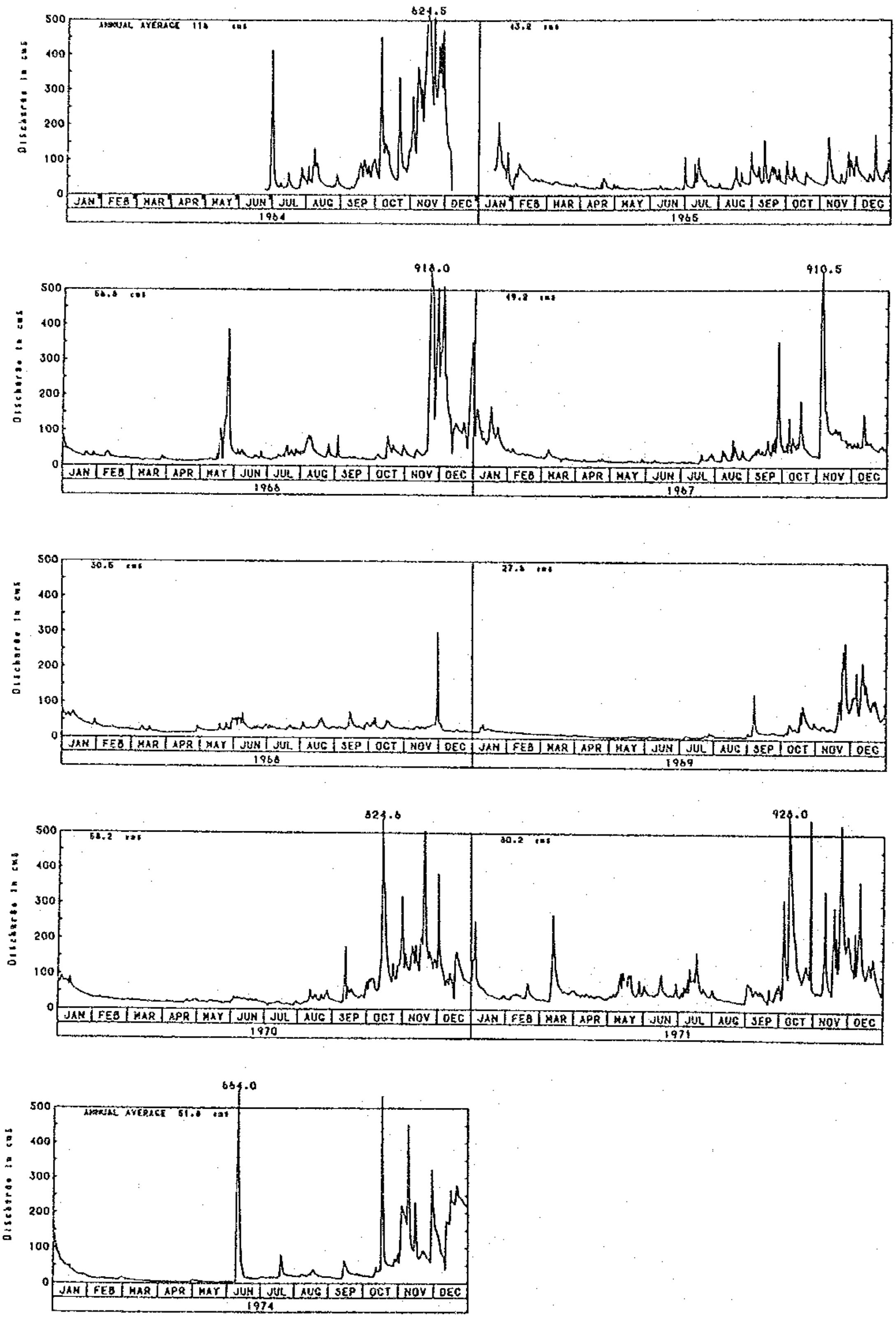
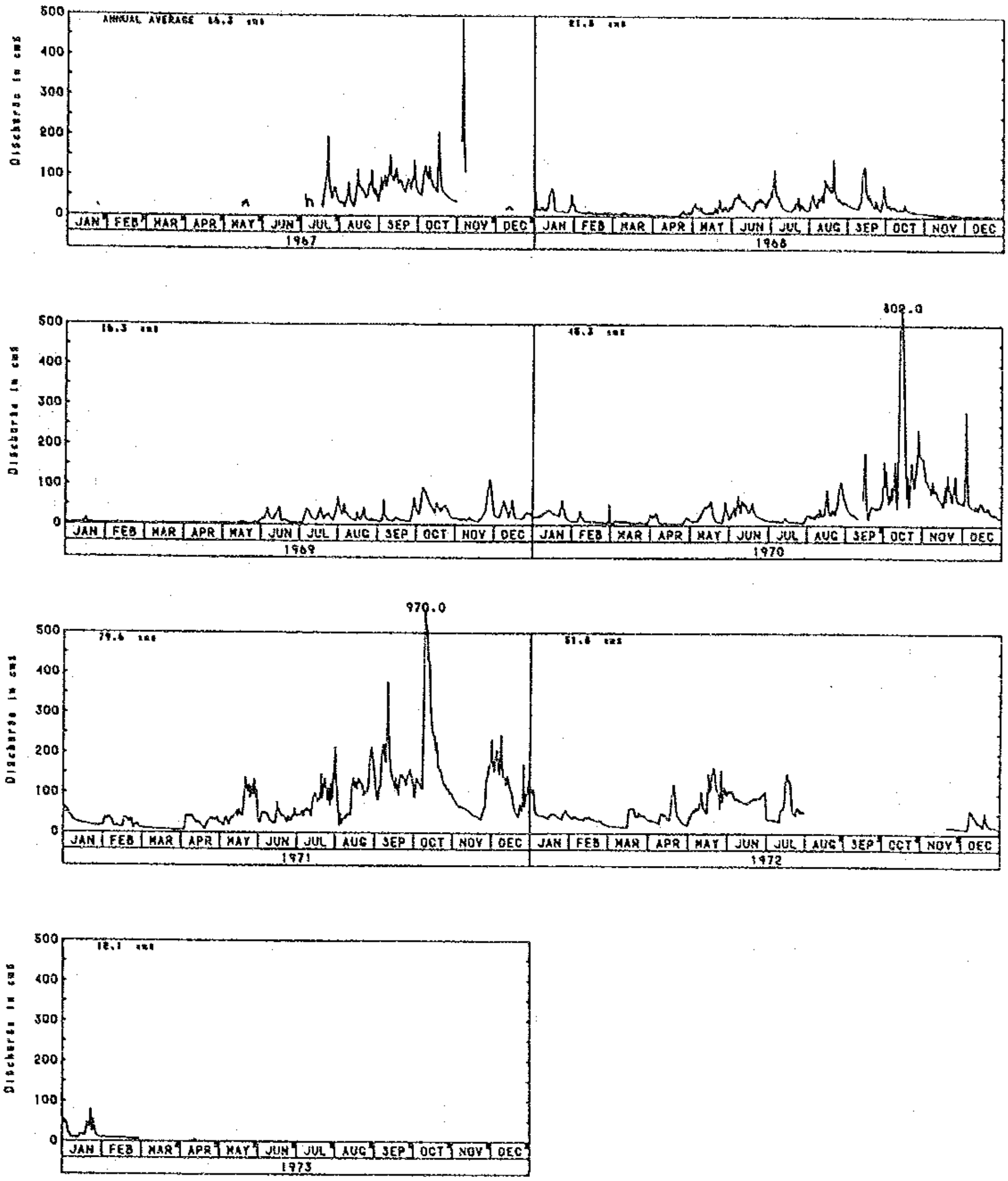


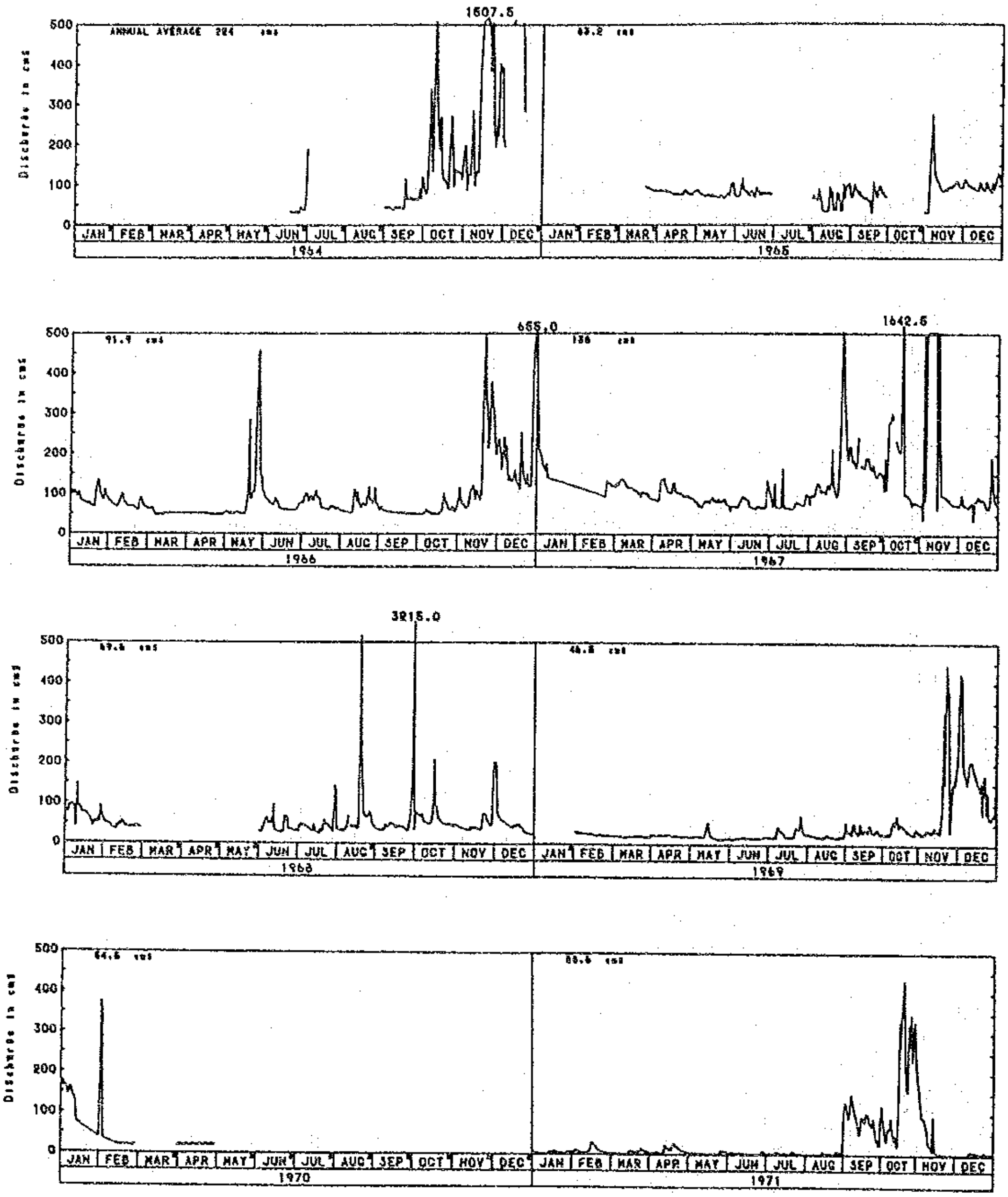
Note : CMS shows cubic meters per second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (1/8) , GUINALVIN



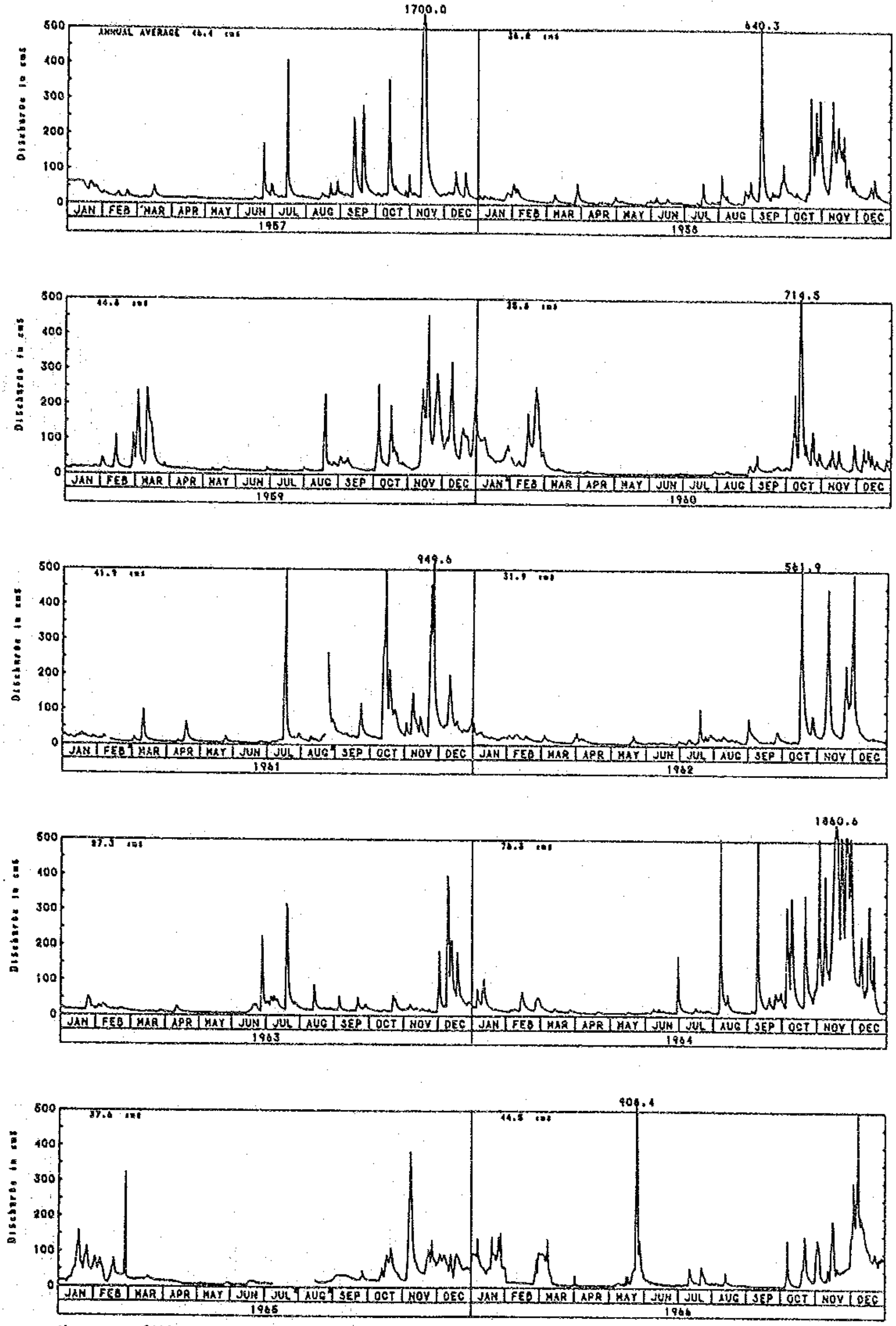
Note : CMS Shows cubic meters Per Second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (2/8) , DULAO



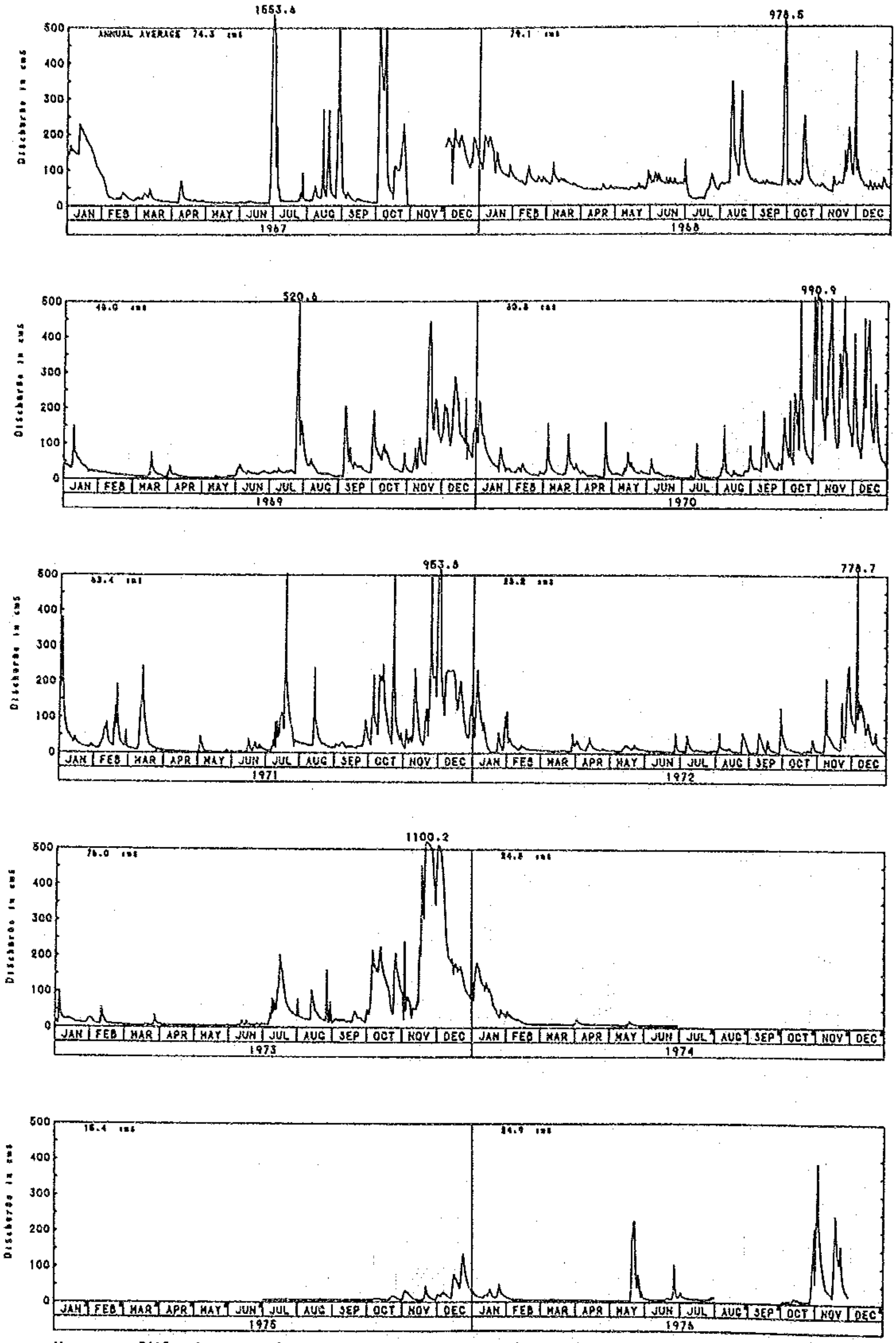
Note : CMS shows cubic meters per second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (3/8) , MINANGA



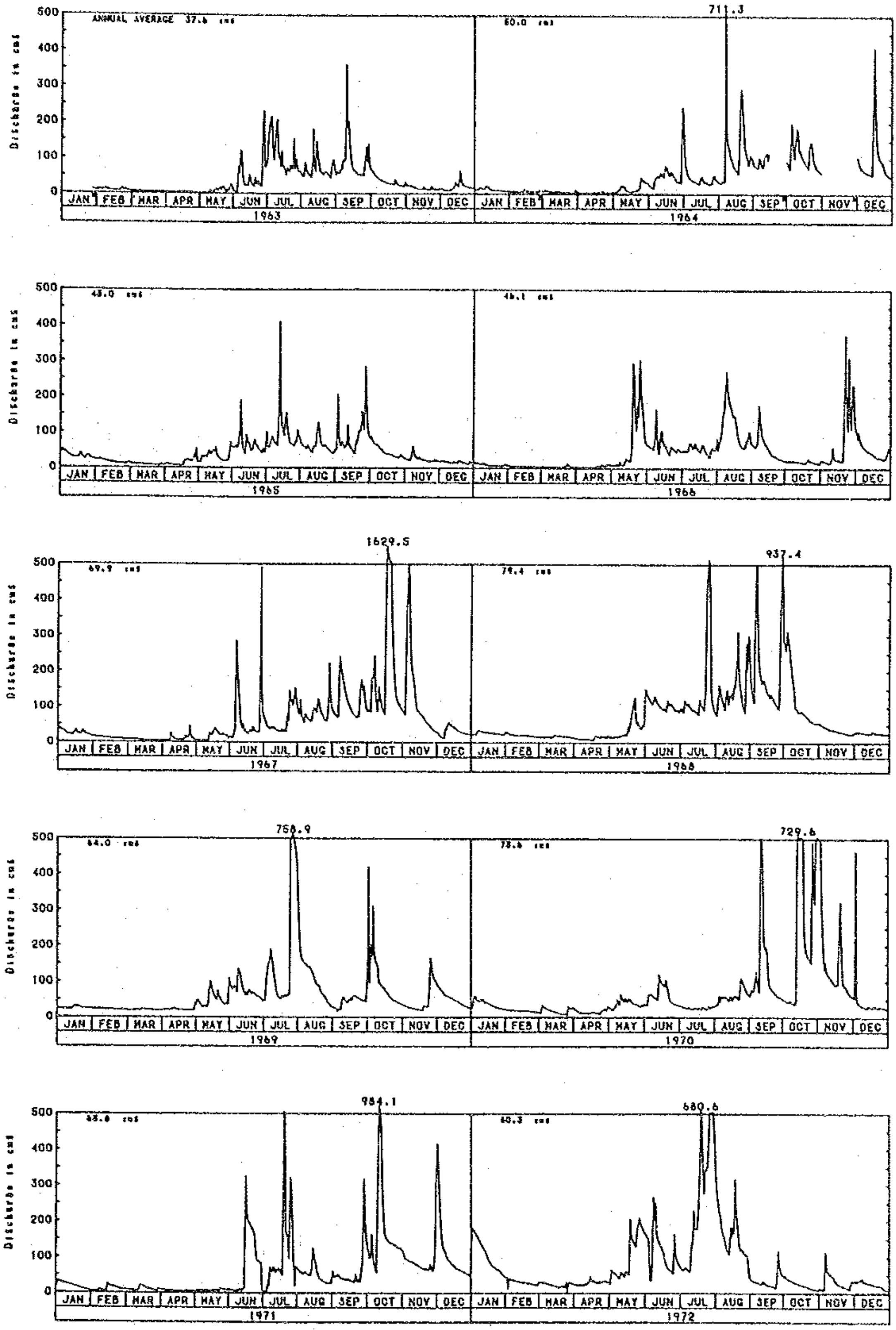
Note : CMS shows cubic meters per second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (4/8) , LARION ALTO (1/2)



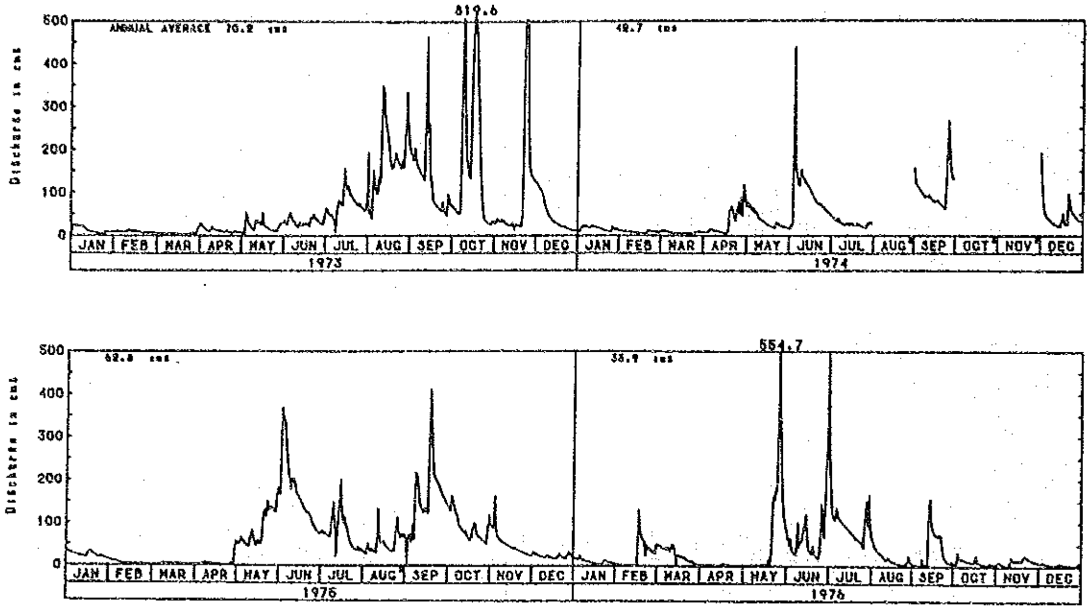
Note : CMS shows cubic meters per second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (5/8) , LARION ALTO (2/2)



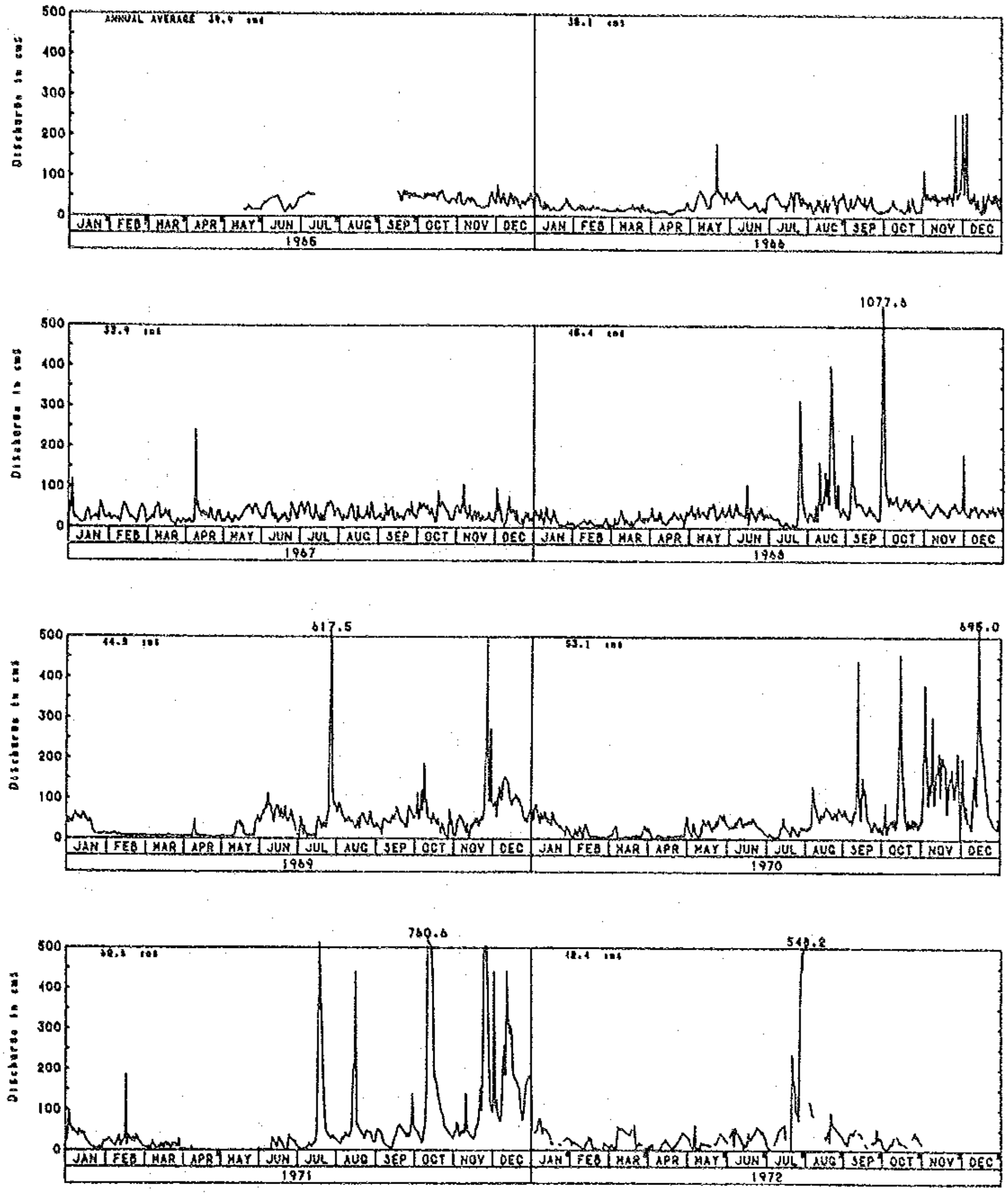
Note : CMS shows cubic meters per second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (6/8) , AMPAWILEN (1/2)



Note : CMS ShowS cubic meterS Per Second.
AsteriSk(*) breakS in recordinG.

Fig. 3.3 DAILY HYDROGRAPH (7/8) , AMPAWILEN (2/2)



Note : CMS Shows cubic meters Per Second.
Asterisk(*) breaks in recording.

