recorded in a series of annual maximum peak discharges, while the basin mean rainfall is unable to estimate for those floods because of no rainfall data in the upstream basin.

In the Study, probable rainfall depth of 5-day basin mean was estimated to enlarge the recorded hourly hyetographs.

The recorded hyetographs during the flood in December 1983, December 1984 and November 1986 were enlarged up to the 5-day rainfall depth with the selected return period from which the simulated peak discharge corresponding to the probable peak discharge is derived at Guillemard Bridge.

The probable rainfall depth and probable flood peak discharges at storage damsites, Kuala Krai and Guillemard Bridge are enumerated in Table II.5.2.

According to the probable distribution of annual peak discharge at Guillemard Bridge, the peak discharge of 15,589 m^3/sec in 1967 corresponds to the probability of once in about 50-year. The simulated 50-year probable flood hydrograph is verified with the flood hydrograph recorded at Guillemard Bridge in 1967 as shown in Fig.II.5.2. The concurrent 50-year probable flood hydrographs at the storage damsites are also simulated as shown in Figs.II.5.3 to II.5.6.

5.4.2 Magnitude of 1967 Flood

The following methods are applied to verify additionally the magnitude of 1967 flood, namely;

(i) Method-1

To estimate the basin mean rainfall in the upstream basin during 1967 flooding referring to the recorded rainfall data in and around the river basin, and

(ii) Method-2

To compare the magnitude of simulated flood peak discharge with the flood mark in 1967 at water level gauging station.

Method-1 is to generate the basin mean rainfall depth on the basis of the correlation analysis among the stations in and around the basin. In case the rainfall data are missing, those data are obtained by multiplying the correlation coefficient between stations. Five-day rainfall depth at the representative fourteen rainfall stations are collected on the basis of the date when the annual maximum peak discharge occurred at Guillemard Bridge. The observation of water level at Guillemard Bridge, however, commenced in 1960 by DID, and the observation of rainfall in the upstream basin has carried out since 1960's. The basin mean five-day rainfall depth during flooding is then calculated for the period from 1960 through 1986. The basin mean five-day rainfall depth during flooding is summarized in Table II.5.3. The data show that the basin mean rainfall depth of more than 500 mm occurred in 1966 (during 1967 flood).

Shown in Fig.II.5.1 is the probable distribution of 5-day rainfall depth estimated by the hyetographs of three types and the estimated 5-day rainfall depth corresponding to the plotting position of concurrent annual maximum peak discharge at Guillemard Bridge. Among three types of hyetographs, the probable distribution of 5-day rainfall depth of 1984 type is well fitted with the plotting position of estimated five-day rainfall depth in 1966 (January, 1967). Besides, the 50-year probable flood hydrograph at Guillemard Bridge simulated by enlarging the hyetograph in 1984 is also well fitted with recorded flood hydrograph in 1967 as shown in Fig.II.5.2.

The recorded hyetograph in 1984 is therefore enlarged up to the estimated rainfall depth of 510.3 mm in 1967 flooding. The simulated 1967 flood hydrograph at Guillemard Bridge and the concurrent flood hydrograph at storage damsites are then simulated by using river basin model as shown in Fig.II.5.7.

Furthermore, Method-2 is applied to verify the magnitude of 1967 flood. According to the water level record during flooding, the maximum water levels during 1967 flooding at Kuala Krai and Guillemard Bridge were surveyed by DID. The highest water levels during the flooding in 1967 were 31.9 m (15,900 m^3/sec) at Kuala Krai and 22.5 m (15,600 m3/sec) at Guillemard Bridge.

The peak discharges of 50-year probable flood are compared with the simulated 1967 flood by using Method-1 and recorded flood peak discharges by Method-2.

Station	Simulated 50-year Probable Flood 1/		Simulated 1967 Flood (Method-1)		Recorded Peak Discharge (Method-2) (cms)
	Peak (cms)	Volume (MCM)	Peak (cms)	Volume (MCM)	
Nenggiri	4,668	845	4,317	814	-
Kemubu	4,624	1,658	4,471	1,617	-
Lower Pergau	2,698	1,062	2,653	1,041	-
Dabong	7,648	2,845	7,422	2,780	-
Lebir	7,102	1,509	6,734	1,453	-
Kuala Krai	17,490	5,416	16,799	5,261	15,900
G/Bridge	16,369	5,397	15,732	5,243	15,600

Note : 1/ The 50-year flood peak discharges of 1984 type are enumerated. (refer to Table II.5.2)

The simulated 1967 flood peak discharges by Method-1 and recorded peak discharges in 1967 by Method-2 are smaller slightly than the simulated 50-year peak discharges. The magnitude of 50-year probable flood therefore covers the safety against 1967 flood.

5.5 Probable Maximum Flood for Storage Dams

Probable maximum flood for storage dam was estimated on the basis of the probable maximum precipitation as described in Section 4.6. The magnitude of probable maximum flood is evaluated referring to the following modified Creager's equation:

$$q = C \cdot A^b \quad \text{(Eq.5.1)}$$

$$b = A^{-0.05} - 1 \quad \text{(Eq.5.2)}$$

where, q : specific discharge in $m^3/sec/km^2$,

A : catchment area in km^2, and

C : Coefficient depending upon the characteristic of the basin.

The envelope curve for C = 100 gives the general trend of all the world maximum flood records with a few exceptions, while it is known that the maximum floods recorded in a region covering Malaysia, Indonesia and Thailand correspond to the envelope curve for C = 34. The Creager's coefficient of the probable maximum flood for storage damsite is enumerated below:

Proposed Damsite	C.A. (km^2)	PMF (cms)	Creager's Coefficient
Nenggiri	3,690	6,394	27
Kemubu	5,630	10,325	38
Lower Pergau	1,280	4,339	29
Dabong	7,480	12,061	40
Lebir	2,480	10,247	55

5.6 Spillway Design Flood for Storage Dams

The probable maximum floods for storage dams are, however, less reliable since the heavy rainfall data in the upstream basin are limited. The magnitude of probable maximum floods is then evaluated under the following criteria:

(i) recorded maximum peak discharge

(ii) 200-year probable peak discharge, and

(iii) peak discharge referring to the largest Creager's coefficient in and around the basin.

The largest peak discharge among the above three floods is adopted to the spillway design flood of concrete gravity dam, while the safety factor of 1.2 is multiplied by the peak discharge for the rockfill type dam according to the dam construction code in Japan.

The comparison of above three peak discharges is given in Table II.5.4. The largest value was adopted for the spillway design flood as follows:

Proposed Damsite	Spillway Design Flood	
	Peak Discharge (cms)	Volume (MCM)
Nenggiri	15,500	2,367
Kemubu	15,000	4,747
Lower Pergau	9,900	4,158
Dabong	16,600	6,057
Lebir	12,400	2,933

The spillway design flood hydrographs for storage dams are shown in Fig.II.5.8. These specific peak discharges for spillway design flood are compared with those of the other dam schemes in the Peninsular Malaysia and other asian countries as shown in Fig.II.5.9.

5.7 Inundation Depth in the Urban Area

5.7.1 Probable Rainfall

The annual maximum rainfall depth at Kota Bharu for various durations are enumerated in Table II.5.5. The 5-day heaviest rainfall of more than 1,000 mm occurred in January 1967, December 1981 and December 1986 for the period from 1956 to 1986. The heaviest rainfall of about 1,500 mm occurred in 1986.

The frequency analysis of annual maximum rainfall for various durations was made as enumerated below.

Return Period (years)	Probable Rainfall Depth (mm)				
	1-day	2-day	3-day	5-day	7-day
50	596	981	1,303	1,699	1,940
30	542	887	1,173	1,354	1,399
20	498	812	1,069	1,237	1,171
10	422	682	888	1,033	922
5	343	546	700	820	706
2	223	340	415	496	453

5.7.2 Inundation Depth at Urban Area

The inundation depth at urban areas in the coastal plain are estimated on the basis of the heighest water level data at Kota Bharu water level gauging station for Kota Bharu and those of

Pasir Mas pumping station for Pasir Mas. Those data are enumerated in Table II.5.6.

The inundation depth at urban areas are plotted referring to the probable distribution of the annual peak discharge at Guillemard Bridge. The heighest inundation depth in the urban areas were recorded at El.11.58 m at Pasir Mas in 1947 and El.6.28 m at Kota Bharu in 1983. As shown in Fig.II.5.10, the dotted line indicates the envelope curve of heighest inundation depth for various probabilities. The data shows the inundation depth is constant against more than 10-year probability.

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Table II.3.1 Area of Thiessen's Polygon

No.	Name of Station	Whole Basin C.A. (sq.km)	Whole Basin Weight	Guillemard Bridge C.A. (sq.km)	Guillemard Bridge Weight
1	Blau	1,740	0.116	1,740	0.144
2	Gua Musang	704	0.047	704	0.058
3	Upper Chiku	868	0.058	868	0.072
4	Kg. Aring	1,698	0.114	1,698	0.141
5	Gemala	1,969	0.132	1,969	0.163
6	Bertam	887	0.059	887	0.073
7	Dabong	869	0.058	869	0.072
8	Lubok Bungor	840	0.056	840	0.070
9	Kg. Lalok	917	0.061	917	0.076
10	Kuala Krai	591	0.040	591	0.049
11	Kg. Jeli	439	0.029	373	0.031
12	Kuala Pertang	441	0.029	415	0.034
13	Machang	441	0.029	74	0.006
14	Lawang	481	0.032	135	0.011
15	Pasir Puteh	432	0.029		
16	Kg. Tandak	224	0.015		
17	To' Uban	358	0.024		
18	Melor	303	0.020		
19	Rantau Panjang	83	0.006		
20	Bachok	170	0.011		
21	Kuala Jambu	185	0.012		
22	Kota Bharu	310	0.021		
	Total	14,950	1.000	12,080	1.000

Note : "Whole Basin" corresponds to the land area of the State of Kelantan of 14,950 sq.km, while the catchment area at Guillemard Bridge is 12,080 sq.km.

Table II.3.2 Area of Thiessen's Polygon contributed to Sub-basin

(Unit:sq.km)

No. of Sub-basin	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Kerai	Jeli	Machang	Lawang	K.Pertang	Total
1	719														719
2	508	10													518
3	388				136										524
4		18			225										243
5					683										683
6					607			35							642
7					318	109									427
8	125	358	87												570
9		318	96			156									570
10			251	16		183									450
11						279									279
12						84	347								431
13								353			373		28		754
14							188	342							530
15							140								140
16							194			115					309
17				619											619
18				283											283
19			170	251											421
20			264	230											494
21				299		66			298						663
22						10			535						545
23									84	199				30	313
24										140					140
25										93		8		323	424
26								110		44		66	107	62	389
Total	1,740	704	868	1,698	1,969	887	869	840	917	591	373	74	135	415	12,080

Table II.3.3 Accumulated Daily Rainfall Depth during 1983 Flood

(Unit : mm)

Station	Weight	3-day Depth	3-day Weighted	4-day Depth	4-day Weighted	5-day Depth	5-day Weighted	6-day Depth	6-day Weighted	7-day Depth	7-day Weighted
Blau	0.144	109.0	15.7	140.2	20.2	146.7	21.1	146.7	21.1	146.7	21.1
G.Musang	0.058	190.9	11.1	260.3	15.1	278.3	16.1	281.3	16.3	281.3	16.3
Chiku	0.072	278.7	20.1	440.5	31.7	464.2	33.4	475.2	34.2	475.2	34.2
Aring	0.141	435.5	61.4	617.4	87.1	643.3	90.7	657.3	92.7	657.3	92.7
Gemala	0.163	191.7	31.2	250.4	40.8	254.4	41.5	256.9	41.9	256.9	41.9
Bertam	0.073	263.3	19.2	389.8	28.5	505.7	36.9	505.7	36.9	505.7	36.9
Dabong	0.072	378.0	27.2	602.0	43.3	648.0	46.7	683.0	49.2	683.0	49.2
Bungor	0.070	505.5	35.4	591.4	41.4	639.1	44.7	639.1	44.7	639.1	44.7
Lalok	0.076	435.0	33.1	633.0	48.1	701.0	53.3	716.0	54.4	716.0	54.4
K.Krai	0.049	564.4	27.7	774.4	37.9	790.2	38.7	797.2	39.1	797.2	39.1
Jeli	0.031	465.2	14.4	544.3	16.9	588.3	18.2	620.3	19.2	621.3	19.3
Pertang	0.034	574.2	19.5	663.1	22.5	683.1	23.2	683.1	23.2	683.1	23.2
Machang	0.006	610.0	3.7	827.0	5.0	892.0	5.4	893.5	5.4	893.5	5.4
Lawang	0.011	447.9	4.9	523.9	5.8	566.4	6.2	610.4	6.7	614.4	6.8
Total	1.000	5,449.3	324.6	7,257.7	444.3	7,800.7	476.2	7,965.7	485.0	7,970.7	485.1
Average		389.2	23.2	518.4	31.7	557.2	34.0	569.0	34.6	569.3	34.7

Table II.3.4 Accumulated Daily Rainfall Depth during 1984 Flood

(Unit : mm)

Station	Weight	3-day Depth	3-day Weighted	4-day Depth	4-day Weighted	5-day Depth	5-day Weighted	6-day Depth	6-day Weighted	7-day Depth	7-day Weighted
Blau	0.144	53.5	7.7	60.5	8.7	76.6	11.0	76.6	11.0	76.6	11.0
G.Musang	0.058	137.0	7.9	137.0	7.9	137.0	7.9	137.0	7.9	137.0	7.9
Chiku	0.072	206.6	14.9	218.1	15.7	239.0	17.2	239.0	17.2	239.0	17.2
Aring	0.141	286.0	40.3	338.9	47.8	381.0	53.7	381.0	53.7	381.0	53.7
Gemala	0.163	189.2	30.8	215.2	35.1	222.7	36.3	222.7	36.3	222.7	36.3
Bertam	0.073	207.3	15.1	259.1	18.9	269.2	19.7	276.2	20.2	276.7	20.2
Dabong	0.072	231.4	16.7	264.0	19.0	273.0	19.7	310.0	22.3	310.0	22.3
Bungor	0.070	266.5	18.7	343.0	24.0	349.0	24.4	378.5	26.5	378.5	26.5
Lalok	0.076	403.4	30.7	475.9	36.2	498.2	37.9	501.2	38.1	501.2	38.1
K.Krai	0.049	285.7	14.0	586.6	28.7	607.7	29.8	667.7	32.7	676.2	33.1
Jeli	0.031	419.5	13.0	465.2	14.4	497.2	15.4	501.2	15.5	515.2	16.0
Pertang	0.034	573.3	19.5	617.7	21.0	624.7	21.2	702.7	23.9	702.7	23.9
Machang	0.006	336.6	2.0	558.7	3.4	619.2	3.7	742.2	4.5	769.2	4.6
Lawang	0.011	494.4	5.4	575.3	6.3	643.8	7.1	740.8	8.1	746.8	8.2
Total	1.000	4,090.4	236.8	5,115.2	287.2	5,438.3	305.0	5,876.8	318.0	5,932.8	319.1
Ave.		292.2	16.9	365.4	20.5	388.5	21.8	419.8	22.7	423.8	22.8

Table II.3.5 Accumulated Daily Rainfall Depth during 1986 Flood

(Unit : mm)

Station	Weight	3-day		4-day		5-day		6-day		7-day	
		Depth	Weighted	Depth	Weighted	Depth	Weighted	Depth	Weighted	Depth	Weighted
Blau	0.144	13.0	1.9	16.5	2.4	22.0	3.2	27.5	4.0	27.5	4.0
G.Musang	0.058	84.3	4.9	96.3	5.6	108.3	6.3	111.3	6.5	111.3	6.5
Chiku	0.072	143.5	10.3	162.4	11.7	192.2	13.8	202.2	14.6	207.2	14.9
Aring	0.141	254.9	35.9	288.4	40.7	341.3	48.1	362.8	51.2	366.3	51.6
Gemala	0.163	120.0	19.6	151.0	24.6	154.0	25.1	157.0	25.6	162.0	26.4
Bertam	0.073	240.3	17.5	309.7	22.6	402.0	29.3	407.0	29.7	411.0	30.0
Dabong	0.072	173.0	12.5	223.0	16.1	289.5	20.8	299.5	21.6	319.0	23.0
Bungor	0.070	246.5	17.3	299.5	21.0	377.0	26.4	393.5	27.5	455.5	31.9
Lalok	0.076	419.5	31.9	502.0	38.2	558.5	42.4	567.0	43.1	579.5	44.0
K.Krai	0.049	467.2	22.9	564.9	27.7	671.1	32.9	691.1	33.9	717.6	35.2
Jeli	0.031	253.6	7.9	328.0	10.2	433.4	13.4	461.9	14.3	528.9	16.4
Pertang	0.034	349.0	11.9	419.0	14.2	499.0	17.0	589.0	20.0	599.0	20.4
Machang	0.006	351.4	2.1	450.8	2.7	566.8	3.4	665.3	4.0	727.8	4.4
Lawang	0.011	316.9	3.5	431.3	4.7	562.8	6.2	604.3	6.6	614.3	6.8
Total	1.000	3,433.1	199.9	4,242.8	242.3	5,177.9	288.4	5,539.4	302.5	5,826.9	315.3
Average		245.2	14.3	303.1	17.3	369.9	20.6	395.7	21.6	416.2	22.5

Table II.3.6 Duration of Design Rainfall

(Unit:mm)

Year	Peak Discharge (cms)	Daily Rainfall Depth				
		3-day	4-day	5-day	6-day	7-day
1960	3,610	120.9	152.6	168.6	174.8	177.5
1961	2,700	95.4	120.5	133.1	138.0	140.2
1962	3,410	115.1	145.3	160.5	166.4	169.0
1963	2,790	106.2	134.0	148.1	153.6	155.9
1964	1,610	75.6	95.4	105.4	109.3	111.0
1965	6,170	170.8	215.6	238.2	247.0	250.8
1966	16,000	365.9	461.8	510.3	529.2	537.3
1967	8,280	201.3	254.1	280.8	291.2	295.7
1968	1,700	73.6	92.9	102.7	106.5	108.1
1969	6,650	141.8	178.9	197.7	205.0	208.2
1970	8,800	160.8	203.0	224.3	232.6	236.2
1971	5,550	107.2	135.3	149.5	155.0	157.4
1972	10,260	248.3	313.4	346.3	359.1	364.7
1973	11,130	286.5	361.6	399.6	414.4	420.8
1974	4,490	123.5	155.8	172.2	178.6	181.3
1975	5,247	117.6	148.4	164.0	170.1	172.7
1976	2,610	67.1	84.7	93.6	97.1	98.6
1977	2,525	58.9	74.3	82.1	85.1	86.5
1978	3,291	122.5	154.7	170.9	177.2	180.0
1979	10,400	261.0	329.4	364.0	377.5	383.3
1980	1,711	75.8	95.7	105.7	109.6	111.3
1981	2,028	67.1	84.7	93.6	97.1	98.6
1982	7,172	170.6	215.3	237.9	246.7	250.5
1983	12,007	324.7	444.3	475.7	485.0	485.1
1984	7,744	236.8	287.2	300.6	318.0	319.1
1985	1,722	82.0	103.4	114.3	118.5	120.4
1986	6,901	199.9	242.3	289.7	302.5	315.3
Ave.	5,797	154.7	195.7	215.9	223.9	227.2
C.C.		0.933	0.955	0.962	0.961	0.960

Note : C.C. means the correlation coefficient between peak discharges and daily rainfall depth.

Table II.3.7 Annual Maximum Peak Discharge at Storage Damsites

Damsite River C.A.(sq.km)	Nenggiri Nenggiri 3,690	Dabong Galas 7,480	Lebir Lebir 2,480
Year			
1972	1255	-	-
1973	1,925	-	-
1974	524	-	-
1975	1,655	1,740	-
1976	436	1,663	951
1977	438	1,705	661
1978	787	2,244	1,190
1979	3,219	6,200	3,940
1980	591	1,007	514
1981	410	1,450	536
1982	1,187	4,736	3,518
1983	1,864	5,920	3,903
1984	1,184	4,250	-
1985	813	1,868	-
1986	560	3,378	-

Table II.3.8 Annual Max. Peak Discharge at Guillemard Bridge

No.	Year	Peak Discharge (cms)	No.	Year	Peak Discharge (cms)
1	1941	2,030	24	1964	1,610
2	1942	11,480	25	1965	6,170
3	1943	4,630	26	1966	16,000
4	1944	5,230	27	1967	8,280
5	1945	12,850	28	1968	1,700
6	1946	3,970	29	1969	6,650
7	1947	13,580	30	1970	8,800
8	1948	3,420	31	1971	5,550
9	1949	7,050	32	1972	10,260
10	1950	8,090	33	1973	11,130
11	1951	2,600	34	1974	4,490
12	1952	1,970	35	1975	5,247
13	1953	4,060	36	1976	2,610
14	1954	4,550	37	1977	2,525
15	1955	2,310	38	1978	3,291
16	1956	2,580	39	1979	10,400
17	1957	6,050	40	1980	1,711
18	1958	1,500	41	1981	2,028
19	1959	3,440	42	1982	7,172
20	1960	3,610	43	1983	12,007
21	1961	2,700	44	1984	7,744
22	1962	3,410	45	1985	1,722
23	1963	2,790	46	1986	6,901

Note : Data from 1941 to 1974 --- "The Kelantan River Basin Study (ENEX)", 1977

Data from 1975 to 1986 ---- Observed data by D.I.D.

