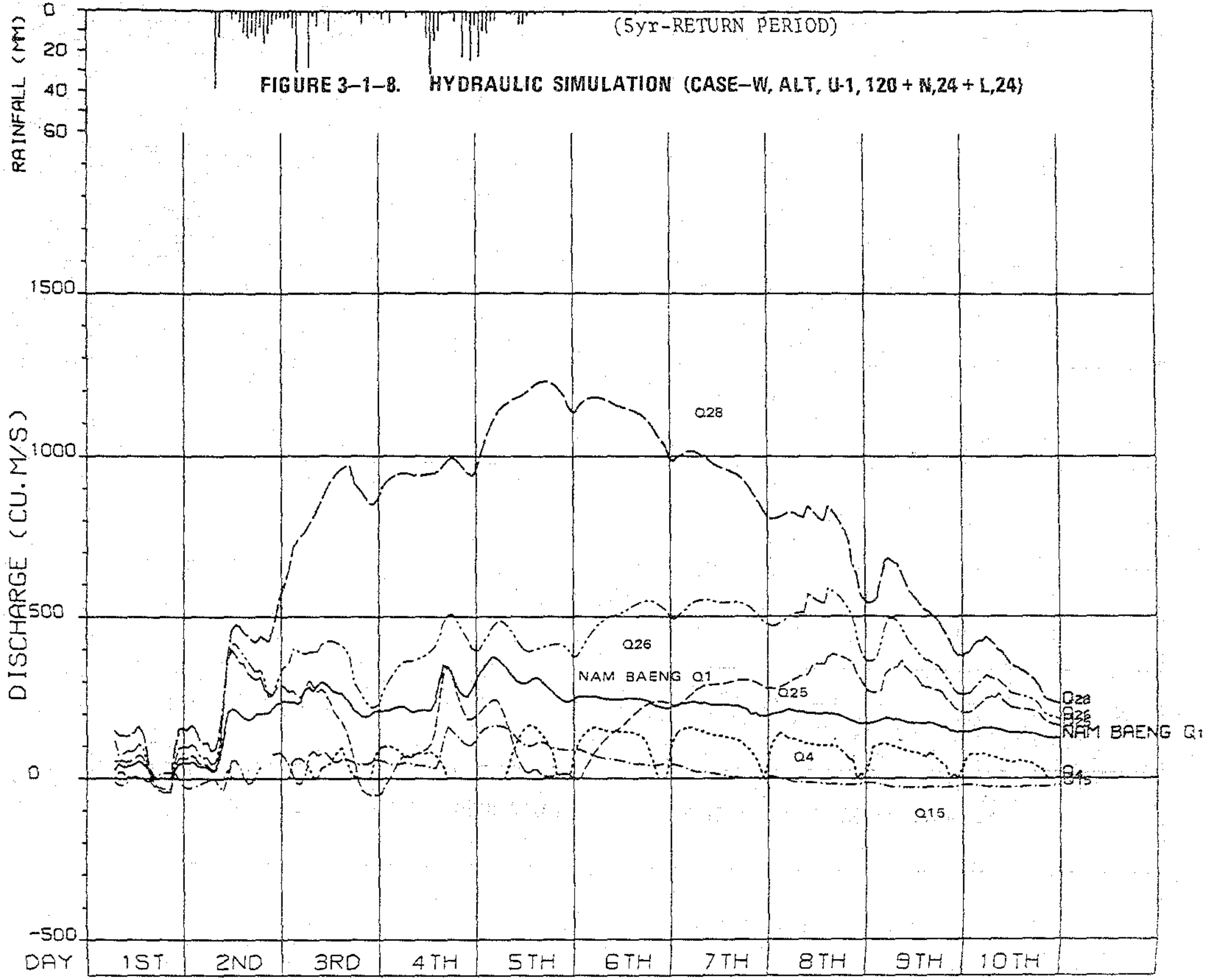


FIGURE 3-1-8. HYDRAULIC SIMULATION (CASE-W, ALT, U-1, 120 + N,24 + L,24)