Fig. 3.3 DAILY HYDROGRAPH (8/8) , PINUKPUK

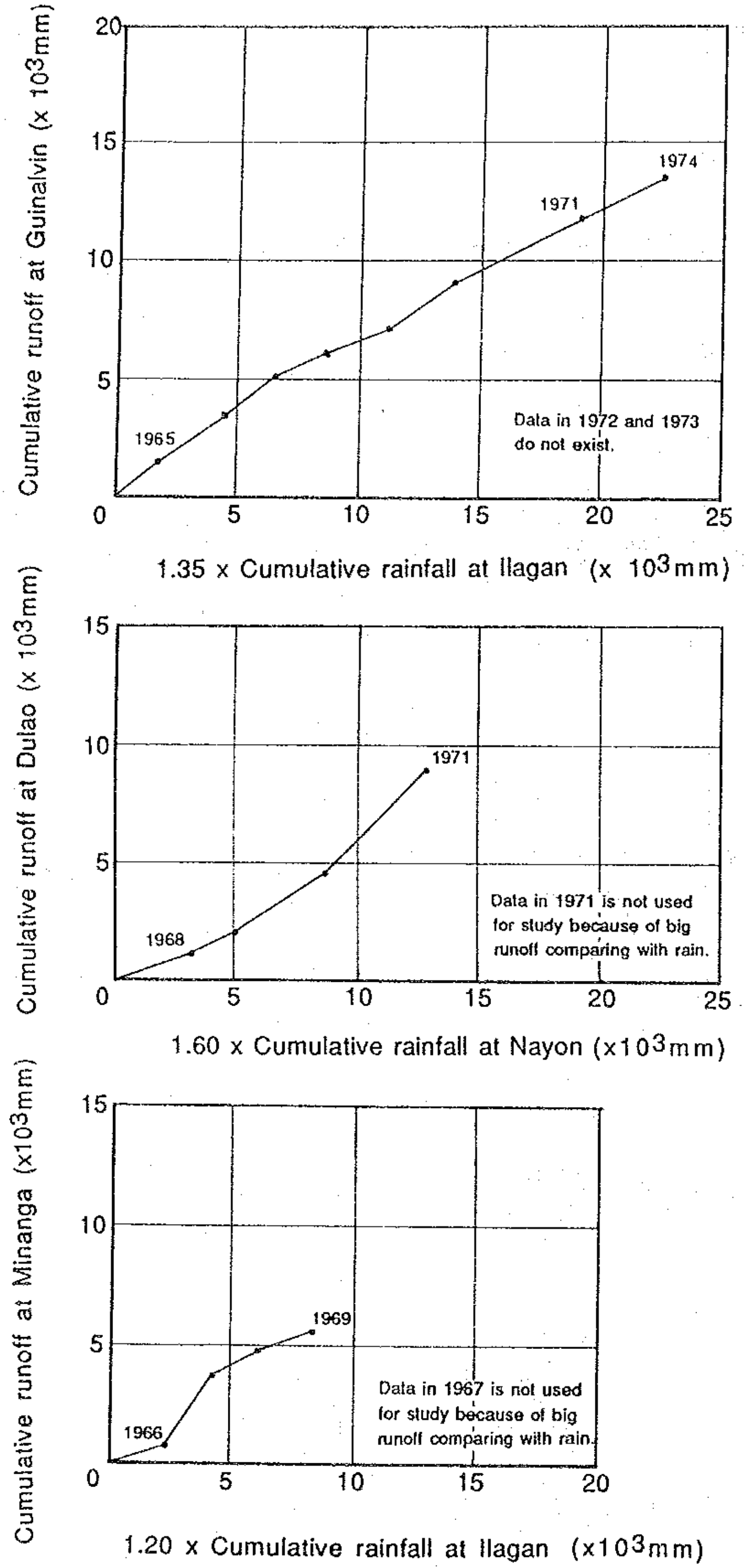


Fig. 3.4 RELATIONSHIP BETWEEN RAINFALL AND RUNOFF (1/2)

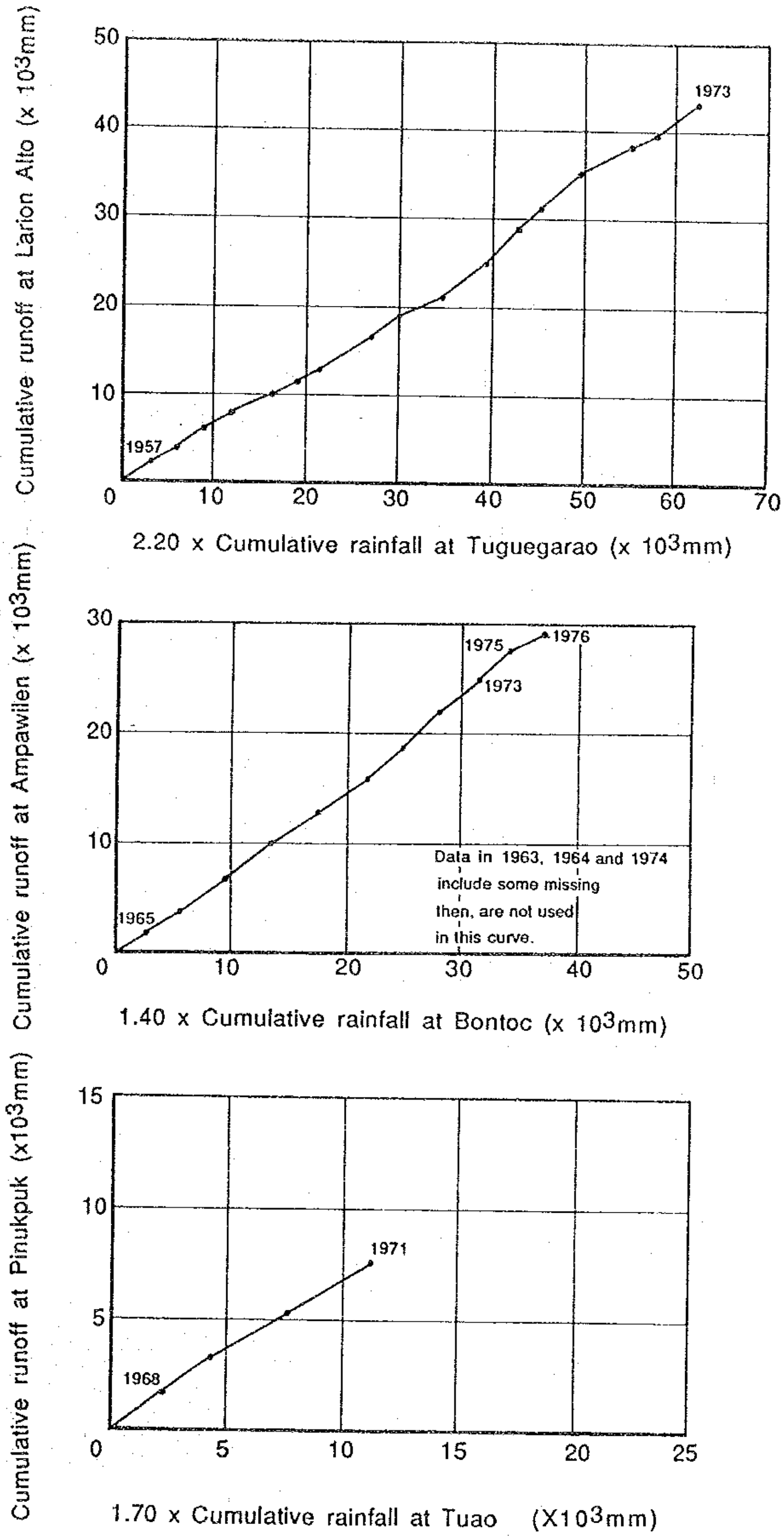


Fig. 3.4 RELATIONSHIP BETWEEN RAINFALL AND RUNOFF (2/2)

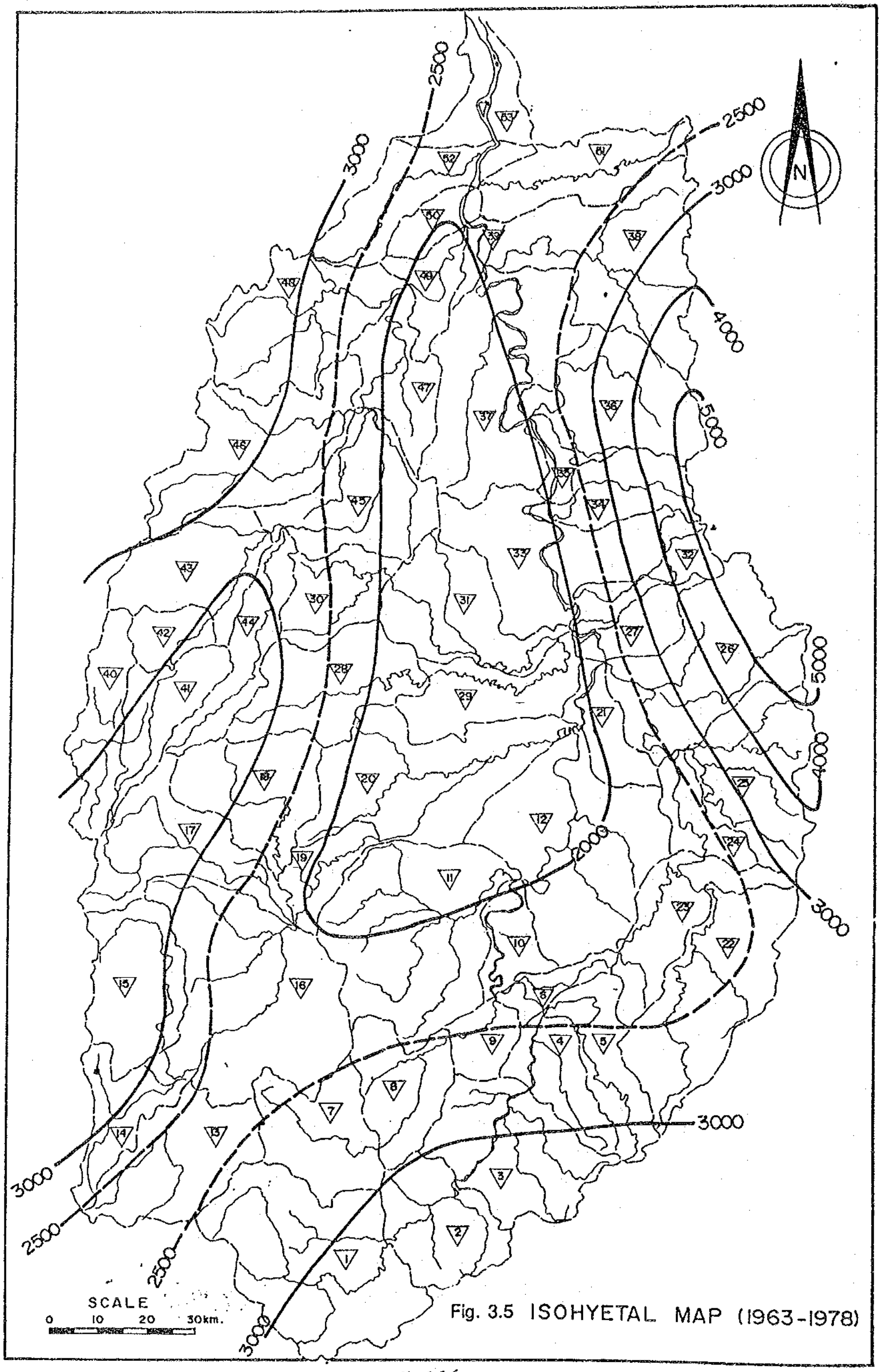
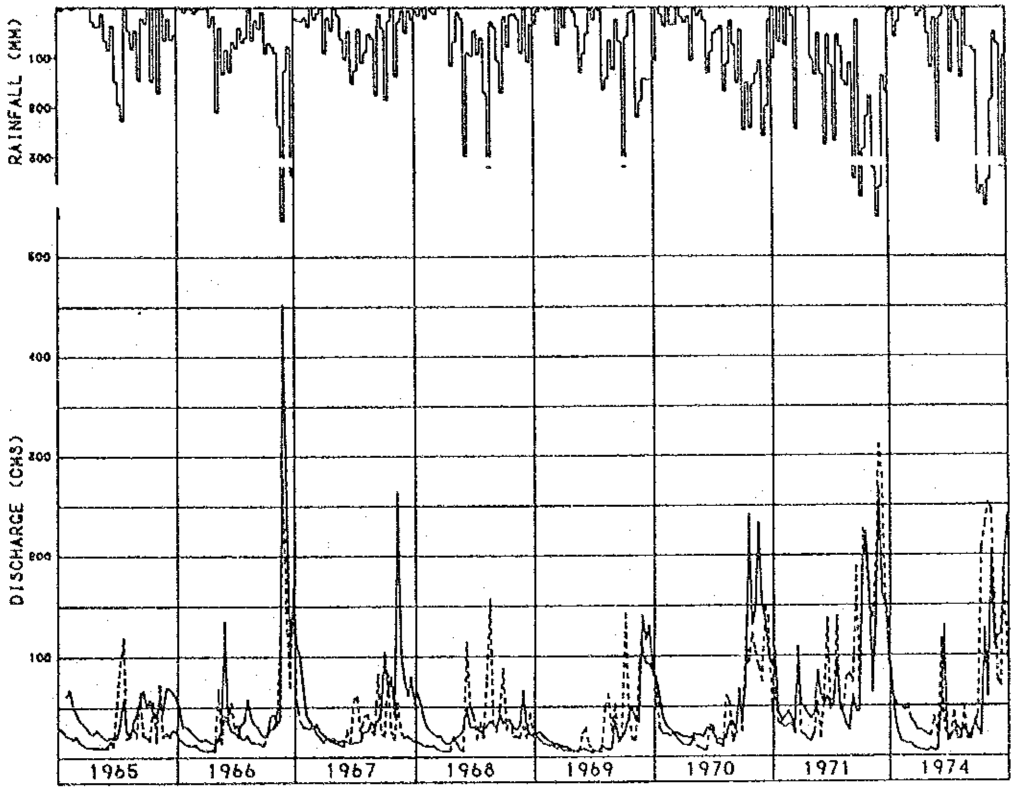
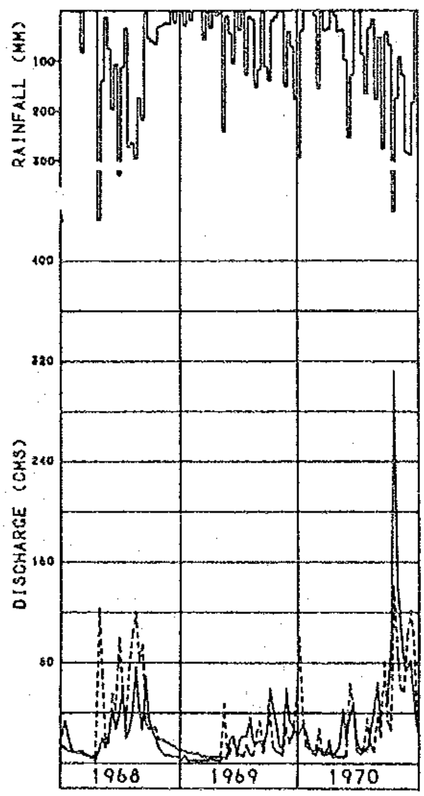


Fig. 3.5 ISOHYETAL MAP (1963-1978)

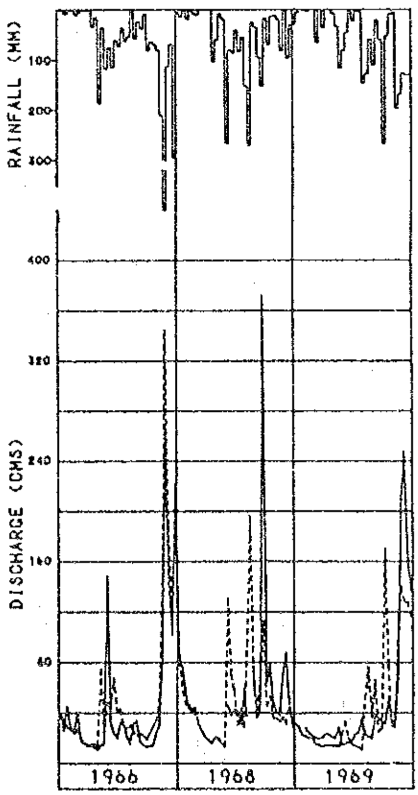


Guinalvin

——— Observed
- - - - - Calculated

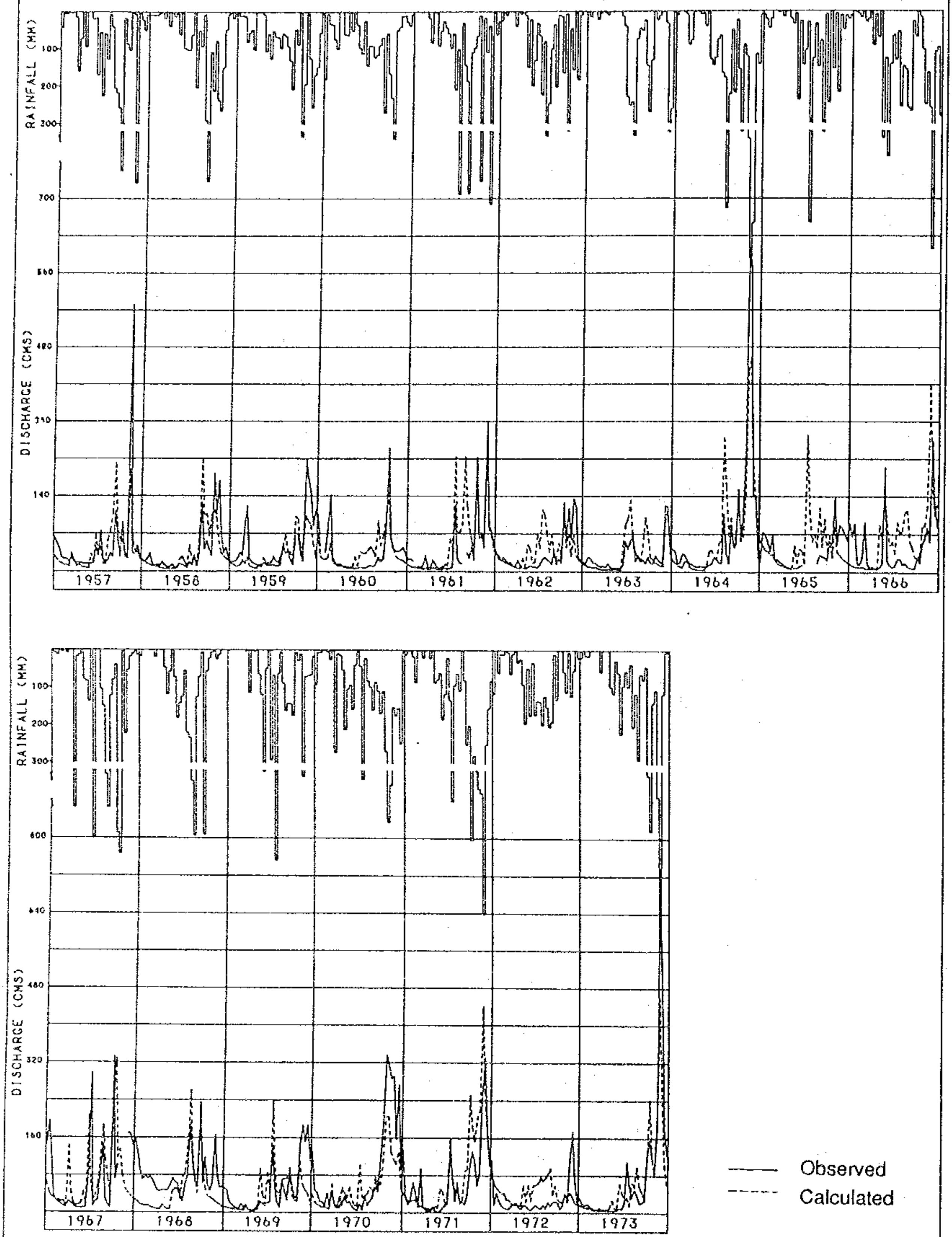


Dulao



Minanga

Fig. 3.6 OBSERVED AND CALCULATED RUNOFF HYDROGRAPH (1/3)



Larion Alto

Fig. 3.6 OBSERVED AND CALCULATED RUNOFF HYDROGRAPH (2/3)

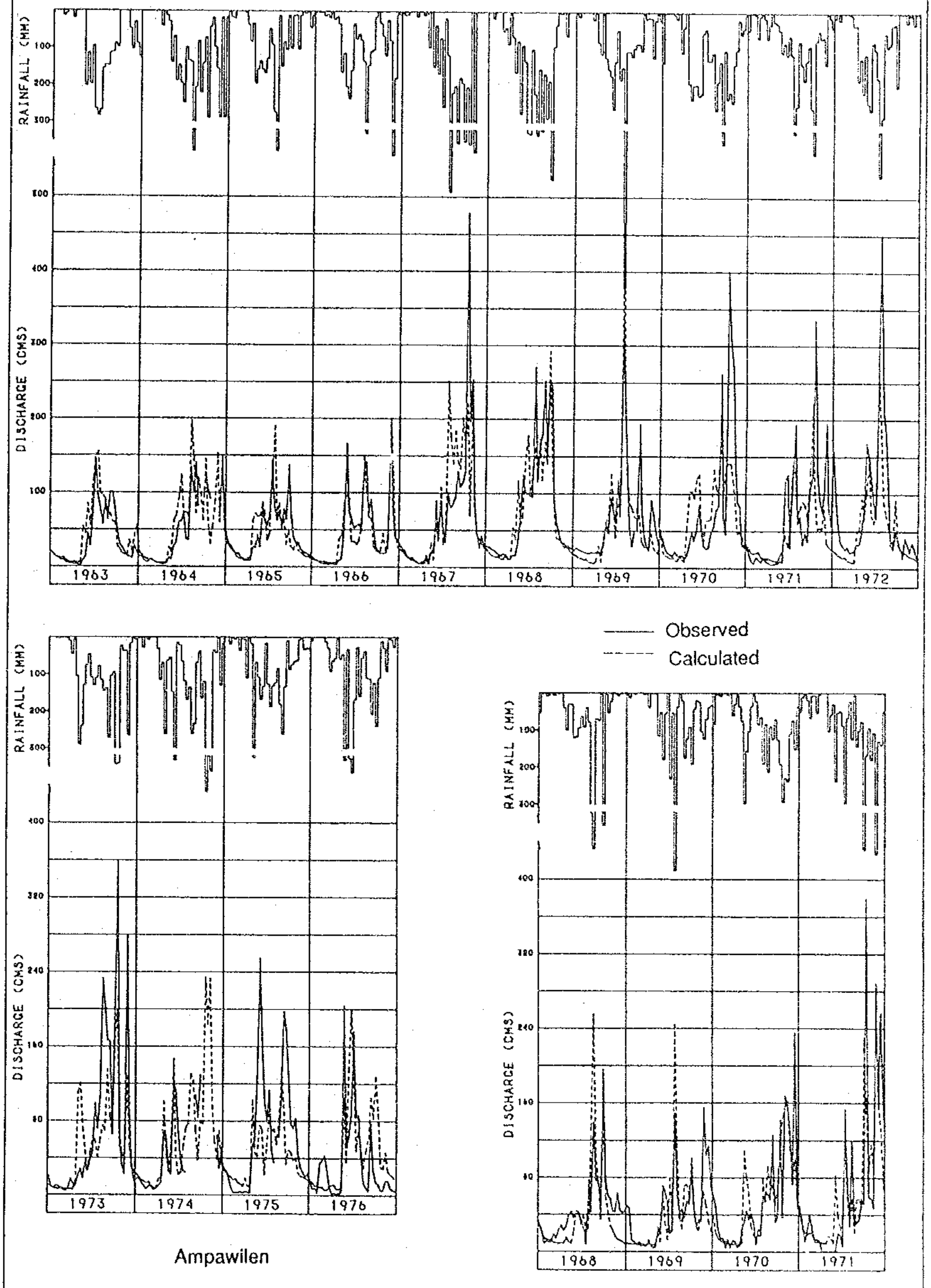


Fig. 3.6 OBSERVED AND CALCULATED RUNOFF HYDROGRAPH (3/3)

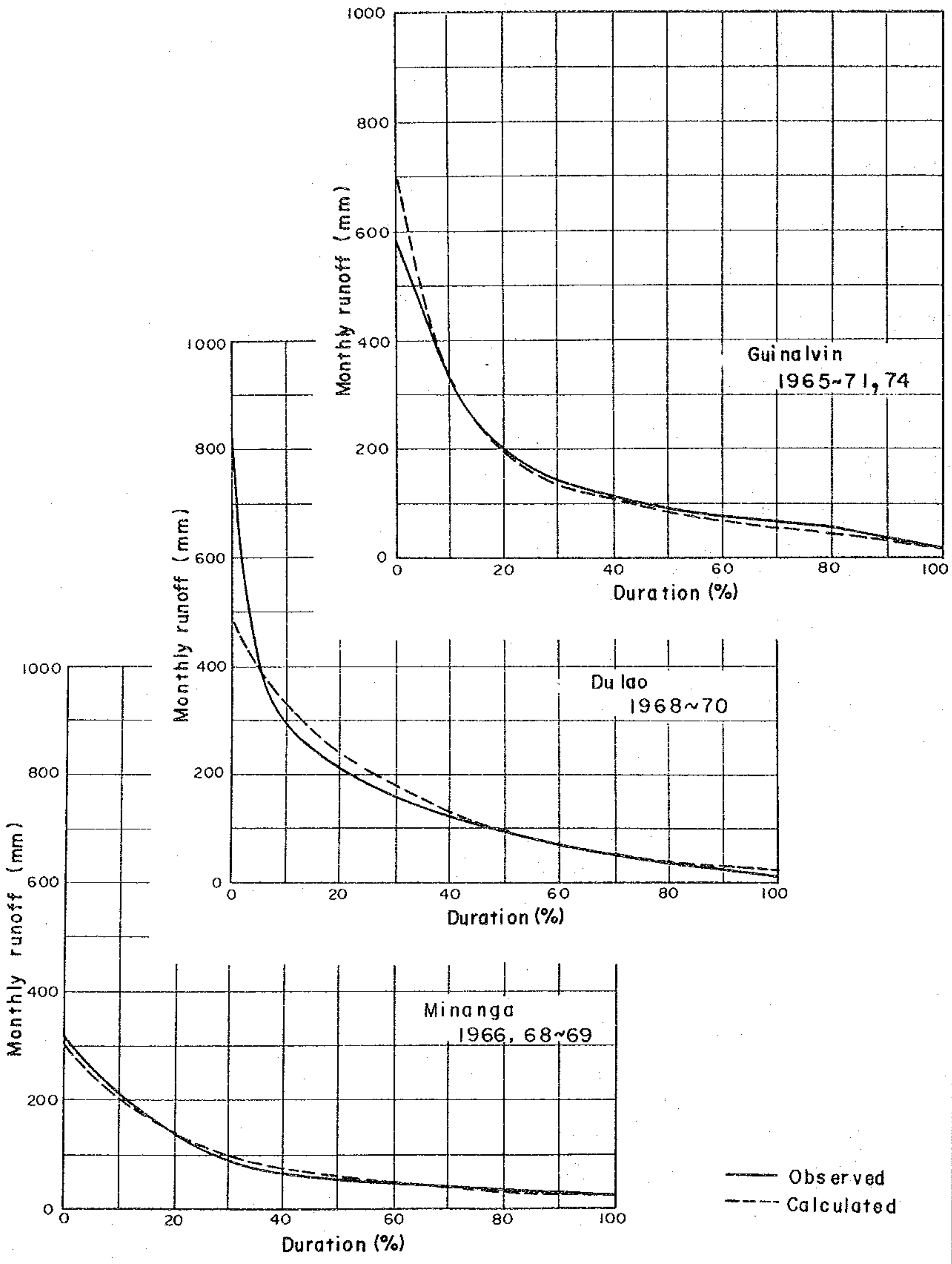


Fig. 3.7 OBSERVED AND CALCULATED FLOW DURATION CURVE (1/2)

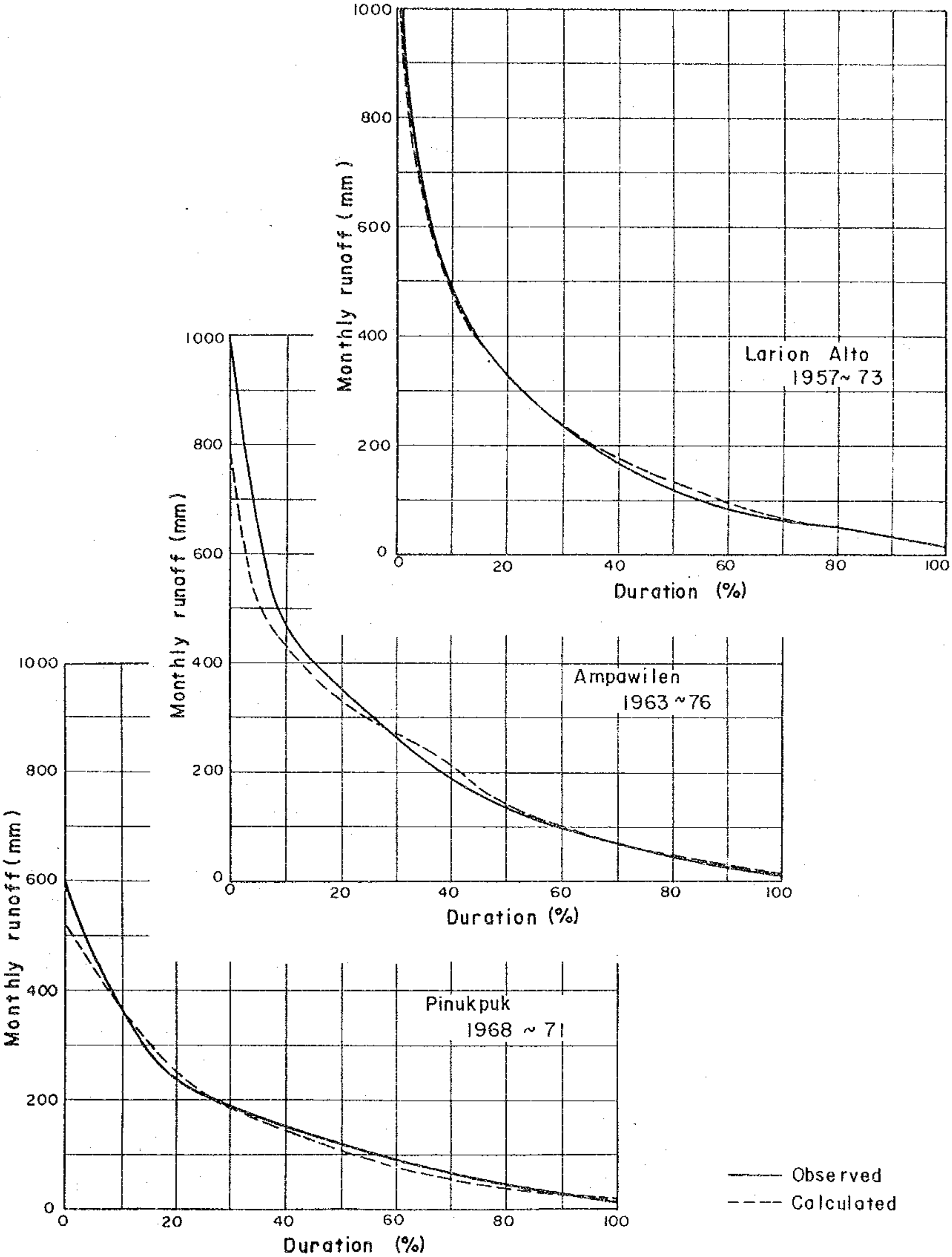
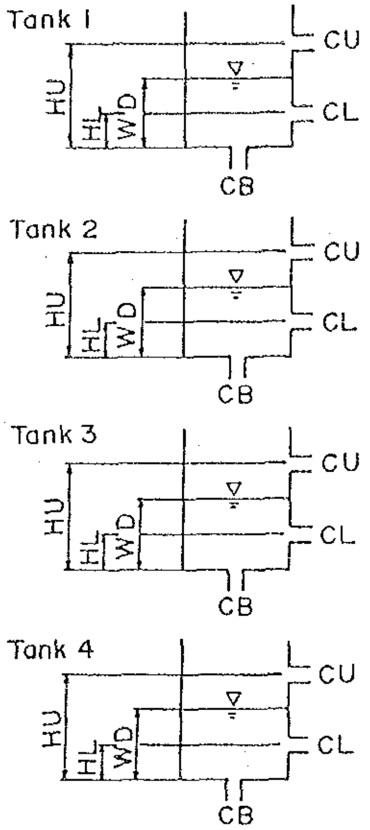


Fig. 3.7 OBSERVED AND CALCULATED FLOW DURATION CURVE (2/2)



CU : Coefficient of upper hole

CL : Coefficient of lower hole

CB : Coefficient of bottom hole

HU : Height of upper hole (mm)

HL : Height of lower hole (mm)

WD : Initial water depth (mm)

Dulao				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.35	0.04	0.02	0.0
CL	0.08	0.02	0.015	0.01
CB	0.25	0.12	0.06	0.001
HU	60	30	5	0
HL	10	10	0	0
WD	40	100	200	800

Minanga				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.25	0.03	0.02	0.0
CL	0.10	0.02	0.015	0.014
CB	0.35	0.12	0.09	0.001
HU	60	30	10	0
HL	30	10	0	0
WD	50	150	150	600

Larion Alto				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.30	0.07	0.03	0.0
CL	0.10	0.03	0.01	0.01
CB	0.30	0.09	0.05	0.001
HU	50	30	10	0
HL	10	10	0	0
WD	20	200	200	700

Ampawilen				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.35	0.05	0.03	0.0
CL	0.12	0.03	0.02	0.01
CB	0.25	0.10	0.06	0.001
HU	60	30	5	0
HL	20	10	0	0
WD	10	100	200	700

Guinalvin				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.35	0.05	0.02	0.0
CL	0.10	0.03	0.01	0.01
CB	0.35	0.15	0.07	0.001
HU	50	30	5	0
HL	10	10	0	0
WD	40	200	200	700

Pinukpuk				
	Tank 1	Tank 2	Tank 3	Tank 4
CU	0.30	0.08	0.02	0.0
CL	0.10	0.05	0.015	0.014
CB	0.30	0.15	0.12	0.001
HU	50	30	5	0
HL	10	10	0	0
WD	20	100	100	700