Table II.3.9 Runoff Parameter for Sub-basin

No.	Name of Basin	C.A. (sq.km)	River Length (km)	River Gradient	K	P	TL (hours)	Base Flow (cms)
1	Berok	719	40.4	1/ 30	42.9	0.500	1.0	36.0
2	Chenderoh	518	23.6	1/ 200	24.3	0.500	1.0	26.0
3	Betis	524	55.4	1/ 350	20.5	0.500	2.0	26.0
4	Chepuan	243	16.2	1/ 20	48.4	0.500	0.0	12.0
5	Perias	683	54.6	1/ 30	42.9	0.500	2.0	34.0
6	Puian	642	45.6	1/ 40	39.3	0.500	2.0	32.0
7	Wias	427	24.8	1/ 20	48.4	0.500	1.0	21.0
8	Upper Galas	570	45.4	1/ 70	33.3	0.500	2.0	56.0
9	Middle Galas	570	28.6	1/ 35	41.0	0.500	1.0	56.0
10	Chiku	450	61.2	1/ 120	28.3	0.500	2.0	88.0
11	Lower Galas 1	433	22.0	1/ 20	48.4	0.500	0.0	85.0
12	Lower Galas 2	277	26.0	1/ 20	48.4	0.500	1.0	55.0
13	Upper Pergau	754	68.4	1/ 60	34.8	0.500	3.0	152.0
14	Middle Pergau	530	24.6	1/ 20	48.4	0.500	1.0	105.0
15	Lower Pergau	140	18.0	1/ 20	48.4	0.500	0.0	28.0
16	Teku	309	22.0	1/ 50	36.8	0.500	0.0	62.0
17	Upper Lebir	619	34.4	1/ 30	42.9	0.500	1.0	31.0
18	Klelinsar	283	18.4	1/ 35	41.0	0.500	0.0	14.0
19	Aring	421	74.4	1/ 90	30.9	0.500	3.0	21.0
20	Relai	494	77.6	1/ 50	36.8	0.500	3.0	25.0
21	Chalil	663	22.8	1/ 300	21.5	0.500	1.0	33.0
22	Rek	545	22.4	1/ 30	42.9	0.500	0.0	109.0
23	Pahi	313	28.8	1/ 35	41.0	0.500	1.0	63.0
24	Taku	140	18.8	1/ 70	33.3	0.500	0.0	14.0
25	Nalu	424	34.0	1/ 60	34.8	0.500	1.0	21.0
26	Sokor	389	31.4	1/ 60	34.8	0.500	1.0	86.0
	Total	12,080						

Table II.3.10 Runoff Parameter for Sub-divided River Channel

No.	Name of Channel	River Length (km)	River Gradient	K	P	TL (hours)	Remarks
1	Upper Nenggiri	49.2	1/ 600	34.0	0.50	1.0	
2	Middle Nenggiri	30.4	1/ 800	42.0	0.65	1.0	
3	Lower Nenggiri	32.0	1/ 1000	58.0	0.75	1.0	
4	Upper Galas	45.0	1/ 900	63.0	0.60	1.0	
5	Middle Galas 1	41.4	1/ 1900	106.0	0.76	1.0	Q<2,500
				53.0	0.95	1.0	Q>2,500
6	Middle Galas 2	25.0	1/ 2300	85.0	0.76	0.0	Q<2,500
				45.0	0.95	1.0	Q>2,500
7	Middle Pergau	18.6	1/ 4000	108.0	0.85	1.0	Q<1,800
				26.0	1.10	2.0	Q>1,800
8	Lower Pergau	15.0	1/ 4000	110.0	0.85	0.0	Q<1,800
				28.0	1.10	0.0	Q>1,800
9	Lower Galas	36.8	1/ 2500	87.0	0.71	1.0	
10	Upper Lebir	26.0	1/ 540	142.0	0.74	0.0	
11	Middle Lebir	39.6	1/ 1700	150.0	0.79	1.0	
12	Lower Lebir-1	16.4	1/ 3000	114.0	0.70	1.0	
13	Lower Lebir-2	20.4	1/ 4000	125.0	0.72	1.0	
14	Kelantan-1	18.8	1/ 5000	142.0	0.60	1.0	Q<6,000
				71.0	0.75	1.0	Q>6,000
15	Kelantan-2	25.4	1/ 5800	152.0	0.60	1.0	Q<7,000
				76.0	0.75	1.0	Q>7,000

Table.II.4.1 Annual Rainfall Depth in the State of Kelantan

(Unit : mm)

Year	Blau	G.Musang	Aring	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang	P.Puteh	Tandak	T.Uban	Melor	Panjang	Bachok	K.Jambu	K.Bharu
1948										2,049										
1949										3,109										
1950										2,864					2,507					
1951										2,684					3,539					
1952																				
1953										2,703										
1954										2,679					2,571					
1955										2,205					2,416					
1956										2,903					2,900					
1957										3,363					3,012			3,002		2,668
1958									2,683	2,082								2,155		2,558
1959					2,856	2,301		1,550	3,997	2,588	1,410		2,703		2,089		2,769		1,884	3,216
1960					1,731			1,467	2,988	2,695	1,378		2,652	3,433			2,187		873	3,109
1961					2,602	2,173		1,860	2,569	2,759	2,135		3,391	3,300			4,084	2,998		3,657
1962					2,297	3,274		2,059		2,713	1,888		1,527	3,196	3,100		3,157	2,581		2,900
1963					2,190	3,046		2,099		2,931	2,521		2,365	3,178			2,123			2,012
1964					2,323	2,830		1,734		2,476			2,733	3,500	2,750		2,230	2,079	2,076	2,230
1965					2,943	3,484				2,766				3,352	2,784			3,726	3,079	3,546
1966		1,923		2,546	3,528	3,594			4,576	2,997	3,702			3,970	3,764	3,650		3,207	3,036	3,486
1967				2,729							4,010					3,710	3,053	3,296		3,699
1968				1,991	2,005	3,120				2,204	2,692			1,559	2,580	2,873	2,275	2,494	2,309	2,509
1969					2,676	3,779		2,198	3,175	2,349	2,502			2,640	2,918	2,835	2,513	2,634	2,179	2,541
1970		2,318			2,806	3,407		1,918	3,168	1,998	2,721			2,322	1,670	2,753	2,942	2,494		2,581
1971				2,159		3,898		2,768	3,467	2,980	2,948			2,926	2,339	3,167	3,138	2,724	2,001	2,667
1972		2,006		2,138		3,743		2,148		2,572	3,034			2,493	2,394	2,360		2,102	1,186	2,081
1973					2,903	4,454	2,992		3,782	3,800				4,818	3,532	3,632		3,825		3,700
1974						1,438	2,280			2,278	2,850			4,748	2,631	3,193		2,603	1,939	2,506
1975						3,161				3,691	3,840			4,444	3,048			3,283		3,104
1976					2,230	3,183				2,847	2,952			2,957	3,149	3,026		3,236	2,923	2,901
1977						2,590				2,131	2,782		3,274	2,705	2,453	2,729		2,735	2,180	2,736
1978		2,041			1,938	3,310	1,963	1,839	2,494	2,395			2,247	2,632	2,021	2,734			1,745	
1979		2,145			1,836	3,717	2,285		2,948	2,265				2,405			2,875	2,632		
1980														2,471	2,592	2,719		2,799	2,839	
1981		2,157			1,354	2,411	1,701							2,517	2,939	2,129		2,762	2,274	
1982		2,168	2,612	2,101	2,127	3,202		1,849	2,851	2,400	2,452	3,074	1,643	2,391	2,358	2,656	2,809	2,597	1,619	1,957
1983	2,200		2,717				2,357	2,776		2,796	3,142	3,217	3,590	2,454	3,051	3,342	3,024	3,470	2,154	2,682
1984	2,207	2,939				3,429		2,815	3,370	3,524	3,241	3,849	2,860	2,959	2,906	2,565	3,056	2,488	3,302	2,279
1985			2,403	2,126	2,873	3,293	1,882	2,529	3,089	3,034	3,005	2,475	3,489	3,297	2,865	2,974	2,286	2,921	2,593	2,858
1986		2,822	2,935	1,620		3,208	1,911	2,328	3,047	2,902	2,728	2,646	2,441	2,914	2,653	2,592	2,341	2,739	2,570	2,877
Max.	2,207	2,939	2,935	2,729	3,528	4,454	2,992	2,815	4,576	3,800	4,010	3,849	3,590	4,818	3,764	3,710	4,084	3,825	3,302	3,700
Min.	2,200	1,923	2,403	1,620	1,354	1,438	1,701	1,467	2,494	1,998	1,378	2,475	1,527	1,559	1,670	2,129	2,123	2,079	873	1,957
No.	2	9	4	8	18	24	8	16	15	35	21	5	13	26	29	19	17	26	20	26
Ave.	2,204	2,280	2,667	2,176	2,401	3,169	2,171	2,121	3,214	2,707	2,759	3,052	2,686	3,061	2,742	2,928	2,757	2,830	2,238	2,810

Table II.4.2 Monthly Mean Rainfall Depth in the State of Kelantan

(Unit:mm)

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Blau	69	103	169	138	270	151	230	68	204	267	236	157	2,062
Gua Musang	85	107	100	140	238	183	181	209	297	272	233	207	2,252
Aring	93	78	51	114	270	158	205	232	289	328	228	378	2,424
Bertam	59	96	69	136	206	90	197	178	242	266	137	280	1,956
Dabong	93	78	72	171	158	138	200	203	193	247	315	311	2,179
Lubok Bungor	190	132	136	137	231	179	179	200	241	372	435	560	2,992
Lalok	85	94	93	111	216	153	188	200	273	258	274	444	2,389
Kuala Krai	106	166	153	108	160	121	124	168	231	175	188	761	2,461
Jeli	152	133	115	184	252	187	199	229	294	332	433	682	3,192
Kuala Pertang	201	107	93	105	166	138	172	195	274	261	379	548	2,639
Machang	170	60	128	91	190	175	187	216	307	253	451	533	2,761
Lawang	98	157	140	129	246	218	264	255	306	303	271	589	2,976
Pasir Puteh	140	71	91	81	170	134	199	198	289	260	493	639	2,765
Tandak	161	71	74	95	201	193	265	277	352	368	456	583	3,096
To' Uban	146	85	71	73	180	178	216	246	288	297	435	571	2,786
Melor	207	74	92	86	155	186	208	242	292	297	534	654	3,027
Bachok	138	60	106	93	122	126	182	192	211	310	624	609	2,773
Kuala Jambu	82	34	61	51	101	121	178	192	208	248	483	464	2,223
Kota Bharu	79	36	66	55	106	101	177	142	209	257	702	743	2,673

Table II.4.3 Annual Maximum 1-Day Rainfall Depth in the State of Kelantan

(Unit:mm)

Year	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang
1947												241.3		
1948												147.3		
1949												199.4		
1950												152.9		
1951												134.9		
1952												107.7		
1953												146.1		
1954												167.6		
1955												105.2		
1956								93.0				87.9		
1957								88.9				143.5		
1958								79.8				62.7		
1959								112.5				87.6		
1960								61.0				133.3		
1961								40.6				146.0		
1962								43.2				215.9		
1963								114.0				185.4		
1964								91.4				137.7		
1965								101.6				181.4		
1966								109.2				128.0	304.8	
1967								235.5		281.2		157.5	419.6	
1968							121.4	99.1		63.5		74.9	106.9	
1969							158.2	165.6		162.8		154.7	188.0	
1970						67.3	95.8	137.7		90.7		103.4	149.6	
1971						117.6	126.2	191.5		335.5		333.2	243.8	
1972		100.1				100.6	110.0	197.9		181.6		320.0	329.7	
1973						148.6	150.9	427.2	202.9	95.0	246.9	346.7		
1974		74.0				91.7	84.0	78.5	82.0	183.0	298.0	212.0	402.5	
1975		92.0				100.6	162.0	226.0	137.0	92.0	283.0	218.0	447.5	
1976		110.0					123.0	85.5	100.0	82.5	97.0	120.0	113.5	
1977		88.0		68.0			69.0	90.0	95.0	63.0	88.0	96.0	104.5	
1978		94.0	86.0	69.0	96.5	107.5	104.0	159.0	81.0	134.0	125.0	147.0	115.0	
1979	88.5	164.0	107.5	265.5	99.5	199.5	241.0	384.0	288.0	159.0	131.5	121.0	155.0	
1980	110.0	71.0			111.5		60.0	69.0			94.0	76.0		
1981		102.0		103.0		81.0	75.0	122.0	96.0	63.0	196.0	87.5	65.5	
1982	89.0	86.0	110.0	136.0	100.5	151.0	102.0	206.0	164.0	274.2	171.0	273.0	97.5	161.8
1983	85.3	125.6	224.6	257.1	97.8	54.5	98.0		243.0	275.7	180.1	263.0	290.0	204.0
1984	65.0	105.0	148.5	204.6	89.0	170.6	131.0	205.5	213.0	88.5	269.5	325.0	383.1	295.7
1985	106.5	91.0	88.0	135.0	70.5	86.5	106.0	104.0	90.0	90.0	94.0	100.0	190.0	104.5
1986	94.0	82.6	68.0	120.3	70.0	106.5	127.8	108.5	218.0	227.3	160.8	559.0	201.8	181.0
Max.	110.0	164.0	224.6	265.5	111.5	199.5	286.3	427.2	288.0	335.5	298.0	559.0	447.5	295.7
Min.	65.0	71.0	68.0	68.0	70.0	54.5	60.0	40.6	81.0	63.0	88.0	62.7	65.5	104.5
Ave.	91.2	99.0	118.9	150.9	91.9	109.0	118.1	140.9	154.6	154.9	173.9	175.0	226.8	189.4

Table II.4.4 Annual Maximum 2-Day Rainfall Depth in the State of Kelantan

(Unit:mm)

Year	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang
1947												373.6		
1948												157.5		
1949												293.9		
1950												226.6		
1951												201.4		
1952												107.7		
1953												237.3		
1954												203.2		
1955												181.4		
1956								136.7				165.6		
1957								154.2				286.8		
1958								79.8				104.7		
1959								136.6				142.2		
1960								102.9				181.8		
1961								81.0				210.0		
1962								83.6				230.6		
1963								164.9				287.5		
1964								110.2				192.1		
1965								195.6				312.7		
1966								164.8				185.1	406.4	
1967								455.0		400.6		295.2	756.9	
1968							134.1	134.4		79.0		115.0	153.9	
1969							213.1	252.0		210.0		217.7	235.0	
1970						107.7	174.5	215.9		179.6		180.6	239.0	
1971						183.4	200.4	196.3		404.1		379.7	328.1	
1972		122.2				151.9	204.0	335.1		340.6		528.3	528.3	
1973						228.1	160.0	736.3	326.9	158.7	366.8	621.5		
1974		104.0				103.1	114.0	95.0	103.0	233.0	341.0	344.0	548.0	
1975		110.0				125.0	206.0	299.0	149.0	108.0	346.0	257.5	543.0	
1976		111.0					126.0	122.5	100.0	83.5	131.0	157.0	166.0	
1977		100.0		114.0			84.0	136.0	120.0	93.5	110.0	132.0	133.0	
1978		126.0	89.5	89.0	171.5	157.5	126.0	263.0	138.0	217.0	227.0	287.0	135.0	
1979	111.0	202.0	186.5	400.5	144.0	350.5	302.0	548.0	413.0	279.0	217.0	194.5	213.0	
1980	110.0	89.0			111.5		82.0	102.0			176.0	123.0		
1981		164.0		103.0		93.7	127.0	149.0	108.0	80.5	244.0	175.0	118.1	
1982	111.0	113.0	167.0	211.0	110.0	210.0	187.0	298.5	245.0	386.2	249.0	418.0	167.3	298.5
1983	95.3	163.3	286.3	357.1	140.8	98.5	143.0		367.0	474.2	333.0	492.0	525.0	380.0
1984	95.5	115.0	183.5	309.0	115.0	222.4	181.0	282.0	285.0	122.5	344.0	480.0	501.8	448.5
1985	106.5	138.0	118.5	146.0	71.0	151.0	108.0	128.0	130.0	156.0	163.0	188.0	204.7	161.0
1986	108.8	91.0	96.5	221.4	83.0	115.5	202.7	197.5	336.0	418.4	218.7	591.0	397.2	273.5
Max.	111.0	202.0	286.3	400.5	171.5	350.5	468.4	736.3	413.0	474.2	366.8	621.5	756.9	448.5
Min.	95.3	89.0	89.5	89.0	71.0	93.7	82.0	79.8	100.0	79.0	110.0	104.7	118.1	161.0
Ave.	105.4	124.9	161.1	216.8	118.4	157.1	162.8	211.9	217.0	232.9	247.6	261.5	331.6	312.3

Table II.4.5 Annual Maximum 3-Day Rainfall Depth in the State of Kelantan

(Unit:mm)

Year	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang
1947												486.9		
1948												182.1		
1949												368.8		
1950												260.9		
1951												265.4		
1952												184.2		
1953												286.8		
1954												240.0		
1955												181.4		
1956								212.4				203.7		
1957								160.5				390.9		
1958								101.6				141.0		
1959								138.4				196.6		
1960								133.4				217.6		
1961								108.4				210.0		
1962								123.5				233.6		
1963								193.9				343.6		
1964								110.2				192.1		
1965								284.5				437.4		
1966								222.7				260.0	505.5	
1967								528.7		468.9		354.4	877.6	
1968							134.1	144.8		97.0		151.3	185.6	
1969							248.4	281.9		247.6		258.6	247.7	
1970						124.2	229.1	246.4		232.9		246.4	248.9	
1971						202.2	268.2	217.4		408.7		389.4	330.9	
1972		174.3				163.8	261.9	529.2		410.5		685.8	638.0	
1973						258.1	199.1	791.9	418.8	166.8	425.7	708.4		
1974		104.0				103.1	144.0	108.0	138.0	270.0	368.0	389.0	612.5	
1975		133.6				139.5	216.0	315.0	184.0	113.5	361.0	286.0	603.0	
1976		113.0					126.0	144.0	100.0	101.5	193.0	227.0	226.0	
1977		102.0		115.0			84.0	142.5	144.0	99.5	173.0	142.0	179.0	
1978		141.0	135.5	99.0	177.5	162.5	138.0	327.0	143.0	242.5	276.0	314.0	224.5	
1979	119.0	235.0	186.5	416.0	146.0	353.0	353.0	584.0	462.0	323.0	254.5	234.0	298.0	
1980	112.5	106.0			111.5		95.0	111.0			190.0	129.0		
1981		164.0		120.0		105.6	154.0	170.0	108.0	98.0	259.0	225.0	126.1	
1982	112.5	121.0	180.0	247.0	118.5	244.5	213.0	368.0	299.0	405.5	309.0	456.0	179.8	351.0
1983	100.8	235.1	395.5	524.3	233.2	99.5	195.0		422.0	659.4	502.9	645.0	742.0	501.0
1984	102.0	115.0	197.9	336.6	122.5	232.5	241.0	294.0	291.0	133.5	372.0	529.0	530.0	478.5
1985	120.5	145.0	137.5	163.0	111.5	151.0	121.0	173.0	148.0	184.5	213.0	238.0	257.3	200.1
1986	122.5	125.0	107.5	284.3	124.0	156.3	240.5	250.5	410.0	516.1	345.8	613.0	522.2	309.0
Max.	122.5	235.1	395.5	524.3	233.2	353.0	613.2	791.9	462.0	659.4	502.9	708.4	877.6	501.0
Min.	100.8	102.0	107.5	99.0	111.5	99.5	84.0	101.6	100.0	97.0	173.0	129.0	126.1	200.1
Ave.	112.8	143.9	191.5	256.1	143.1	171.9	199.3	250.6	251.4	272.6	303.1	312.6	396.6	367.9

Table II.4.6 Annual Maximum 5-Day Rainfall Depth in the State of Kelantan

(Unit:mm)

Year	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang
1947												508.9		
1948												207.0		
1949												446.5		
1950												261.5		
1951												310.1		
1952												185.2		
1953												415.5		
1954												248.1		
1955												137.2		
1956								252.4				283.1		
1957								165.2				395.8		
1958								160.0				157.3		
1959								146.5				115.8		
1960								173.4				147.3		
1961								149.0				247.6		
1962								107.5				236.4		
1963								203.3				395.4		
1964								118.7				192.1		
1965								328.9				507.3		
1966								240.8				271.6	470.7	
1967								542.4				357.3	1028.9	
1968							134.1	155.3				132.1	195.0	
1969							278.1	351.7				311.6	263.0	
1970						171.2	296.6	362.0		298.7		291.6	261.9	
1971						228.8	299.5	315.5	263.1	410.2		353.1	333.4	
1972		205.2				187.9	325.9	619.4	303.3	492.8		772.7	785.9	
1973						293.2	250.8	847.3	473.9	192.2	478.5	796.8		
1974		121.0				106.1	204.0	92.5	150.0	297.0	430.0	425.0	777.0	
1975		149.6				175.6	227.0	335.0	197.0	154.0	378.0	445.0	701.0	
1976		150.0					126.0	236.0	121.0	130.5	258.0	292.0	293.5	
1977		148.0		136.0			95.0	182.5	117.0	117.0	251.0	197.0	175.0	
1978		154.0	138.5	115.0	177.5	162.5	188.0	430.0	192.0	263.5	340.0	355.0	261.0	
1979	206.0	309.0	259.0	452.5	181.0	429.0	413.0	665.5	509.0	362.5	328.5	282.5	334.0	
1980	107.5	132.0			111.5		119.0	121.5			195.0	176.5		
1981		196.0		119.0		115.2	170.0	203.0	125.0	145.0	289.0	225.0	182.6	
1982	112.5	127.0	218.0	259.0	118.5	255.0	243.5	479.0	308.0	418.5	354.0	477.0	227.0	388.4
1983	150.0	278.0	461.3	641.0	252.2	123.0	255.0		495.0	790.0	520.9	836.0	892.0	580.5
1984	97.0	177.0	232.9	381.0	122.5	243.0	283.0	375.0	306.0	162.0	522.0	641.5	682.0	619.5
1985	140.0	134.0	123.0	184.0	92.0	193.0	157.0	269.5	170.0	173.0	194.0	262.0	264.0	208.5
1986	167.0	157.0	192.2	341.6	154.0	402.0	293.5	377.0	546.0	672.0	471.5	635.0	760.9	486.0
Max.	206.0	309.0	461.3	641.0	252.2	429.0	703.4	847.3	546.0	790.0	522.0	836.0	1028.9	619.5
Min.	97.0	121.0	123.0	115.0	92.0	106.1	95.0	92.5	117.0	117.0	194.0	115.8	175.0	208.5
Ave.	140.0	174.1	232.1	292.1	151.2	207.7	240.5	300.2	285.1	317.4	357.9	348.4	467.8	456.6

Table II.4.7 Probable Maximum Daily Rainfall Depth (1/2)

Station	Return Period (years)	Rainfall depth (mm) 1-day	2-day	3-day	5-day
Blau	200	167	231	287	336
	100	156	216	268	308
	50	145	201	249	279
	20	130	180	223	241
	10	119	165	204	235
	5	107	148	184	211
Gua Musang	200	207	271	346	432
	100	191	250	317	395
	50	175	228	287	357
	20	154	200	248	307
	10	138	178	217	268
	5	121	155	186	227
Upper Chiku	200	389	509	679	805
	100	350	459	609	722
	50	311	409	538	639
	20	259	341	444	528
	10	218	289	371	443
	5	176	235	295	354
Kg. Aring	200	515	781	981	1,165
	100	462	699	876	1,039
	50	409	617	771	912
	20	339	508	630	743
	10	284	423	522	612
	5	227	335	408	476
Gemala	200	165	282	355	409
	100	155	259	324	372
	50	144	235	294	334
	20	130	203	253	284
	10	119	179	221	246
	5	107	153	188	206
Bertam	200	279	445	461	601
	100	254	403	419	544
	50	229	361	377	486
	20	196	305	320	410
	10	171	261	277	350
	5	144	216	231	288
Dabong	200	331	488	627	730
	100	300	441	564	659
	50	269	393	502	587
	20	227	329	418	491
	10	195	280	353	417
	5	161	229	286	340

Table II.4.8 Probable Maximum Daily Rainfall Depth (2/2)

Station	Return Period (years)	Rainfall depth (mm)			
		1-day	2-day	3-day	5-day
Lubok Bungor	200	518	835	946	1,071
	100	463	744	844	958
	50	408	652	742	845
	20	334	530	606	694
	10	277	436	501	578
	5	217	338	391	456
Kg. Lalok	200	483	748	884	979
	100	435	671	792	878
	50	387	594	670	776
	20	323	490	577	641
	10	274	410	482	537
	5	223	327	382	428
Kuala Krai	200	537	819	1,001	1,213
	100	481	733	895	1,083
	50	425	648	788	952
	20	351	533	646	777
	10	293	445	536	643
	5	233	353	422	502
Kg. Jeli	200	516	641	749	876
	100	466	584	685	801
	50	416	526	619	725
	20	350	450	533	624
	10	298	391	465	546
	5	245	329	395	465
Kuala Pertang	200	577	807	943	1,105
	100	518	727	851	994
	50	459	647	758	883
	20	380	540	634	735
	10	319	458	539	620
	5	256	371	439	501
Machang	200	743	1,165	1,376	1,701
	100	667	1,043	1,233	1,521
	50	590	922	1,090	1,341
	20	489	759	899	1,100
	10	410	633	751	914
	5	328	502	597	720
Lawang	200	571	908	1,047	1,357
	100	516	823	949	1,228
	50	461	737	851	1,098
	20	388	622	720	924
	10	331	533	619	790
	5	272	441	514	650

Table II.4.9 Hourly Rainfall Records More Than 300mm/day

Hour	Station Year From To	A.Lanas 1984 Dec.22 Dec.23	Machang 1984 Dec.22 Dec.23	B.Nyior 1984 Dec.22 Dec.23	Kg.Tandak 1986 Nov.29 Nov.30	R.Panjang 1986 Nov.29 Nov.30	Ratio	Accumulated Ratio
1		9.0	29.9	2.7	6.6	5.2	0.027	0.027
2		11.1	29.0	16.7	6.6	5.2	0.035	0.062
3		11.7	27.4	26.5	9.8	5.2	0.041	0.103
4		12.8	29.6	18.3	19.4	5.2	0.045	0.147
5		17.8	27.0	18.2	19.4	5.2	0.046	0.193
6		24.1	21.0	14.1	17.5	5.2	0.044	0.237
7		8.9	21.0	20.0	16.6	9.8	0.041	0.278
8		11.9	4.1	6.4	16.6	12.2	0.030	0.307
9		22.3	1.0	18.9	27.9	12.2	0.047	0.355
10		37.9	6.6	4.1	31.5	12.2	0.054	0.408
11		19.1	13.3	0.5	20.8	20.2	0.043	0.451
12		13.3	10.6	8.0	20.8	27.0	0.046	0.497
13		7.9	13.3	6.2	12.9	30.6	0.041	0.537
14		7.6	31.0	36.7	10.6	34.9	0.064	0.602
15		15.4	32.4	22.2	10.6	43.7	0.068	0.670
16		12.2	30.5	42.4	10.6	19.9	0.060	0.729
17		14.4	23.0	28.0	4.8	19.9	0.047	0.777
18		4.0	19.7	26.7	4.5	12.1	0.034	0.811
19		18.1	18.5	17.8	1.9	5.5	0.032	0.843
20		21.6	12.0	10.6	1.6	5.5	0.027	0.870
21		22.9	12.0	22.3	12.8	5.5	0.040	0.910
22		4.9	12.0	17.0	15.3	5.5	0.029	0.939
23		14.8	12.0	5.9	15.3	5.5	0.030	0.969
24		11.7	9.4	28.7	5.0	5.5	0.031	1.000
Total		355.4	446.3	418.9	319.4	318.9	1.000	
Max		37.9	32.4	42.4	31.5	43.7		

Table II.4.10 Derivation of Probable Maximum Precipitation

Station	Thiessen Area (sq.km)	1-day P.M.P. (mm)	Area Reduction Factor	1-day P.M.P. (mm)	1-day 100-year (mm)	Maximi-zation Factor
Blau	1,740	490	0.38	186	156	1.194
Gua Musang	704	599	0.41	246	191	1.286
Upper Chiku	868	1,098	0.39	428	350	1.223
Kg. Aring	1,698	1,449	0.38	551	462	1.192
Gemala	1,969	489	0.38	186	155	1.199
Bertam	887	816	0.38	310	254	1.221
Dabong	869	883	0.38	336	300	1.118
Lubok Bungor	840	1,493	0.39	582	463	1.258
Kg. Lalok	917	1,365	0.38	519	435	1.192
Kuala Krai	591	1,669	0.43	718	481	1.492
Kg. Jeli	373	1,462	0.56	819	466	1.757
Kuala Pertang	74	1,489	0.90	1,340	518	2.587
Machang	135	2,067	0.82	1,695	667	2.541
Lawang	415	1,619	0.53	858	516	1.663
Total	12,080					
Weighted Average		1,013		423	321	

Table II.4.11 Basin Mean Probable Maximum Precipitation

Station	Rainfall Depth (mm)					Total
	1st day	2nd day	3rd day	4th day	5th day	
Blau	24	71	186	62	24	367
Gua Musang	50	86	246	76	50	508
Upper Chiku	69	184	428	133	69	883
Kg. Aring	96	281	550	211	97	1,235
Gemala	28	124	185	78	29	444
Bertam	76	182	310	77	19	664
Dabong	53	158	336	138	53	738
Lubok Bungor	73	350	582	126	73	1,204
Kg. Lalok	51	281	519	145	51	1,047
Kuala Krai	140	376	718	242	140	1,616
Kg. Jeli	102	209	819	177	102	1,409
Kuala Pertan	185	541	1,340	321	185	2,572
Machang	366	955	1,695	483	366	3,865
Lawang	231	511	858	231	209	2,040

Table II.5.1 Mean Annual Runoff

Description	Water Level Gauging Station			
	Chegar Atas	Dabong	Tualang	G.Bridge
River	Nenggiri	Galas	Lebir	Kelantan
C.A. (sq.km)	3,690	7,480	2,480	12,080
Mean Rainfall (mm)	2,250	2,550	2,750	2,700
Mean Annual Runoff				
Discharge (cms)	119	(*) 555	113	600
Volume (MCM)	3,770	17,500	3,564	18,900
Runoff depth (mm)	1,010	2,340	1,440	1,590
Specific Runoff (l/s/sq.km)	32	74	46	50
Runoff/Rainfall	0.45	0.92	0.52	0.59

Note : Discharge data at Dabong are not reliable.

Table II.5.2 Comparison of Probable Rainfall Depth and Probable Flood Peak Discharges

Return Period (years)	Basin Mean Rainfall (mm)	Hyetograph Type	Hyetograph Depth (mm)	Hyetograph Ratio of Expansion	Probable Flood Peak Discharge (cms) Nenggiri Damsite	Kemubu Damsite	Pergau Damsite	Dabong Damsite	Lebir Damsite	Kuala Krai	Guillemard Bridge
	699	1983	475.7	1.47	4,204	5,597	3,462	9,451	6,231	18,841	18,331
100	580	1984	300.6	1.93	5,527	5,255	2,961	8,559	8,052	19,669	18,373
	695	1986	289.7	2.40	3,432	5,205	3,084	8,626	7,039	18,806	18,382
	633	1983	475.7	1.33	3,482	4,943	3,145	8,431	5,561	16,831	16,383
50	530	1984	300.6	1.76	4,668	4,624	2,698	7,648	7,102	17,490	16,369
	626	1986	289.7	2.16	2,959	4,559	2,837	7,682	6,201	16,696	16,314
	576	1983	475.7	1.21	2,901	4,352	2,907	7,557	4,997	15,110	14,714
30	490	1984	300.6	1.63	3,957	4,134	2,519	6,911	6,342	15,758	14,768
	571	1986	289.7	1.97	2,556	4,078	2,666	6,995	5,539	15,092	14,749
	533	1983	475.7	1.12	2,486	3,939	2,715	6,918	4,559	13,826	13,468
20	450	1984	300.6	1.50	3,248	3,796	2,392	6,402	5,604	14,318	13,437
	524	1986	289.7	1.81	2,212	3,716	2,503	6,444	4,983	13,777	13,466
	-	1983	475.7	-	-	-	-	-	-	-	-
10	395	1984	300.6	1.31	2,327	3,152	2,159	5,497	4,626	12,095	11,422
	452	1986	289.7	1.56	1,584	3,102	2,248	5,542	4,104	11,685	11,429
	-	1983	475.7	-	-	-	-	-	-	-	-
5	316	1984	300.6	1.05	1,204	2,409	1,791	4,383	3,259	9,184	8,665
	351	1986	289.7	1.21	868	2,363	1,871	4,393	2,893	8,878	8,680

Note : The above values are calculated on the basis of the return period at Guillemard Bridge.

Table II.5.3 Five (5) Days Rainfall Depth during Annual Maximum Peak Discharge

(Unit:mm)

Year	Blau	G.Musang	Chiku	Aring	Gemala	Bertam	Dabong	L.Bungor	Lalok	K.Krai	Kg.Jeli	Pertang	Machang	Lawang	Average
1960	73.1	110.1	119.4	276.9	121.1	152.6	193.5	157.5*	216.4	221.7	236.8	247.3*	450.4	227.5	168.6
1961	64.4	88.1	73.9	229.4	106.0	101.2	176.8	151.8*	145.9	143.6	175.7	163.8*	379.7	147.7	133.1
1962	71.9	107.2	113.4	270.7	119.1	145.9	191.3	107.5*	207.2	211.5	228.8	236.4*	441.1	217.1	160.5
1963	68.4	98.1	94.6	251.1	112.9	124.6	184.4	136.6*	178.1	179.2	203.5	201.9*	411.9	184.1	148.1
1964	57.6	71.0	38.6	192.6	94.3	61.3	163.8	146.2*	91.2	82.9	128.3	99.0*	324.9	85.7	105.4
1965	38.1	21.6	261.0	424.8	142.5	148.6	40.2	328.9*	435.9	465.1	426.9	507.3*	187.7*	476.1	238.2
1966	127.2	247.0	402.6	572.6	581.2	455.0	701.9	676.9	631.2	708.4	617.0	767.2	1028.9*	724.6	510.3
1967	104.8	190.3	263.2	427.1	140.8	218.2	215.3	542.4*	439.3	468.9	316.5	356.4*	207.0*	331.8	280.8
1968	52.1	56.9	26.3	179.8	104.4	10.1	175.0*	180.9*	72.2	61.9	169.2	154.9*	185.6*	139.2	102.7
1969	77.1	120.2	140.3	298.8	129.6	182.1	202.9*	340.0*	248.9	257.8	271.3	294.5*	271.6*	272.6	197.7
1970	110.3	204.4	164.1	323.7	178.7	139.4*	257.1*	330.2*	285.8	298.7*	260.2	279.4*	242.6*	258.2	224.3
1971	63.6	86.1	69.8	225.2	149.5	208.8*	224.9*	224.6*	139.6*	136.6*	137.7	111.8*	90.7*	98.0	149.5
1972	111.1	206.3*	277.1	441.6	236.6	187.9*	321.1*	619.4*	460.9*	492.8*	621.0	772.7*	773.4*	729.8	346.3
1973	129.5	253.0	323.1	489.7	288.7	272.4*	378.7*	882.6*	474.0*	571.9*	523.0*	734.1*	862.2	692.9	399.6
1974	47.0	44.0*	152.7	311.7	67.3	190.2*	134.0*	74.5*	268.1*	279.0*	386.0*	413.0*	655.0*	385.9	172.2
1975	76.2	118.1*	80.0	235.8	139.2	108.1*	213.5*	229.0*	155.4*	154.1*	141.0*	462.0*	155.5*	432.8	164.0
1976	46.2	42.0*	60.1	215.1	30.6	68.4	58.0*	130.5*	101.0*	120.0*	200.0*	130.5*	188.0*	115.9	93.6
1977	43.5	35.1*	58.4	115.0*	31.1	102.7	94.0*	97.5*	148.0*	117.0*	97.0*	146.5*	139.0*	131.2	82.1
1978	49.0	49.0*	164.0*	323.5*	74.5*	99.8*	142.0*	339.0*	144.0*	298.5*	292.0*	287.0*	483.9*	265.5	170.9
1979	146.0*	309.0*	186.5*	530.0*	319.8*	399.0*	413.0*	665.5*	509.0*	342.5*	328.5*	282.5*	197.5*	261.2	364.0
1980	65.7*	91.4*	80.8	236.6	12.5*	109.0	89.0*	0.0*	156.6	155.5*	185.0*	176.5*	390.5	159.8	105.7
1981	14.5	34.0*	71.0	118.0*	57.3	62.6*	123.0*	202.0*	91.0*	58.5*	277.0*	225.0*	431.5*	206.2	93.6
1982	113.0*	138.0*	218.0*	259.0*	118.5*	249.5*	216.0*	431.0*	308.0*	418.5*	322.0*	477.0*	669.0*	362.0*	237.9
1983	150.0*	278.0*	461.3*	641.0*	254.0*	505.8*	648.0*	638.7*	701.0*	790.0*	576.9*	683.6*	892.5*	567.0*	475.7
1984	76.5*	137.0*	232.9*	381.0*	209.0*	243.0*	273.0*	349.0*	498.0*	607.6*	506.6*	641.5*	586.0*	600.0*	300.6
1985	82.5*	134.0*	2.5*	209.0*	88.1*	36.5*	157.0*	269.5*	88.0*	85.0*	104.0*	53.0*	237.0*	44.5*	114.3
1986	28.0*	109.0*	192.2*	341.1*	154.0*	402.0*	289.5*	377.0*	558.5*	656.0*	471.5*	499.0*	567.0*	555.5*	289.7
Max.	150.0	309.0	461.3	641.0	581.2	505.8	701.9	882.6	701.0	790.0	621.0	772.7	1028.9	729.8	510.3
Min.	14.5	21.6	2.5	115.0	12.5	10.1	40.2	0.0	72.2	58.5	97.0	53.0	90.7	44.5	82.1
Ave.	77.3	125.1	160.3	315.6	150.4	184.6	232.5	319.6	287.2	310.5	303.8	348.3	424.1	321.2	215.9

Remarks : Mark '*' means recorded rainfall data.

Table II.5.4 Spillway Design Flood

(Unit : cms)

Criteria	Storage Dam				
	Nenggiri	Kemubu	Lower Pergau	Dabong	Lebir
Catchment Area (sq.km)	3,690	5,630	1,280	7,480	2,480
(1) Recorded Largest Flood					
- Simulated (1967 Flood)	4,317	4,471	2,653	7,422	6,734
- Recorded	2,177	-	-	6,200	4,728
(2) 200-year Probable Flood					
- 1983 type	7,200	7,237	4,264	10,284	5,849
- 1984 type	10,820	9,536	4,483	12,588	10,380
- 1986 type	5,954	7,914	3,814	10,152	8,256
(3) Creager's coefficient (C=55)	15,500	15,000	9,900	16,600	12,400

Note : The safety factor of 1.2 was multiplied to the peak discharges of rockfill dams.