Fig. 3.8 TANK MODEL AND CALIBRATED COEFFICIENT

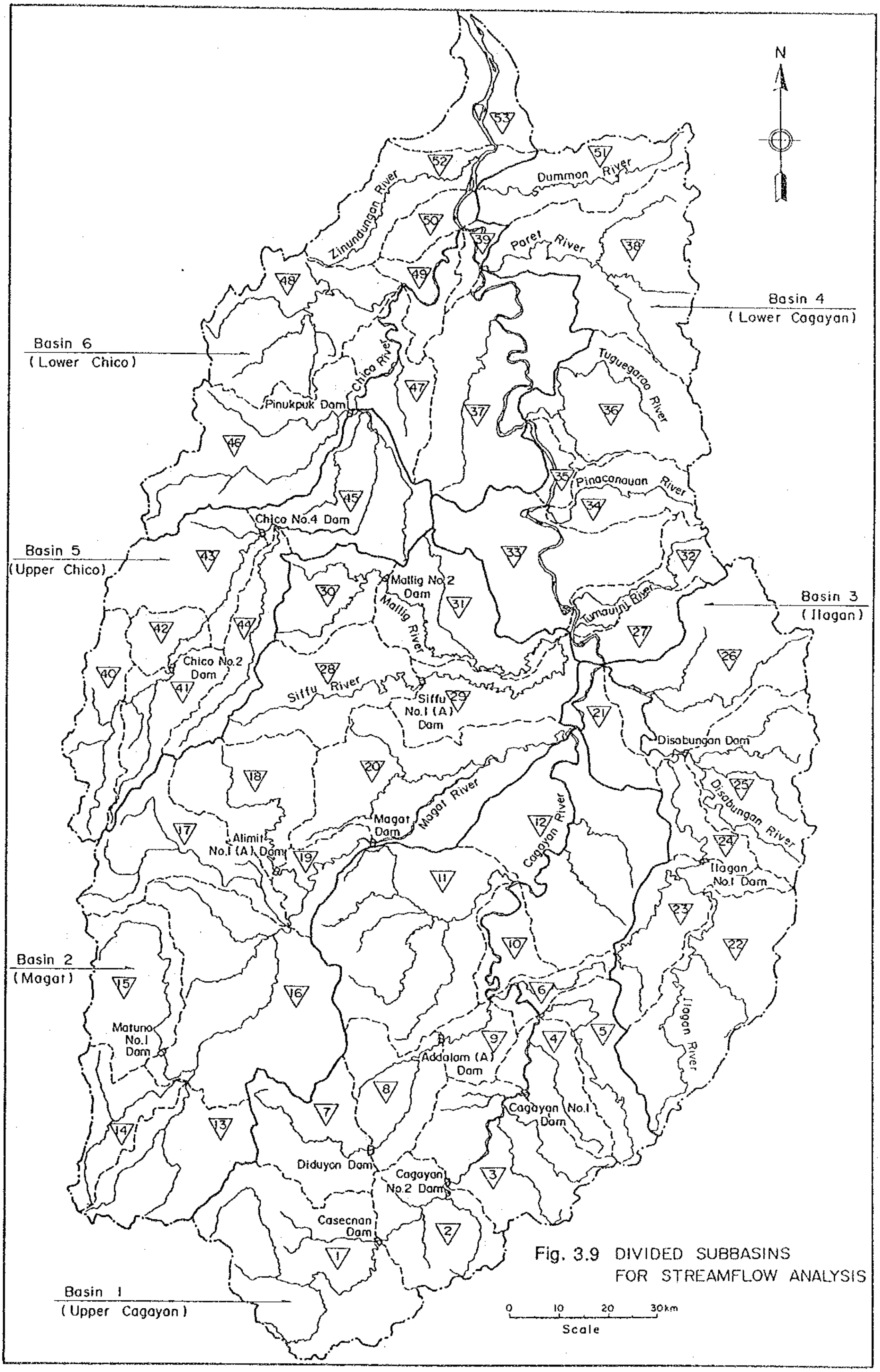


Fig. 3.9 DIVIDED SUBBASINS FOR STREAMFLOW ANALYSIS

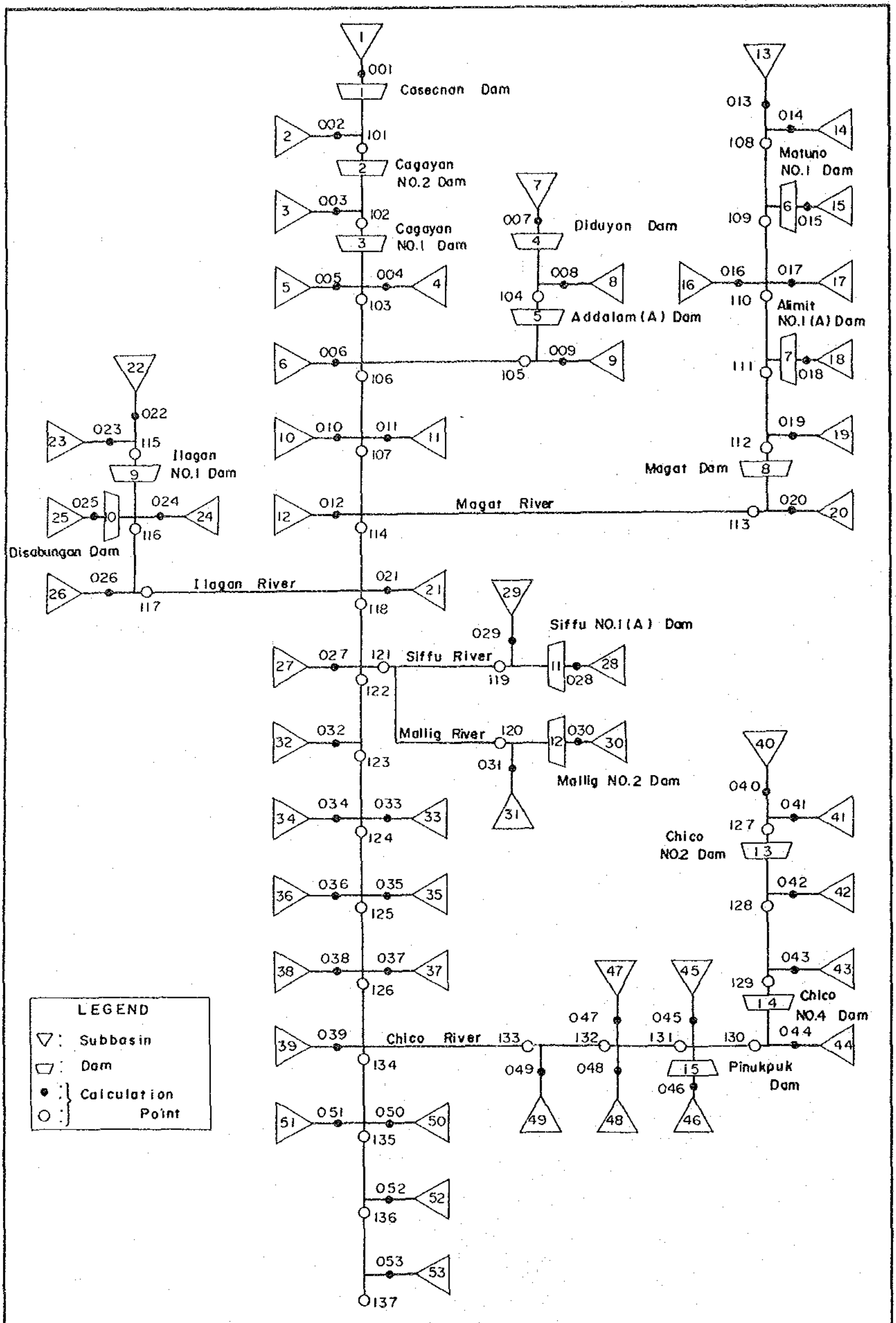


Fig. 3.10 RIVER SYSTEM MODEL FOR STREAMFLOW ANALYSIS

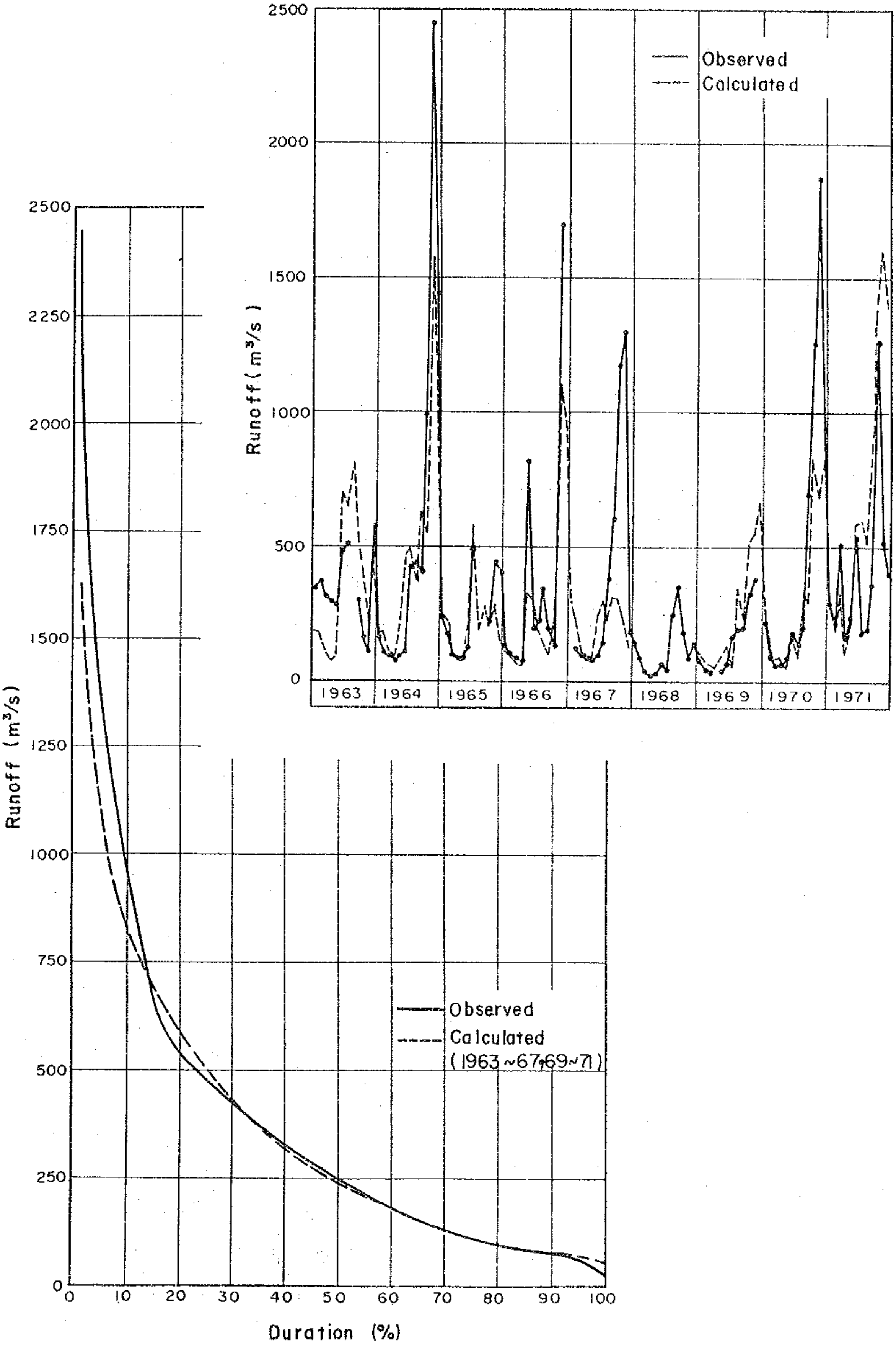


Fig.3.11 HYDROGRAPH AND DURATION CURVE AT PALATTAO

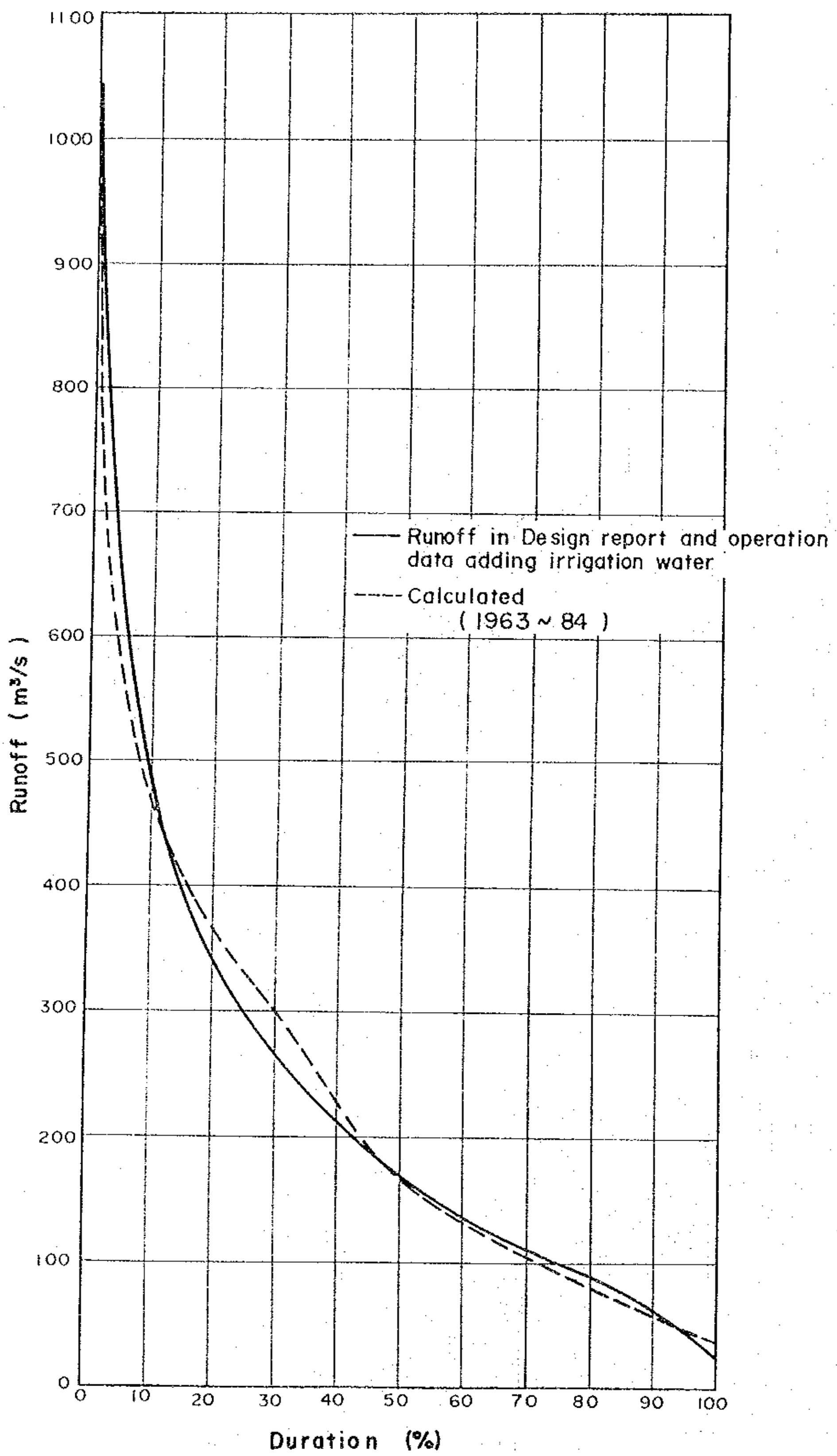


Fig. 3.12 FLOW DURATION CURVE AT MAGAT DAMSITE

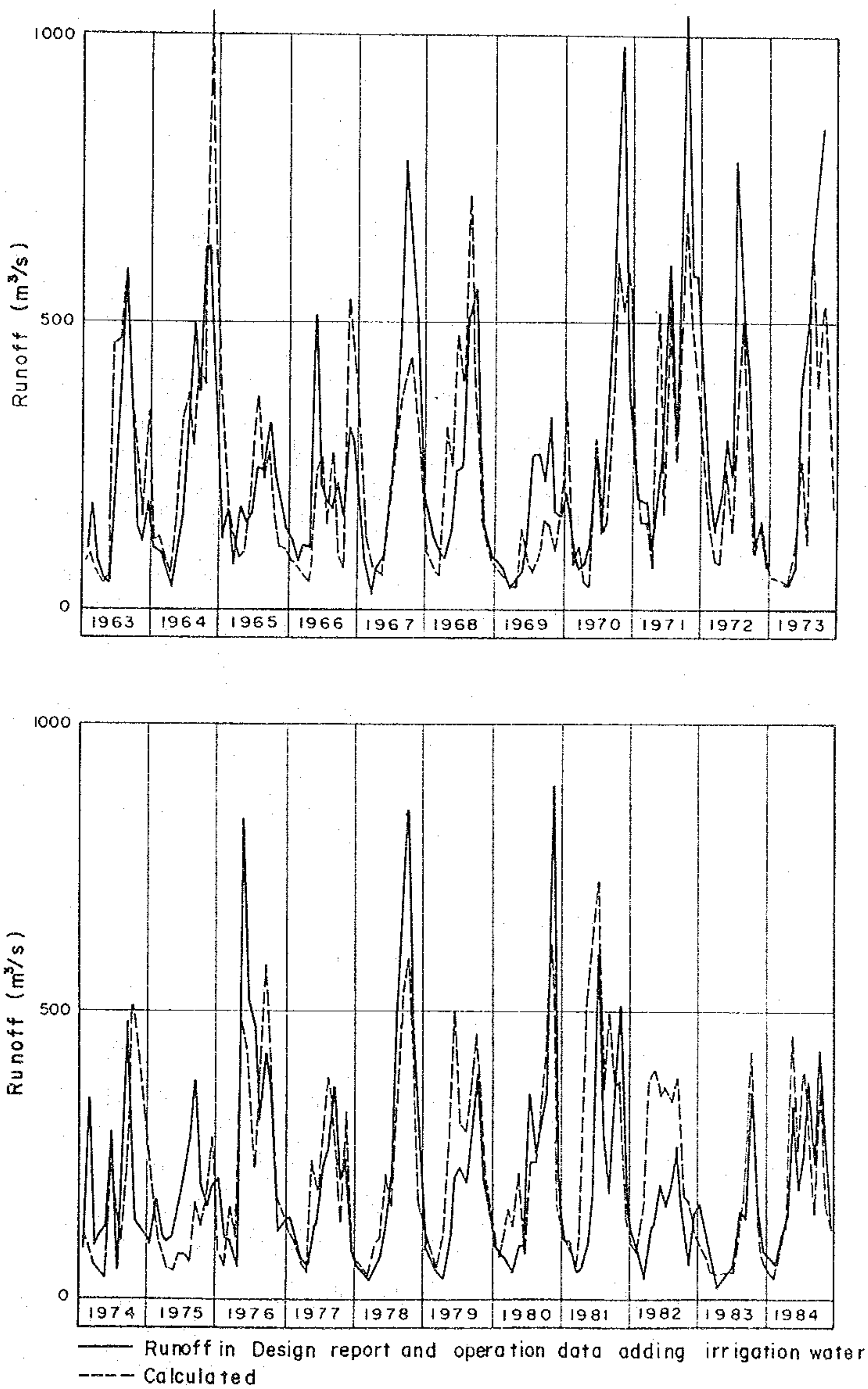


Fig. 3.13 HYDROGRAPH AT MAGAT DAMSITE

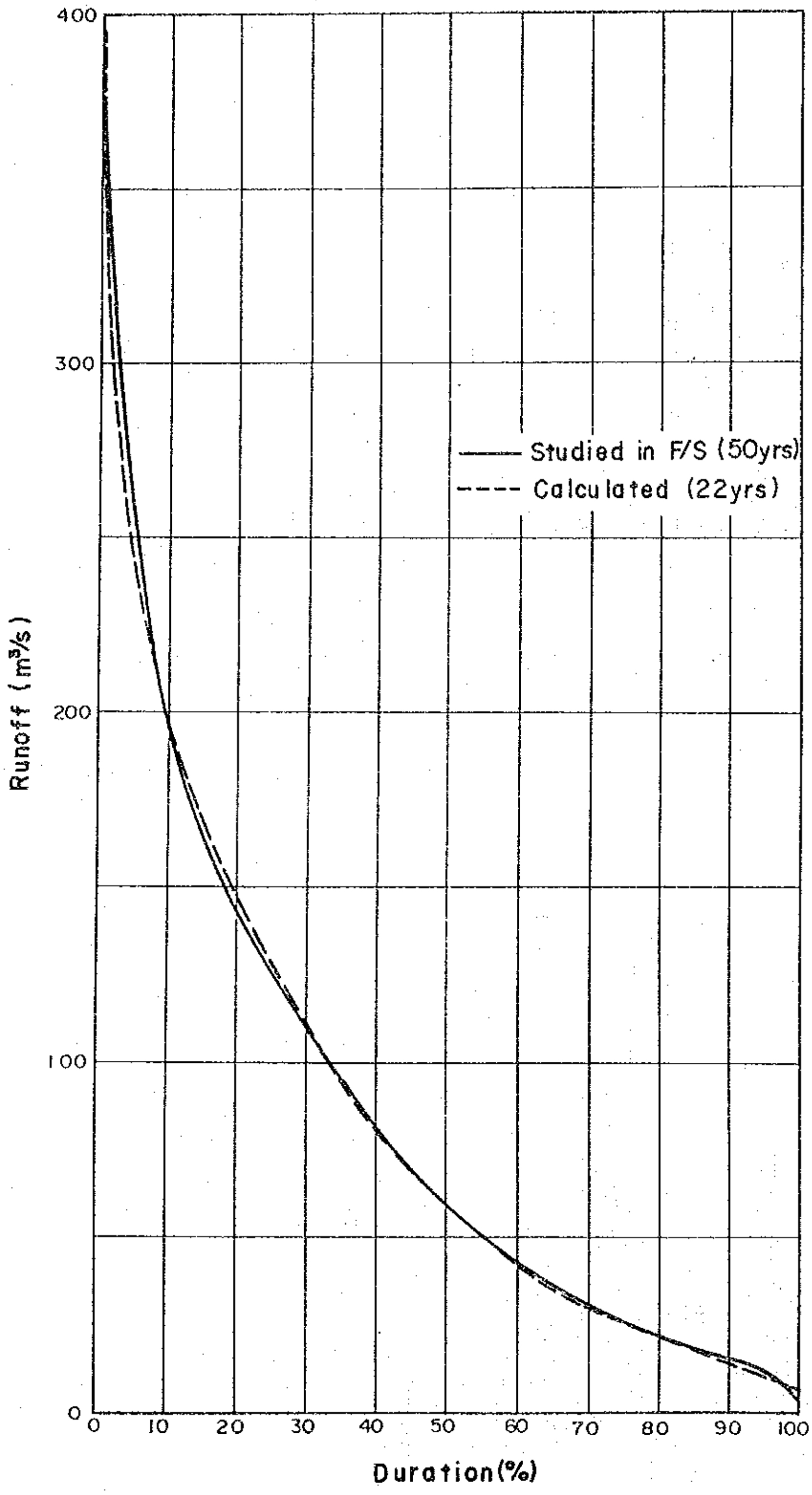


Fig. 3. 14 FLOW DURATION CURVE AT CHICO 4 DAMSITE

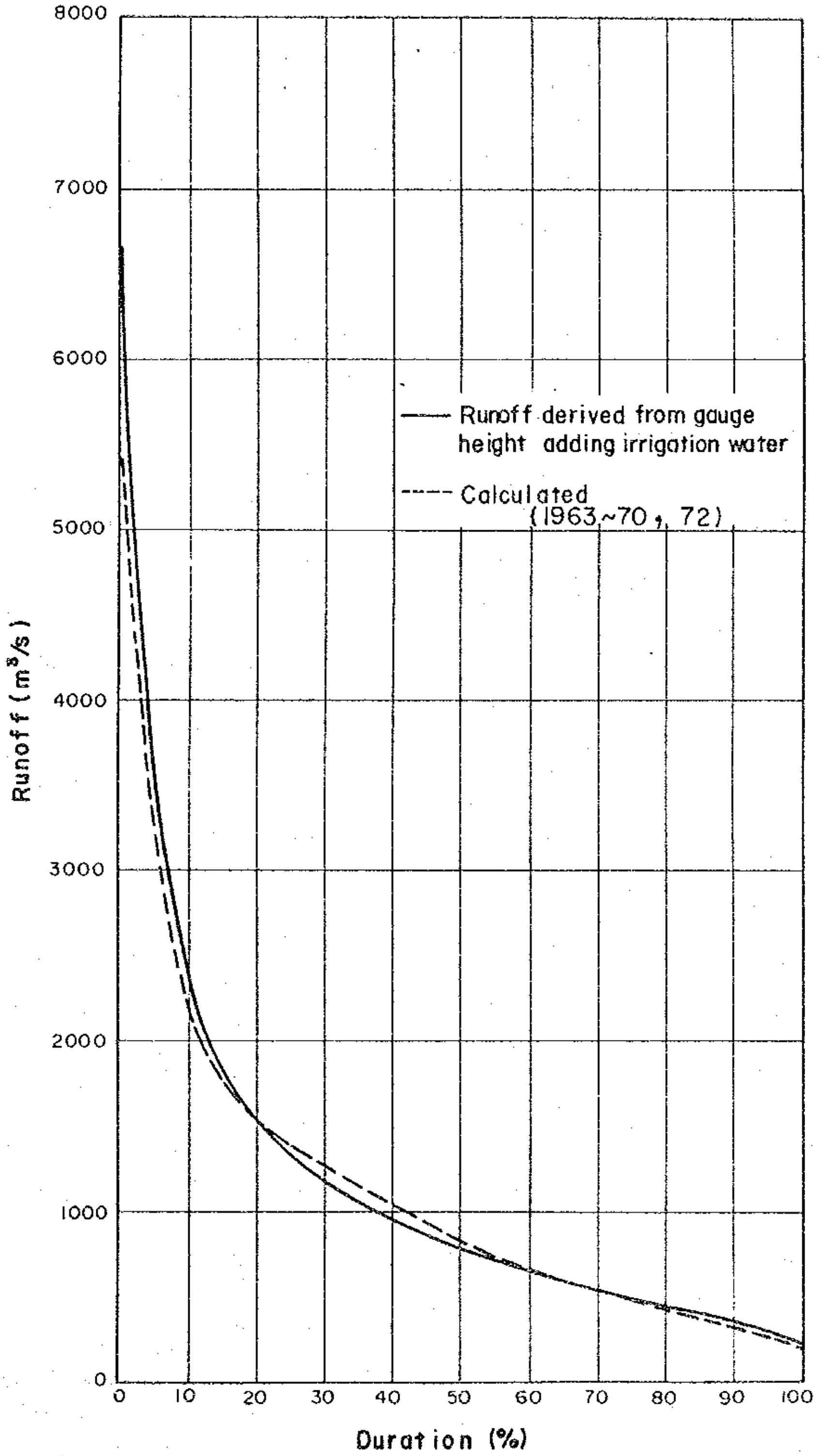


Fig.3.15 FLOW DURATION CURVE AT NASSIPING

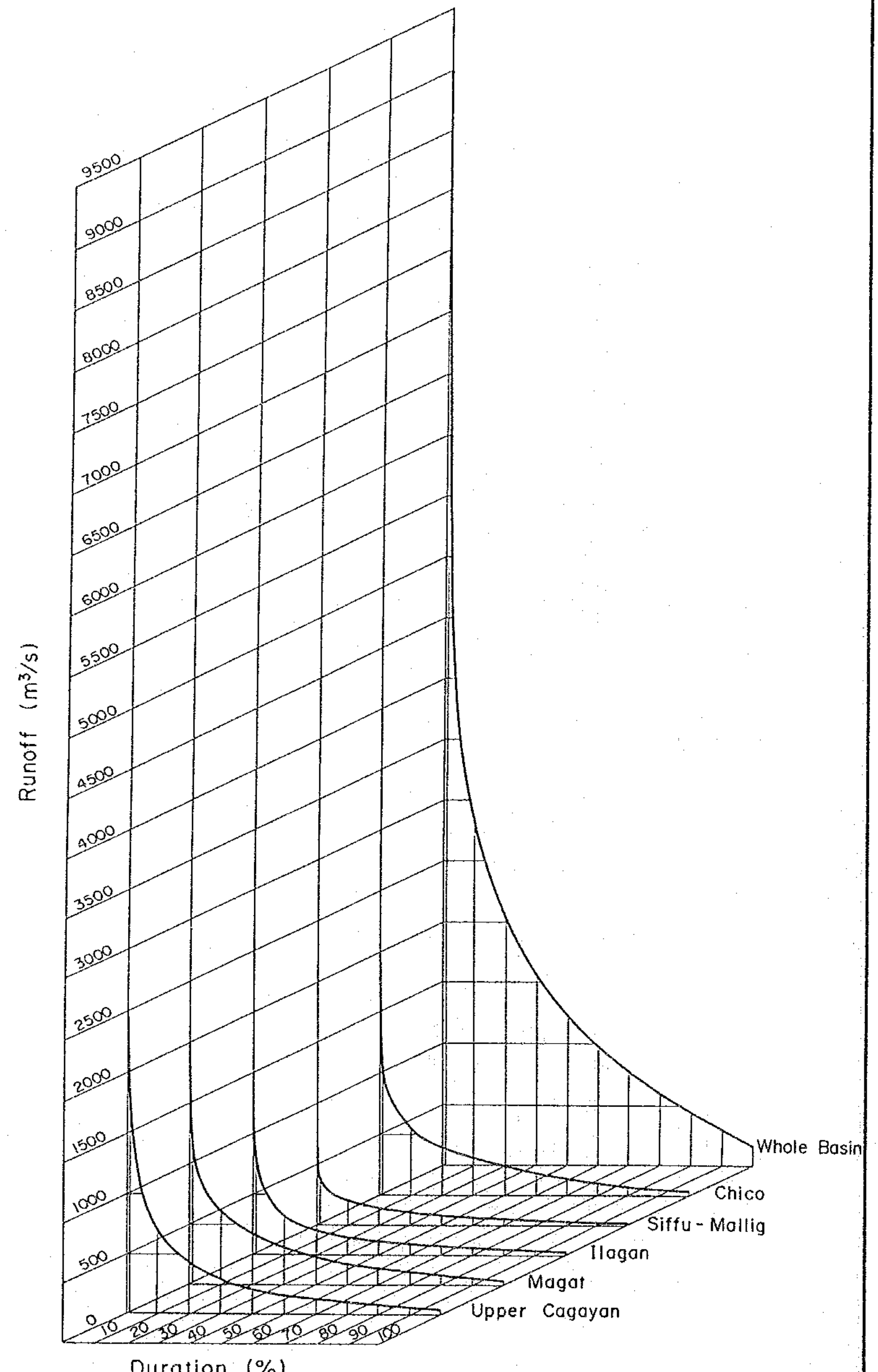


Fig. 3.16 DURATION CURVE OF ESTIMATED 10-DAY RUNOFF (1963-1984)