Table II.5.5 Annual Maximum Rainfall Depth at Kota Bharu

(Unit:mm)

Year	1-day	2-day	3-day	5-day	7-day
1956	195.6	356.9	407.7	519.2	700.8
1957	109.5	163.8	236.0	365.5	386.8
1958	153.7	263.9	360.7	525.7	607.5
1959	263.4	469.6	675.3	837.1	924.3
1960	195.6	312.4	356.1	443.9	503.3
1961	204.5	255.3	278.2	333.4	466.9
1962	148.6	231.2	325.4	386.7	419.8
1963	115.3	140.2	149.1	224.3	283.8
1964	175.3	238.8	242.6	242.6	242.9
1965	310.4	414.5	550.1	743.4	907.7
1966	167.6	292.6	330.1	371.5	391.6
1967	585.0	984.3	1,238.6	1,384.6	1,397.8
1968	160.5	268.2	283.9	375.3	453.1
1969	326.1	559.0	594.8	607.8	698.2
1970	228.6	268.7	279.9	288.5	309.3
1971	187.7	300.5	313.5	393.7	460.0
1972	132.3	177.5	242.5	296.6	332.4
1973	302.3	431.6	522.3	658.9	715.6
1974	235.5	287.5	332.5	380.5	414.5
1975	194.0	269.5	329.5	386.5	404.0
1976	351.0	470.0	535.0	629.0	687.5
1977	176.5	261.5	290.5	378.5	388.0
1978					
1979	230.0	380.0	446.0	504.5	671.0
1980					
1981	431.4	787.3	1,042.5	1,122.5	1,178.5
1982	162.5	253.5	257.5	265.5	341.5
1983	212.8	393.5	535.2	722.2	732.5
1984	228.0	290.0	402.0	438.5	450.0
1985					
1986	555.0	852.0	1,235.5	1,463.0	1,614.5
Average	240.7	370.5	456.9	546.1	610.1
Maximum	585.0	984.3	1,238.6	1,463.0	1,614.5
Minimum	109.5	140.2	149.1	224.3	242.9

Table II.5.6 Inundation Depth in the Urban Areas

Year	Guillemard Bridge		Highest Water Level	
	Peak Discharge (cms)	Exceed. Pro-Bability (%)	Kota Bharu (El:m)	Pasir Mas (El:m)
1941	2,030	83.0		
1942	11,480	10.6		
1943	4,630	46.8		
1944	5,230	44.7		
1945	12,850	6.4		
1946	3,970	55.3		
1947	13,580	4.3	5.78	11.58
1948	3,420	63.8		
1949	7,050	29.8		
1950	8,090	23.4		
1951	2,600	76.6		
1952	1,970	87.2		
1953	4,060	53.2		
1954	4,550	48.9		
1955	2,310	80.9		
1956	3,580	59.6		
1957	6,050	38.3	4.87	9.14
1958	1,500	97.9		
1959	3,440	61.7	4.41	7.01
1960	3,610	57.5		
1961	2,700	72.3		6.68
1962	3,410	66.0	4.41	6.89
1963	2,790	70.2		6.19
1964	1,610	95.7	2.68	4.71
1965	6,170	36.2	5.27	8.47
1966	16,000	2.1	6.21	10.18
1967	8,280	21.3	5.60	9.17
1968	1,700	93.6	2.98	5.18
1969	6,650	34.0	5.41	8.73
1970	8,800	19.2	5.72	9.42
1971	5,550	40.4	5.18	8.34
1972	10,260	17.0	5.94	9.83
1973	11,130	12.8	6.03	10.06
1974	4,490	51.1	4.99	8.14
1975	5,247	42.6	5.27	8.32
1976	2,610	74.5	3.81	6.33
1977	2,525	78.7	3.67	6.52
1978	3,291	68.1	4.66	7.42
1979	10,400	14.9	6.24	11.38
1980	1,711	91.5		5.67
1981	2,028	85.1	3.88	6.39
1982	7,172	27.7	5.80	9.80
1983	12,007	8.5	6.28	10.60
1984	7,744	25.5	5.97	9.89
1985	1,722	89.4		5.70
1986	6,901	31.9	5.70	9.60

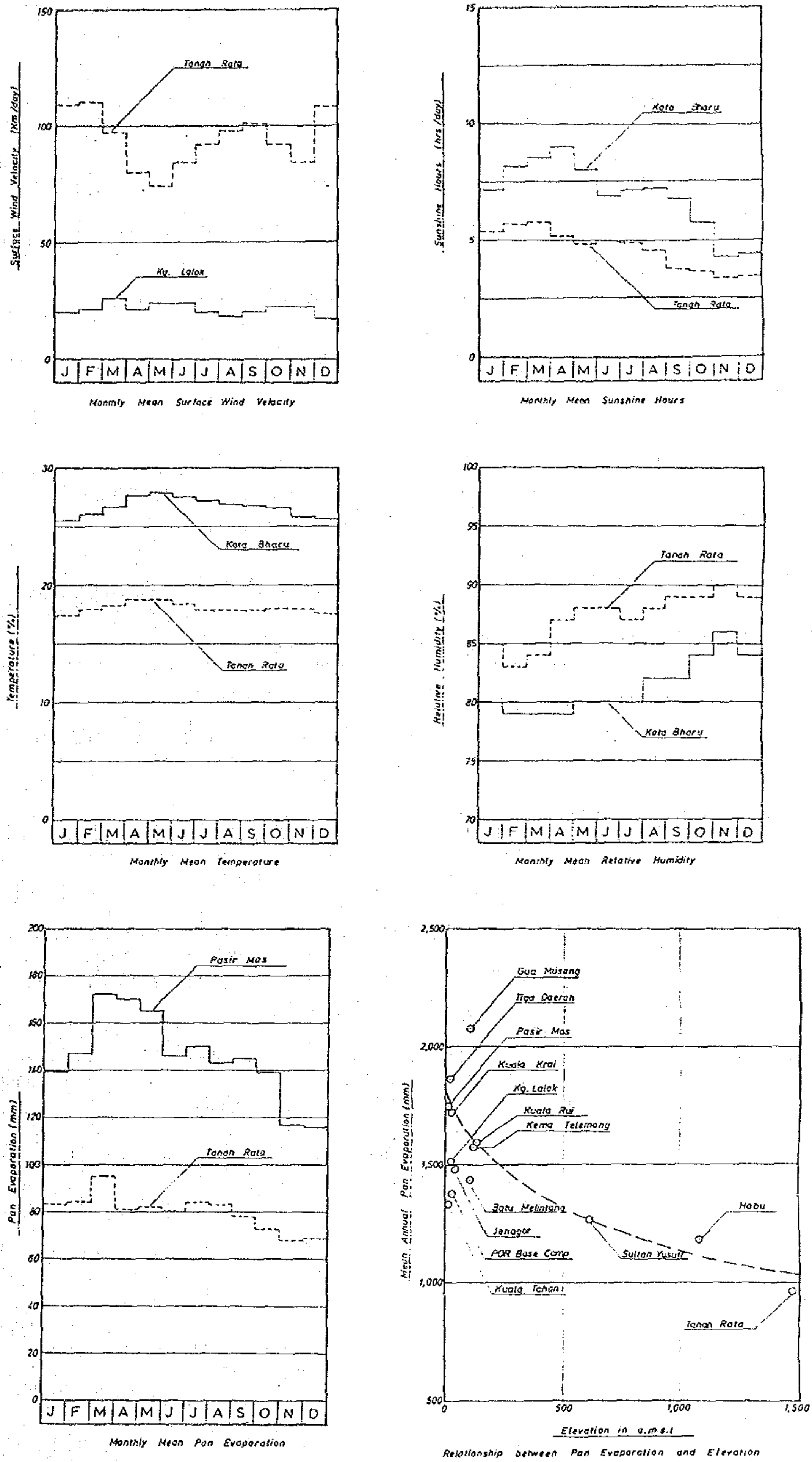

Fig.II.2.1

Hydrometeorological Data in the Kelantan River Basin

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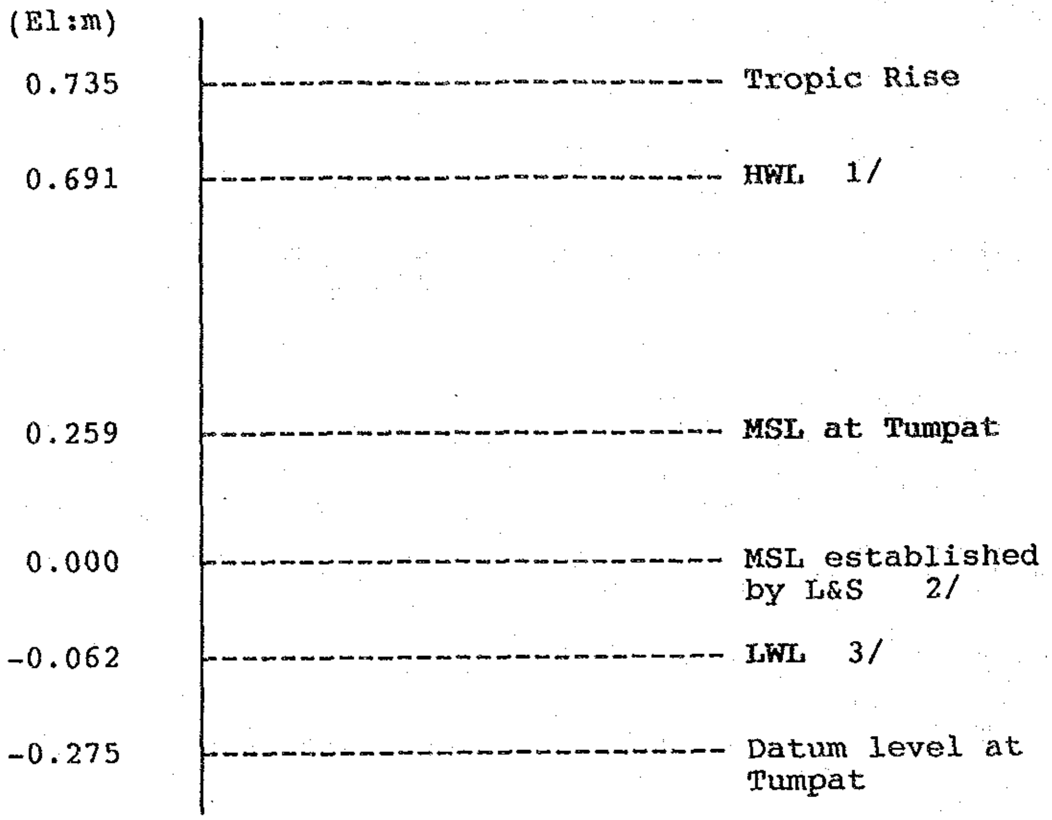

Note : 1/ HWL is determined at the average of Highest Sea Level at the date of new moon throughout the year of 1988.

2/ MSL of the above is derived from the MSL at Tumpat established by DMS subtracting the difference between MSL by L&S and MSL by DSM at Kuala Terengganu.

3/ LWL is determined at the average of Lowest Sea Level at the date of new moon throughout the year of 1988.

Remarks L&S : Land and Survey Dept.
DSM : Dept. of Survey and Mapping

Fig.II.2.2

Tidal Range at Tumpat

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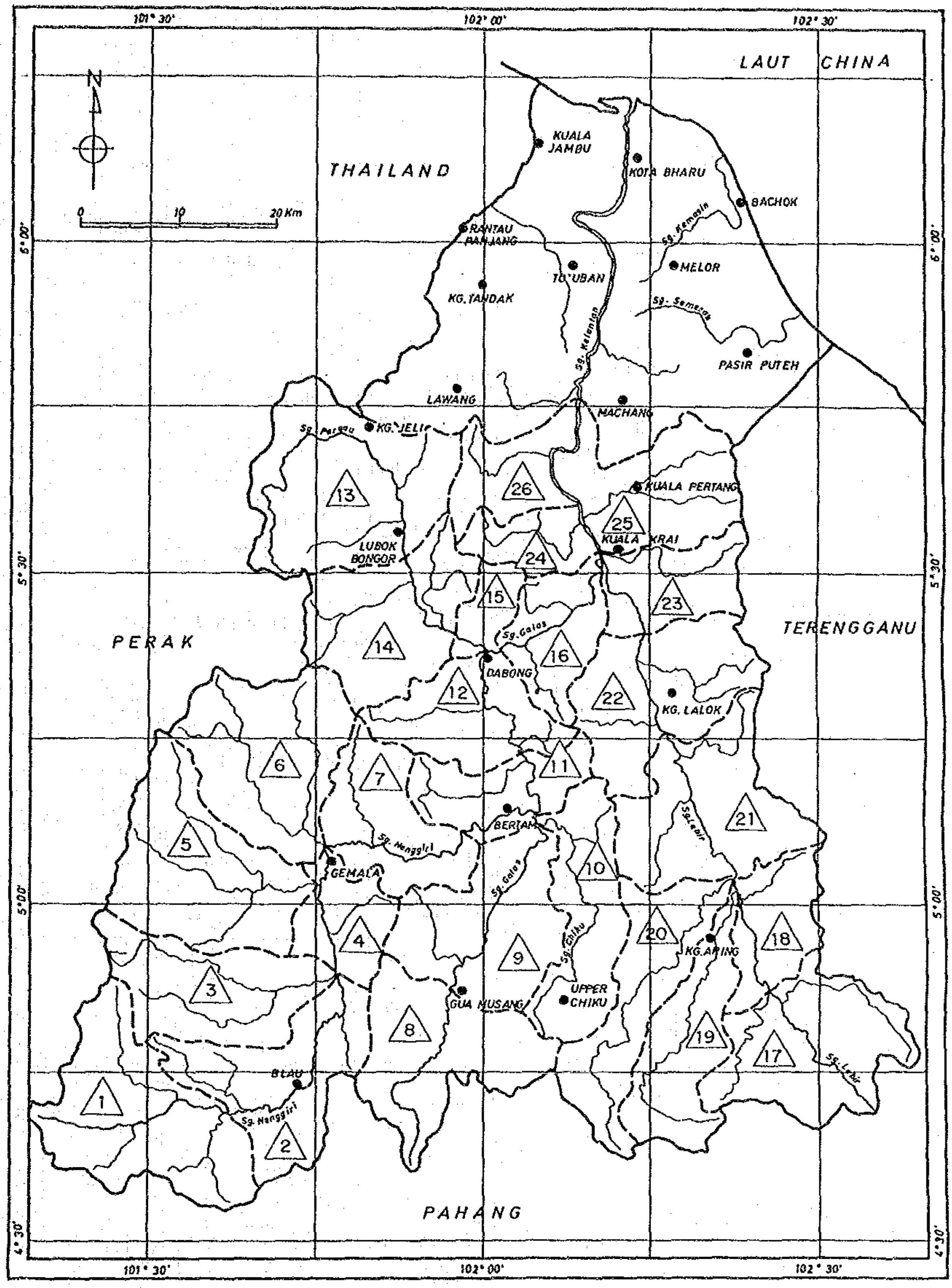

Fig.II.3.1

Location Map of Sub-basin

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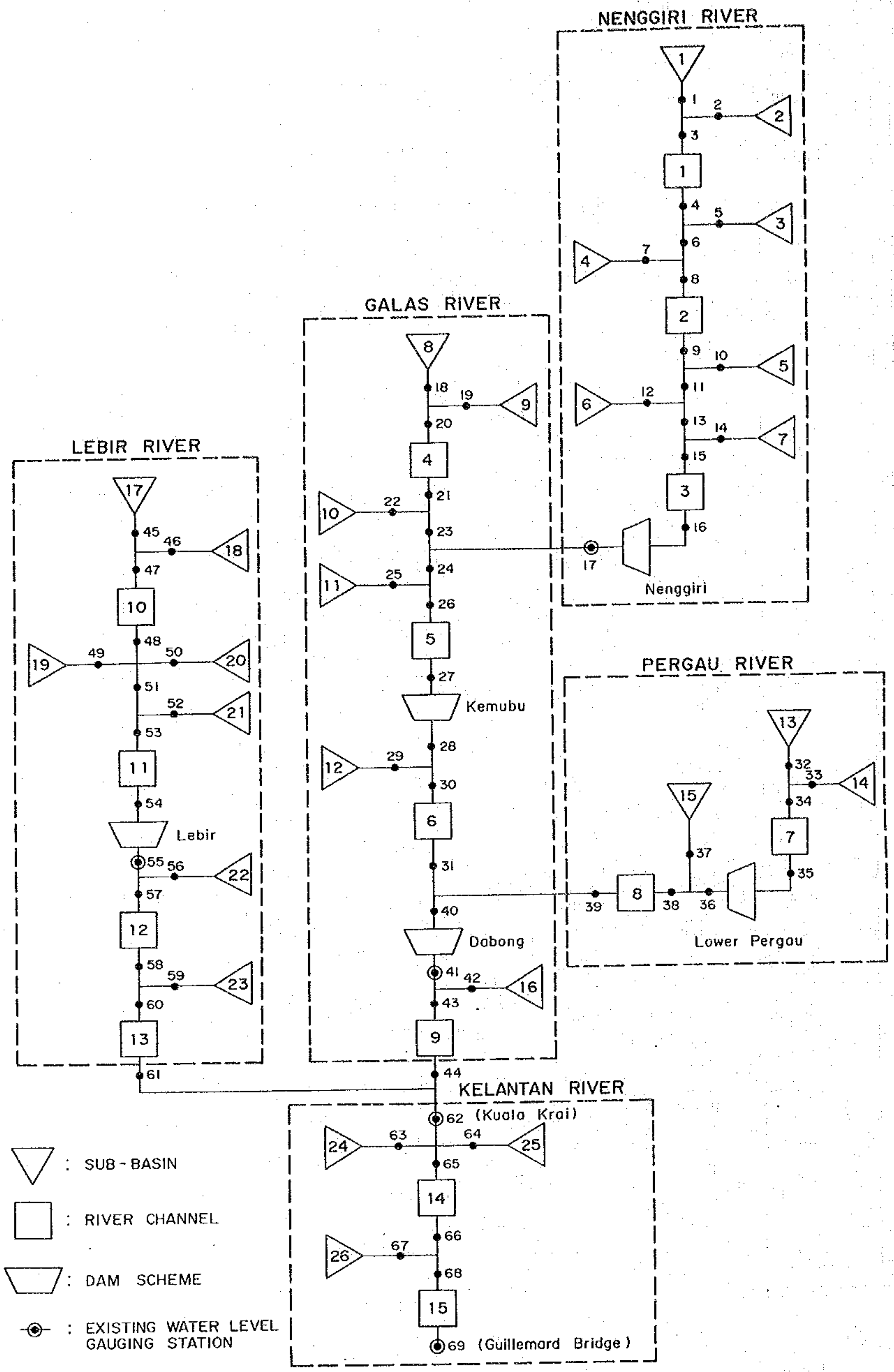

Fig.II.3.2

River Basin Model

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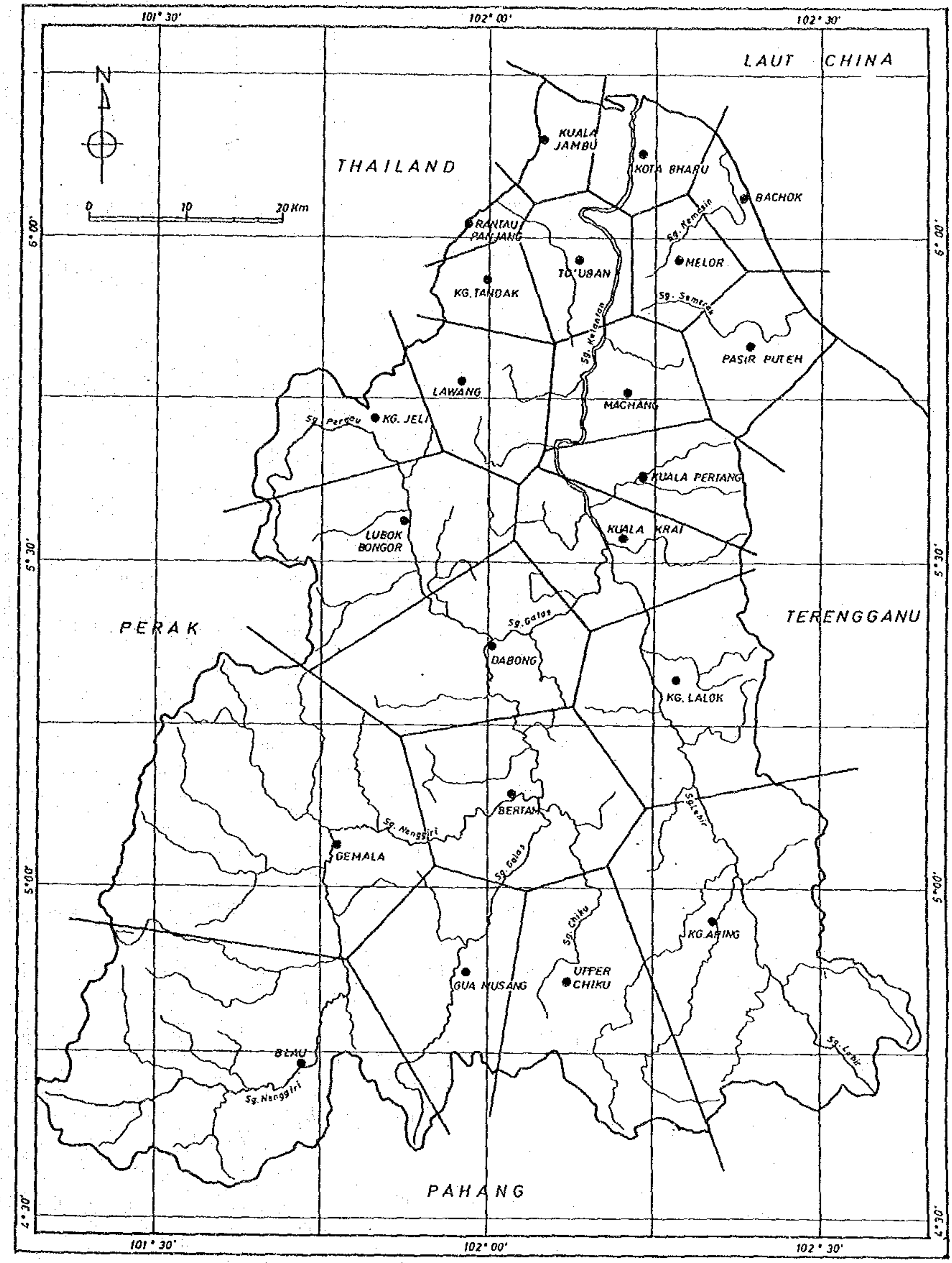

Fig.II.3.3

Arrangement of Thiessen's Polygon

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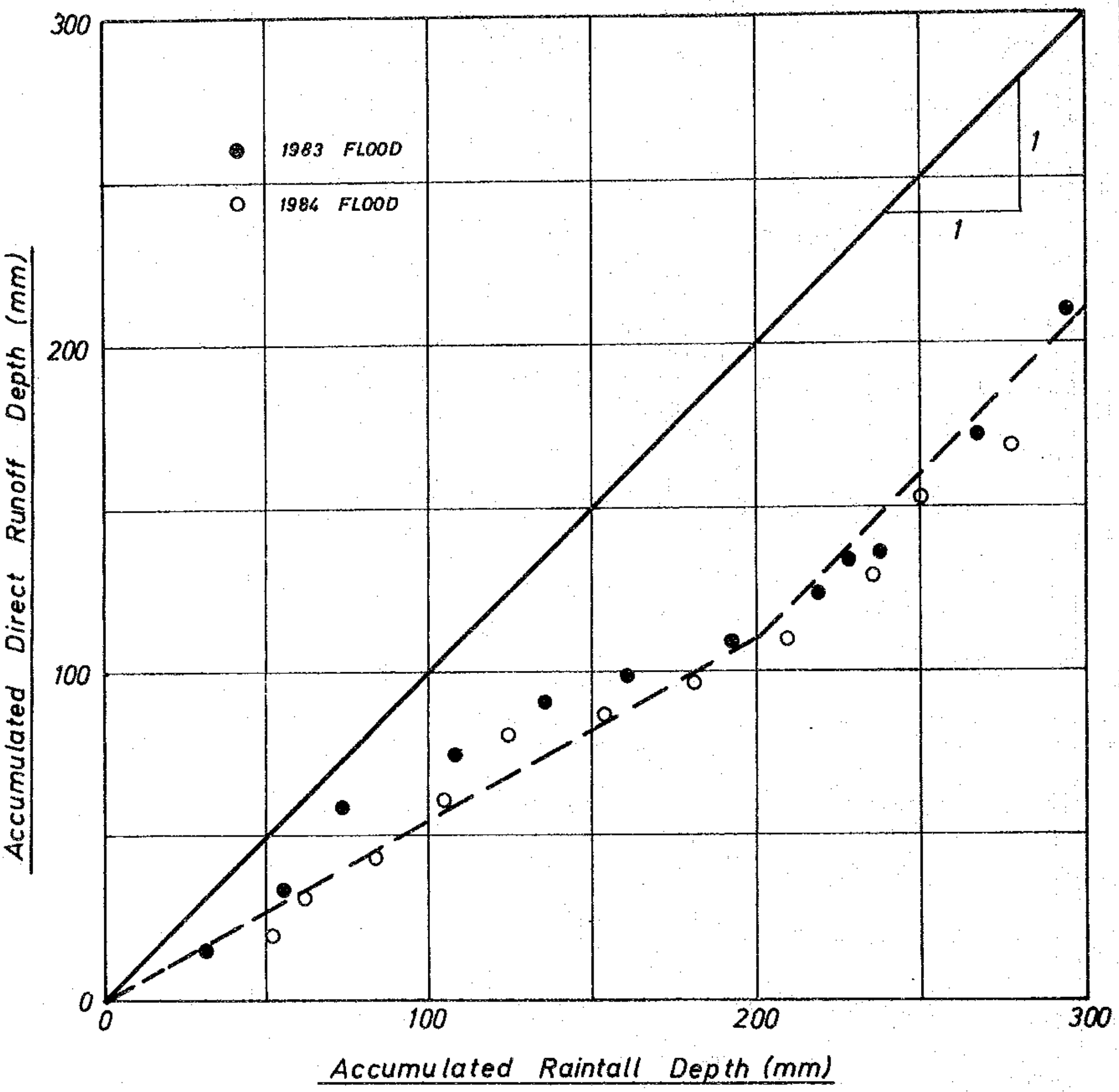

Fig.II.3.4

Estimation of Runoff Coefficient

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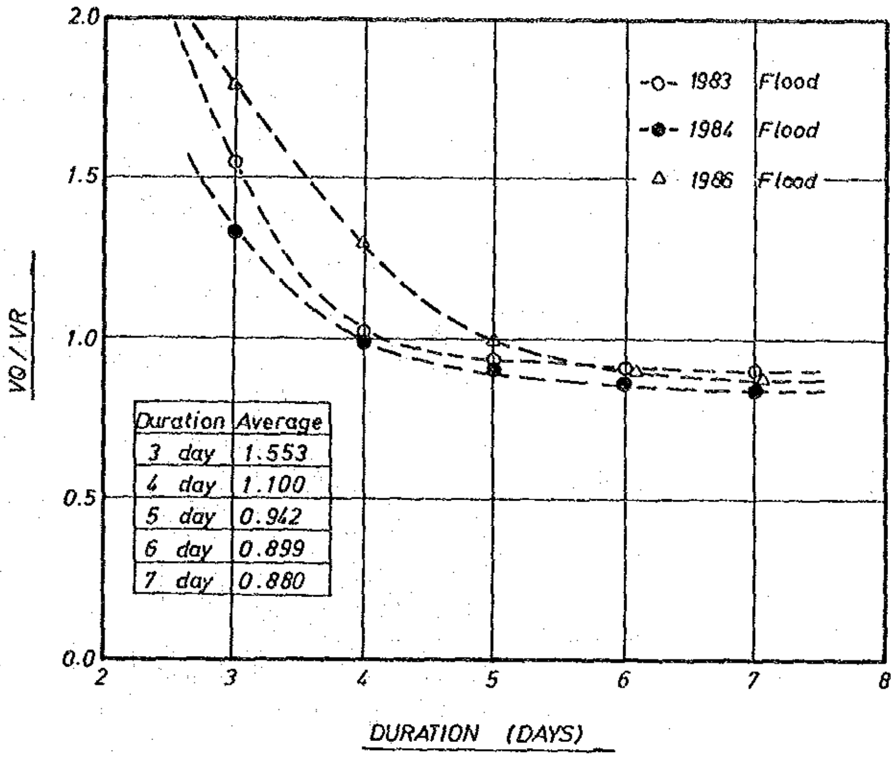

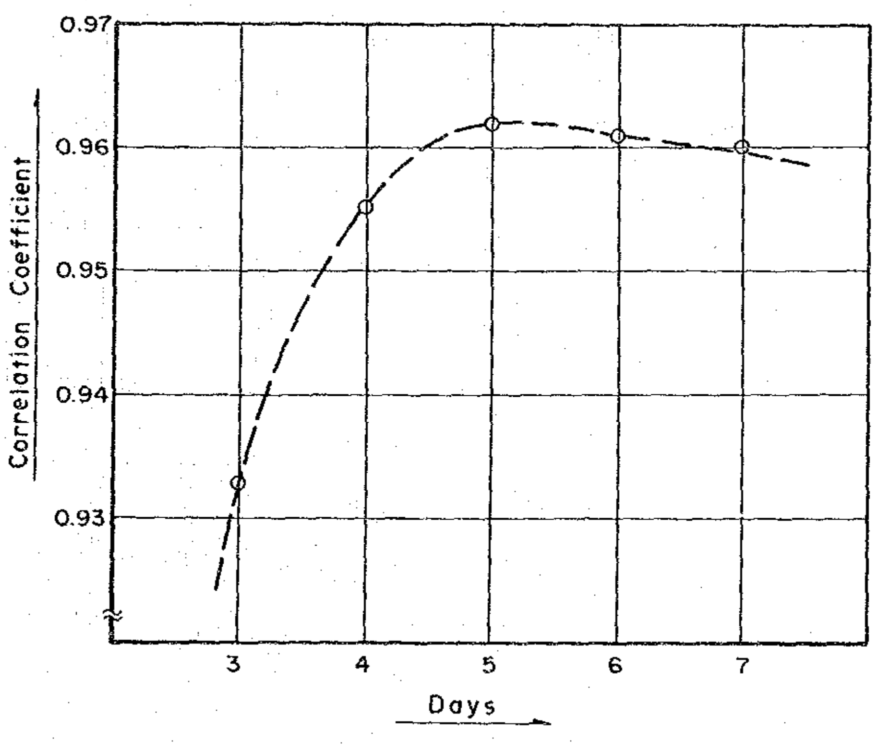

Fig.II.3.5

Duration of Probable Rainfall

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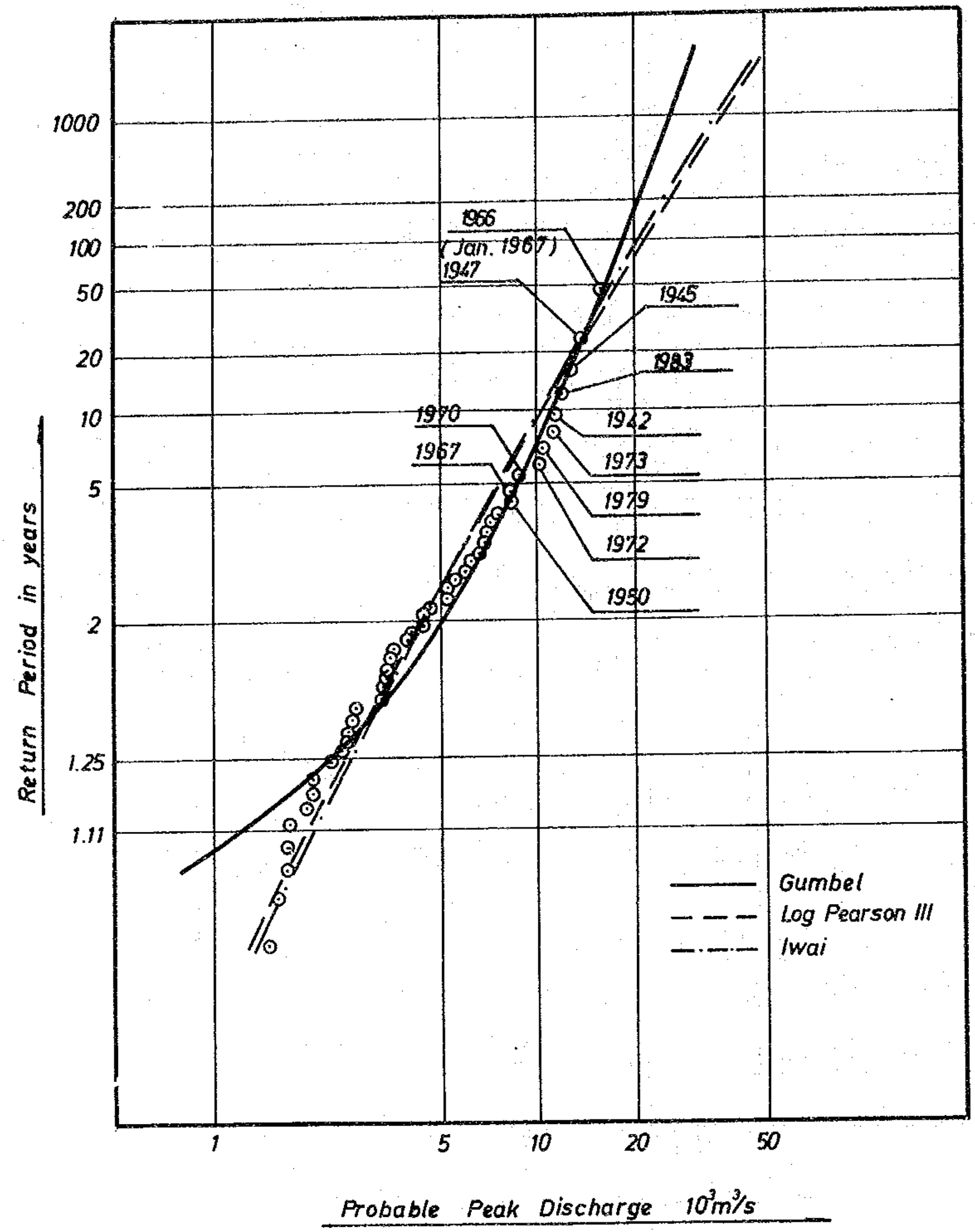

Fig.II.3.6

Probable Distribution of Annual Maximum Peak Discharge at Guillemard Bridge

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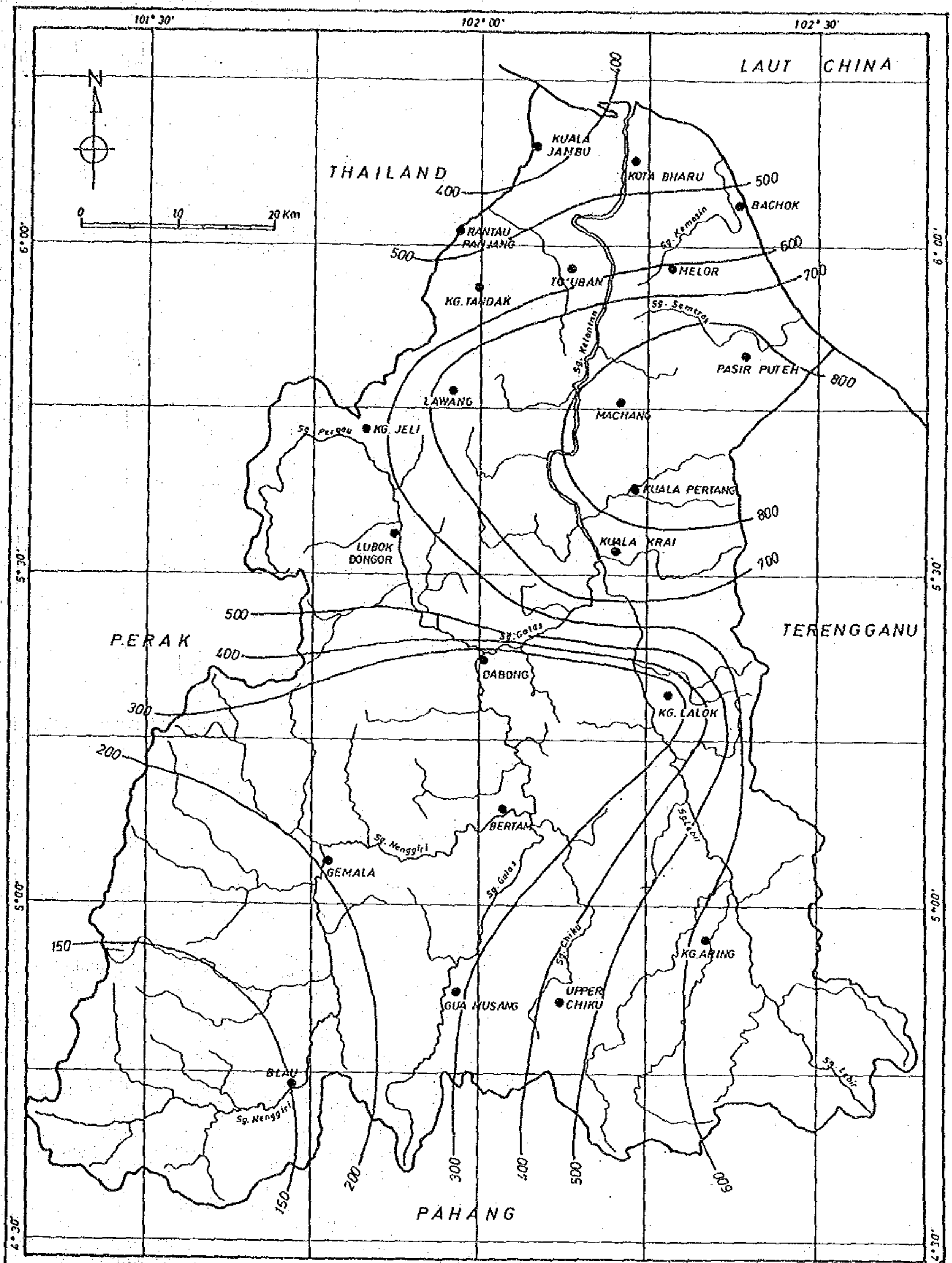

Fig.II.3.7

Isohyetal Map of Monsoon Rainfall (Dec.2 to 6, 1983)

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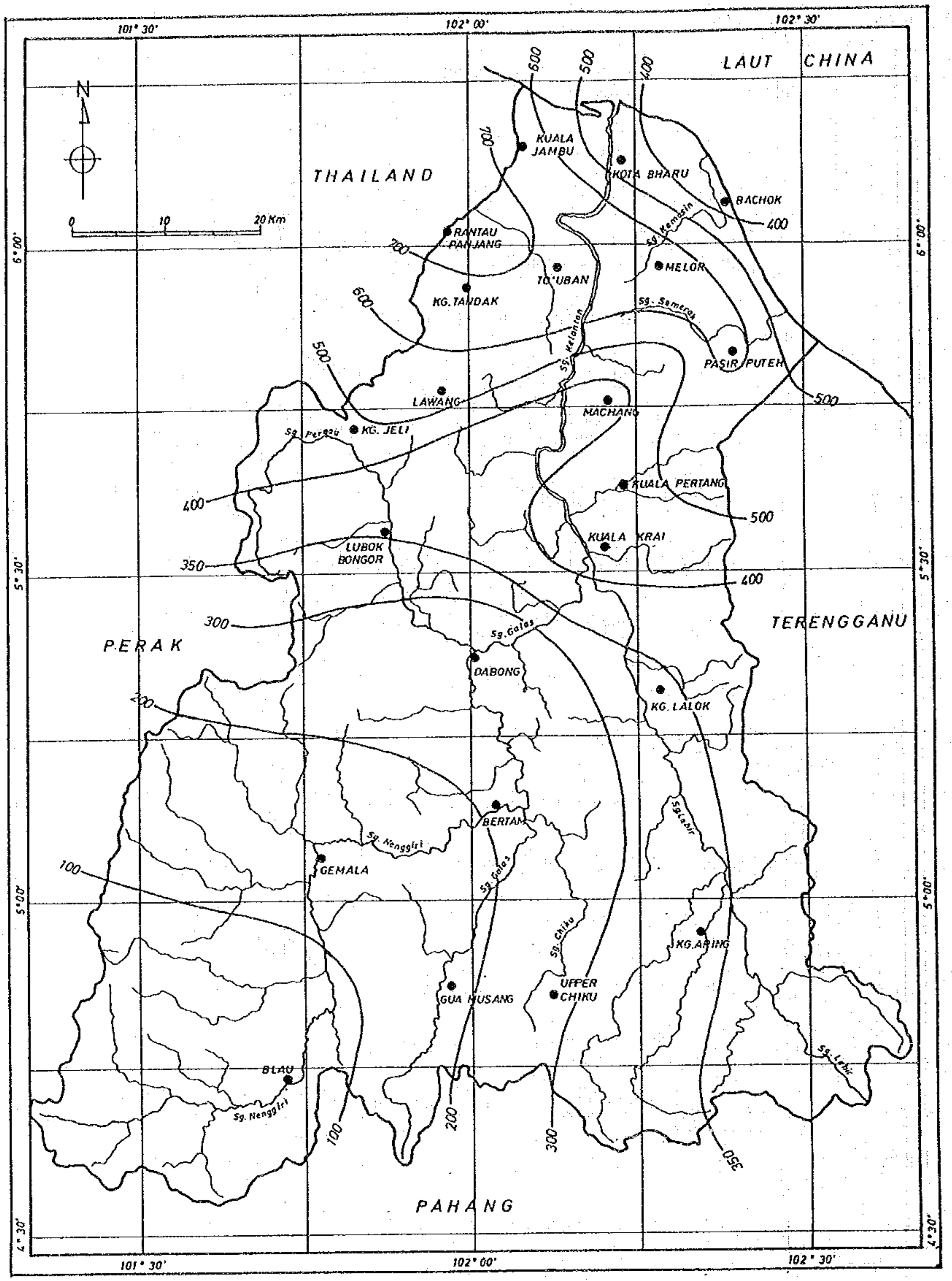

Fig.II.3.8

Isohyetal Map of Monsoon Rainfall
(Dec.21 to 25, 1984)