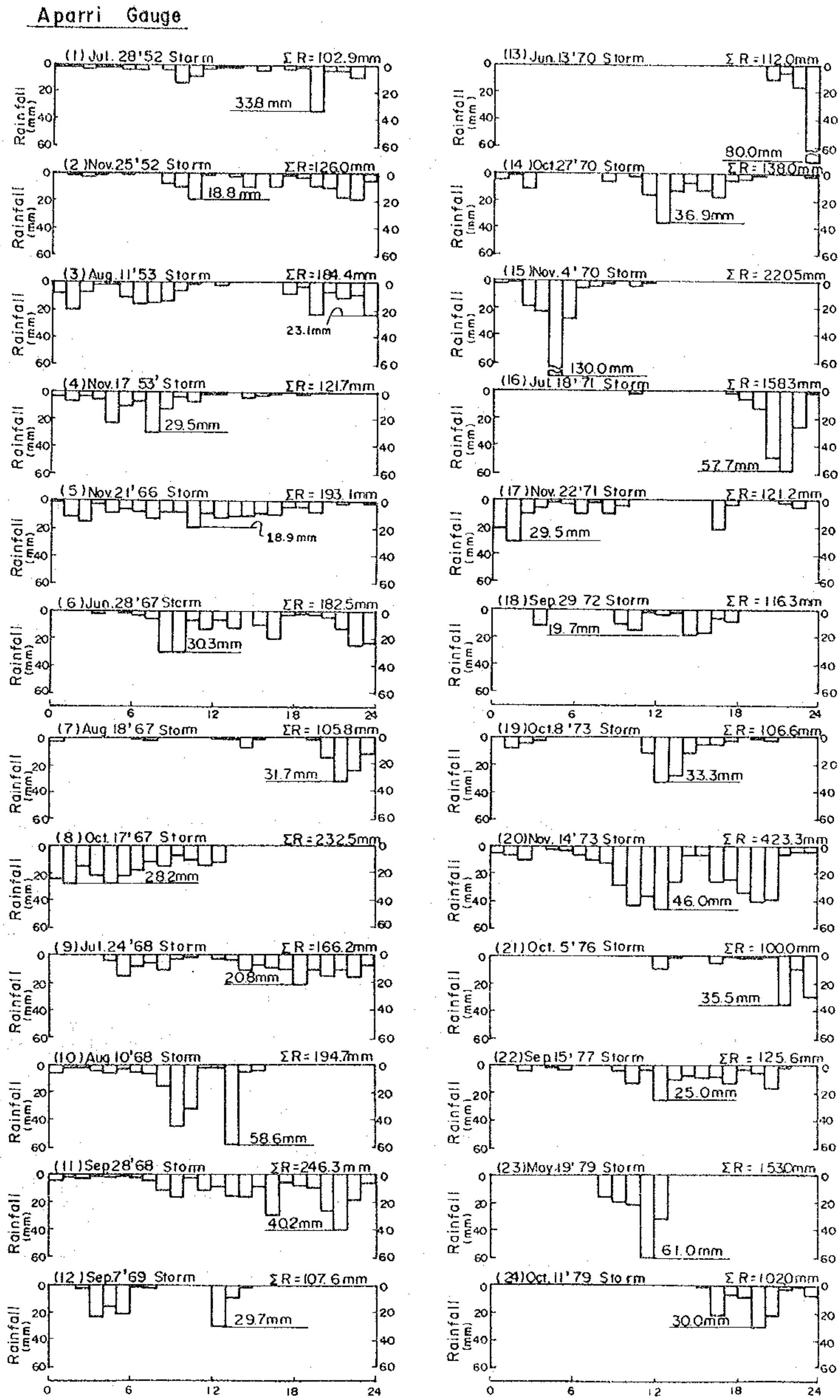
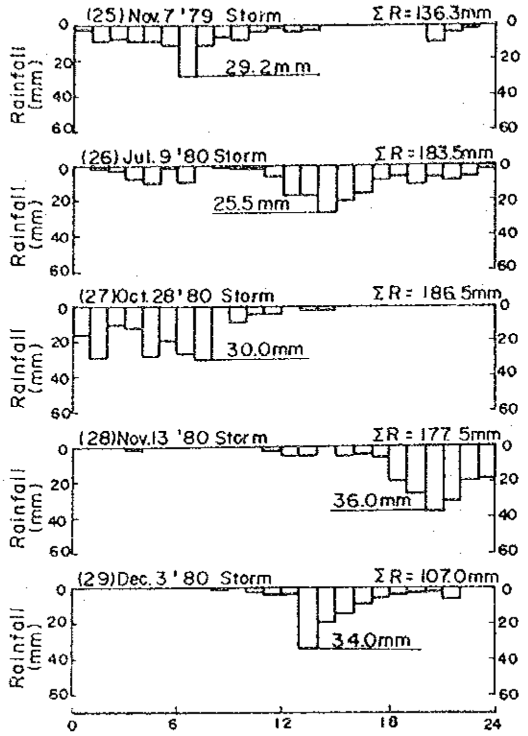


Fig. 4. 1 STORM RECORDS (1)

Aparri Gauge



Tuguegarao Gauge

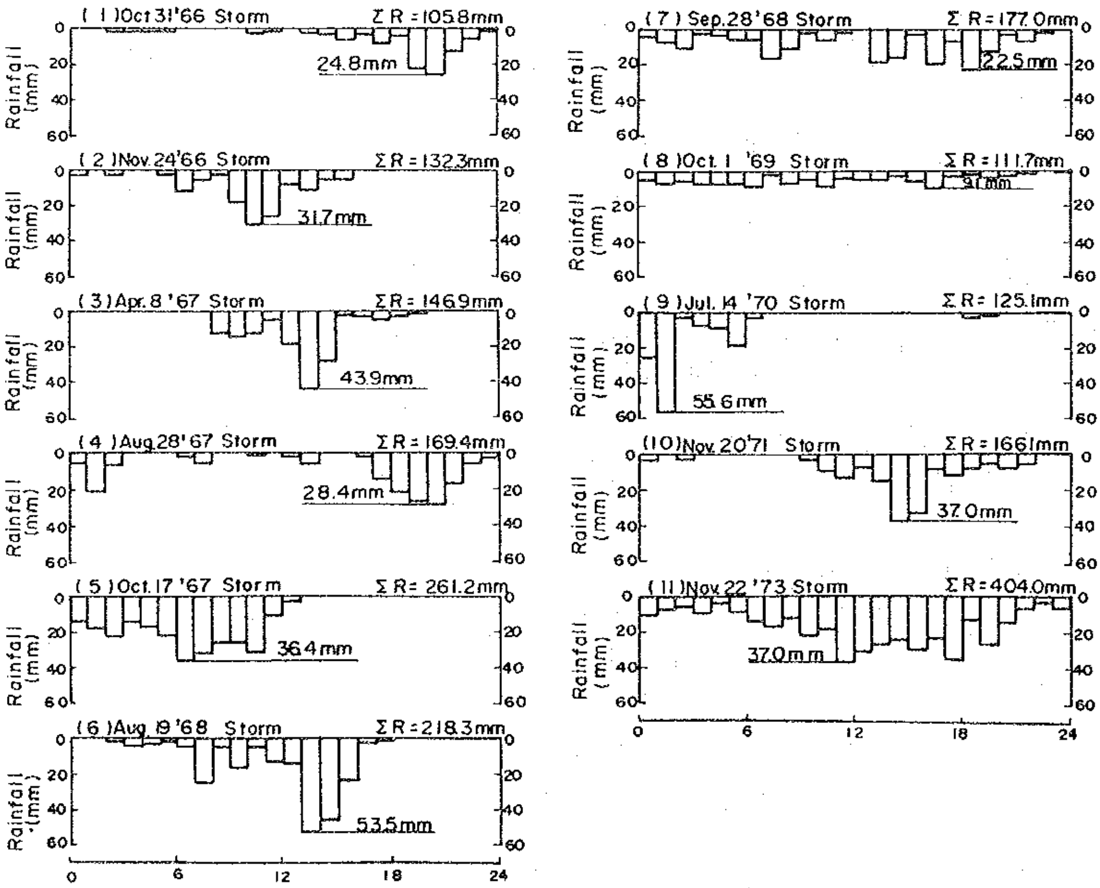
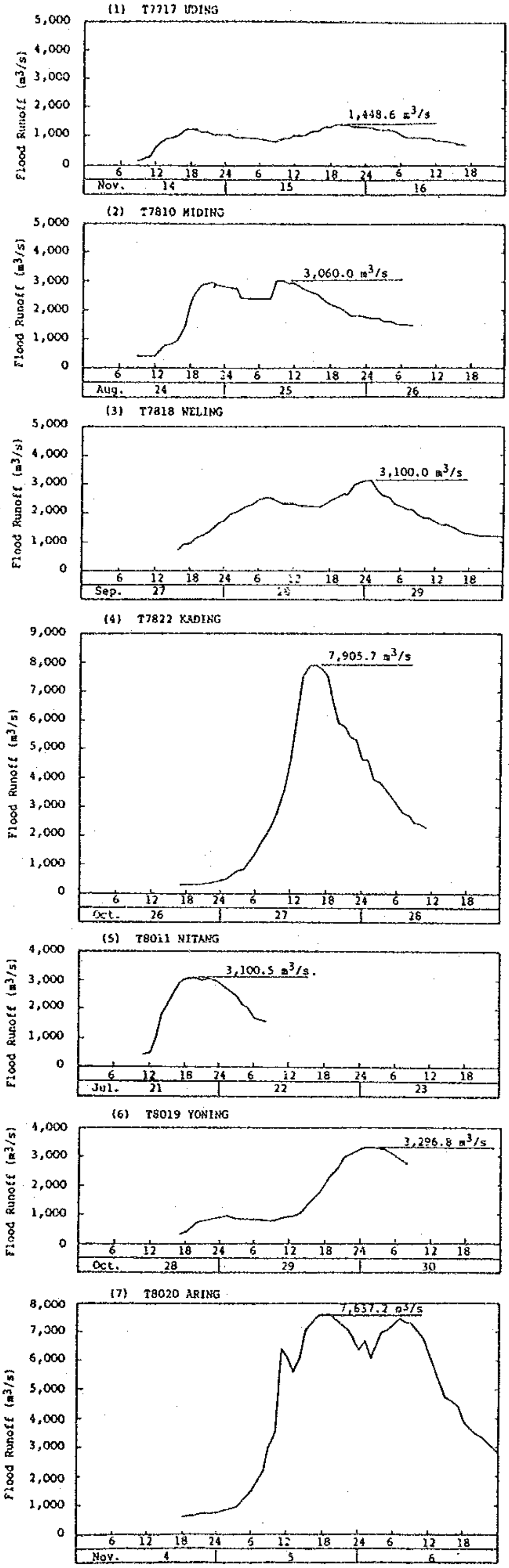


Fig. 4.1 STORM RECORDS (2)



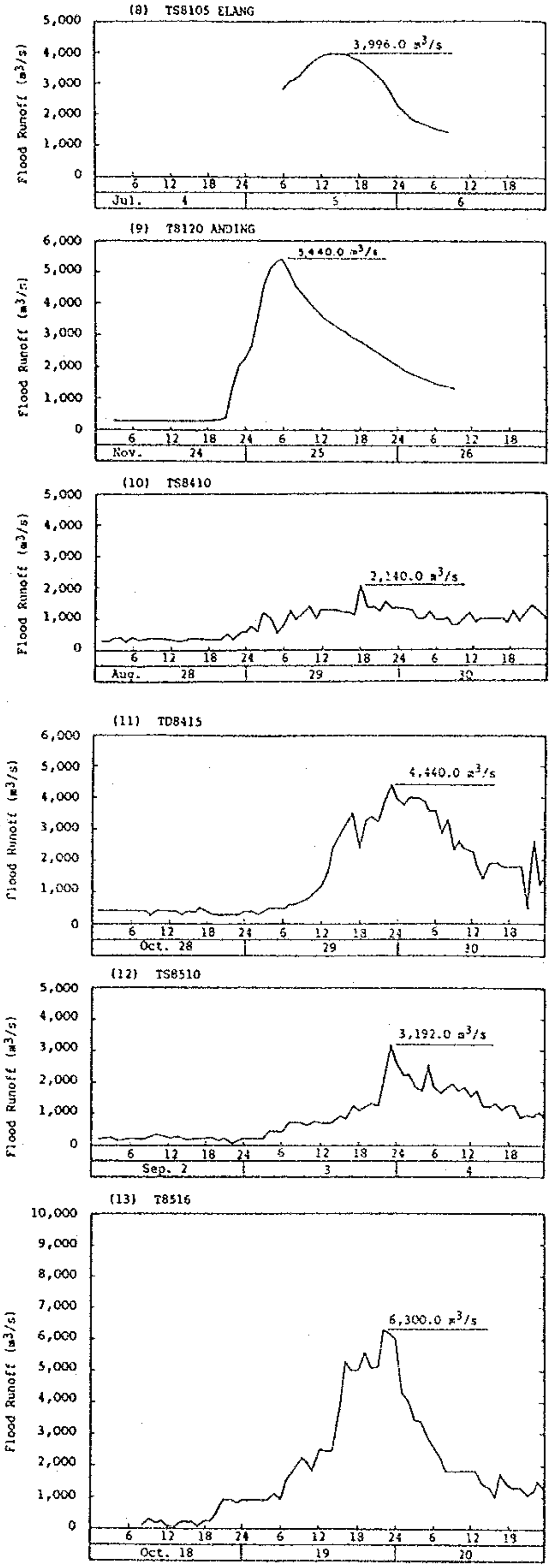


Fig. 4.2 FLOOD HYDROGRAPH AT MAGAT DAMSITE

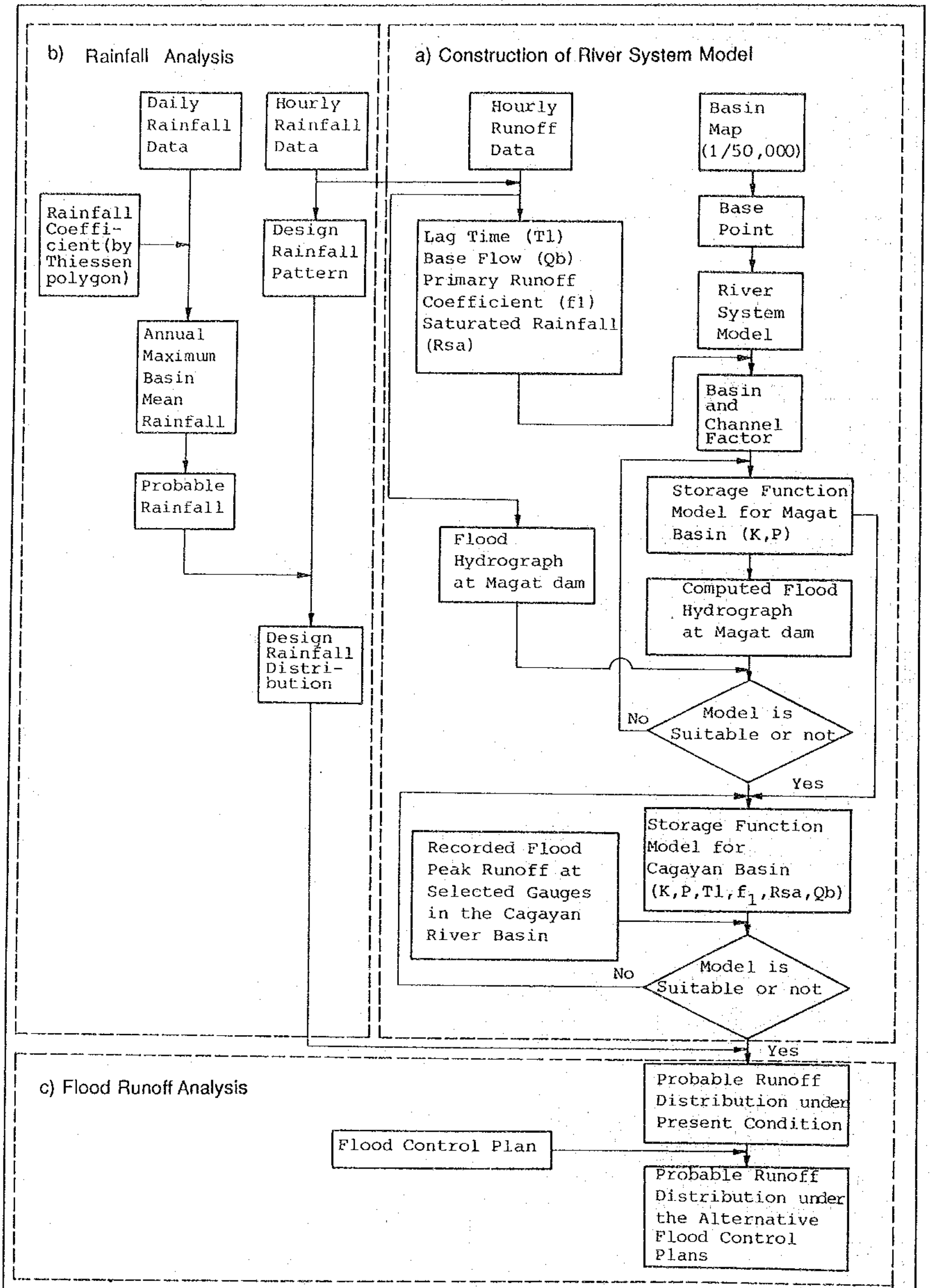


Fig. 4.3 FLOW CHART FOR FLOOD ANALYSIS

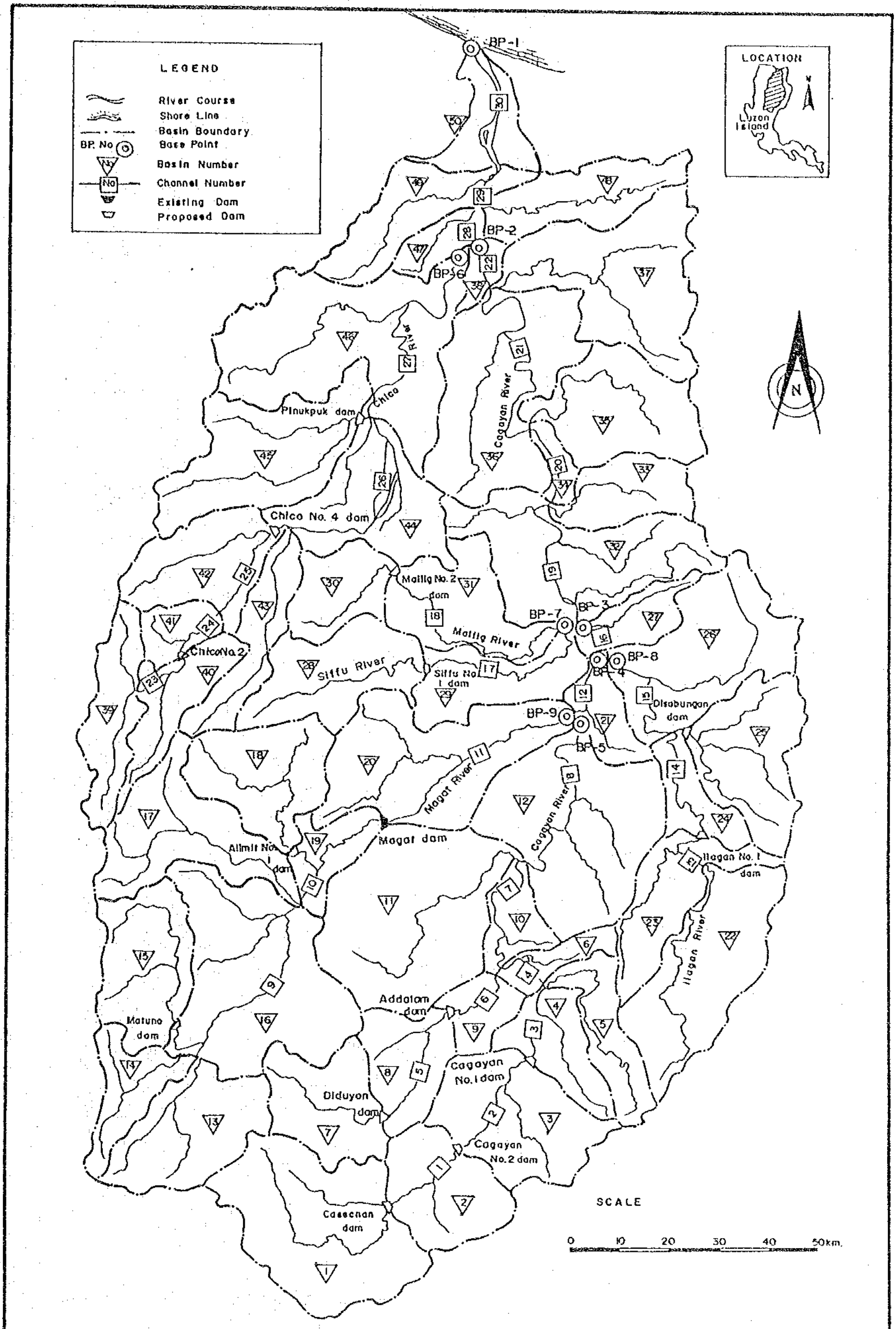


Fig. 4.4 BASIN DIVISION IN THE CAGAYAN RIVER SYSTEM

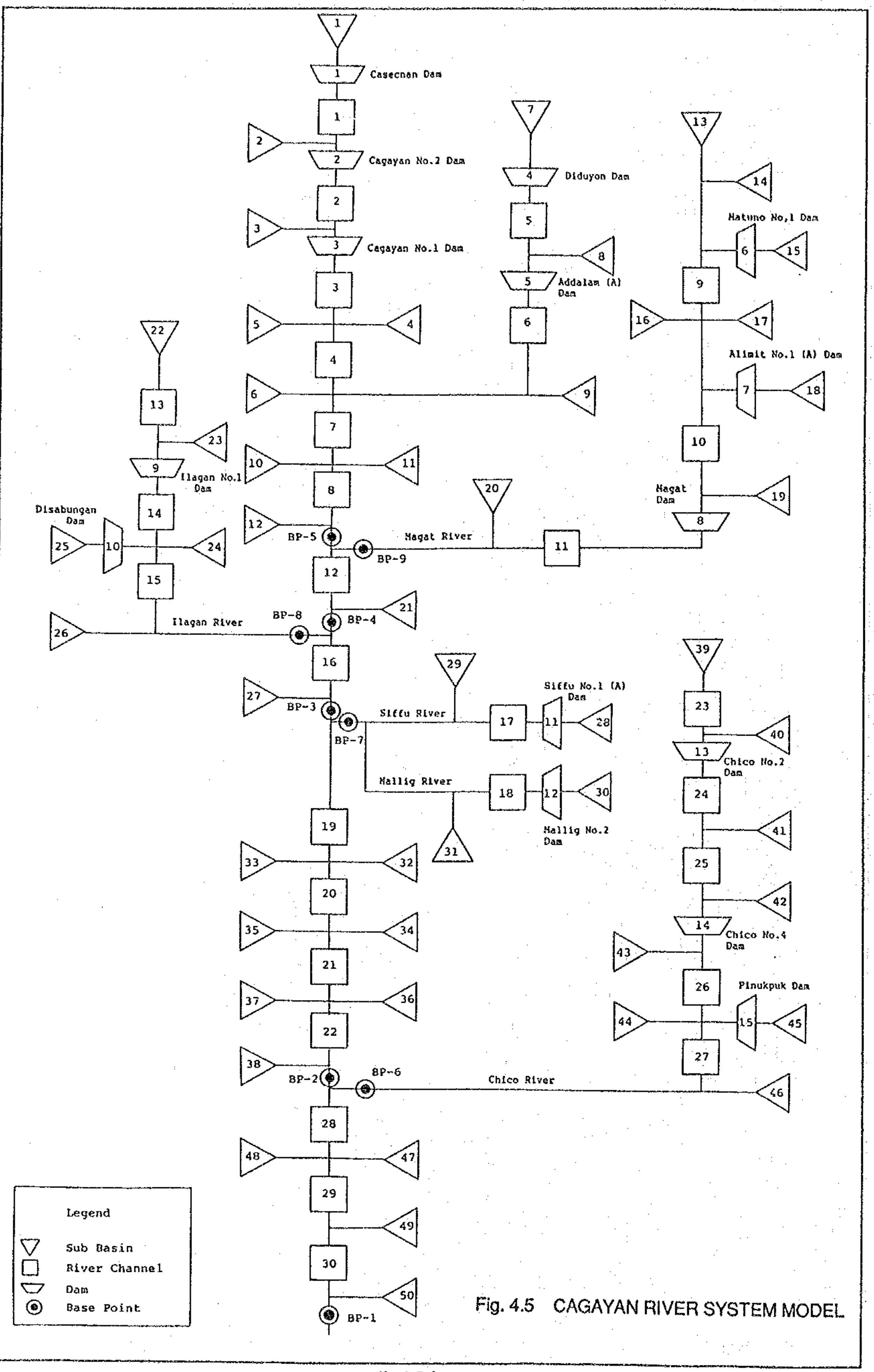


Fig. 4.5 CAGAYAN RIVER SYSTEM MODEL

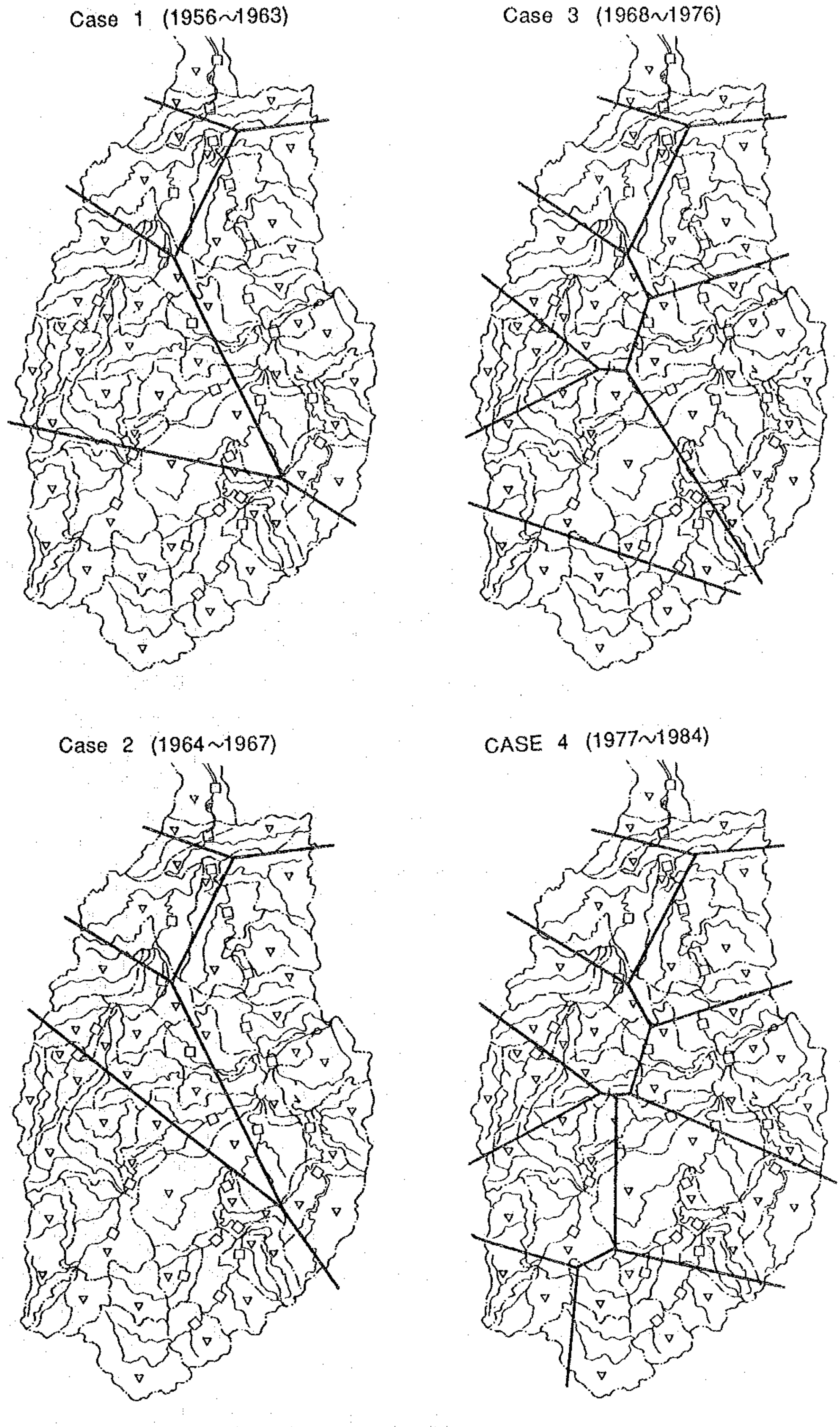
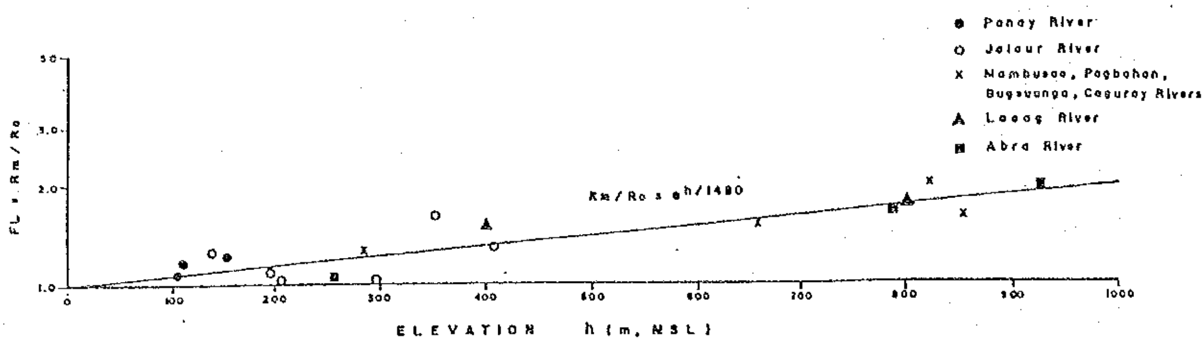


Fig. 4.6 THIESSEN POLYGON OF CAGAYAN RIVER BASIN

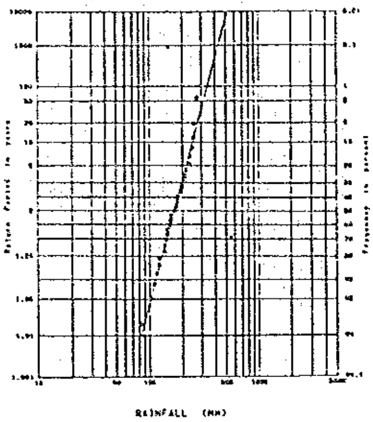


RIVER NAME	STREAM GAGING STATION	DRAINAGE AREA (A: Km^2)	Qann / A (mm / yr)	RUNOFF RATE (mm / yr)	Rm (Qann / f: A) (mm / yr)	FL (Rm / Ro)	AVERAGE BASIN ELEVATION (m, MSL)	Ro (mm / yr)
PANAY RIVER	STA. RITA CUARTERO	880	1780	0.7	2540	1.20	158	2120
	PALAGUIAN MAAYON	265	1480	0.6	2470	1.16	120	2120
	TUNALALUD MAMBUSAO	307	1350	0.6	2250	1.06	111	2120
JALAUR RIVER	ALIBUNAN CALINOG	120	1990	0.8	2480	1.28	418	1940
	SIMSIMAN CALINOG	169	2490	0.8	3110	1.60	359	1940
	POBLACION, PASSI	534	1450	0.6	2420	1.25	180	1940
	PADER, DUEÑAS	247	1390	0.7	1990	1.02	295	1940
	SAN MATIAS DINGLE	1065	1240	0.6	2070	1.07	193	1940
	MINA, POTOTAN	188	1170	0.6	1950	1.01	213	1940
	CALYAN POTOTAN	1490	1420	0.6	2370	1.22	156	1940
MAMBURAO R.	CABACO ABRA DE ILOG	189	3251	0.8	4064	1.59	833	2555
PAGBAHAN R.	TALABIAN, MAMBURAO	283	3660	0.8	4450	2.00	844	2229
BUGSUANGA	BATASAN SAN JOSE	434	2723	0.7	3890	1.50	862	2590
CAGURAY R.	OTOYAN SAN JOSE	136	2688	0.8	3360	1.25	270	2698
LAOAG RIVER	POBLACION LAOAG	1355	2214	0.7	3163	1.49	401	2117
	MANALAC SOLSONA	73	2723	0.8	3404	1.77	804	1928
ABRA RIVER	BANAOANG BANTAY	4813	2512	0.6	4187	1.67	779	2513
	PANG-OT LAGAYON	664	3619	0.7	5170	1.97	952	2620
	LINGSAD PENERUBIA	120	2295	0.8	2869	1.03	267	2780

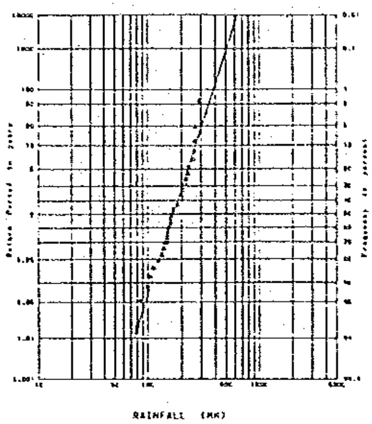
Source : Nationwide Flood Control Plan

Fig. 4.7 ADJUSTMENT FACTOR FOR BASIN MEAN ELEVATION

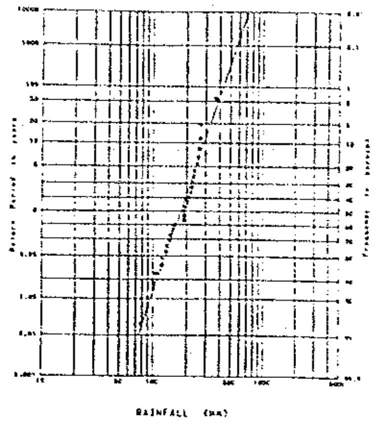
Station: Base Point No.1



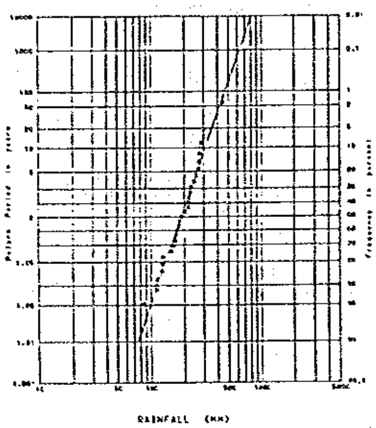
Station: Base Point No.2



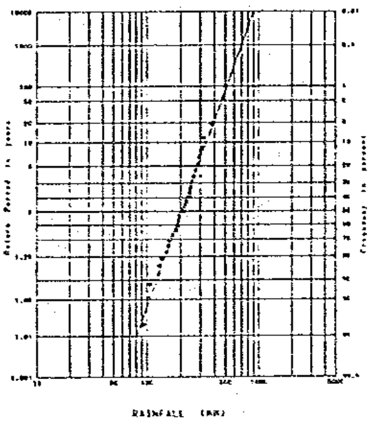
Station: Base Point No.3



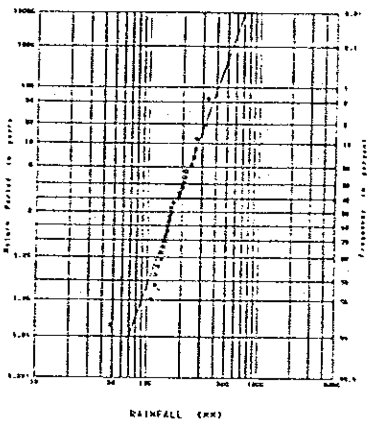
Station: Base Point No.4



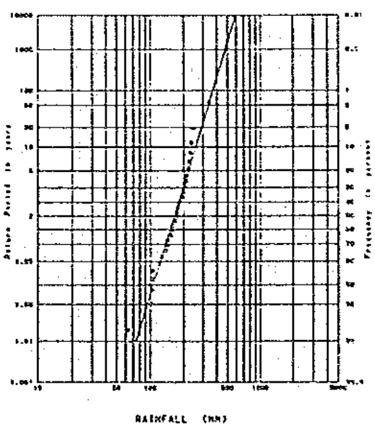
Station: Base Point No.5



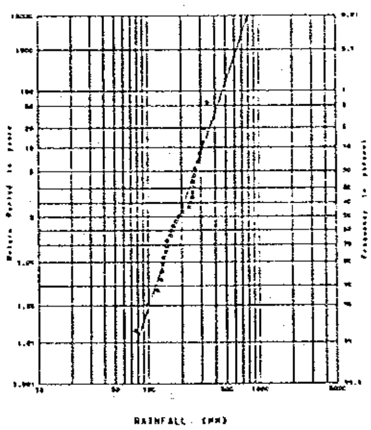
Station: Base Point No.6



Station: Base Point No.7



Station: Base Point No.8



Station: Base Point No.9

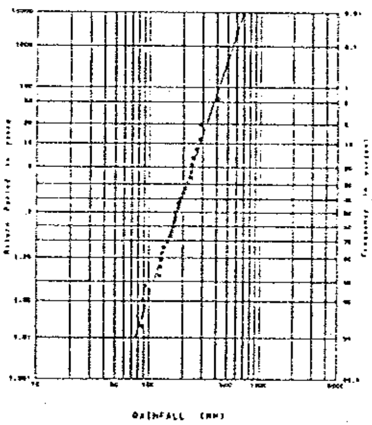
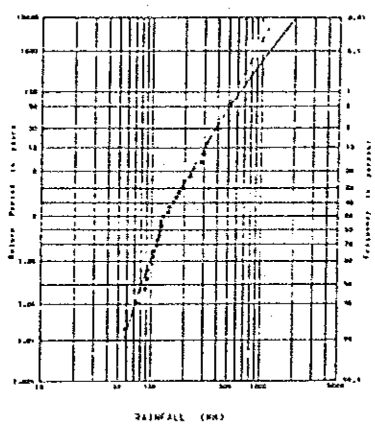
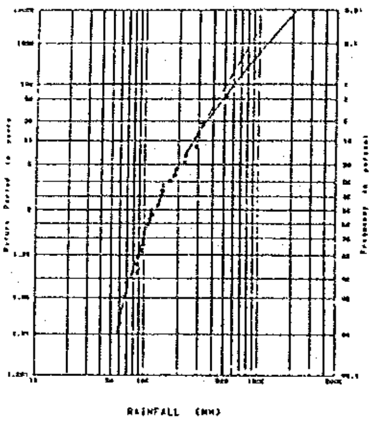


Fig. 4.8 FREQUENCY CURVE OF ANNUAL MAXIMUM RAINFALL(1/3)

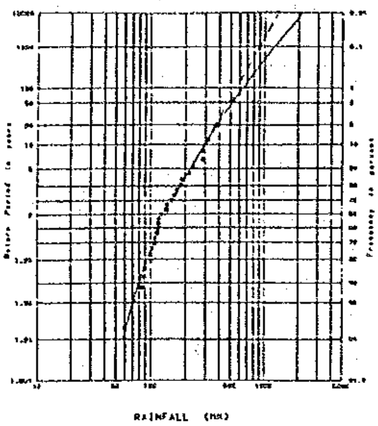
Station: Casecnan Dam



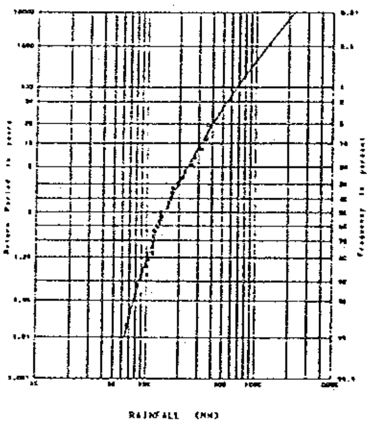
Station: Cagayan No.1 Dam



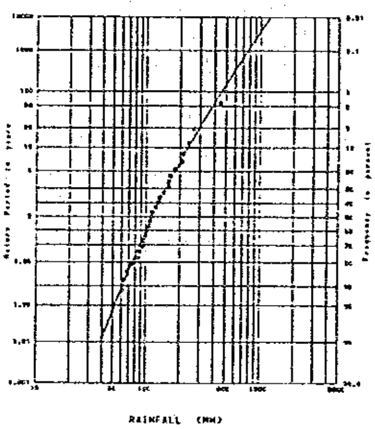
Station: Cagayan No.2 Dam



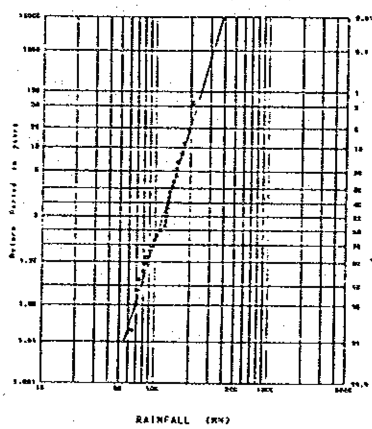
Station: Diduyon Dam



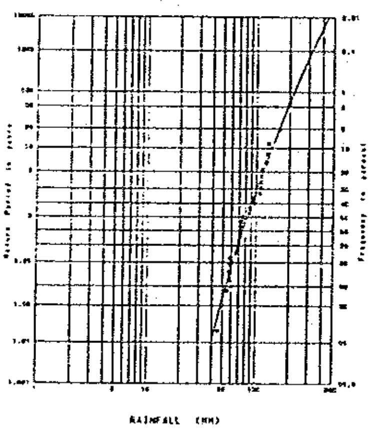
Station: Addalam (A) Dam



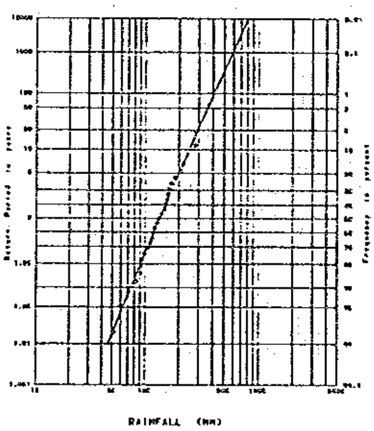
Station: Matuno No.1 Dam



Station: Alimit Dam



Station: Ilagan No.1 Dam



Station: Disabungan Dam

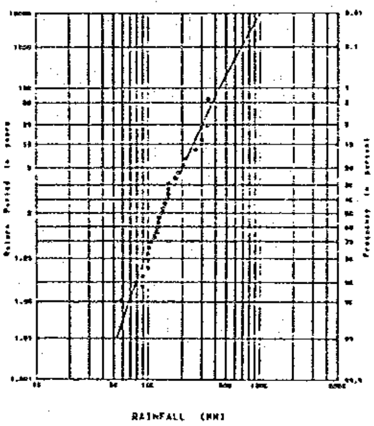
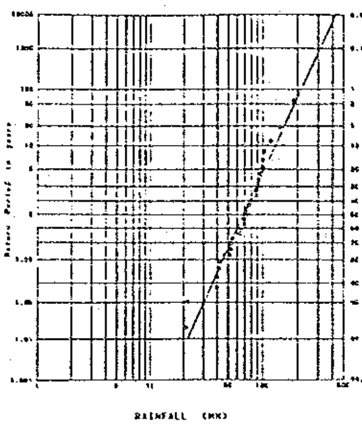
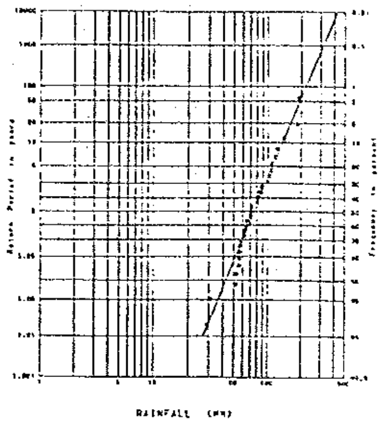


Fig. 4.8 FREQUENCY CURVE OF ANNUAL MAXIMUM RAINFALL(2/3)

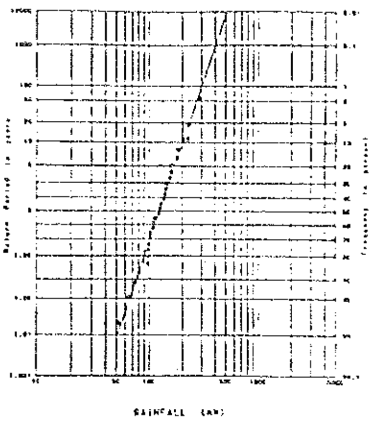
Station: Siffu No.1 (A) dam



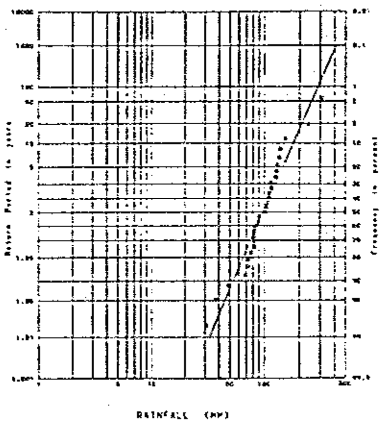
Station: Mallig No 2 Dam



Station: Chico No.2 Dam



Station: Chico No.4 Dam



Station: Pinukpuk Dam

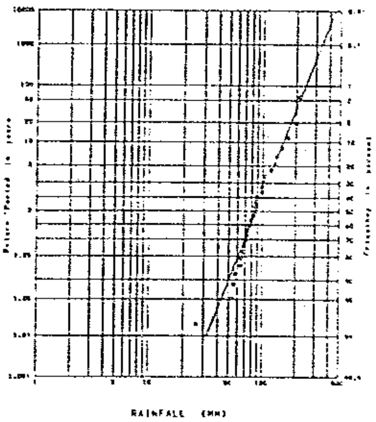
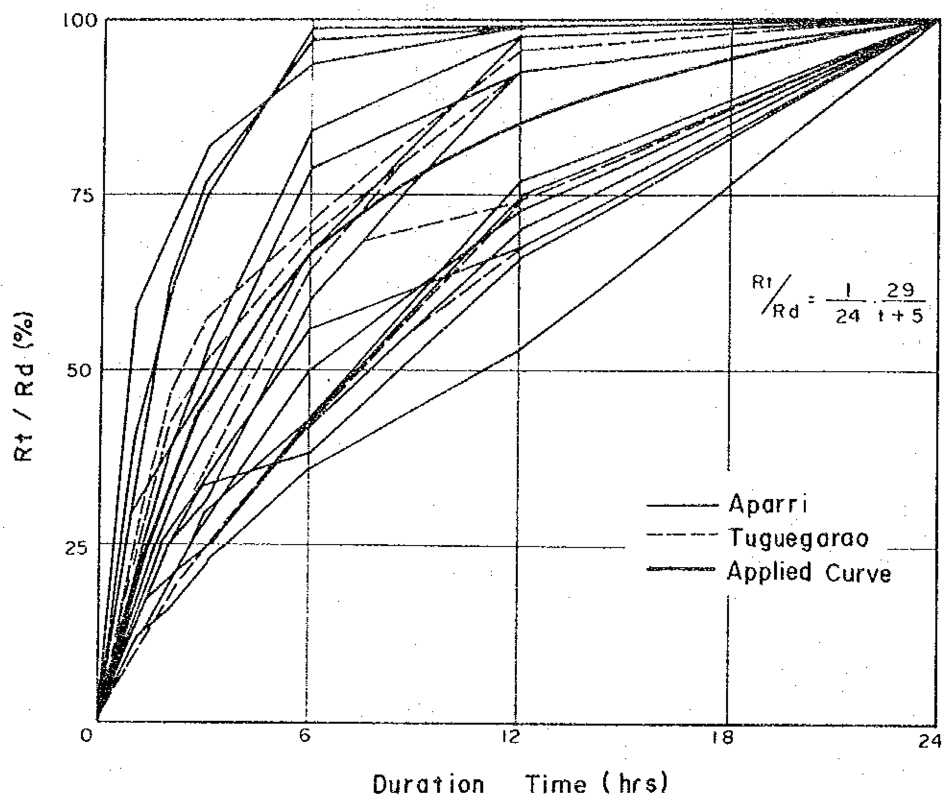


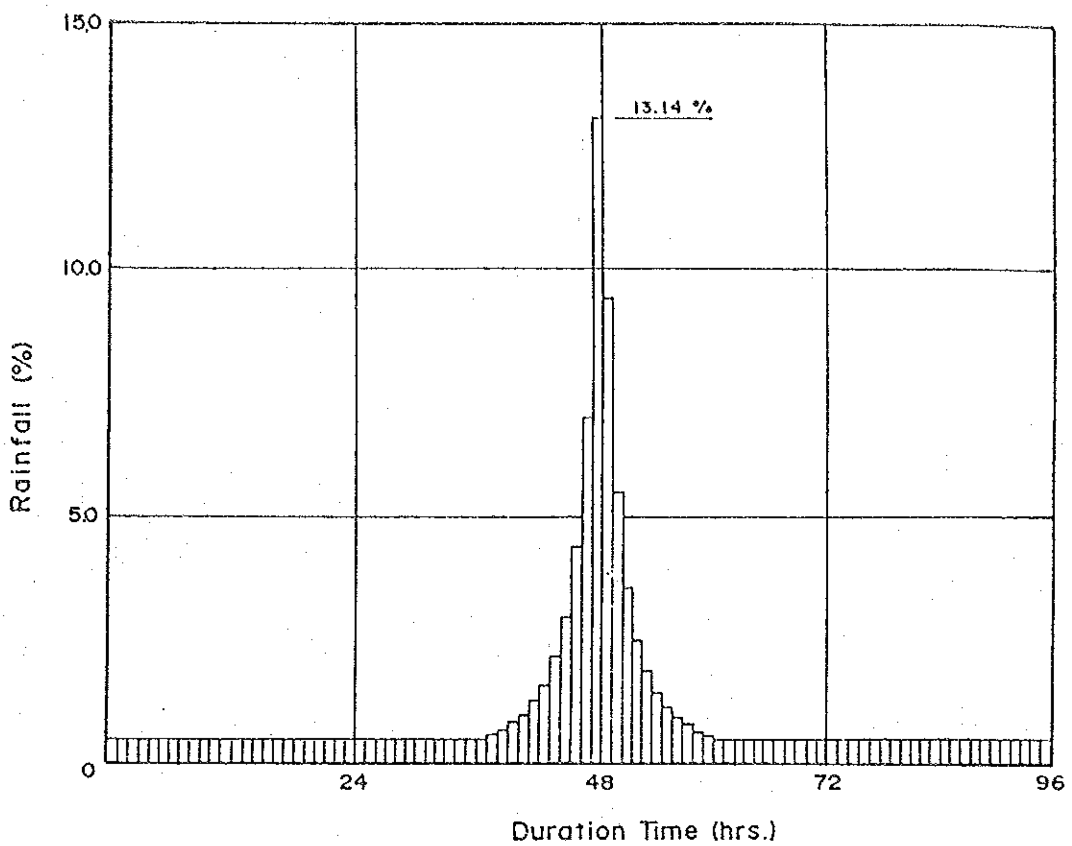
Fig. 4.8 FREQUENCY CURVE OF ANNUAL MAXIMUM RAINFALL(3/3)



t (hrs)	Rt / Rd (%)	t (hrs)	Rt / Rd (%)
1	20.14	13	1.97
2	14.38	14	1.77
3	10.79	15	1.59
4	8.39	16	1.44
5	6.71	17	1.31
6	5.49	18	1.19
7	4.58	19	1.09
8	3.87	20	1.01
9	3.32	21	0.93
10	2.88	22	0.86
11	2.52	23	0.80
12	2.22	24	0.74

Note : 1. Hourly rainfall records of which daily rainfall was larger than 150mm during the years from 1951 to 1984 are used.
2. Rt, Rd : Rainfall at duration (t) and daily rainfall.

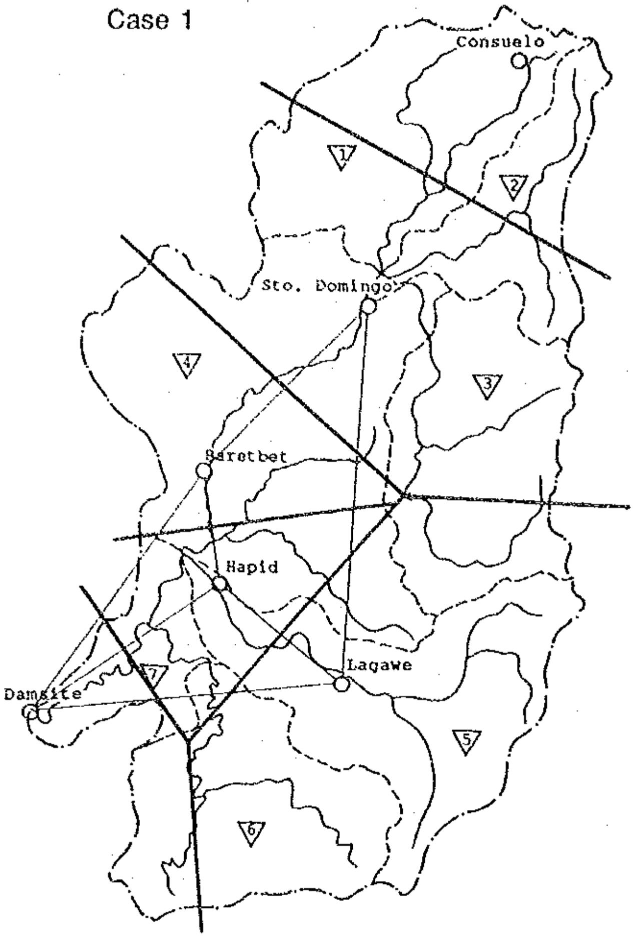
Fig. 4.9 RELATIONSHIP BETWEEN RAINFALL RATE AND DURATION TIME



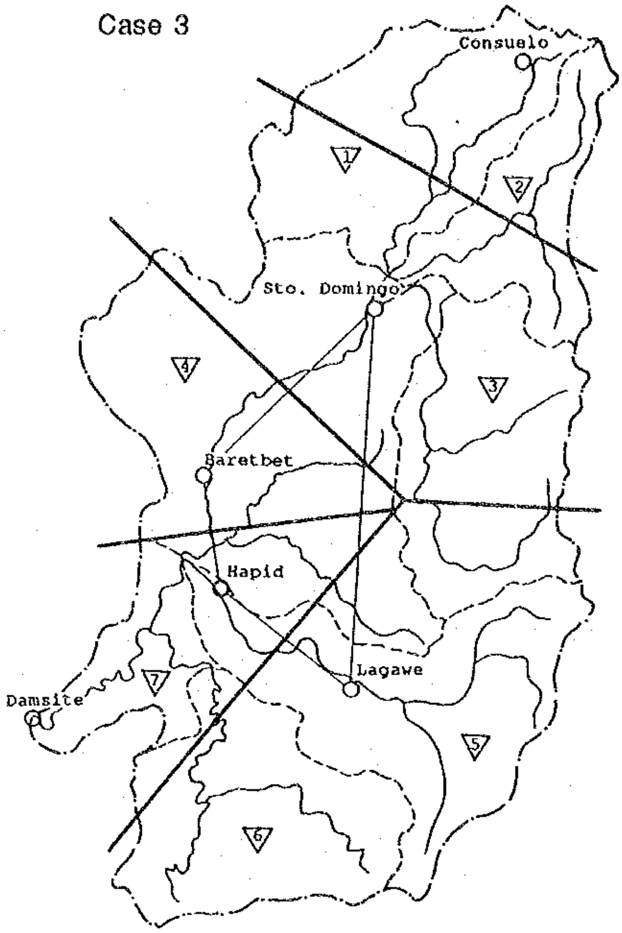
t (hr)	Rainfall (%)	t (hr)	Rainfall (%)	t (hr)	Rainfall (%)	t (hr)	Rainfall (%)
1	0.48	25	0.48	49	9.38	73	0.48
2	0.48	26	0.48	50	5.47	74	0.48
3	0.48	27	0.49	51	3.58	75	0.48
4	0.48	28	0.49	52	2.52	76	0.48
5	0.48	29	0.49	53	1.88	77	0.48
6	0.48	30	0.49	54	1.45	78	0.48
7	0.48	31	0.49	55	1.15	79	0.48
8	0.48	32	0.49	56	0.94	80	0.48
9	0.48	33	0.49	57	0.78	81	0.48
10	0.48	34	0.49	58	0.66	82	0.48
11	0.48	35	0.49	59	0.56	83	0.48
12	0.48	36	0.49	60	0.49	84	0.48
13	0.48	37	0.52	61	0.49	85	0.48
14	0.48	38	0.61	62	0.49	86	0.48
15	0.48	39	0.71	63	0.49	87	0.48
16	0.48	40	0.85	64	0.49	88	0.48
17	0.48	41	1.04	65	0.49	89	0.48
18	0.48	42	1.29	66	0.49	90	0.48
19	0.48	43	1.64	67	0.49	91	0.48
20	0.48	44	2.17	68	0.49	92	0.48
21	0.48	45	2.99	69	0.49	93	0.48
22	0.48	46	4.38	70	0.49	94	0.48
23	0.48	47	7.04	71	0.48	95	0.48
24	0.48	48	13.14	72	0.48	96	0.48

Fig. 4.10 HOURLY RAINFALL DISTRIBUTION

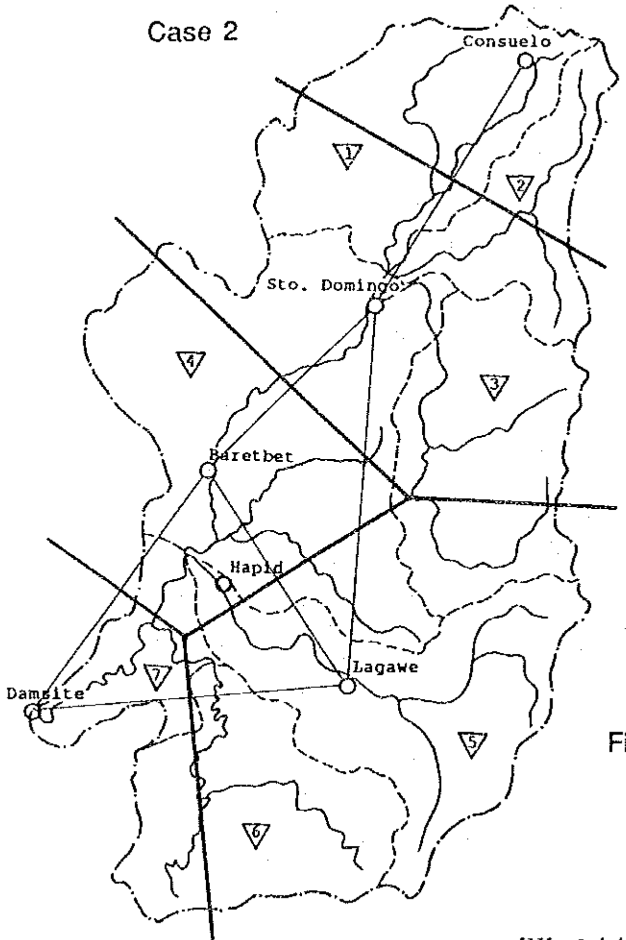
Case 1



Case 3



Case 2



Thiessen Weight

(1) Case 1 (for storm No. 1,2,4,6,7)

Basin No	Damsite	Hapid	Baretbet	Lagawe	Sto. Domingo	Consuelo
1	–	–	–	–	0.42	0.58
2	–	–	–	–	0.53	0.47
3	–	–	0.01	0.32	0.67	–
4	–	0.13	0.45	0.10	0.32	–
5	–	0.12	–	0.88	–	–
6	0.25	0.05	–	0.70	–	–
7	0.44	0.56	–	–	–	–

(2) Case 2 (for Storm No. 8)

Basin No	Damsite	Hapid	Barotbet	Lagawe	Sto. Domingo	Consuelo
1	–	–	–	–	0.42	0.58
2	–	–	–	–	0.53	0.47
3	–	–	0.01	0.32	0.67	–
4	–	–	0.54	0.14	0.32	–
5	–	–	0.03	0.97	–	–
6	0.26	–	–	0.74	–	–
7	0.71	–	0.24	0.05	–	–

(3) Case 3 (for Storm No. 10,12)

Basin No	Damsite	Hapid	Baretbet	Lagawe	Sto. Domingo	Consuelo
1	–	–	–	–	0.42	0.58
2	–	–	–	–	0.53	0.47
3	–	–	0.01	0.32	0.67	–
4	–	0.13	0.45	0.10	0.32	
5	–	0.12	–	0.88	–	–
6	–	0.26	–	0.74	–	–
7	–	1.00	–	–	–	–

Note: ▽1 ; Basin No. 1

Fig. 4.11 THIESSEN POLYGON OF MAGAT DAM BASIN

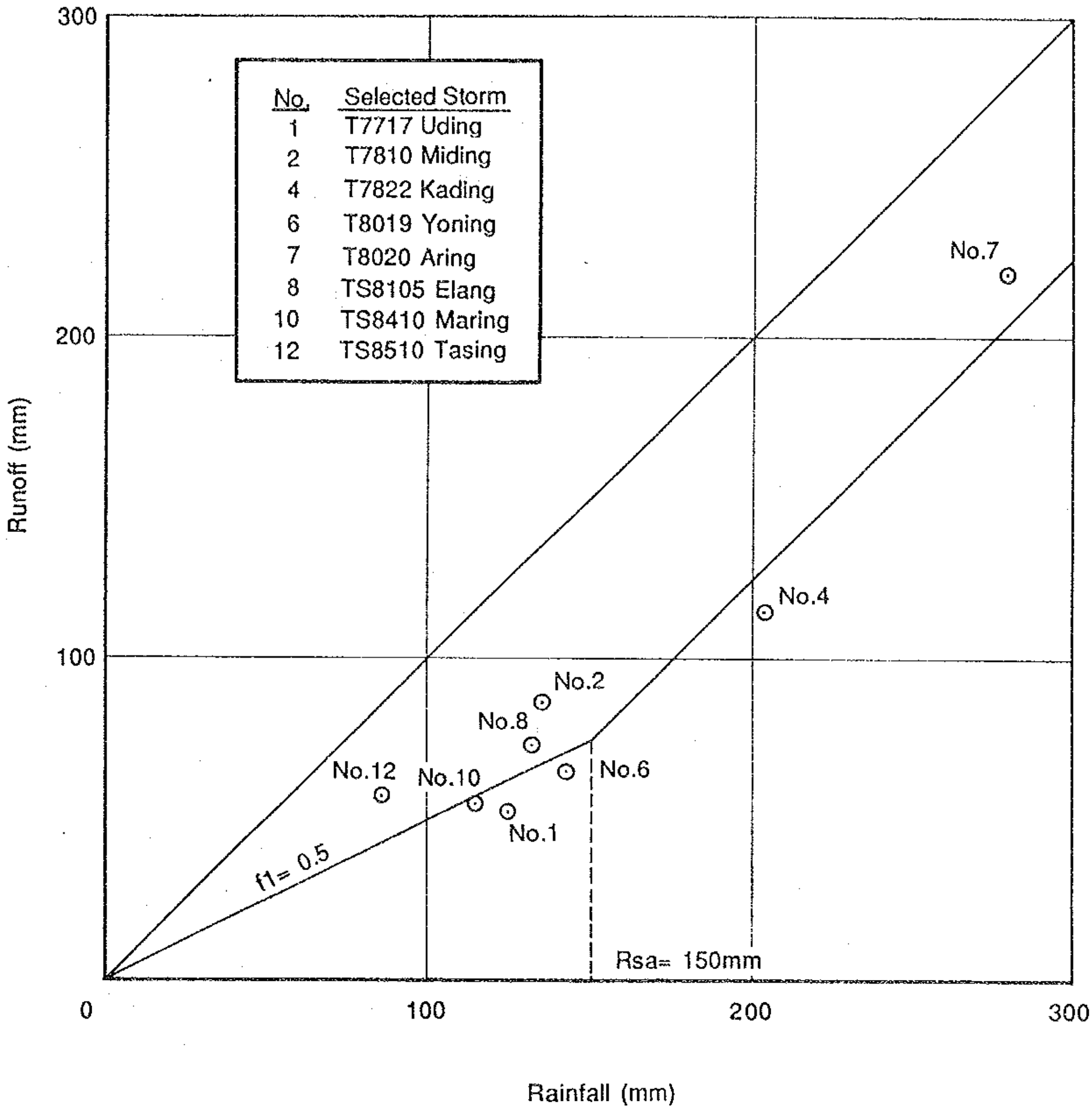
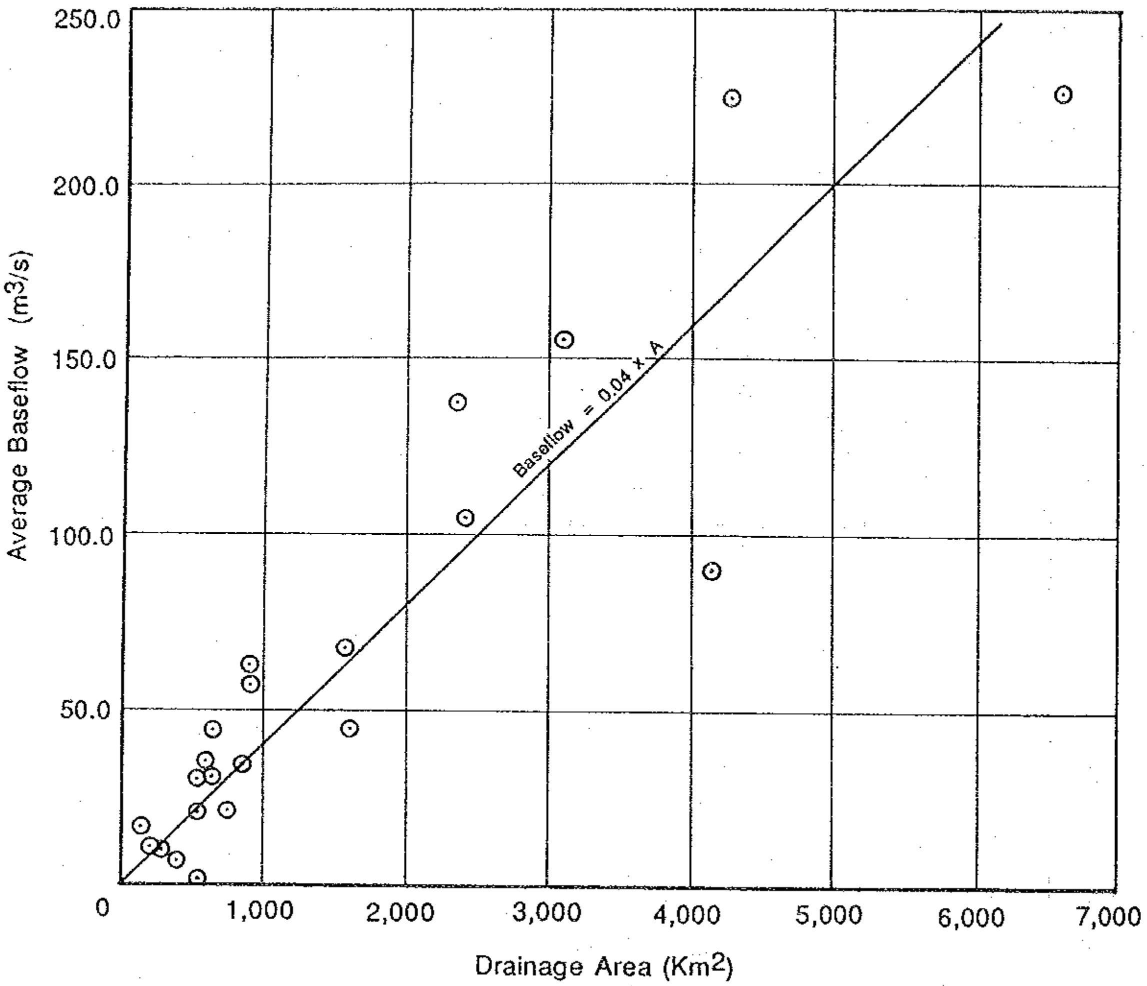