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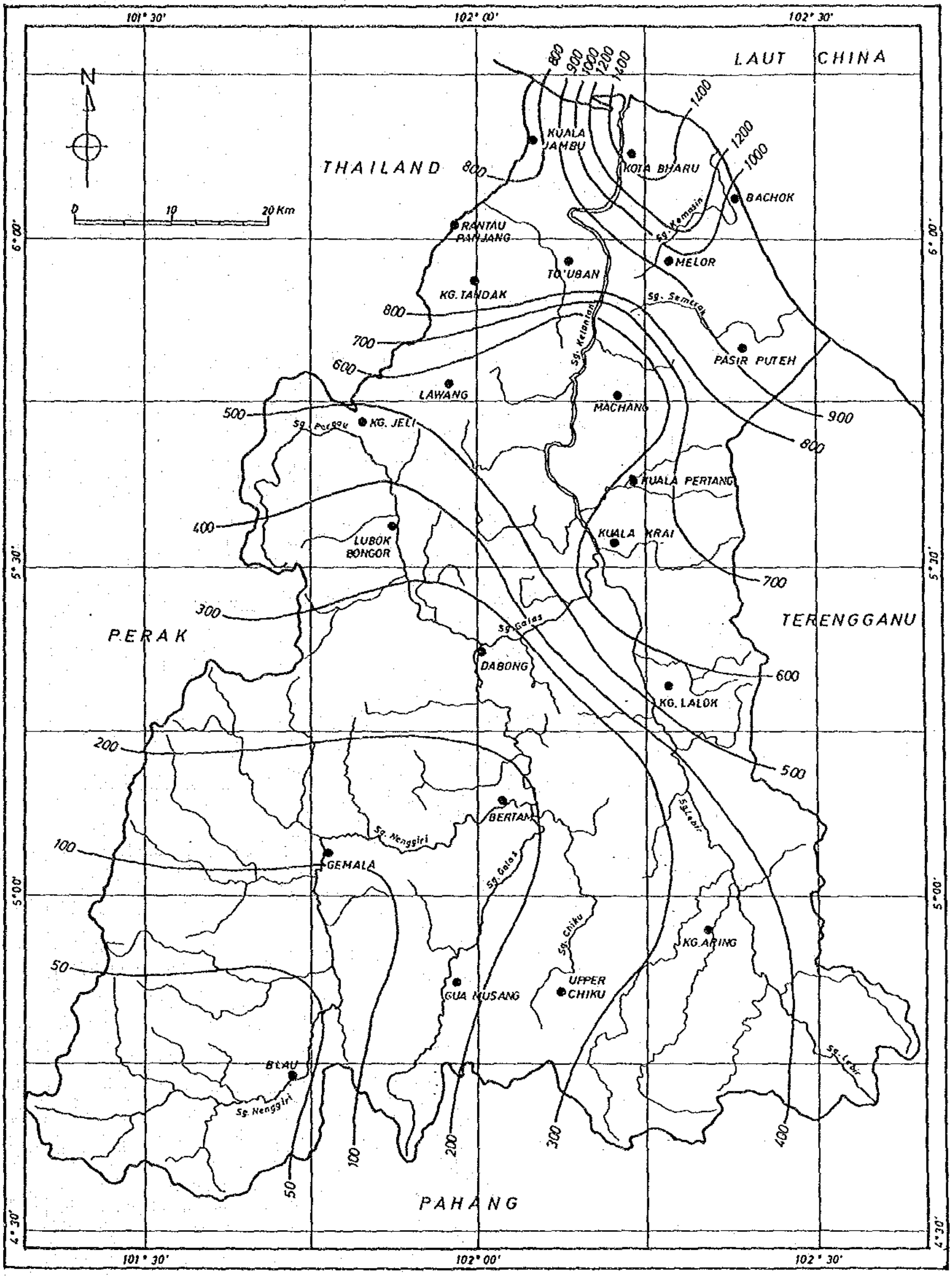

Fig.II.3.9

Isohyetal Map of Monsoon Rainfall
(Nov.26 to Dec.1, 1986)

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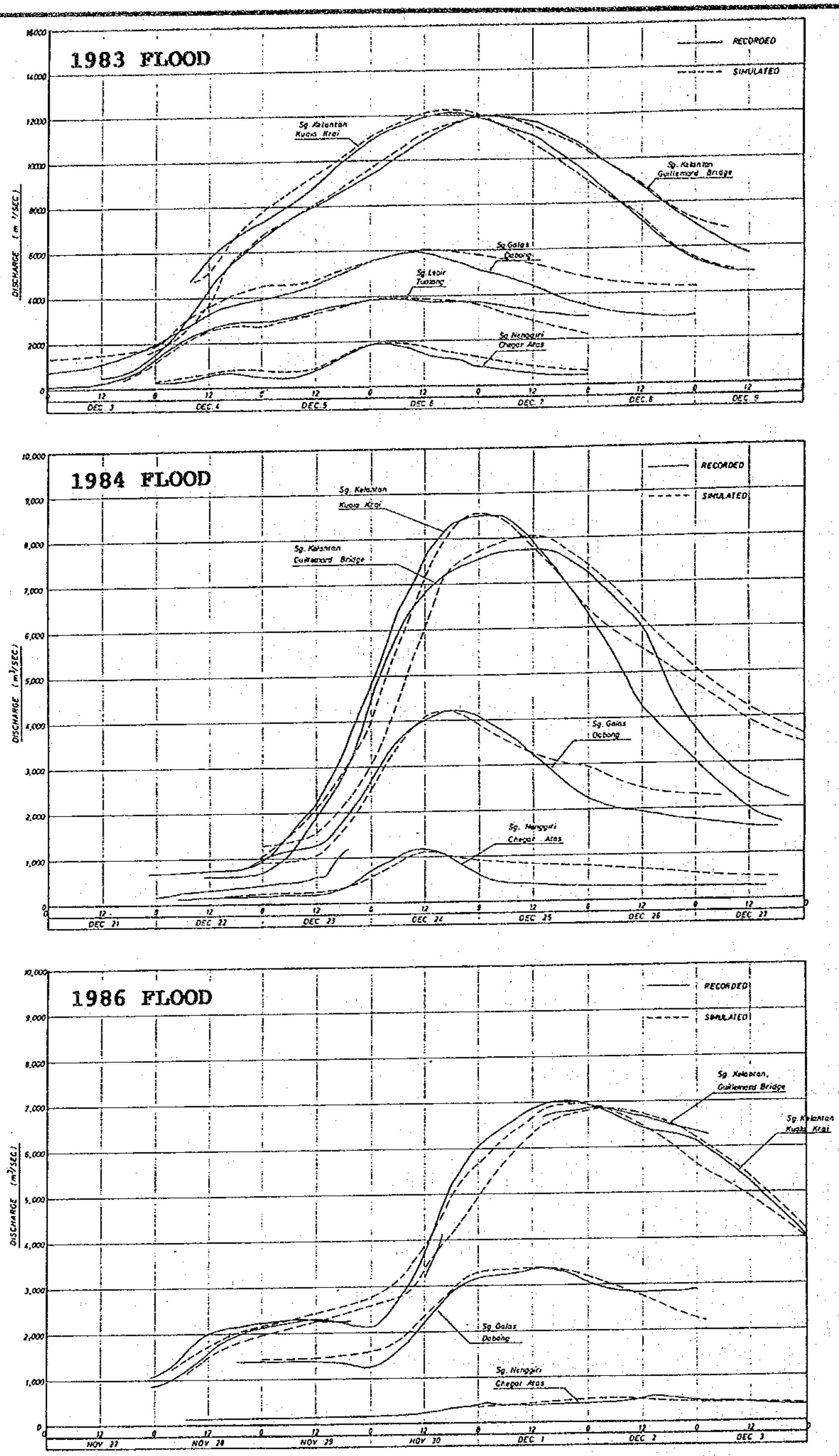

Fig.II.3.10

Comparison of Recorded and Simulated Flood Hydrographs

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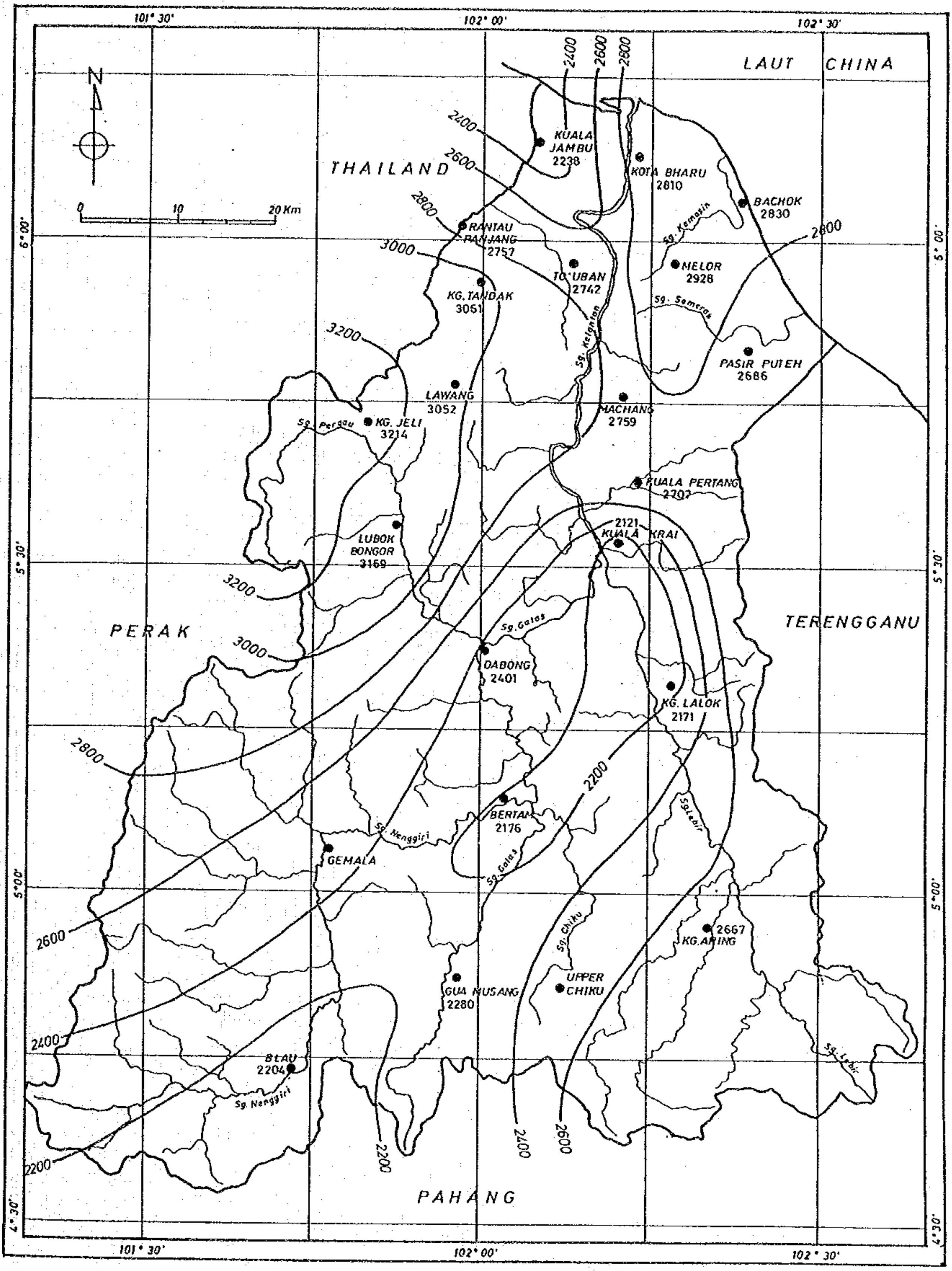

Fig.II.4.1

Isohyetal Map of Annual Mean Rainfall Depth

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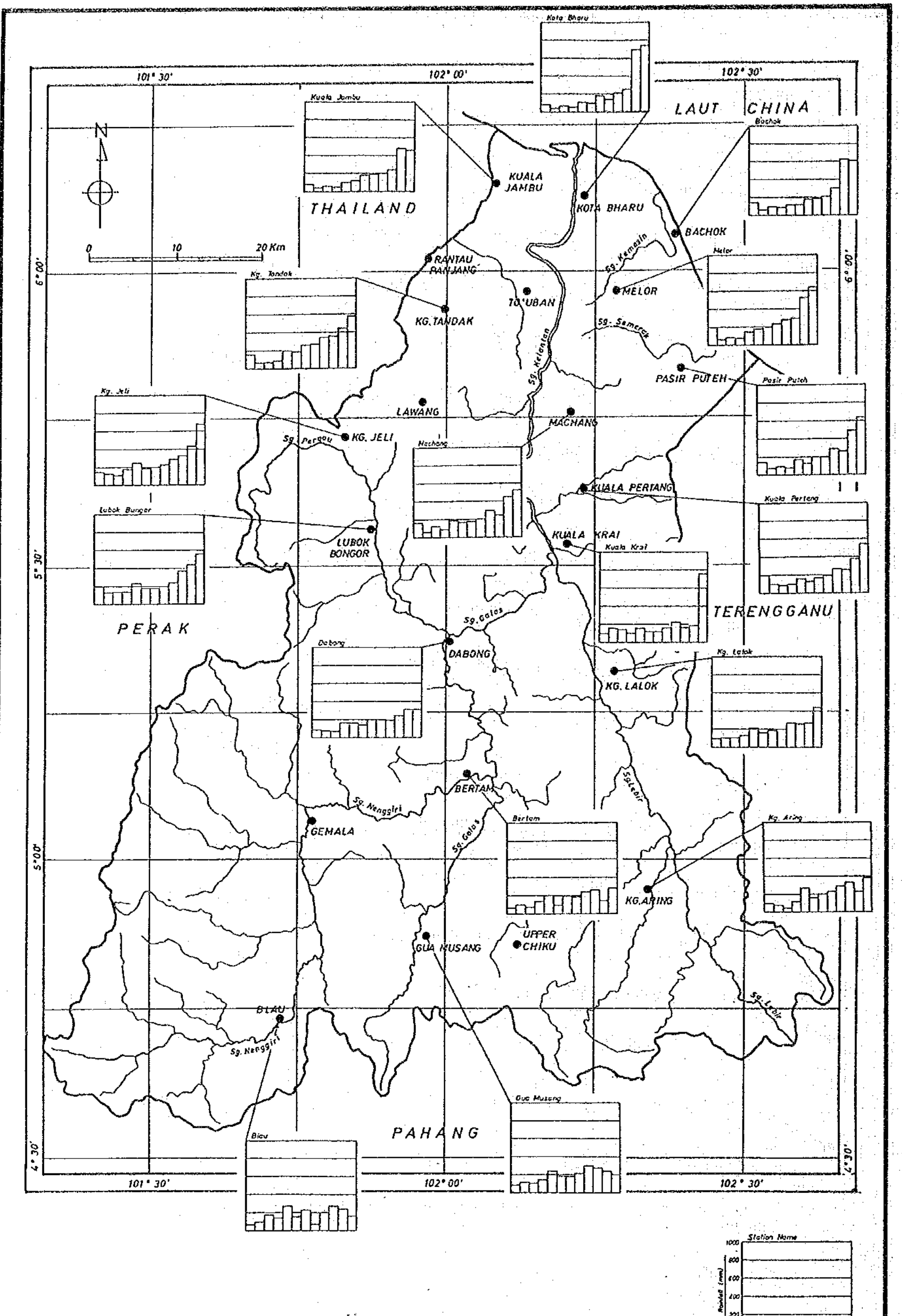

Fig.II.4.2

Monthly Mean Rainfall Depth

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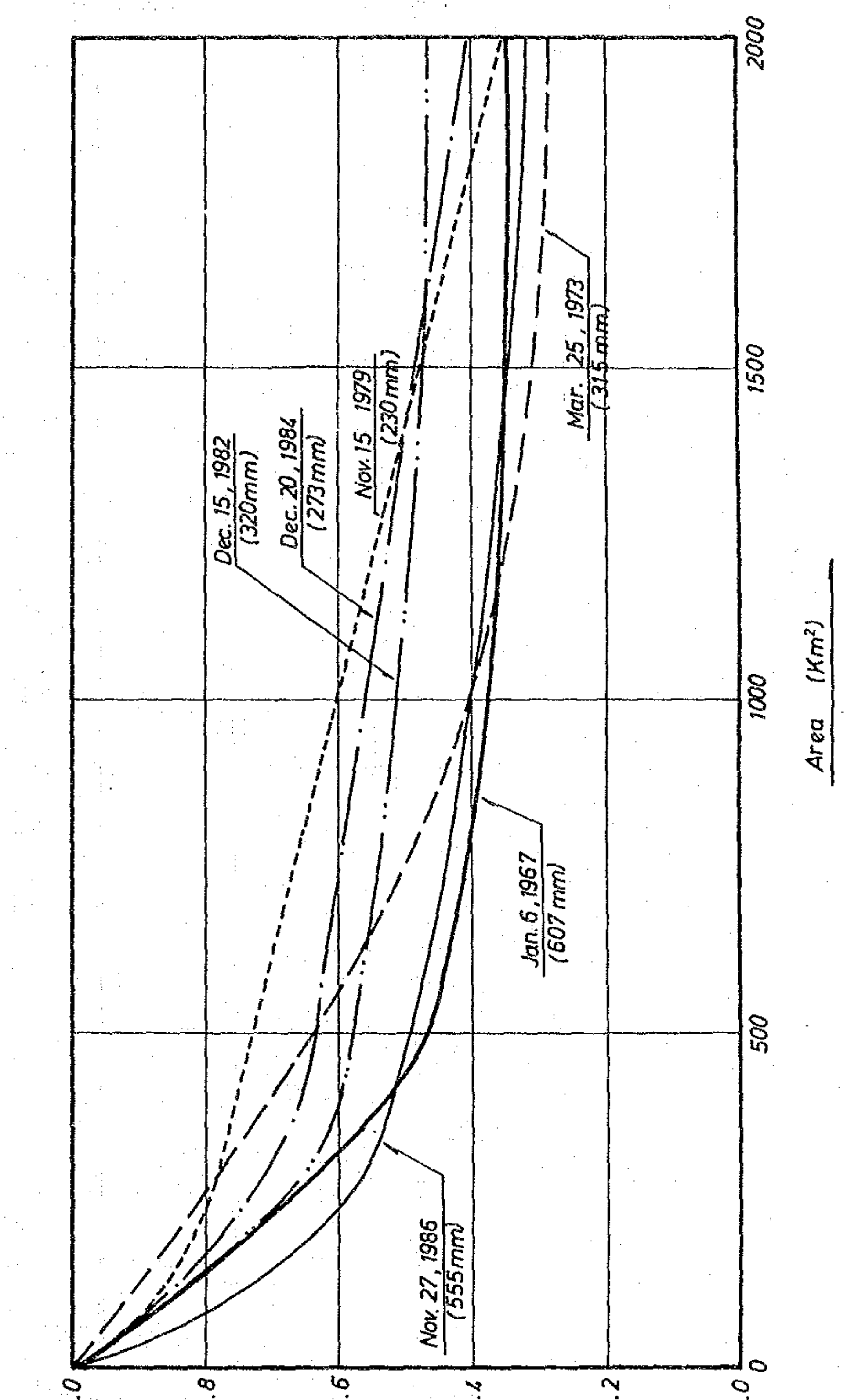

Fig.II.4.3

Relationship between Daily Rainfall Depth and Area

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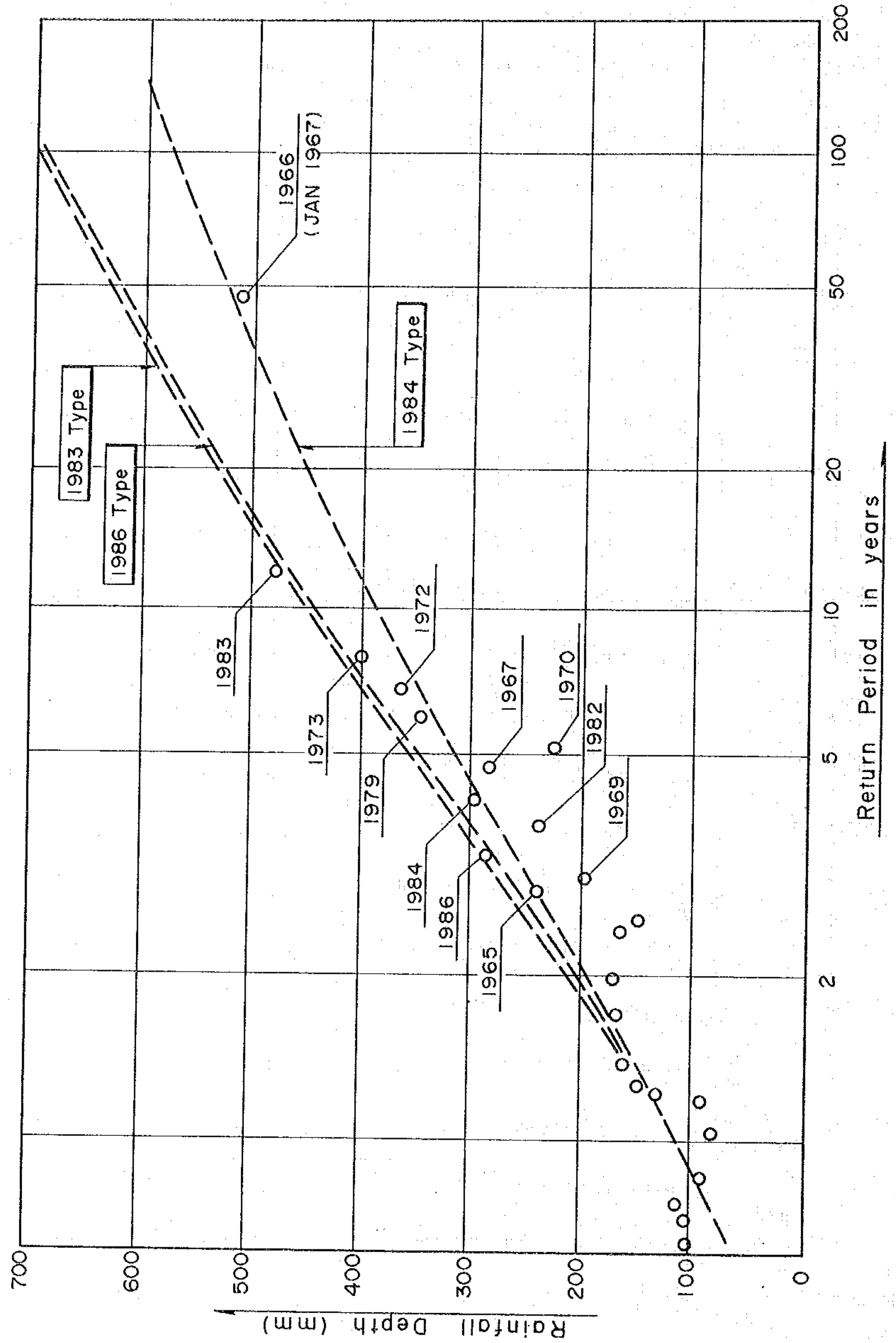