Fig. 4.12 PRIMARY RUNOFF COEFFICIENT (f1) AND SATURATED RAINFALL (Rsa)



Station	Drainage Area (Km²)	Average Baseflow (m³/s)	Station	Drainage Area (km²)	Average Baseflow (m³/s)
Calaoagan	308	10.39	Dipalin	198	11.06
Calantac	907	62.08	Oscariz	4,150	89.97
Escolta	655	30.90	Dulao	573	21.28
Larion Alto	655	44.51	Hapid	606	34.72
Pinukpuk	856	33.59	Camandag	261	10.82
Antagan	170	17.39	Pangal	4,244	85.78
Ampawilen	751	21.23	Panang	2,392	105.83
Taed	391	6.63	Guinalvin	921	56.60
Malalam	3,123	180.00	Bante	558	30.11
Palattao	6,626	237.52	Bato	1,649	45.48
Supang	57	1.08	Dippadiw	2,380	138.25
Minanga	1,565	67.68			

Fig. 4.13 BASEFLOW CURVE

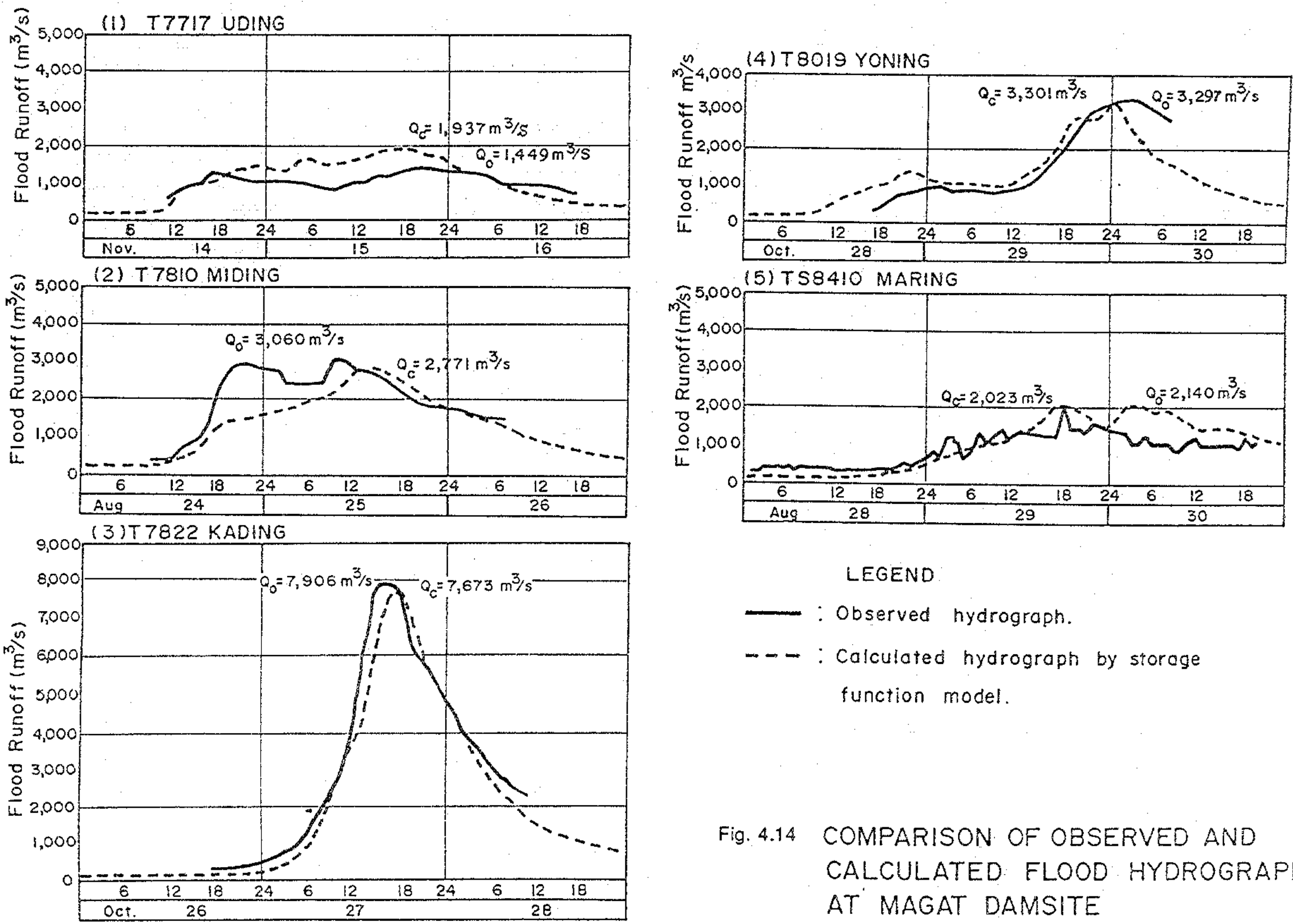


Fig. 4.14 COMPARISON OF OBSERVED AND CALCULATED FLOOD HYDROGRAPH AT MAGAT DAMSITE

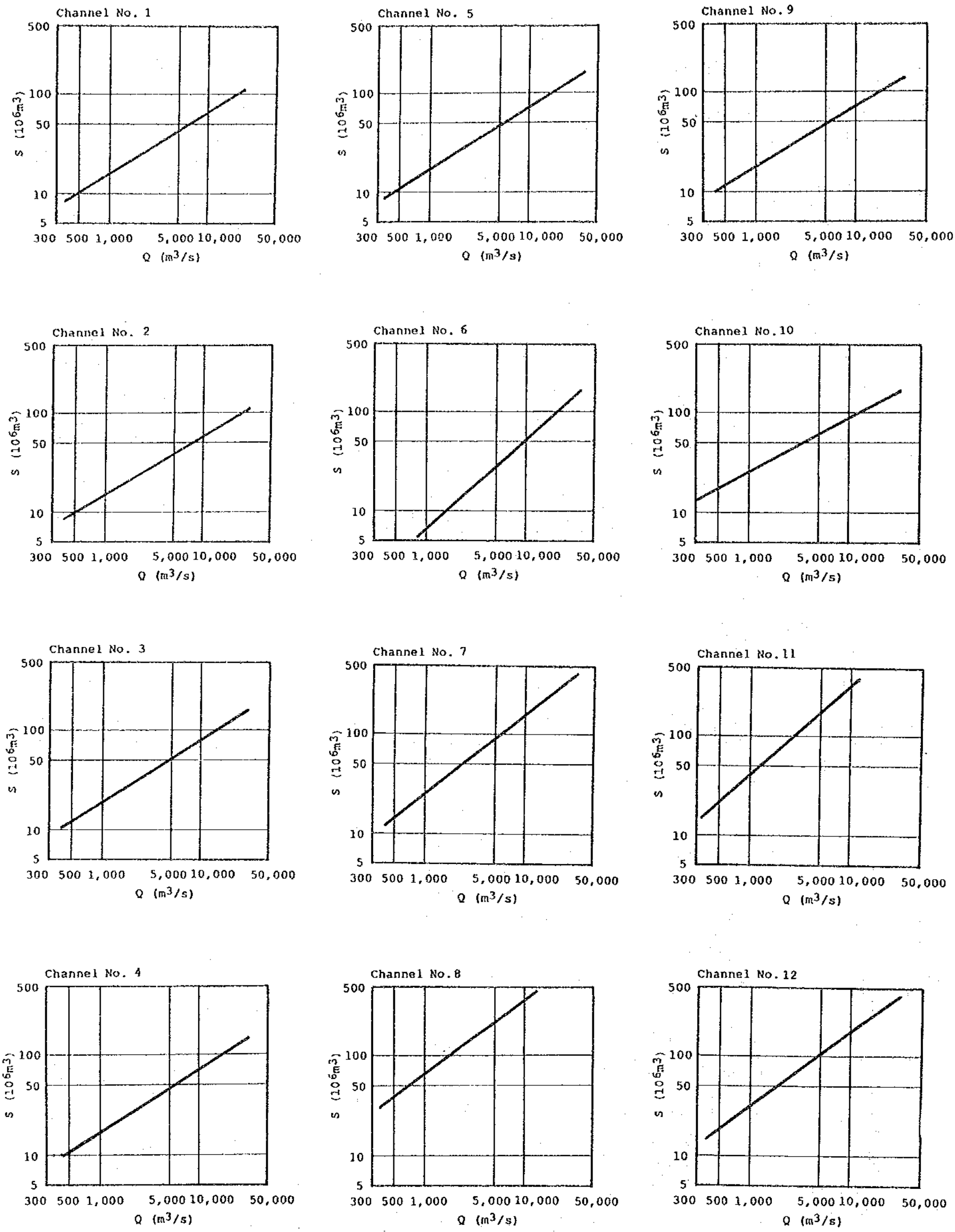


Fig. 4.15 CHANNEL STORAGE CURVE UNDER THE PRESENT RIVER CONDITION (1/3)

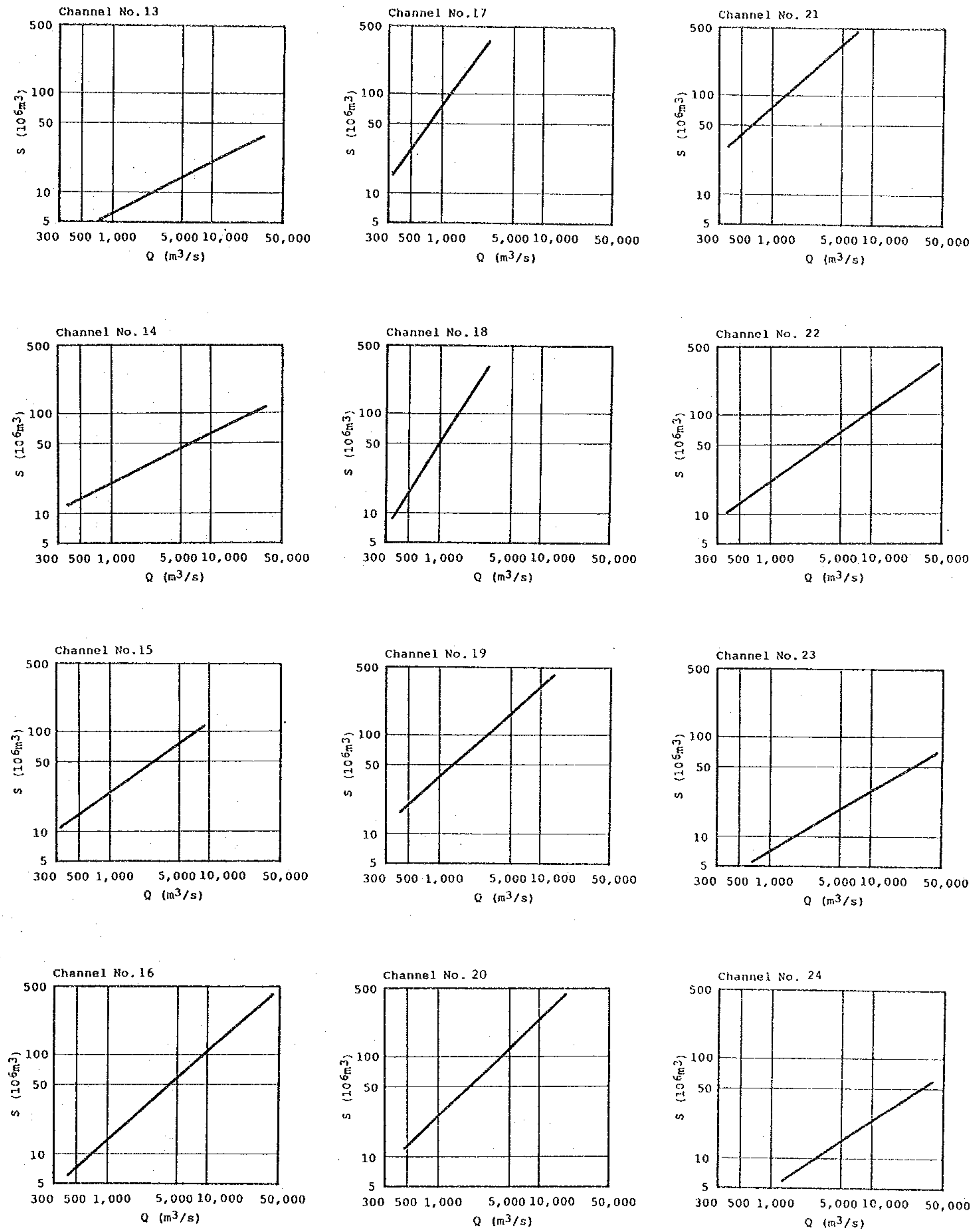


Fig. 4.15 CHANNEL STORAGE CURVE UNDER THE PRESENT RIVER CONDITION (2/3)

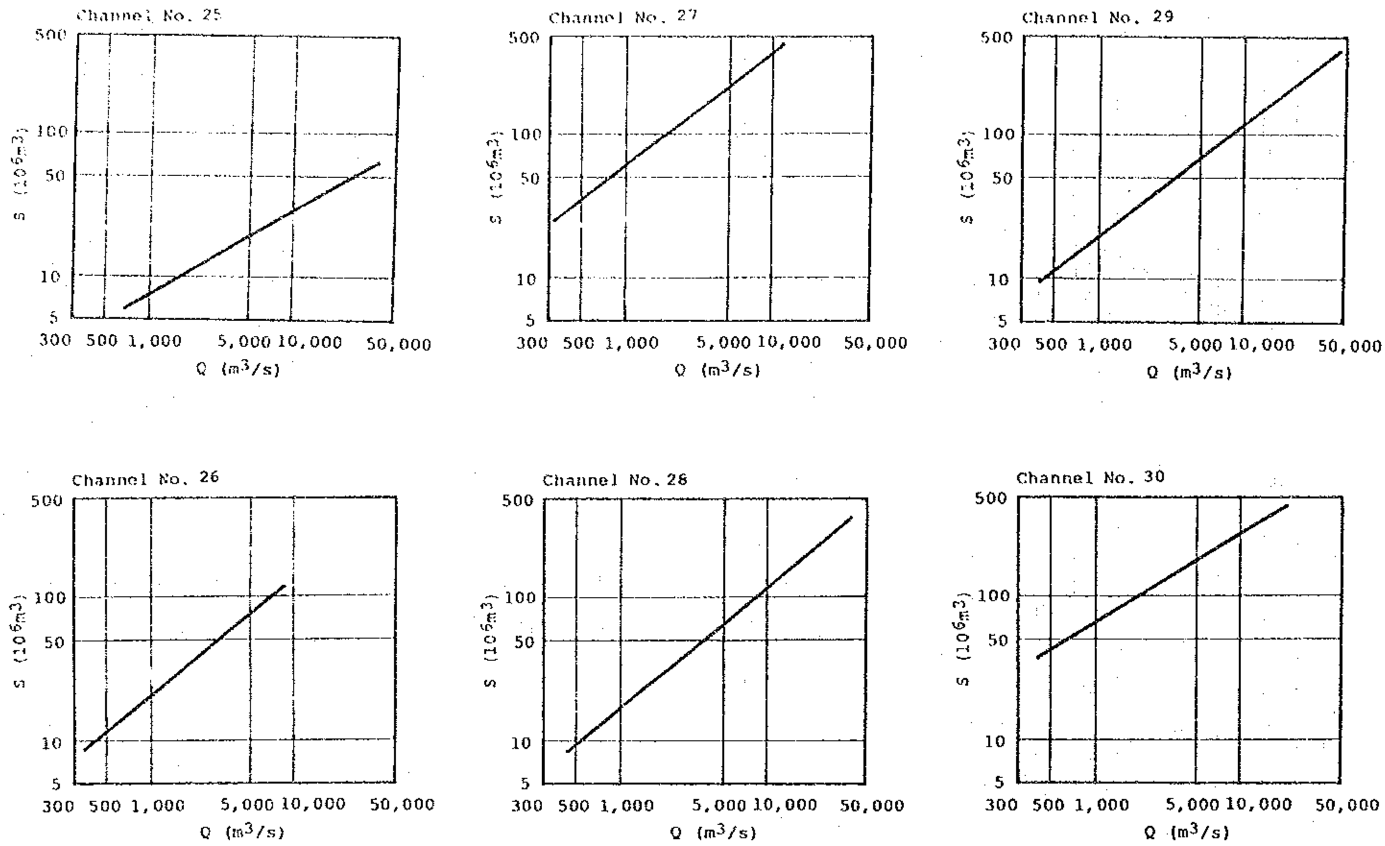
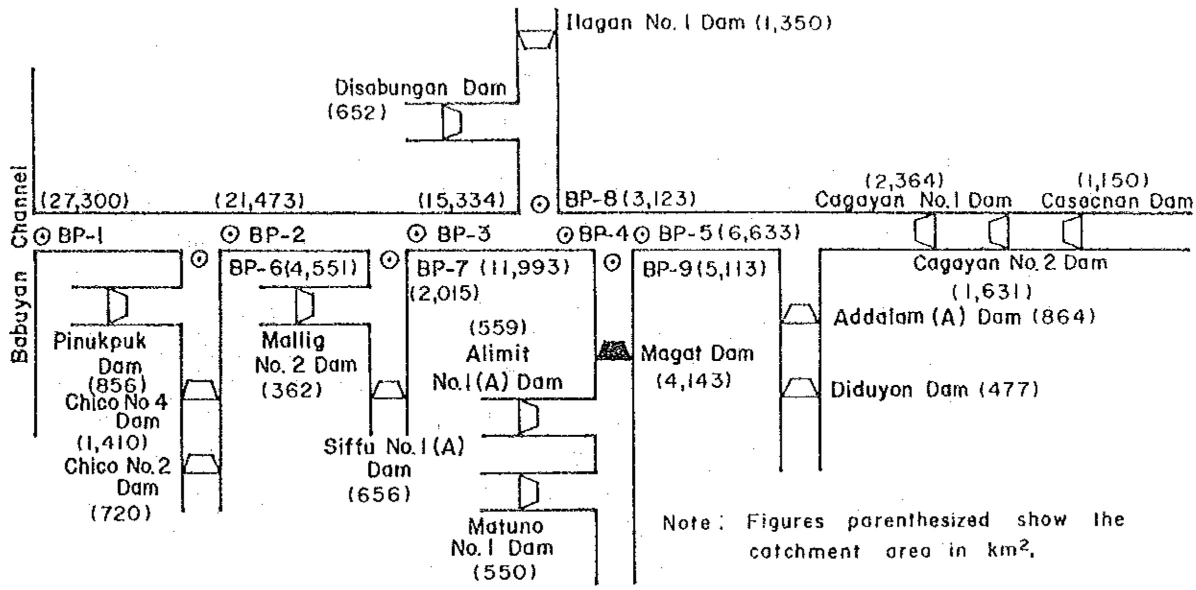


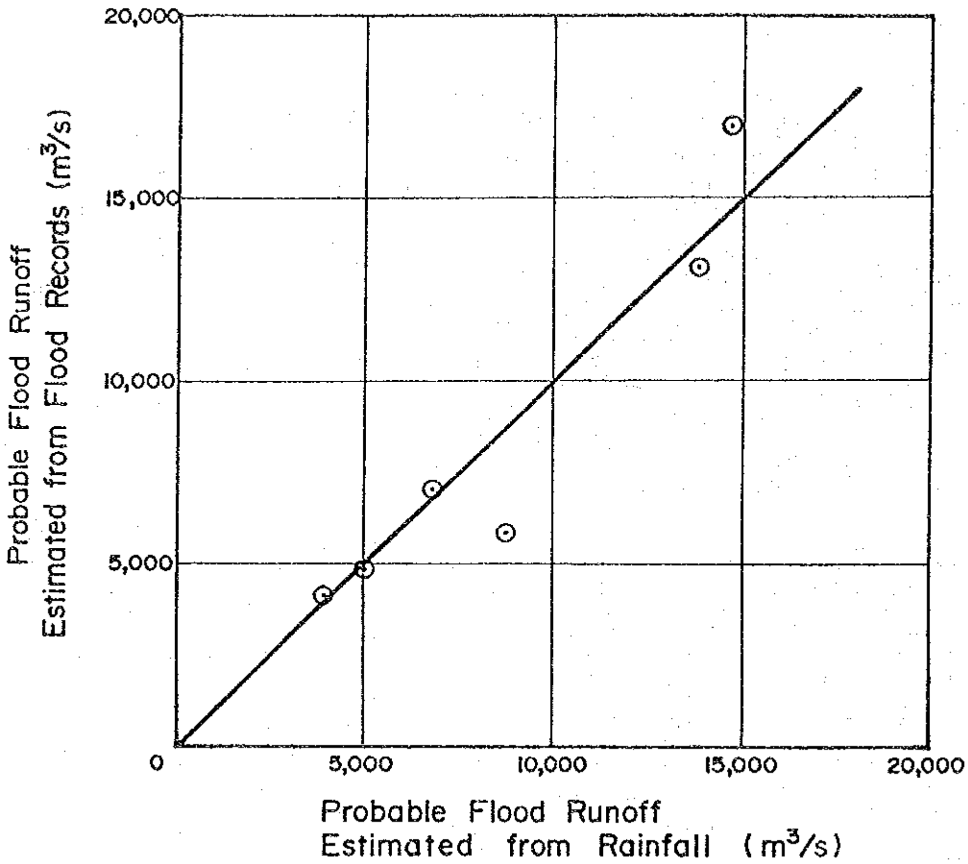
Fig. 4.15 CHANNEL STORAGE CURVE UNDER THE PRESENT RIVER CONDITION (3/3)



Unit: m^3/s

	Base Point	1/2	1/5	1/10	1/25	1/50	1/100	1/200	1/1,000	1/10,000
Probable Flood Peak (1-day)	Casecnan	3,600	5,800	7,500	9,700	14,500	20,700	26,000	42,000	72,800
	Cagayan No.2	3,800	5,800	7,300	9,200	13,500	19,400	24,000	38,000	65,900
	Cagayan No.1	2,500	4,500	6,200	8,500	12,500	17,200	22,000	34,000	59,400
	Diduyon	1,300	2,000	2,600	3,700	5,200	7,500	9,500	14,500	25,000
	Addalam (A)	600	1,300	1,900	2,900	4,200	5,650	7,500	13,000	24,550
	Matuno No.1	750	1,050	1,300	1,550	1,800	2,050	2,300	3,000	4,150
	Alimit No.1 (A)	450	700	850	1,100	1,350	1,650	2,000	3,200	5,750
	Magat	-	-	-	-	-	-	-	-	-
	Ilagan No.1	1,750	3,200	4,300	6,350	7,600	8,950	11,500	17,000	28,050
	Disabungan	1,050	1,900	2,700	3,800	5,400	7,600	9,200	14,000	24,750
	Siffu No.1 (A)	400	700	950	1,300	1,600	1,950	2,500	4,000	7,100
	Mallig No.2	300	400	600	800	950	1,100	1,400	2,200	3,950
	Chico No.2	850	1,350	1,750	2,300	2,850	3,550	4,000	5,300	9,250
	Chico No.4	800	1,450	2,000	2,750	3,600	4,500	5,400	7,800	12,250
	Pinukpuk	700	1,200	1,600	2,200	2,700	3,150	4,000	6,300	10,700
Without Magat Dam	Base point No.1	6,200	9,900	12,000	15,700	18,100	21,400			
	Base point No.2	5,800	9,400	11,500	15,300	17,700	21,000			
	Base point No.3	6,100	10,300	12,900	17,700	20,900	25,300			
	Base point No.4	5,400	9,300	11,600	16,200	19,300	23,500			
	Base point No.5	3,300	5,900	7,200	10,100	12,500	14,700			
	Base point No.6	2,000	3,000	3,800	5,200	7,500	8,700			
	Base point No.7	1,200	1,600	2,000	2,700	3,000	3,300			
	Base point No.8	2,000	3,400	4,700	6,700	7,600	9,400			
	Base point No.9	2,700	4,500	6,000	7,200	9,500	10,600			
With Magat Dam	Base point No.1	6,200	9,700	11,600	15,000	17,300	20,300			
	Base point No.2	5,700	9,300	11,200	14,600	16,900	19,900			
	Base point No.3	6,100	9,800	12,000	16,100	19,000	22,600			
	Base point No.4	5,400	9,000	10,900	14,700	17,600	21,000			
	Base point No.5	3,300	5,900	7,200	10,100	12,500	14,700			
	Base point No.6	2,000	3,000	3,800	5,200	7,500	8,700			
	Base point No.7	1,200	1,600	2,000	2,700	3,000	3,300			
	Base point No.8	2,000	3,400	4,700	6,700	7,600	9,400			
	Base point No.9	2,500	3,500	4,300	5,000	6,300	7,000			

Fig. 4.16 PROBABLE FLOOD PEAK RUNOFF DISTRIBUTION UNDER THE PRESENT RIVER CONDITION



Station Name	River Name	Drainage Area (Km^2)	100 Yr Runoff (m^3/s)	
			From Flood Record	From Rainfall
Calantac	Paret	907	4,805	4,999
Larion Alto	Tuguegarao	655	4,095	3,906
Pasonglao	Chico	1,987	7,028	6,680
Palattao	Cagayan	6,626	16,951	14,686
Minanga	Ilagan	1,565	5,789	8,713
Oscariz	Magat	4,150	13,144	13,729

Fig. 4.17 COMPARISON OF PROBABLE FLOOD RUNOFF ESTIMATED FROM RAINFALL AND FLOOD RECORDS

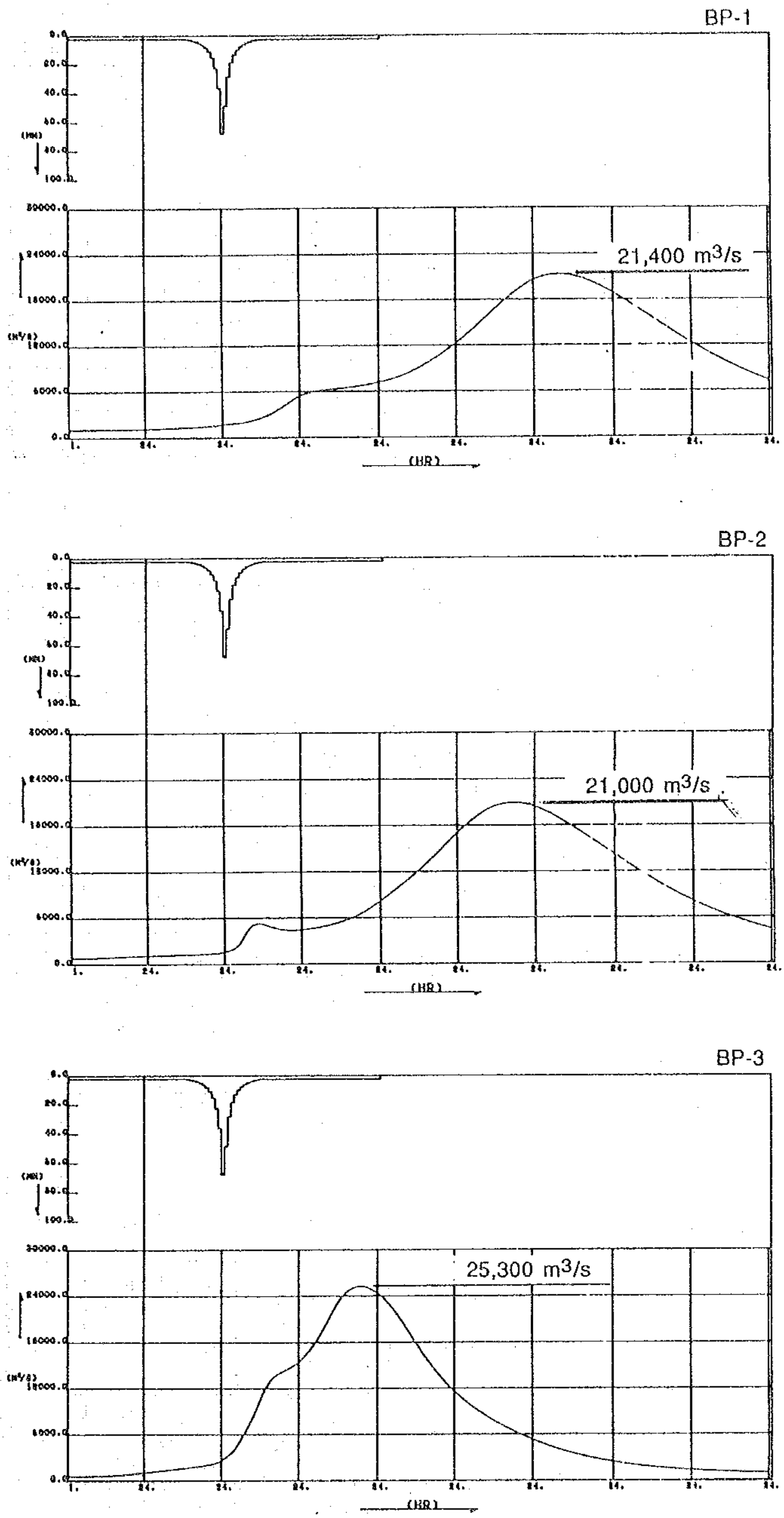
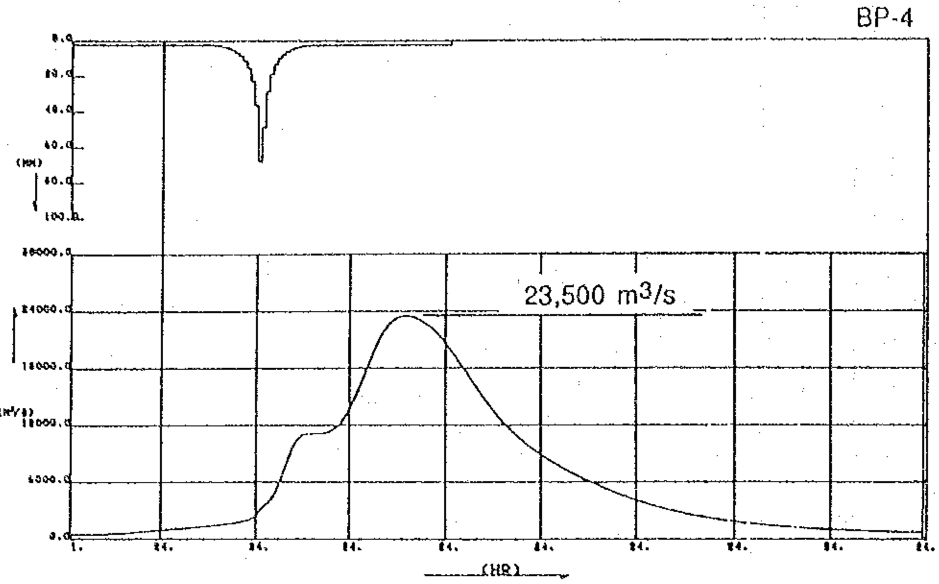
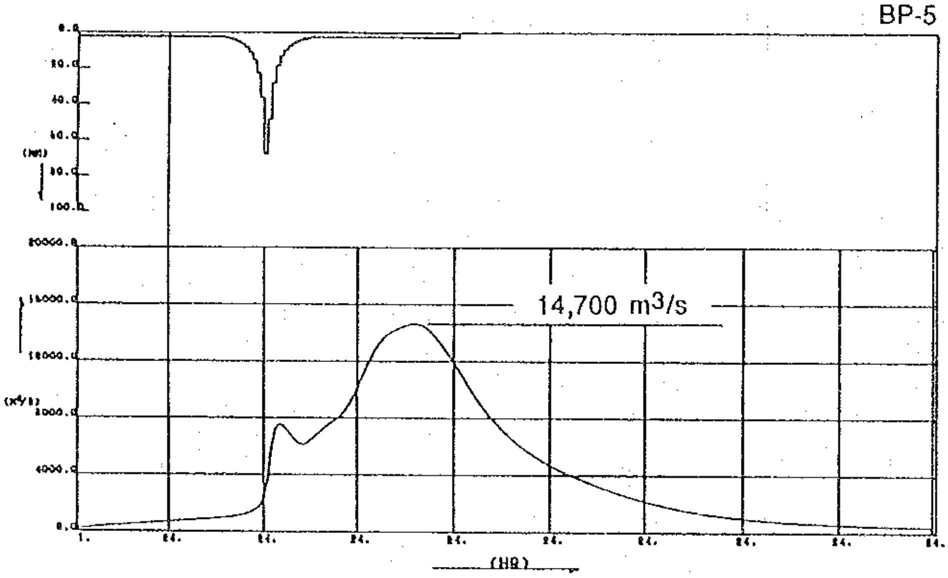