Fig.II.5.1

Plotting Position of 5-day Rainfall Depth

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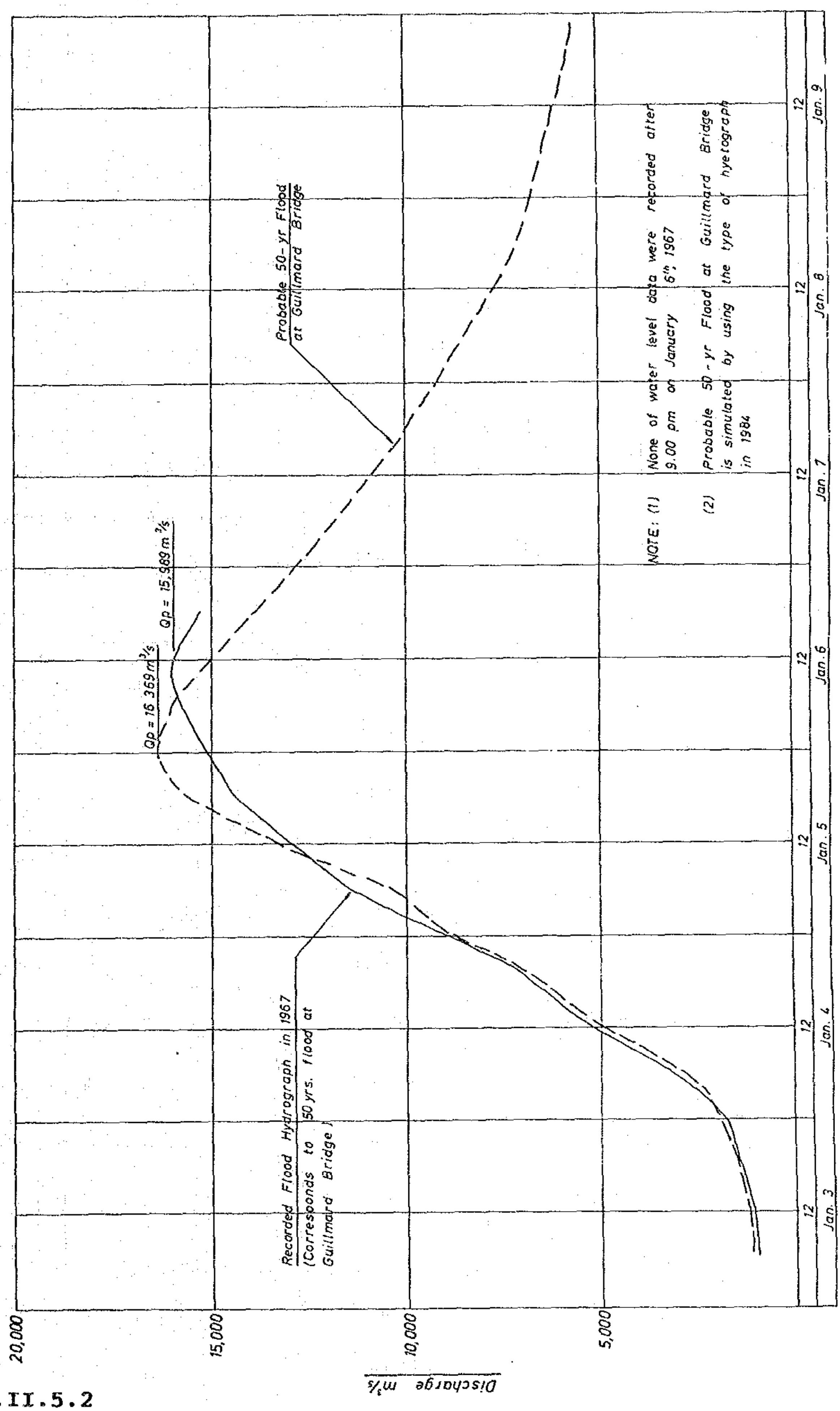

Fig. II.5.2

Comparison between 50-yr Probable Flood and Recorded Flood Hydrograph in 1967

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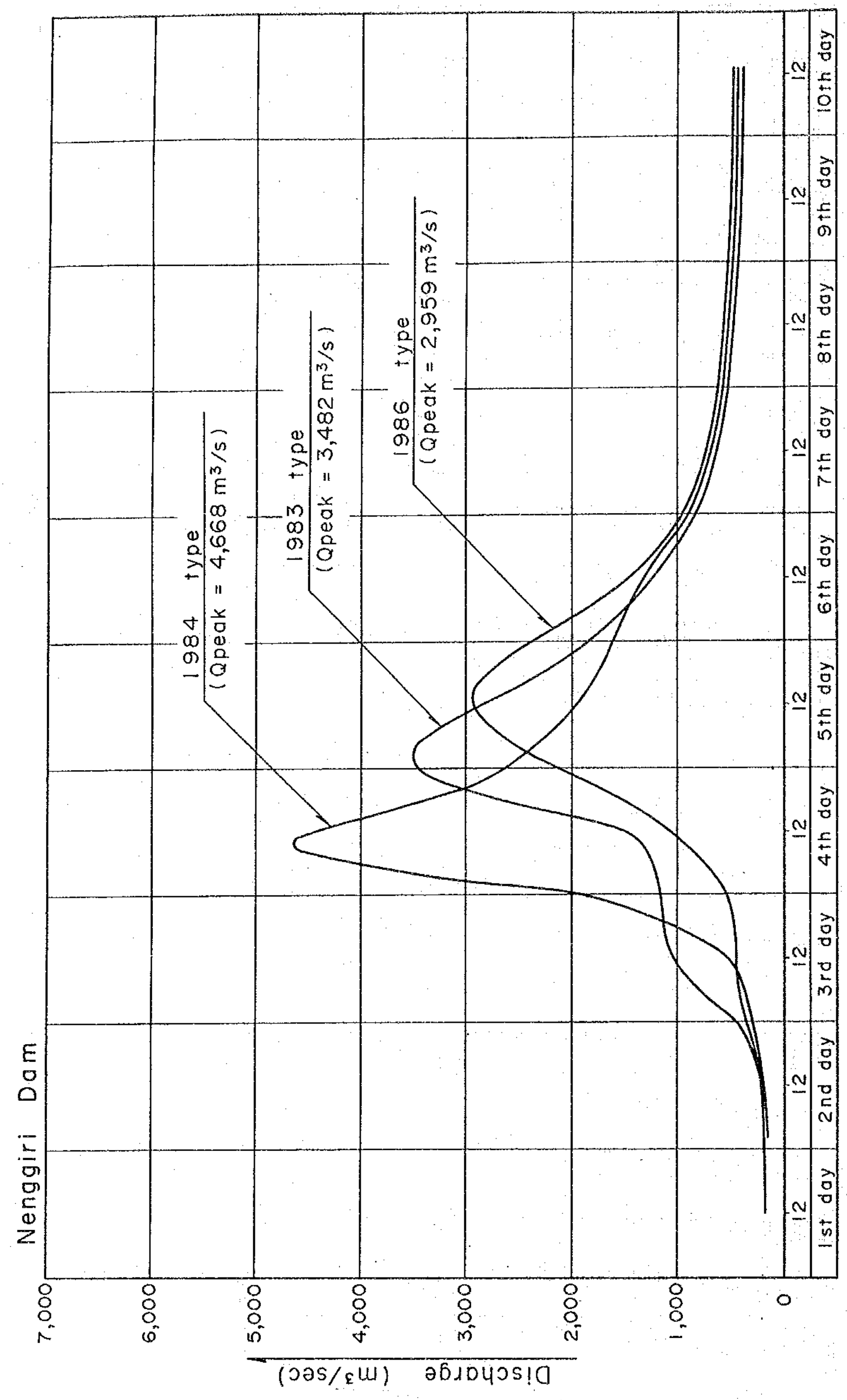

Fig.II.5.3

Probable Flood Hydrograph at Nenggiri Damsite

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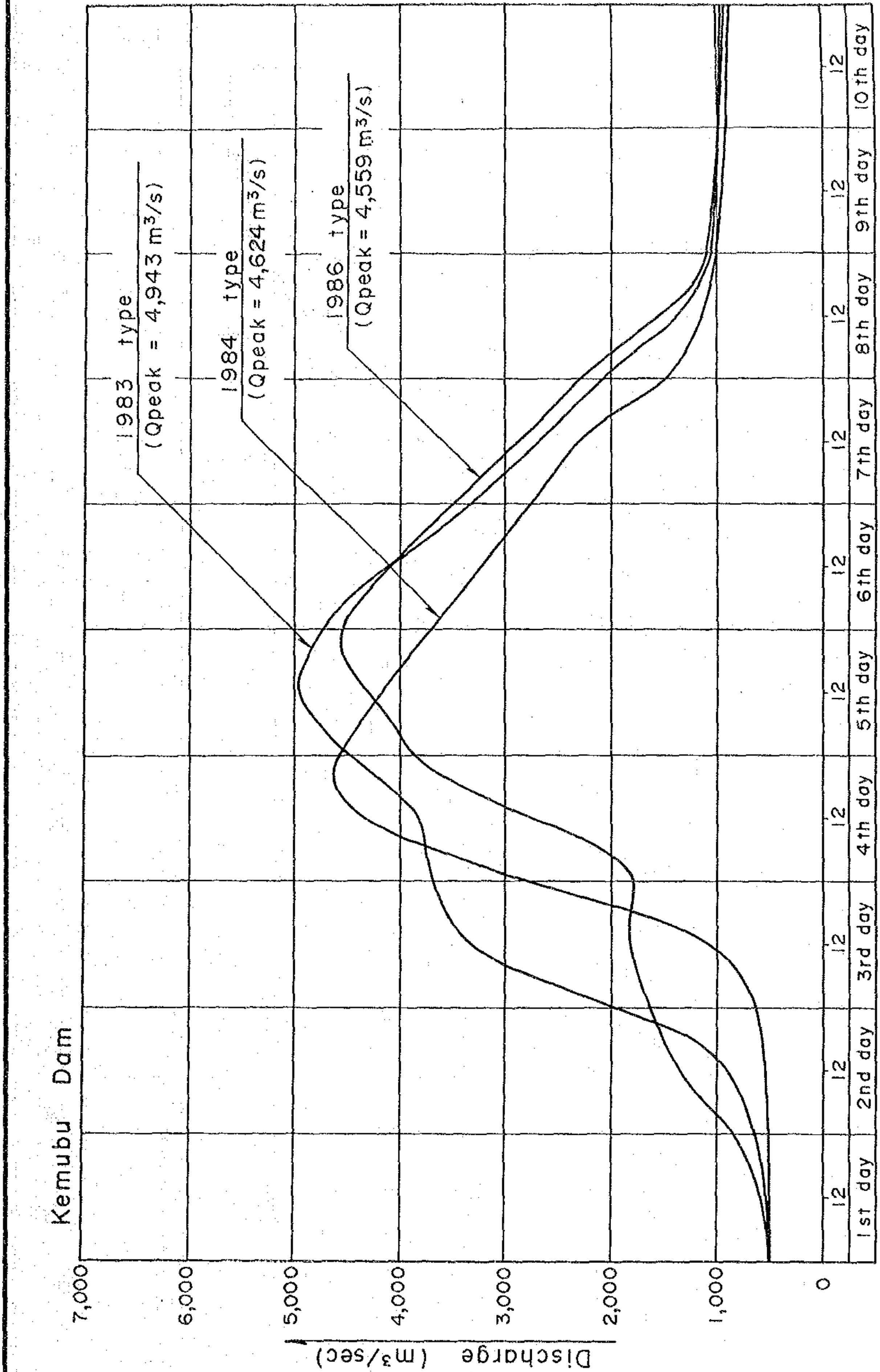

Fig.II.5.4

Probable Flood Hydrograph at Kemubu Damsite

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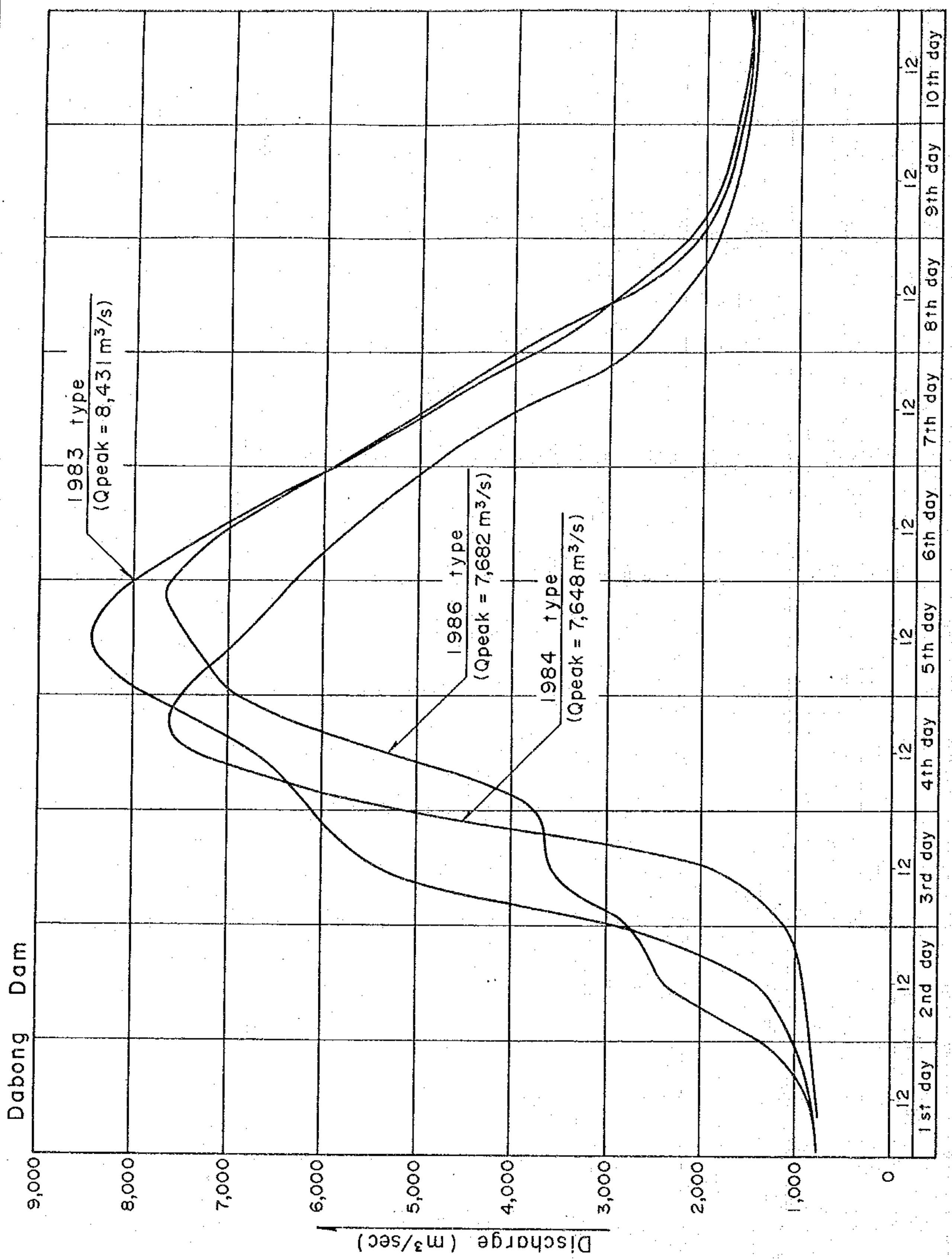

Fig.II.5.5

Probable Flood Hydrograph at Dabong Damsite

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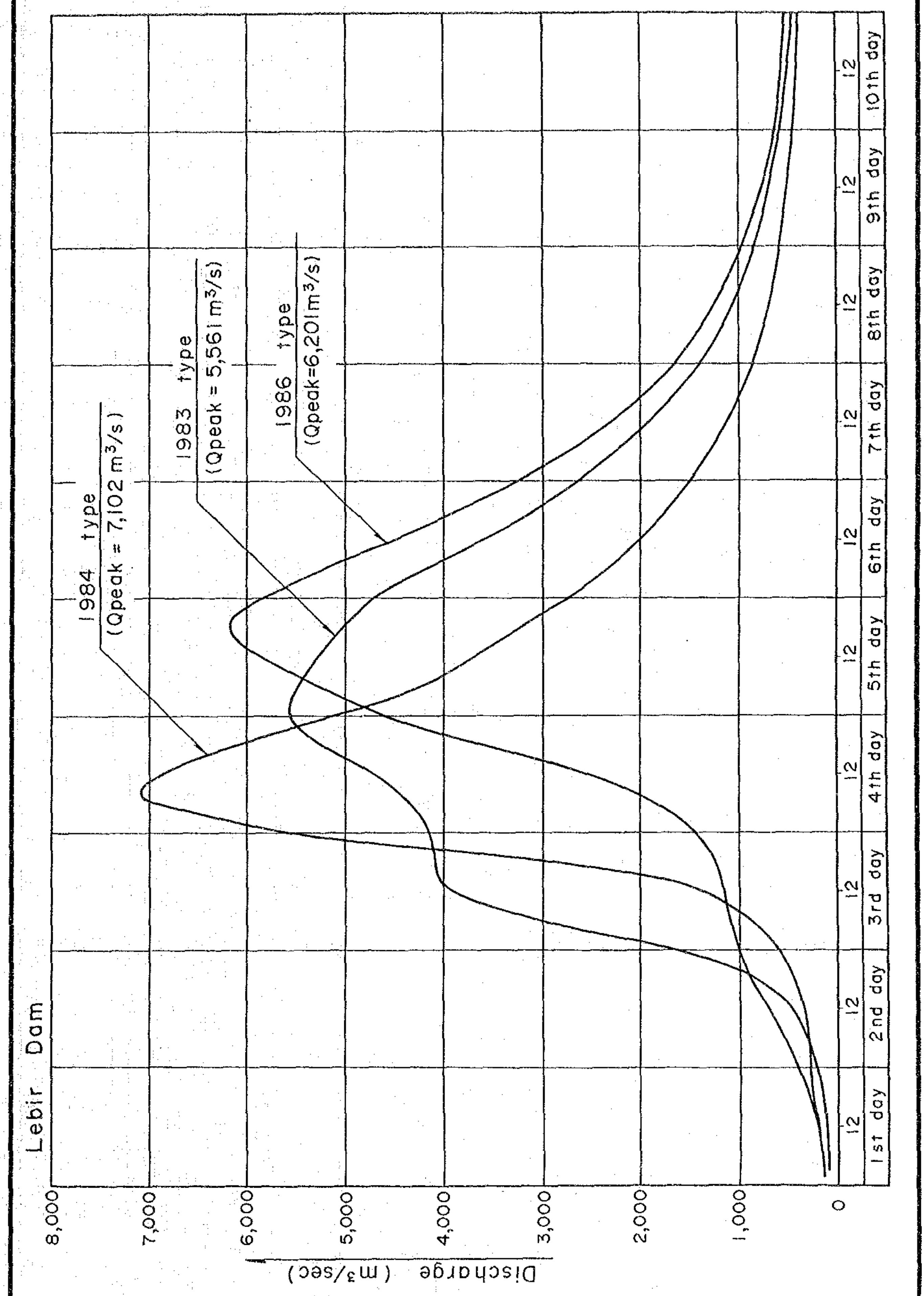