Fig. 4.18 100-YR FLOOD HYDROGRAPH (1/3)





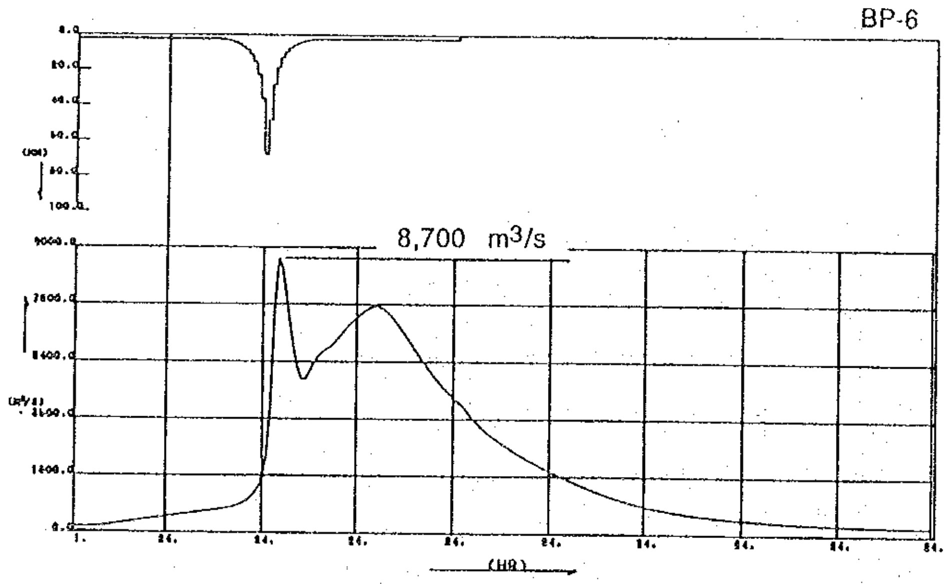
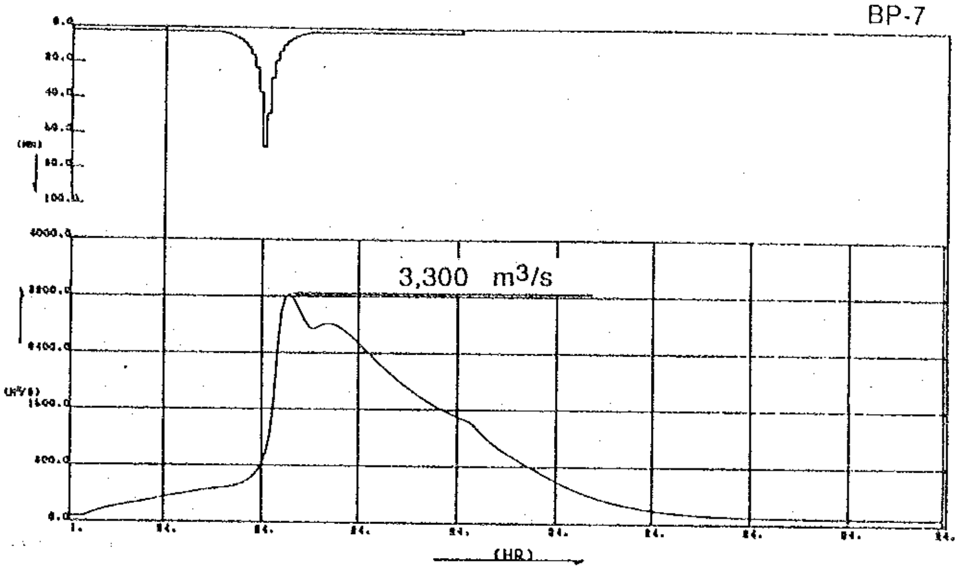
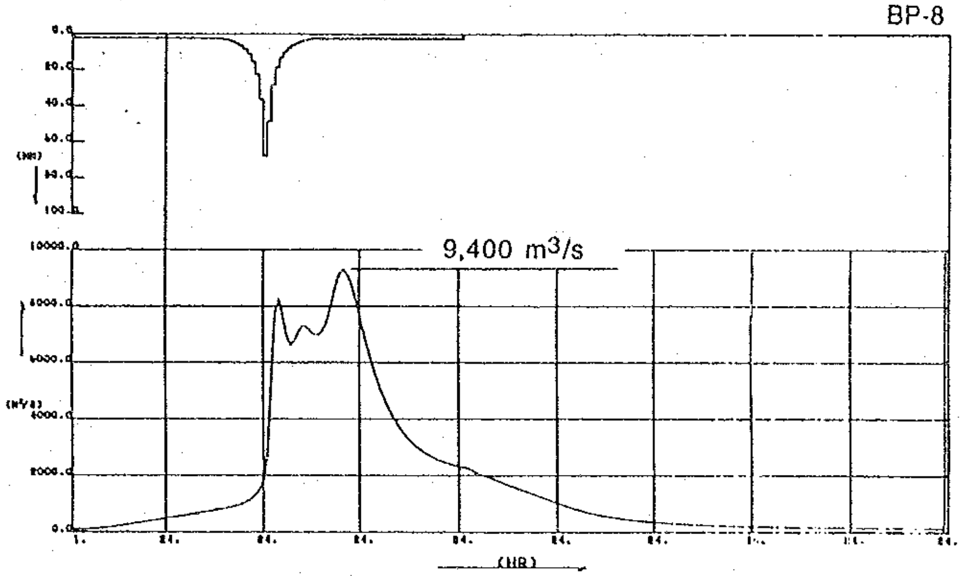


Fig. 4.18 100-YR FLOOD HYDROGRAPH (2/3)





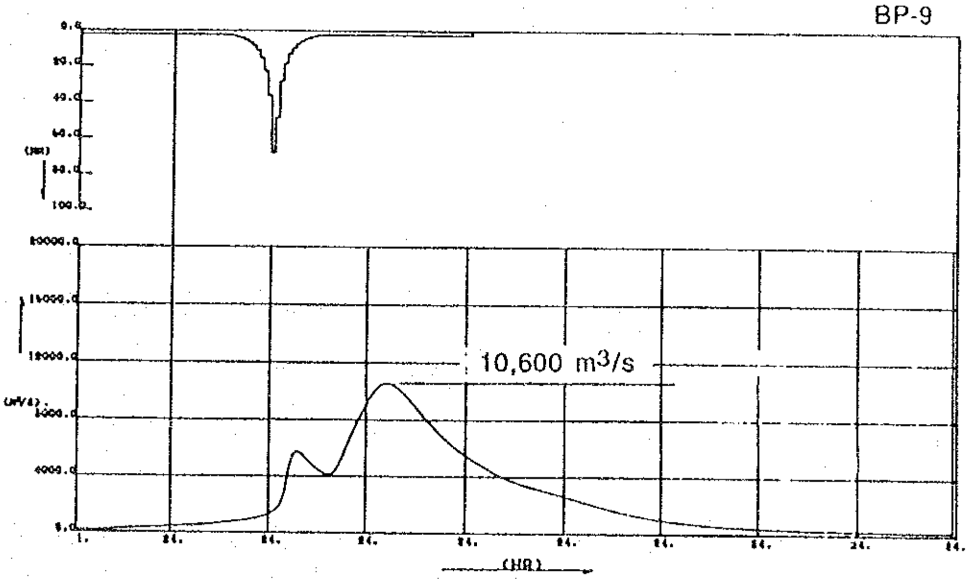


Fig. 4.18 100-YR FLOOD HYDROGRAPH (3/3)

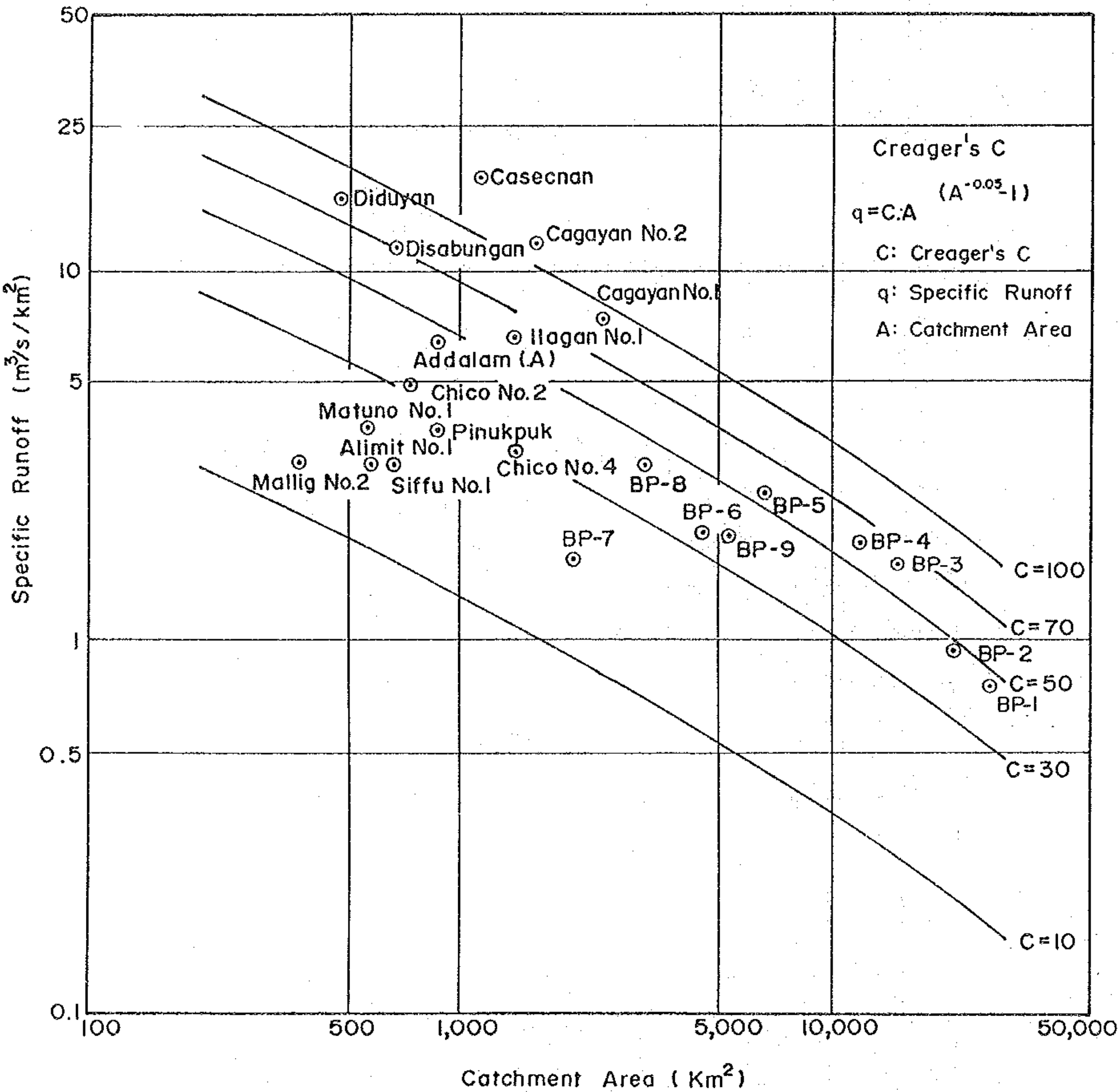
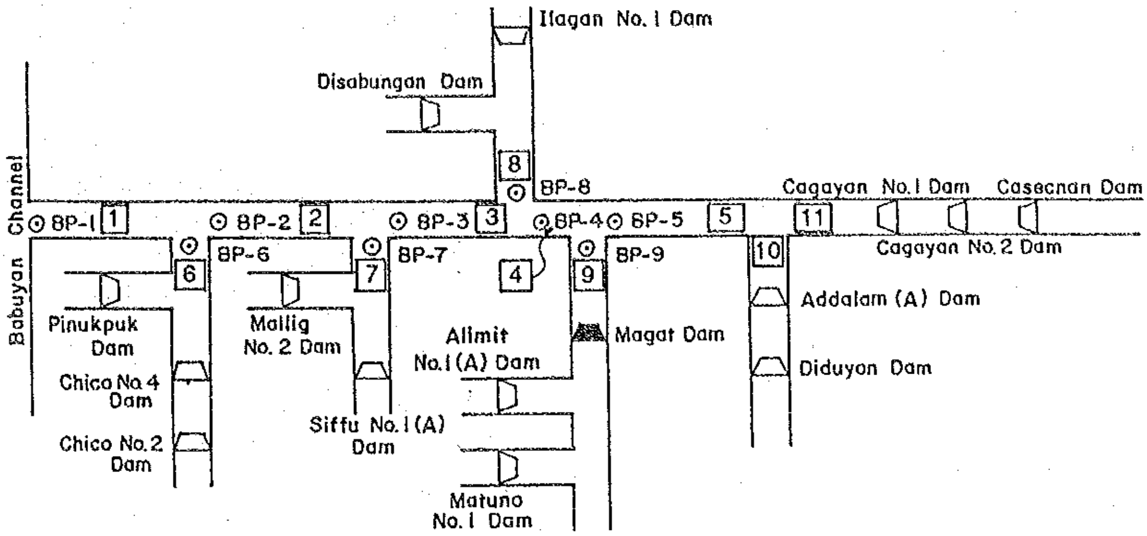


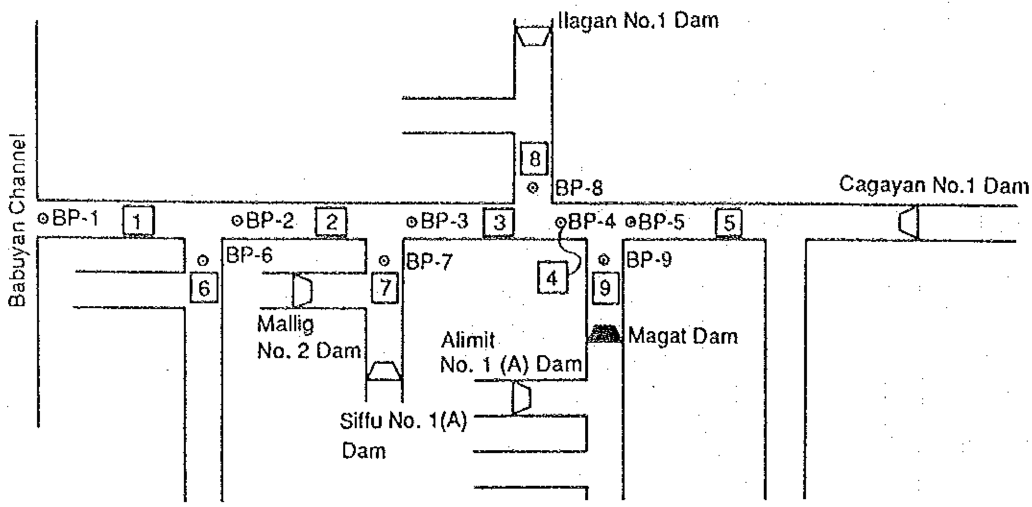
Fig. 4.19 SPECIFIC FLOOD PEAK RUNOFF (100 YR.)



(Unit: m³/s)

Base Point	Alt. OD	Alt. 5D	Alt. 9D	Alt.ODM	Alt.5DM	Alt.9DM	(Present Condition)
BP-1	27,300	25,200	24,900	27,400	25,300	25,000	(21,400)
BP-2	26,500	24,500	24,000	26,600	24,500	24,100	(21,000)
BP-3	27,400	24,600	24,300	27,400	24,600	24,300	(25,300)
BP-4	25,300	23,100	22,800	25,300	23,100	22,800	(23,500)
BP-5	15,100	14,000	13,500	15,100	14,000	13,500	(14,700)
BP-6	8,700	8,700	8,600	8,700	8,700	8,600	(8,700)
BP-7	3,300	3,200	3,200	3,300	3,200	3,200	(3,300)
BP-8	9,700	8,200	8,000	9,700	8,200	8,000	(9,400)
BP-9	12,600	9,700	9,700	12,600	9,700	9,700	(10,600)
Stretch							
1	27,400	25,300	25,000	27,600	25,400	25,100	(21,600)
2	28,800	25,600	25,200	28,800	25,600	25,200	(26,600)
3	27,500	24,600	24,300	27,500	24,600	24,300	(25,600)
4	25,900	23,100	22,800	25,900	23,100	22,800	(23,900)
5	16,300	15,100	13,500	16,300	15,100	13,500	(16,000)
6	8,700	8,700	8,600	8,700	8,700	8,600	(8,700)
7	3,300	3,200	3,200	3,300	3,200	3,200	(3,300)
8	9,900	8,200	8,000	9,900	8,200	8,000	(9,400)
9	13,800	9,700	9,700	13,800	9,700	9,700	(10,600)
10	4,800	4,800	3,100	4,800	4,800	3,100	(4,800)
11	12,100	9,100	9,100	12,100	9,100	9,100	(12,100)

Fig. 4.20 100-YEAR PROBABLE FLOOD PEAK RUNOFF DISTRIBUTION FOR ALTERNATIVE FRAMEWORK PLANS



With Dike (25-year Probable)(Unit: m^3/s)

		w/5 Dams	w/5 Dams and Improved Narrows
BP-1		17,800	17,900
BP-2		17,100	17,200
BP-3		16,900	16,900
BP-4		15,600	15,600
BP-5		9,400	9,400
BP-6		5,200	5,200
BP-7		2,700	2,700
BP-8		5,700	5,700
BP-9		6,600	6,600
Stretch	1	17,800	17,900
"	2	17,700	17,700
"	3	16,900	16,900
"	4	15,600	15,600
"	5	10,000	10,000
"	6	5,200	5,200
"	7	2,700	2,700
"	8	5,700	5,700
"	9	6,600	6,600

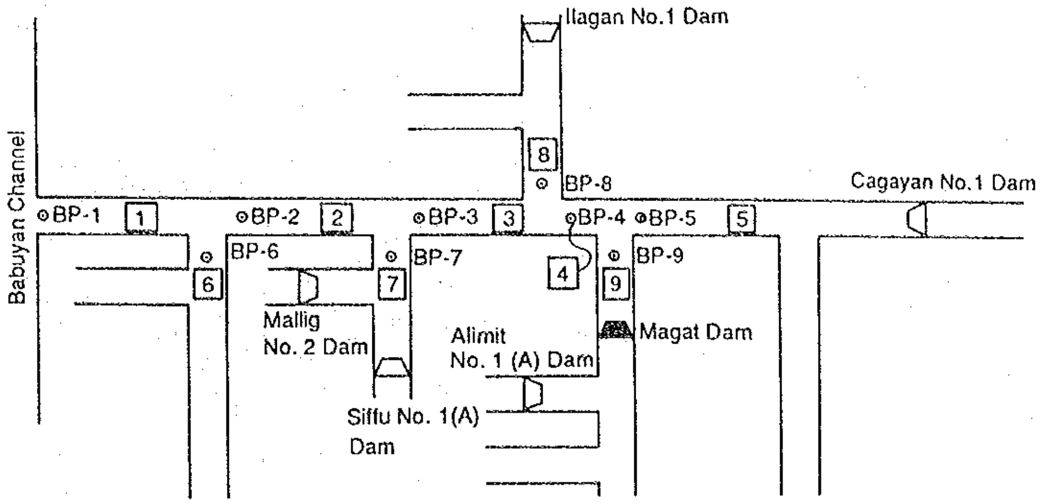
With Improved Narrows and 5 Dams (Unit: m^3/s)

	Probability	1/2	1/5	1/10	1/25	1/50	1/100
BP-1		6,200	9,600	11,500	15,000	17,300	20,500
BP-2		5,800	9,200	11,100	14,600	16,900	20,100
BP-3		6,000	9,800	12,000	16,300	19,400	23,600
BP-4		5,400	8,900	11,000	15,100	18,100	22,200
BP-5		3,100	5,300	6,500	9,100	11,300	13,500
BP-6		2,000	3,000	3,800	5,200	7,500	8,700
BP-7		1,200	1,600	2,000	2,700	3,000	3,200
BP-8		1,800	2,800	3,700	5,700	6,500	8,200
BP-9		2,500	4,000	5,300	6,400	8,300	9,300
Stretch 1		6,200	9,700	11,600	15,100	17,500	20,700
" 2		6,500	10,400	12,700	17,100	20,200	24,500
" 3		6,100	9,800	12,000	16,300	19,400	23,700
" 4		5,400	8,900	11,000	15,100	18,100	22,200
" 5		3,100	5,500	6,700	9,800	12,300	14,700
" 6		2,000	3,000	3,800	5,200	7,500	8,700
" 7		1,200	1,600	2,000	2,700	3,000	3,200
" 8		1,800	2,800	3,700	5,700	6,500	8,200
" 9		2,500	4,000	5,300	6,400	8,300	9,300

Without Project (Unit: m^3/s)

	Probability	1/2	1/5	1/10	1/25	1/50	1/100
Stretch 1		6,300	10,000	12,100	15,900	18,300	21,600
" 2		6,400	11,000	13,700	18,700	22,000	26,600
" 3		6,100	10,300	12,900	17,800	21,100	25,600
" 4		5,400	9,400	11,700	16,300	19,500	23,900
" 5		3,300	6,000	7,400	10,700	13,400	16,000
" 6		2,000	3,000	3,800	5,200	7,500	8,700
" 7		1,200	1,600	2,000	2,700	3,000	3,300
" 8		2,000	3,400	4,700	6,700	7,600	9,400
" 9		2,700	4,500	6,000	7,200	9,500	10,600

Fig. 4. 21 PROBABLE FLOOD PEAK RUNOFF DISTRIBUTION FOR LONG TERM PLAN (1/3)



With Cagayan No.1 Dam (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,200	9,700	11,800	15,400	17,800	21,100
BP-2	5,700	9,200	11,300	15,000	17,400	20,700
BP-3	6,000	9,900	12,400	17,000	20,100	24,500
BP-4	5,300	8,900	11,100	15,500	18,500	22,700
BP-5	3,100	5,300	6,500	9,100	11,300	13,500
BP-6	2,000	3,000	3,600	5,200	7,500	8,700
BP-7	1,200	1,600	2,000	2,700	3,000	3,300
BP-8	2,000	3,400	4,700	6,700	7,600	9,400
BP-9	2,700	4,500	6,000	7,200	9,500	10,600
Stretch [1]	6,200	9,800	11,900	15,600	18,000	21,300
" [2]	6,400	10,600	13,200	18,000	21,300	25,800
" [3]	6,000	9,900	12,300	17,100	20,300	24,800
" [4]	5,300	9,000	11,200	15,700	18,800	23,100
" [5]	3,100	5,500	6,700	9,800	12,300	14,700
" [6]	2,000	3,000	3,800	5,200	7,500	8,700
" [7]	1,200	1,600	2,000	2,700	3,000	3,300
" [8]	2,000	3,400	4,700	6,700	7,600	9,400
" [9]	2,700	4,500	6,000	7,200	9,500	10,600

With Ilagan No.1 Dam (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,100	9,700	11,800	15,300	17,700	20,800
BP-2	5,700	9,300	11,300	14,900	17,300	20,400
BP-3	6,000	10,200	12,700	17,300	20,500	24,800
BP-4	5,400	9,300	11,600	16,200	19,300	23,500
BP-5	3,300	5,900	7,200	10,100	12,500	14,700
BP-6	2,000	3,000	3,800	5,200	7,500	8,700
BP-7	1,200	1,600	2,000	2,700	3,000	3,300
BP-8	1,800	2,800	3,700	5,700	6,500	8,200
BP-9	2,700	4,500	6,000	7,200	9,500	10,600
Stretch [1]	6,200	9,800	11,900	15,500	17,900	21,100
" [2]	6,400	10,900	13,500	18,300	21,600	26,000
" [3]	6,100	10,300	12,700	17,400	20,700	25,000
" [4]	5,600	9,400	11,700	16,300	19,500	23,900
" [5]	3,300	6,000	7,400	10,700	13,400	16,000
" [6]	2,000	3,000	3,800	5,200	7,500	8,700
" [7]	1,200	1,600	2,000	2,700	3,000	3,300
" [8]	1,800	2,800	3,700	5,700	6,500	8,200
" [9]	2,700	4,500	6,000	7,200	9,500	10,600

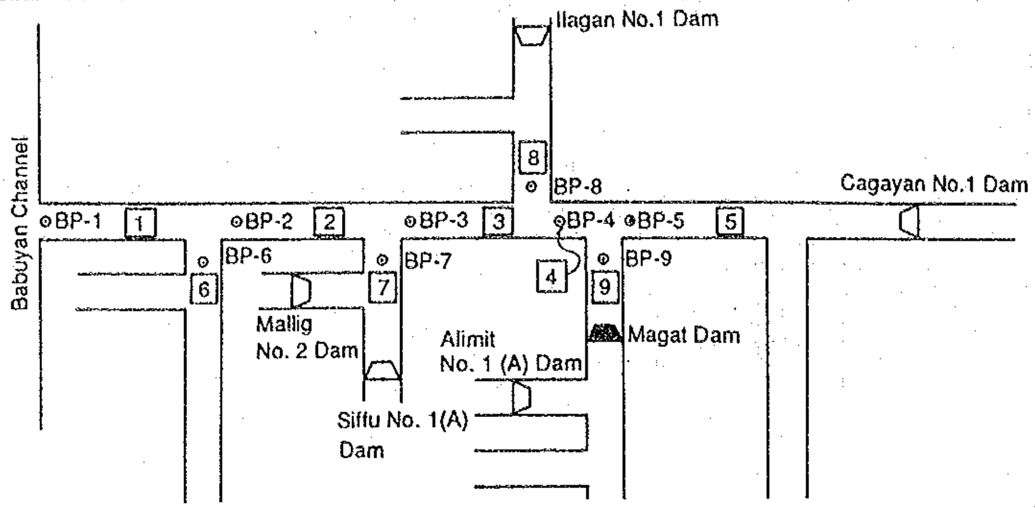
(25-year Probable) (Unit: m³/s)

	W/Siffu No.1(A) Dam	W/Mallig No.2 Dam
BP-1	15,500	15,600
BP-2	15,100	15,200
BP-3	17,700	17,700
BP-4	16,200	16,200
BP-5	10,100	10,100
BP-6	5,200	5,200
BP-7	2,700	2,700
BP-8	6,700	6,700
BP-9	7,200	7,200
Stretch [1]	15,700	15,800
" [2]	18,500	18,600
" [3]	17,800	17,800
" [4]	16,300	16,300
" [5]	10,700	10,700
" [6]	5,200	5,200
" [7]	2,700	2,700
" [8]	6,700	6,700
" [9]	7,200	7,200

With Improved Narrows (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,300	10,000	12,200	15,900	18,400	21,700
BP-2	5,800	9,500	11,700	15,500	17,900	21,300
BP-3	6,200	10,300	12,900	17,700	20,900	25,300
BP-4	5,400	9,300	11,600	16,200	19,300	23,500
BP-5	3,300	5,900	7,200	10,100	12,500	14,700
Stretch [1]	6,300	10,100	12,300	16,100	18,600	22,000
" [2]	6,400	11,000	13,700	18,700	22,000	26,600
" [3]	6,100	10,300	12,900	17,800	21,100	25,600
" [4]	5,400	9,400	11,700	16,300	19,500	23,900
" [5]	3,300	6,000	7,400	10,700	13,400	16,000

Fig. 4.21 PROBABLE FLOOD PEAK RUNOFF DISTRIBUTION FOR LONG TERM PLAN (2/3)



With Magat Dam (200 MCM) (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,200	9,800	11,900	15,600	18,000	21,300
BP-2	5,800	9,400	11,500	15,200	17,600	20,900
BP-3	6,100	10,300	12,700	17,300	20,500	24,800
BP-4	5,600	9,400	11,600	16,000	19,100	23,300
BP-9	2,500	4,000	5,300	6,400	8,300	9,300
Stretch 1	6,200	9,900	12,000	15,800	18,200	21,500
" 2	6,400	10,900	13,500	18,300	21,500	26,000
" 3	6,100	10,300	12,800	17,400	20,600	25,000
" 4	5,600	9,400	11,600	16,100	19,200	23,400
" 9	2,500	4,000	5,300	6,400	8,300	9,300

With Magat Dam (300 MCM) (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,100	9,600	11,600	15,200	17,500	20,700
BP-2	5,700	9,200	11,200	14,700	17,100	20,300
BP-3	5,900	9,700	12,000	16,300	19,300	23,200
BP-4	5,400	8,900	10,900	15,000	17,900	21,700
BP-9	2,200	3,400	4,400	5,300	6,900	7,700
Stretch 1	6,100	9,700	11,700	15,300	17,700	20,900
" 2	6,200	10,400	12,800	17,300	20,400	24,400
3	5,900	9,800	12,100	16,400	19,400	23,400
" 4	5,400	8,900	10,900	15,000	18,000	21,800
" 9	2,200	3,400	4,400	5,300	6,900	7,700

with Magat Dam (400 MCM) (Unit: m³/s)

	Probability 1/2	1/5	1/10	1/25	1/50	1/100
BP-1	6,000	9,300	11,200	14,600	16,800	19,800
BP-2	5,600	8,900	10,700	14,100	16,400	19,300
BP-3	5,600	9,300	11,400	15,500	18,400	21,900
BP-4	5,100	8,400	10,300	14,100	16,900	20,300
BP-9	2,000	2,900	3,700	4,400	5,600	6,200
Stretch 1	6,000	9,400	11,300	14,700	16,900	19,900
" 2	5,900	9,900	12,200	16,400	19,400	23,100
" 3	5,600	9,300	11,500	15,500	18,400	22,000
" 4	5,100	8,400	10,300	14,200	17,000	20,400
" 9	2,000	2,900	3,700	4,400	5,600	6,200

Fig. 4.21 PROBABLE FLOOD PEAK RUNOFF DISTRIBUTION FOR LONG TERM PLAN (3/3)

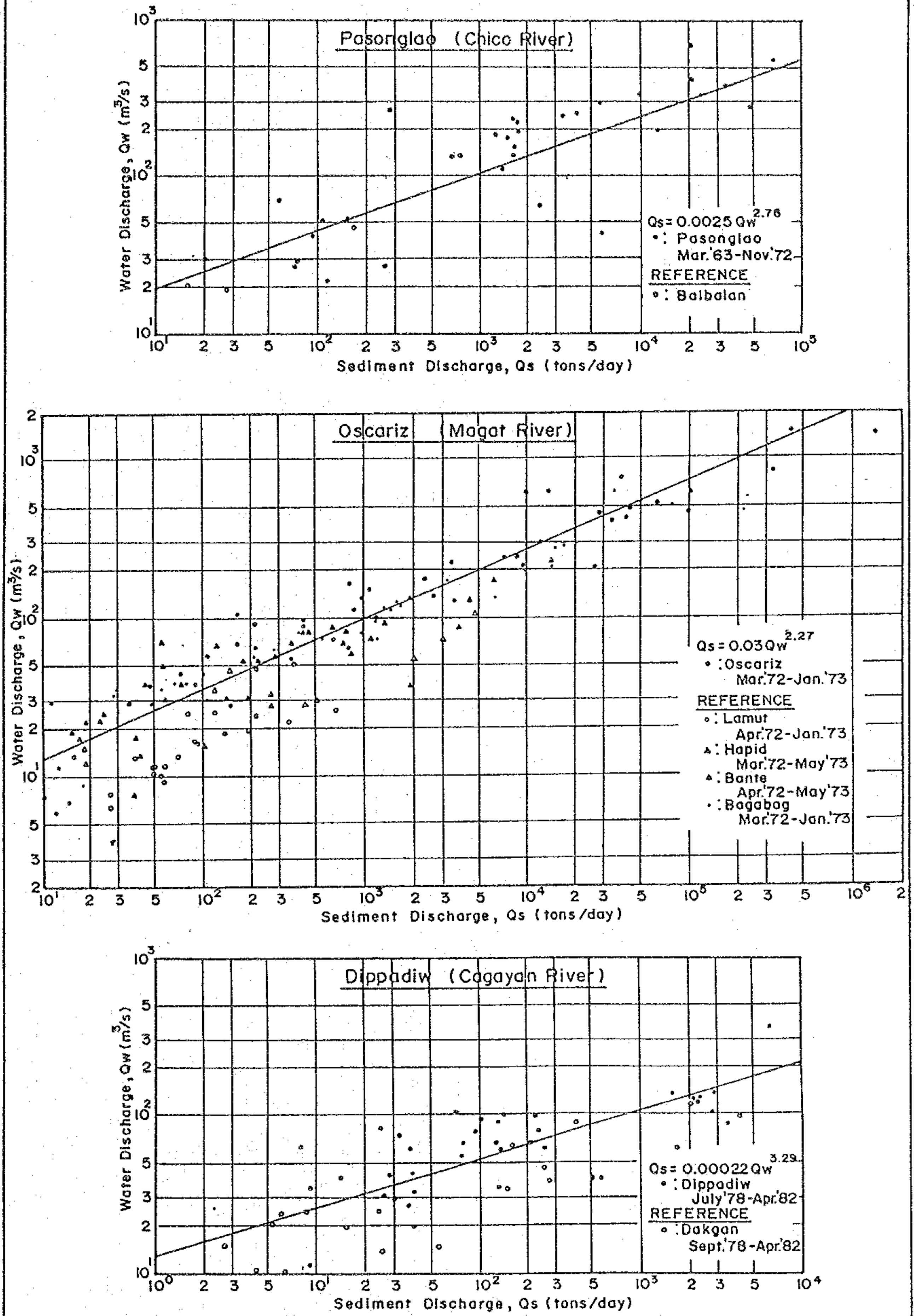


Fig. 5.1 SEDIMENT RATING CURVE IN THE CAGAYAN RIVER

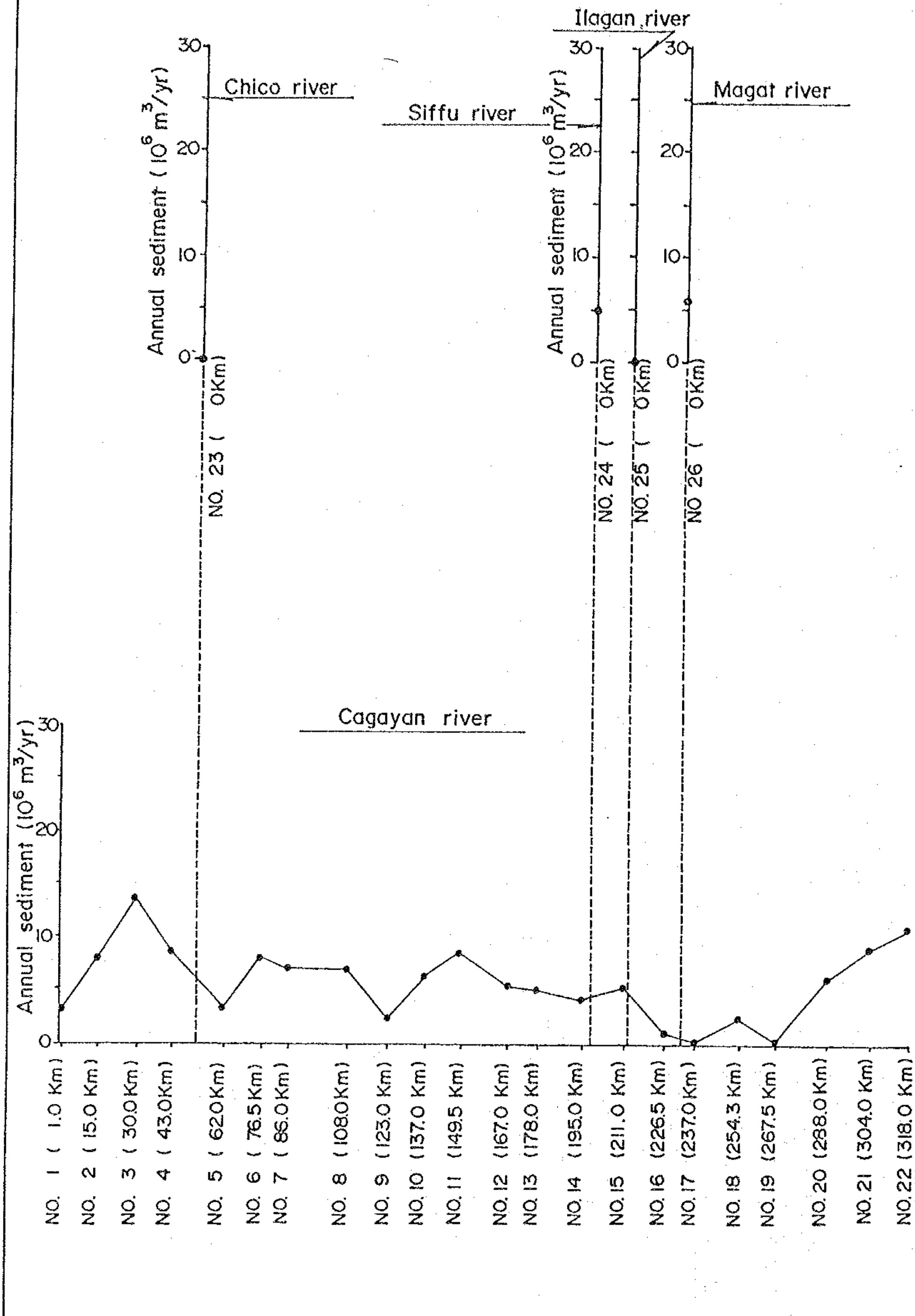


Fig. 5.2 SEDIMENT TRANSPORT CAPACITY

ANNEX GE

GEOLOGY

ANNEX GE

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I INTRODUCTION

In the Cagayan valley, Northern Luzon, Philippine inhabitants are suffering from awful and frequent flood by heavy rain and typhoon every rainy season so that dam construction is required for flood control. In addition, irrigation and power generation are also desired to promote the agricultural and industrial production. Accordingly, the dam will be multipurpose type.

In connection with it, this project "The Master Plan Study on the Cagayan River Basin Water Resources Development" was carried out by Japan International Cooperation Agency (JICA) cooperating with GOP, DPWH, NIA and NAPOCOR from October 1985 Geological reconnaissance survey has practised at two terms namely (1) from November-December 1985, and (2) July 1986.

The main purposes in geological survey are as follows:

- (1) To collect existing data and reports from government agencies concerned,
- (2) To analyze aerophotographs and landsat images for interpretation of surface deposit, mega-trend of geological structure,
- (3) To carry out field reconnaissance survey for General geological condition of the basin.
- (4) To carry out field reconnaissance survey at prospective damsites and river channels to be rehabilitated,
- (5) To explore the construction materials for dam roughly,
- (6) To estimate rough grouting quantity for dam foundation.

II DATA COLLECTION

During the course of the field work, the Study Team visited various offices concerned, exchanged view with officials and collected data. Main data are the publications by various ministries and feasibility reports on Chico No. 4 dam, Diduyon dam, Matuno dam and Casecnan dam. The publications by Bureau of Mines furnished rather detailed information with regard to the geology of the Study area.

III GENERAL GEOLOGY

3.1 General Geology of the Philippines

The Philippine Archipelago forms as a part of the Circum-Pacific volcanic and seismic belt and defined by island arcs marginal basins. It has a maximum North-South length of 1600 km and an average width of 400 km.

The region is characterized by lithologies and regional structure developed during Cretaceous-Tertiary period. During this period there was an extensive ultramatic intrusion, tectonism, andesitic and dacitic volcanism and the sediments are diverse including sandstone, conglomerate, tuffs, siltsone, shale, reef limestone and coal. Diorite, quartzdiorite and andesitic stocks were intruded at various times. The oldest rock found in the region are Cretaceous spilite, shale, greywacke and chert.

The present geologic features of the Philippine are recognized as a model for an actively developing islands. This geologic features are divided into four zones as follows;

1. Stable zone (Palawan and Sulu region)
2. Mobile Belt zone (covers Luzon, part of Visaya and Mindanao)
3. Manila Trench
4. Mindanao and East Luzon Trench

The Stable zone includes Palawan, Cuyo islands Sulu sea, Southern Mindanao and Zamboanga. This region is characterized by aseismicity, less absence of Tertiary activity, prevalence of quartzose and alkalirich sedimentary rocks.

The Mobile belt extends longitudinally through Luzon, Visaya and Mindanao. It is characterized by pronounce earthquake activity, active and recently active volcanoes, prevalence of Mesozoic to Tertiary igneous rocks and greater rocks deformation and metamorphism.

The Mindanao and East Luzon Trench separates the east and south of the belts from the Philippine sea and Manila Trench separates Luzon from the South China sea. (Refer to Fig. 3.1)

3.2 General Geology of Northern Luzon

(1) Physiography

Northern Luzon proper belongs to the mobile belt of the Philippines and four major physiographic and structural provinces are recognized in this region. These are 1) Ilocos basin, 2) Cordillera Central, 3) Sierra Madre and Caraballo range and 4) Cagayan basin. (Refer to Fig. 3.2)

The Ilocos basin forms the coastal folded belt of Northern Luzon and extends north and south between the high Cordillera Central and South China sea. Structurally this region is characterized by intensely folded and faulted north-trending asaticlines. The major fault trends are north-south and northwest-southeast with a secondary fault system trending generally northeast-southwest.

The Cordillera central is located along the east side of the Cagayan valley, it is composed of intermediate to mafic plutonic masses with great thickness of bedded volcanics and metasediments (basalt and greywackes) along the marginal areas. Silicic intrusives and extrusive are known in this area. In cordillera central major lineaments have a north-south orientation essentially parallel with the trends in the mountains. Infolded and down-dropped blocks of Miocene carbonates and clastics occur at many places.

Sierra Madre and Caraballo mountains form the eastern and southern margins respectively of the Cagayan valley. They are composed of intermediate (andesitic) igneous rocks in their cores with early Tertiary bedded metavolcanics and metasediments along their margins, coarse crystalline diorite intrusive are also known to occur at various places.

The Cagayan basin is a sedimentary trough whose sedimentary rock is dated late Paleogene to Recent. The thickness was calculated to be more than 7,000 meters. Rock in the basin are predominantly sedimentary clastics with interformational limestone. Volcanic and volcanoclastics constitute the next widely distributed rocks in the area. A Cretaceous to Paleogene volcanic and sedimentary rocks form the basement upon which the sediments were deposited. Rocks within the basin also include intrusive, consisting mainly of diorite and granodiorite distributed generally at the core of the mountain ranges.

(2) Faults

Numerous faults are also present in Northern Luzon. They are generally presistent over long distances and oriented parallel to the longitudinal direction of the Cordillera central. The most prominent of these faults are; 1) the Kabugao Fault in Apayao, 2) the Vigan-Vintar Fault in Ilocos province, 3) the Hapao-Kalinga Fault at the eastern part of Cordillera and 4) the Baloy-Abra Faults wherein the Baloy fault transect the mid-section of the lower half of the Cordillera while the Abra fault runs parallel to the Abra river.

(3) Seismicity of Northern Luzon

In Northern Luzon, many earthquakes are experienced yearly. The epicenters according to magnitude are shown in Fig. 3.3. Significant seismic area is off the Manila Bay and west coastline; which corresponds to eastward subduction of Manila Trench, and south-eastern coast; which corresponds to westward subduction of East Luzon Trench. And relatively fewer earthquakes occurred within Cagayan Valley, but nevertheless of significant intensites. On the whole, intense earthquakes is assumed to be tectonic origin and rarely of volcanic nature.

The major earthquake, the Isabela Earthquake, occurred in December 29, 1949, in Aurora, Isabela in the west of the Cagayan River. The epicenter of this earthquake was located in the vicinity of 17°00′ N latitude and 121°38′ E longitude. Though it is not among the weverest ever experienced in the Philippines as far as intensity or damage, it had greatest extent of other earthquake in the recent. The intensity of tremors by Rossi-Forel scale was as follows:

Tuguegarao	Intensity	VII
Cabanatuan	"	VI
Aparri	"	VI
Manila	"	VI
Baguio	"	V

The earthquake was decidedly of tectonic origin due to readjustments of rock strata within the earth's crust. No volcanic action occurred in connection with this earthquake.

By the way, the design acceleration of earthquake was calculated in the report of feasibility study about Diduyon Hydroelectric Development Project. According to the report, the design acceleration for the Diduyon Dam is determined about 120 gals. Diduyon damsite is relatively very near to the eastern seismic area. Therefore, the design acceleration of 120 gals is regarded as adequate and almost maximum figure for any other proposed damsites in the Cagayan Valley.

(4) Analysis of Landsat Image

In addition to geological data gathered from various government agency, a false-colored landsat image (1983) is available with a scale of 1:500,000. The photograph covers the whole part of northern Luzon from 16^{o}N to 20^{o}N. (Refer to Fig. 3.4)

Many major lineaments interpreted, lie in the south-western part of Northern Luzon and decrease in north and eastern area. This major lineaments occupies the cordillera mountain region, west of the Cagayan basin.

Generally, lineaments trend north and branches into north-east and north-west direction. West of the Cagayan basin, the intensity of lines is higher in comparison to the eastern region.

Strong and clear lineaments is traceable for about a hundred kilometer long and continue more as many small lineaments of several kilometers from major lines.

The trends, distribution and extent of interpreted lineaments corresponds to the major structural elements in Northern Luzon. In Cordillera region, this lines represents the infolded and faulted of Miocene rocks and in Sierra Madre and Caraballo region these represents the NE-SW normal faults. In Magat and Chico rivers area, these lineaments comprise the faulted and folded belt of the region.

The most strong and clear lineaments, that lie in the west-southern part of Northern Luzon was interpreted as the Philippine Fault Zone which runs from Lingayen Gulf through Dingalan Bay.

3.3 General Geology of Cagayan River Basin

(1) Physiography

The Cagayan river basin is a north-south trending asymmetrical trough circumscribed by a channel in the north and major mountain ranges along the south, east and west sides. The basin measures about 240 km long and 85 km wide. It underlies an area of approximately 20,000 sq. km. It is gently sloping and shallow along the eastern side but deep and highly disturbed along the western flank. The basin can be divided into two main physiographic regions namely the mountainous regions and highs are composed of great mountain ranges: Central Cordillera, Sierra Madre and Caraballo Mountains.

(2) Stratigraphy

The stratigraphy of all Cagayan valley is not necessarily unified at present, because rock facies rather varies in the lateral. Thus, stratigraphy is mainly adopted from Darkee and Pederson.

Rocks in Cagayan basin is represented by a thick sequence of pre-Tertiary metamorphic and plutonic rocks. These were uplifted by igneous intrusions during the Late Tertiary and Quaternary. An Oligocene to Pliocene marine section occupies the main basin area. It is up to 9,000 m thick along the flanks but attains a maximum thickness of over 12,000 m at the centre of the basin. The Oligocene section consists of basic lava flows, metamorphosed conglomerate, tuff breccia and tuffaceous sandstone and siltstone. Late Pleistocene to Recent sands, silts, gravels and pyroclastics are found generally in the central basin area and the sequence is entirely non-marine.

Rocks exposures in the area are divided into West side and East side of the Cagayan valley and they are classified according to rock formation. From top to bottom they are:

West Side	East Side
Holocene Deposit	Holocene Deposit
Awiden Mesa Formation	Awiden Mesa Formation
Ilagan Formation	Ilagan Formation
Mabaca River Group	Callao Limestone
Sicalao Limestone	Gatangan Creek Formation
Basement Complex	Basement Complex

HOLOCENE DEPOSIT

Holocene deposit consists of a-luvium, volcanic materials and terrace gravel. Alluvium materials are gravel, sand, clay and other fluviatiles, they are generally found along the river channel and flood plains. Terrace gravel are particularly well developed along the Chico river at Tabuk, Kalinga where at least three levels of terraces demonstrate recent isostatic adjustment or changes in base level. Other terraces occur near Butigui on the Siffu river, along the Magat river at Oscariz Isabela and of Jones Isabela.

AWIDEN MESA FORMATION

Awiden Mesa Formation is nearly equivalent to Tabuk Formation on the geological map Fig. 3.5. This formation is distributed in the central plain of Cagayan Valley.

This formation is composed of welded tuffs and tuffaceous sediments of a dacitic type. It is characterized by the presence of bipyramidal quartz phenocrysts (generally less than 5 percent) and euhedra of hornblends and sodic feldspar. The tuffaceous sediments are various shades of tan and gray and show variable clast sizes and rounding, though they maintain their homogeneity of composition. The quartz euhedra commonly form an erosional residue which a sparkling appearance to the surface of the ground where the formation is present.

The Awiden Mesa Formation is overlain by Holocene deposit and uncomformably overlies folded strata of Tertiary age in the type area. The maximum thickness is found at Awiden Mesa, 6 kilometers northwest of Lubuangan, Kalinga sub-Province, Mountain Province. Scattered sections of the formation in Kalinga show that it is a valley-filling deposit unconformable on an irregular surface of deformed Miocene rocks. At Awiden Mesa, the tuff beds attain a thickness of at least 300 meters.

ILAGAN FORMATION

Ilagan Formation extends on the hilly lands which make margin of central plain in Cagayan valley.

This formation are applied to rock exposures along the Ilagan river. This formation is sandstone which exhibit the typical fluviatile depositional nature. No detailed description of the formation is given because great lateral lithological variations occur in short distances. The best exposures occur along the Tao Tao, Siffu, and Mallig rivers. A very good exposure is also present on the flanks of the Pangul anticline, which is breached to the Buluan formation. The uppermost units of the Ilagan are well exposed on the Enrile and Tumauini anticlines.

MABACA RIVER GROUP

Mabaca River Group is nearly equivalent to Lubuagan Formation which makes mountaneous zone extending over the outer margin of Cagayan valley.

This group represents all strata occurring west of (below) the Ilagan Formation escarpment near the mouth of the Mabaca river and east of (above) the Sicalao Limestone. This formation is a thick terrigeneous sequence of lutites and interbedded arenites and locally some pyroclastics. The rocks of the Mabaca River Group could be subdivided, from top to bottom, into:

Buluan-Formation
Balbalan - Formation
Asiga - Formation

BULUAN FORMATION

The Buluan Formation consists mostly of siltstones, while part of it is a shaly structure. Finely grained intercalated sandstones, and small pebble conglomerates occur. The individual beds do not exceed 50 cm at the bottom of the formation, and 15 cm on the upper part. Depending on the degree of lithification, the silt/claystones can furthermore be divided into resistant and non-resistant units with regard to weathering and erosion.

BALBALAN FORMATION

The Balbalan Formation is a graywake, sandstone/siltstone sequence, with a thickness of 1,165 m at its type locality. The sandstones range from fine to coarse-grained, with inclusions of pebble zones. Few conglomerates occur with pebble size mafic igneous clasts. Sandy claystone, with sandstone intercalations, form the transition to the overlying Buluan formation. Occassionally, well indurated claystones can also be found in the lower part. From the Macaba river to the south of the Chico river region, the Balbalan Formation contains more conglomerates than in a typical section. The fraction of sandstone decreases respectively. Claystone, siltstone, and sandy siltstone layers occur more frequently, however, they are not as well indurated, and thus prone to loose their strength when exposed to the surface. Although the Balbalan Formation is a mappable unit throughout the eastern part of Kalinga, its upper and lower boundaries are difficult to distinguish by their facies changes. Broader transition zones occur to the south, which can often be misinterpreted as the underlying Asiga, or the overlying Buluan Formation.

ASIGA FORMATION

The Asiga Formation, partially overlying the basement, forms the oldest unit of the Mabaca River Group. It is distinguished by its high claystone portion of 60%, with the remaining 40% being arenites. The lithogic beds are thinly stratified. They are best exposed along the Pasil river, from Ableg to the east, and in the western part of the region. Detailed investigation at the Pasil river bridge determined that this part is not the upper portion of the Asiga Formation. Despite the alternation of siltstone/sandstone layers, the siltstone content including all siltstone laminae in sandstone beds, does not exceed 15%.

SICALAO LIMESTONE

Sicalao Limestone is rather continuously scattering at western and southern-southeastern margin of Cagayan valley. This is called Ibulao Limestone at southern portion of Lagawe.

This limestone is a massive-bedded calcarenites and calcirudites. With the Cagayan valley, the Sicalao Limestone is correlative with the Callao Limestone on the margins of the Baggao embayment, along the north flank of the Casiggayan nose, and the northeast peninsula of Luzon. The formation can be traced nearly continuously along the west margin of the Cagayan valley from Luna, Apayao, near the north coast, southward to the vicinity of Salegseg, Kalinga. In the latter region the formation is absent because of Miocene faulting and erosion and subsequent Neogene tectonic activity. North of the Saltan river at Salegseg is a large gently east-dipping limestone mass (Mt. Kilkilang), and in the Saltan river at the south and the Mabaca river at the north there is no limestone present.

CALLAO LIMESTONE

Callao Limestone is distributed at the east margin of Cagayan valley.

The type area of the Callao Limestone is at Barrio Callao, Cagayan. The section described here was measured at Callao Canyon in which right bank, the significant cave develops; Callao Cave, along the Pinacanauan de Tuguegarao river. The formation is a calcarenite, it is thin-bedded at the top and becoming more poorly bedded and thicker-bedded in lower part. The Callao limestone south of the type area is the age equivalent of the middle part of the Mabaca river group of the west of the valley and the Baggao embayment. The basal part of the limestone, which migrates downward across the time lines north of the type area toward the Baggao embayment, is the age equivalent of progressively lower and lower units of the Mabaca River Group, until the Callao Limestone of Intal river region on the south margin of the Baggao embayment is the age equivalent of the Sicalao Limestone of the west margin of the Cagayan valley.

GATANGAN CREEK FORMATION

Gatangan Creek Formation is distributed at outer margin of Cagayan valley, and it is the age nearly correspond to lower section of Lubuagan Formation.

The Gatangan creek formation is composed of graywacke sand-stone and layers of claystone. It is overlain by the Callao limestone and underlain by andesite flows of the basement complex. Exposure along the Gatangan creek are excellent and nearly continuous and the formation is 1,010 m. thick. The Gatangan creek formation is the age equivalent of the Asiga and Balbalan formation of the lower Mabaca River Group. It is lithologically similar to the Asiga formation is some respects but has a greater percentage of coarse clastics.

BASEMENT COMPLEX

Basement complex is distributed over the mountaineous land surrounding the Cagayan valley.

Basement complex is composed of some type indistinctly bedded mafic agglomerates, or an interbedded sequence of pyroclastics and indurated sedimentary rocks. The anticlinal peninsula area southeast of CapOe Engano contains an estimated thickness of 2,440 meters of interbedded pyroclastics and "metasediments". Along the western margin of the valley mafic flows, agglomerates, and some thin indurated graywackes and conglomerates occur in the basement complex beneath sedimentary section. These rock types are exposed in every major drainage feature, such as the Abulug, Matalag, Mabaca, Saltan, and Pasil rivers. In the southwestern margin of the Cagayan valley and around the isolated outcrops of sedimentary rocks of the fault-preserved Kiangan-Ibulao Gato area the mountains are composed of metasediments and interbedded igneous rocks.

In most places it was also observed that the indistinctly bedded basement rocks have about the same structural attitude as the overlying clastics or carbonates of the sedimentary section. Some exceptions to this general conformity were found along the south side of the Baggao embayment (Intel river) where there is nearly a right-angle convergence of strikes between the basement and the overlying limestones.

(3) Folding

Folding, faulting, and intrusion by igneous rocks are well displayed in the Kalinga foothills and the Cagayan anticlinal belt (Fig. 3.6). The intensity of folding in these areas decreases from west to east. The folds of the Kalinga foothills are very large, in part nearly isoclinal, and much broken by normal and strike-slip faults. Andesite-diorite stocks are present. It is not improbable that these folds are slightly older than those on the east within the Cagayan Anticlinal belt.

The folds of the Cagayan anticlinal belt form three general groups.

The folds of the Cagayan anticlinal belt form three general groups. The western trend extends from Butigui anticline north-ward to Camcamalog anticline. These folds have weak west flanks and in the case of Camcamalog some asymmetry in the west is present. The next trend on the east, extending from the Tumauini anticline N. 30 W. to the Tuao fold, consists of folds 15-20 kilometers long with vertical closures of 700-1,300 meters on beds within the Ilagan formation. The folds of this trend are characterized by high-angle reverse faults along their east flanks. The component folds of this trend are arranged en echolon from southeast to northwest either by folding (Tumauini-South Tumauini) or epianticlinal strike-slip faulting (Dagupan-North Dagupan).

The third group includes all folds in the northern and eastern third of the Cagayan anticlinal belt. The easternmost folds of this area are asymmetrical toward the east, e.g., Enrile anticline, whose west flank dips 5 - 10^{o} and whose east limb is vertical. The piat anticline in the western part of this area is asymmetrical toward the west as opposed to the eastward asymmetry of the Faire anticline, which is separated from Piat anticline by the Tabang syncline. This is the area where the fold trends change in direction from north-south to east-northeast.

(4) Intrusions

Along a trend bearing N 20^{o} W in the Kalinga Foothills are six andesite-diorite intrusives. West of the Pasunglao ferry on the Chico river are three intrusives. They seem to bear no or Nanong intrusive has a diameter of about 3,000 meters and is emplaced within the northwest-dipping limb of the Tappao syncline. Northeast of and associated with this stock is a well defined group of radial tension faults. The Mambucayan intrusive on the east is about 1,000 meters in diameter and is located in the axial region of the isoclinal beds of the Mambucayan nose. The position of this stock may be only fortuitous and its true relation may be that both it and the small Dalimuno intrusive (750 meters in diameter), the middle one of the three, may be located along a radial tension fracture which extended eastward from the Naneng intrusive. Metamorphic aureoles do not extend beyond 50 meters into the sediments adjacent to the intrusives.

Another large intrusion is present along the Mabaca river west of Asiga, Kalinga. Southward, intrusions have been recognized in the Pinto nose and three small intrusives are located at Cordon, Nueva Vizcaya. All of these intrusives lie on the same general trend of N. 20° W.

(5) Faults

The major faults of the Cagayan valley are shown in Fig. 3.5. In general, there are two major zones of faulting. One of these extends along the west margin of the valley from the vicinity of Aglipay, Nueva Vizcaya, northward to Talifugo, Apayao. There this fault zone narrows, leaves the sedimentary region, and continues north-northwest in the basement rocks for 80 kilometers or more. The second important trend of faulting is along the south margin of the Sicalao-Casiggayan high. The faults of these two major zones of importance are either wrench faults, or a combination of the two different types of movement at different periods of time.

The Dummun river fault zone along the south margin of the Casiggayan nose is one of the most important ruptures, as it separates the Sicalao-Casiggayan high and Aparri Plain block from the southern part of the Cagayan valley. This fault is defined by surface mapping and is characterized by some hot springs along its trace. It is indicated on air photographs by prominent lineaments that continue eastward across the Sierra Madre to the east coast. Bathymetric data support the supposition that this zone continues north and east into the Pacific for a short distance. This east-west trend is approximately in the same latitude as the eastward offset in the coastline of northeastern Luzon. This suggests that the offset is the manifestation of right-lateral movement along the Dummun river fault zone which may have begun in late Miocene time and had recurrent movement in Pleistocene time.

This fault possibly had its origin as a normal fault in middle or late Miocene as demonstrated by seismic data that indicate possibly 1,000 meters or more of late Miocene strata on the downthrown (south) side of the fault near Gattaran, Cagayan. The change in anticlinal trend, from north-south in the latitude of Tuguegarao to northeast-southwest in the Paret river area suggests some possible drag effect in late Pliocene time of the southern Cagayan valley block against the Aparri Plain block along the Dummun river fault zone.

Of the faulting along the sest margin of the Cagayan valley, the fault systems in the Kalinga Foothills are most accessible, best exposed, and because of the maximum amount of Miocene rocks known to occur in this region, it is probably the most important region to consider relative to the faulting along the west side. One of these fault zones, the Cogowi Creek fault is 3 kilometers wide in the Mallig river area, being comprised of much distorted, faulted, and triturated Miocene sediments. It is in this zone that numerous small oil and gas emanations are found. This fault zone separated the Kalinga Foothills from the Cagayan anticlinal belt. At the Pasunglao ferry near Tabuk, Kalinga, this zone has about 4,000 meters of throw and indirect evidence indicates a strikeslip component of more than 6 kilometers as demonstrated by offset in anticlinal axes and Ilagan formation outcrops of the Tuga nose and Topac anticline. The total length of the Cogowi Creek fault zone is about 50 kilometers and it is upthrown on the west.

The western part of the Kalinga foothills has two major fault zones that trend north-south, of which the northernmost is the Kalinga fault zone and the southern one is the Chico river fault zone. The combined length of these two zones exceeds 80 kilometers. The west side is upthrown along both zones. In the Pasil river bridge area, north of Lubuagan, Kalinga, an imbricate anastomosing relation occurs between these two zones. Combined strike-slip movement on the faults has offset (left-lateral) the syncline at Lubuagan town 10 kilometers. In general the Kalinga foothills region appears to have moved up and north relative to the Cagayan anticlinal belt.

(6) Mineral Resources of Cagayan River Basin

A digest of all available data on Philippine mineral resources can be referred by published book; Data on Philippine mineral Resources, by Bureau of Mines.

The mineralization of Luzon is in close relation with the granitic intrusive rocks which are consist of diorite, quartz-diorite and granodiorite, intruded in Oligocene to Miocene age.

The mineralization which is generally termed as porphyry copper deposit, occurs dissemination network and vein types in the intermediate to acidic phutanic-hypabyssal intrusive masses and their peripheral volcanic rocks. The typical and principal minerals are pyrite, chalcopyrite and bonite, with small amount of the secondary minerals.

The location of mineral resources/mineral mines is indicated in Fig. 3.7 Location Map of Mineral Resources, that is restricted in the Cagayan valley and its periphyery. Significant mineralized district and mine is concentrating in the following area: around the Pasil river (left tributary of Chico river), western area of Santiago, southern are of Bayombong (Dupax), most-upstream area of Cagayan river, eastern area of Ilagan river and its periphery. As above-stated, every location corresponds to the developing area of older volcanics or intruded pultonics.

Generally the following important problem will occur, when a dam constructed near the mineral mine:

- 1) compensation for mine, especially of high-price useful mineral like a gold.

- 2) flowing out of mining poison.

Almost of selected damsites and their reservoir do not locate at that mineralized district. Only two dam, Ilagan No. 1 and Casecnan may relate to it, however, since the mineralization is very slight (Ilagan No. 1) or damsite and reservoir is far from mine (Casecnan), the problem is regarded as minor.