Fig.II.5.6

Probable Flood Hydrograph at Lebir Damsite

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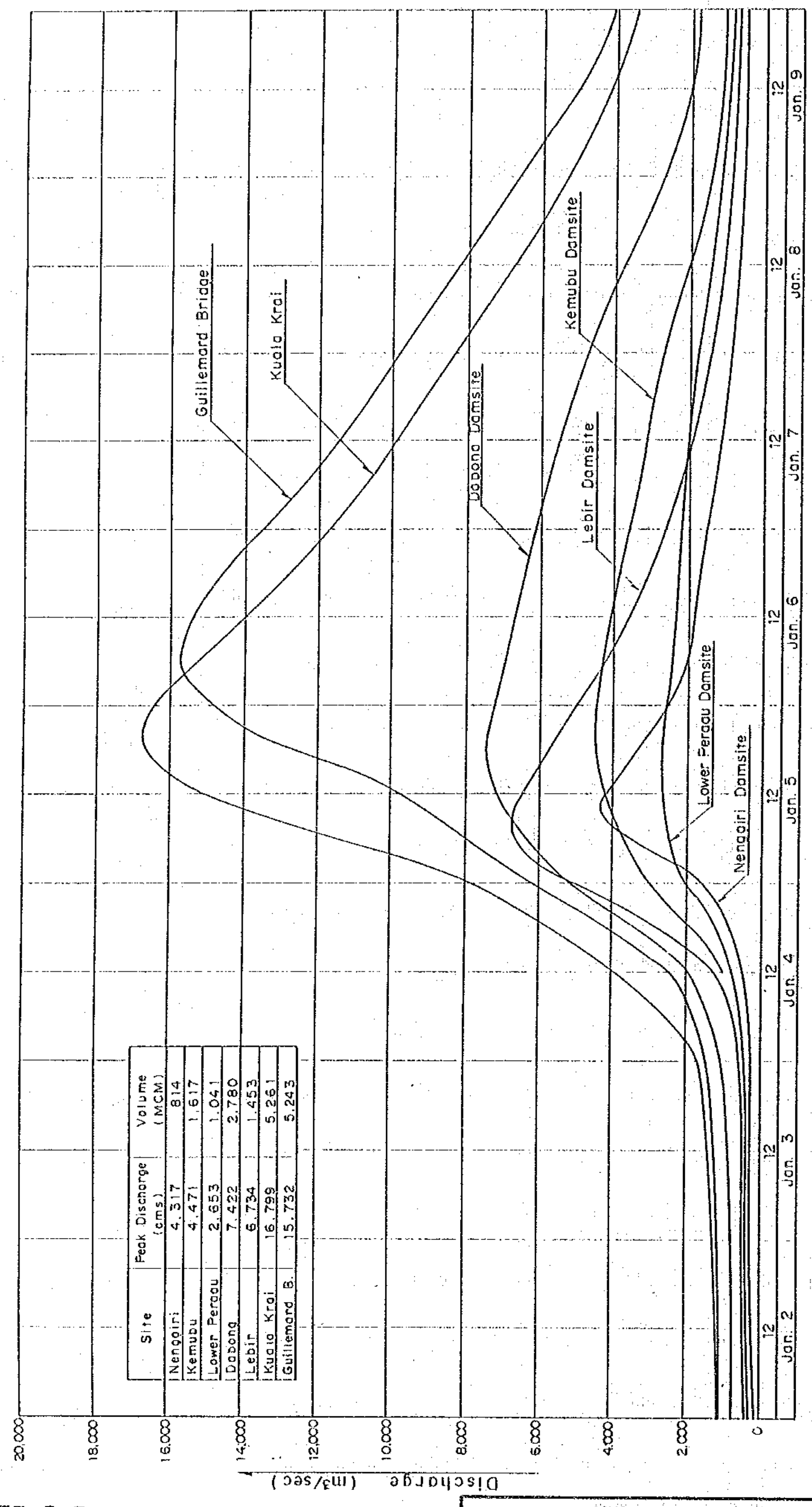

Site	Peak Discharge (cms)	Volume (MCM)
Nenggiri	4,317	814
Kemubu	4,471	1,617
Lower Pergau	2,653	1,041
Dabong	7,422	2,780
Lebir	6,734	1,453
Kuala Krai	16,799	5,261
Guillemard B.	15,732	5,243

Fig.II.5.7

Simulated 1967 Flood Hydrograph

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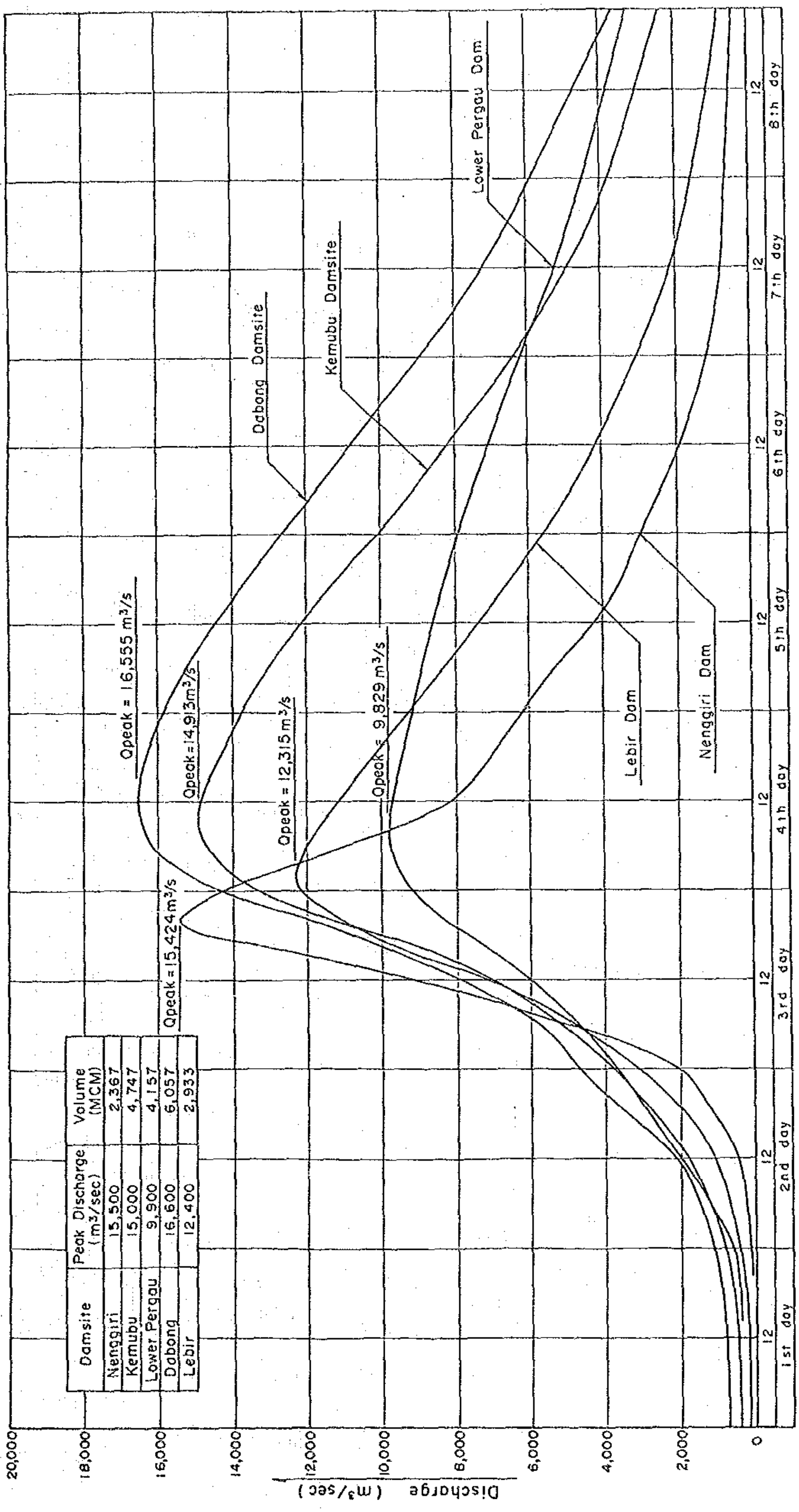

Fig.II.5.8

Spillway Design Flood

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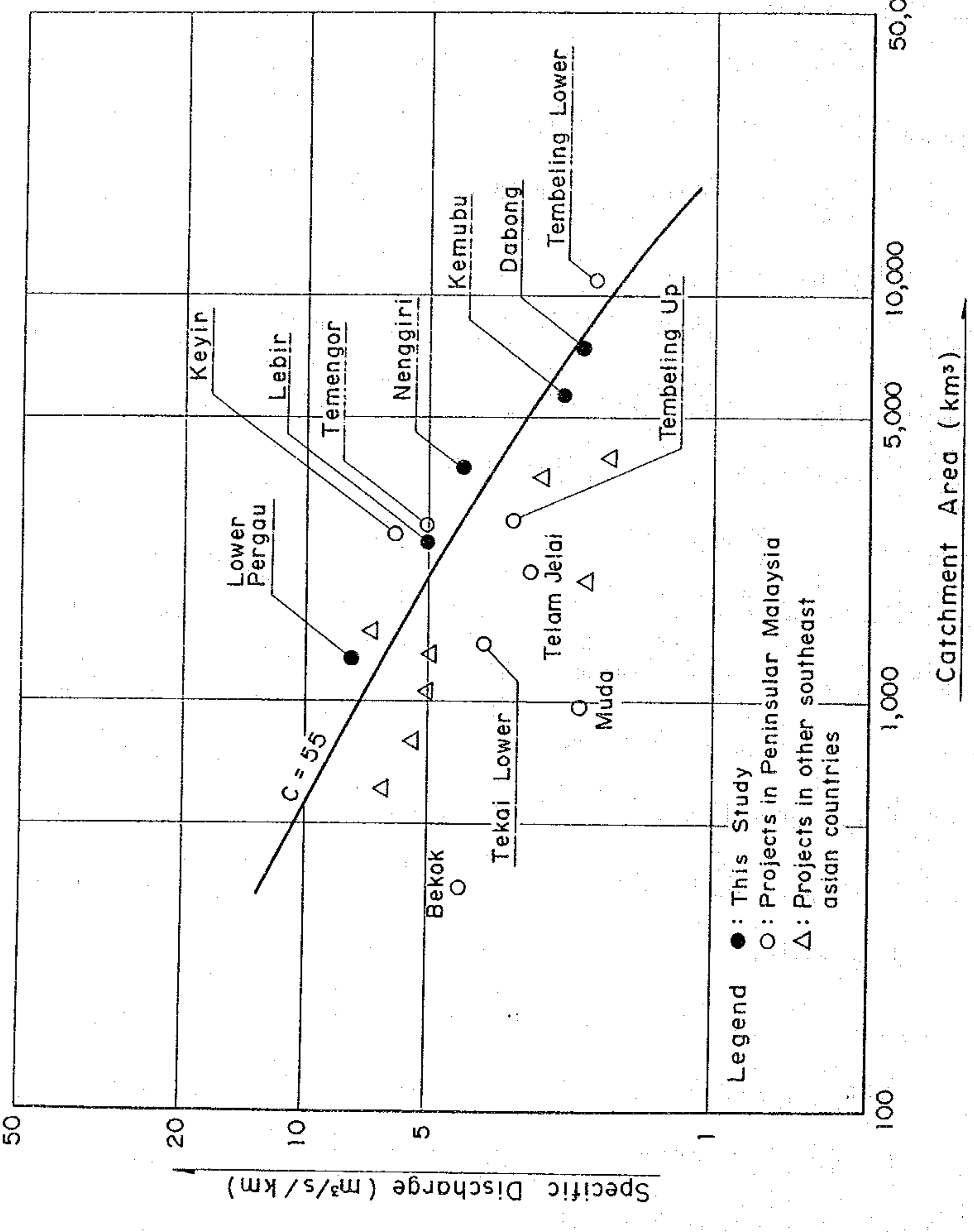

Fig.II.5.9

Regional Specific Peak Discharge for Spillway Design Flood

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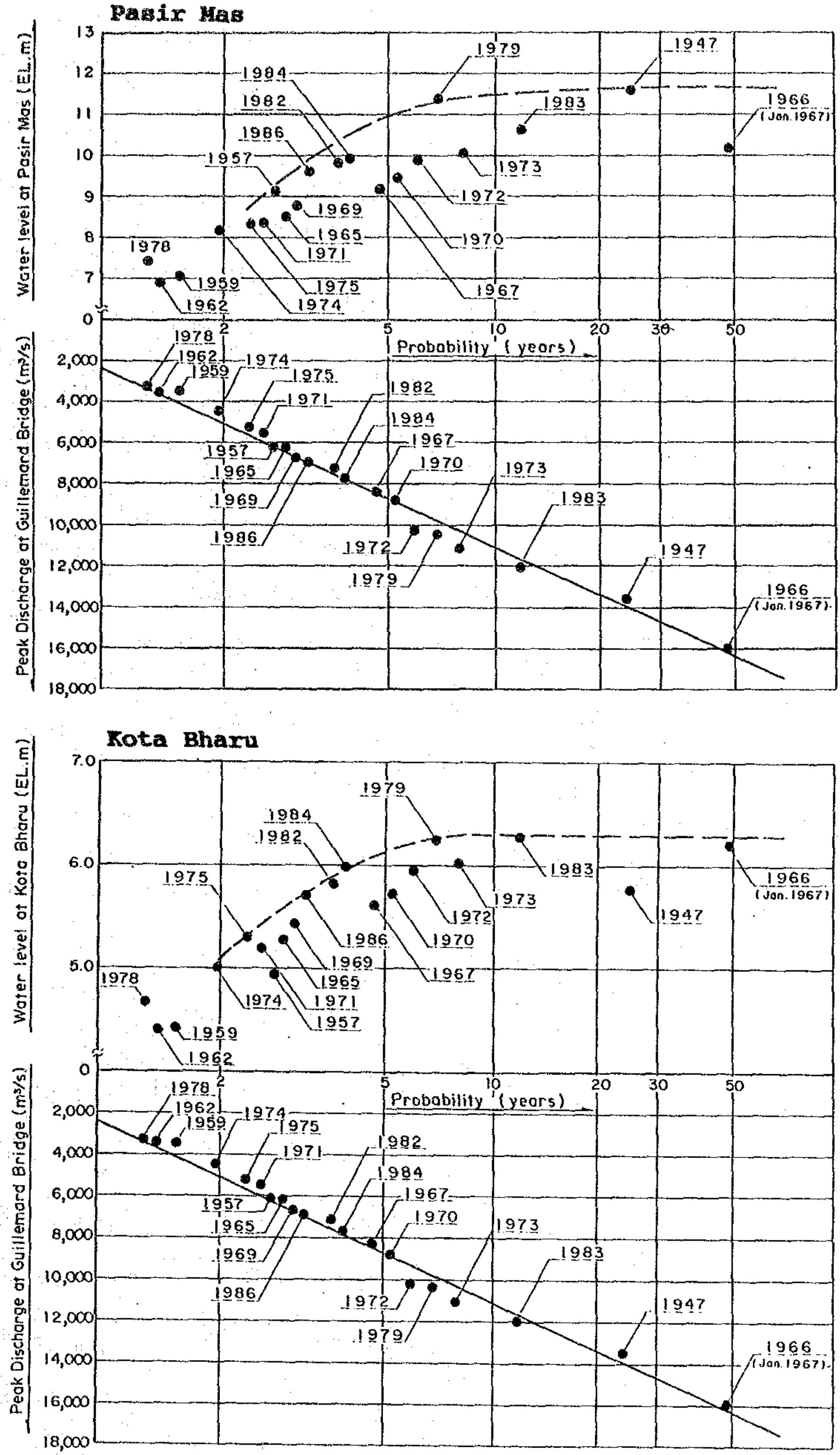

Fig.II.5.10

Inundation Depth in the Urban Areas

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Calculation of the Travelling Time of Flood

Although several empirical formula have been proposed to estimate the travelling time of flood, the following two methods are adopted to the Study.

(1) Kraven's equation

The travelling time of flood is calculated by the equation;

$$T = L / W \quad \text{(Eq.A.1)}$$

where, T : travelling time (sec),
L : length of river channel (= 250 km), and
W : velocity of flood wave propagation (m/sec).

in which, the velocity of flood wave propagation is defined by the river bed gradient (I) as follows;

W = 3.5 m/sec for $I > 1/100$
3.0 m/sec for $1/100 < I < 1/200$
2.1 m/sec for $I < 1/200$

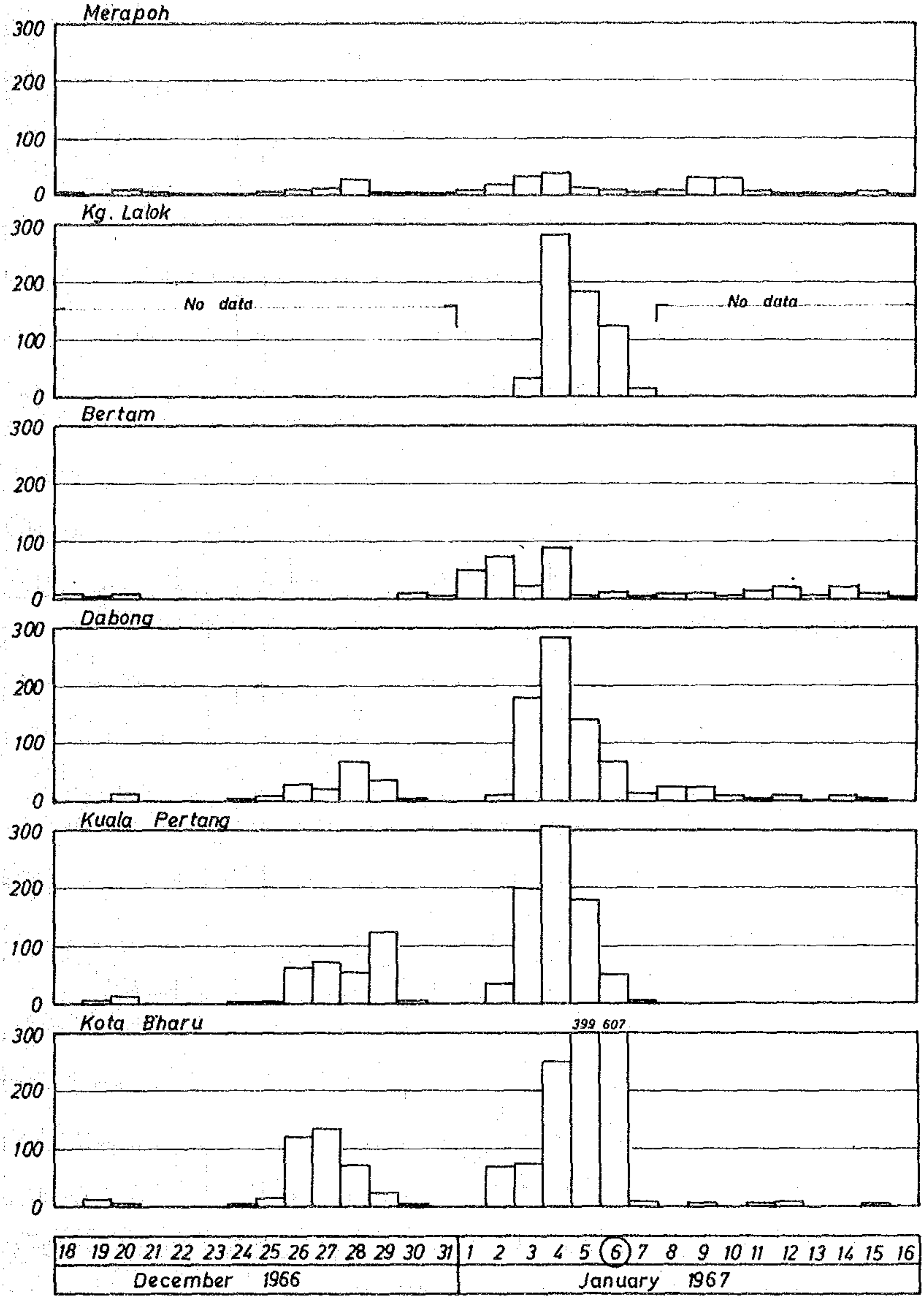
The travelling time of flood is estimated at 1.378 days.

(2) Empirical equation (Ministry of Construction, Japan)

$$T = 1.67 \times 10^{-3} \left(L / S^{0.5} \right)^{0.7} \quad \text{(Eq.A.2)}$$

where, T : travelling time (hrs),
S : average gradient of river bed (= 1/1500), and
L : river length (= 250,000 m).

The travelling time of flood is estimated at 5.404 days.



Daily Rainfall During 1967 Flood
(Qpeak = 16,000 m^3/sec on Jan. 6 at G/Bridge)

Fig.A.1

Daily Rainfall during 1967 Flood

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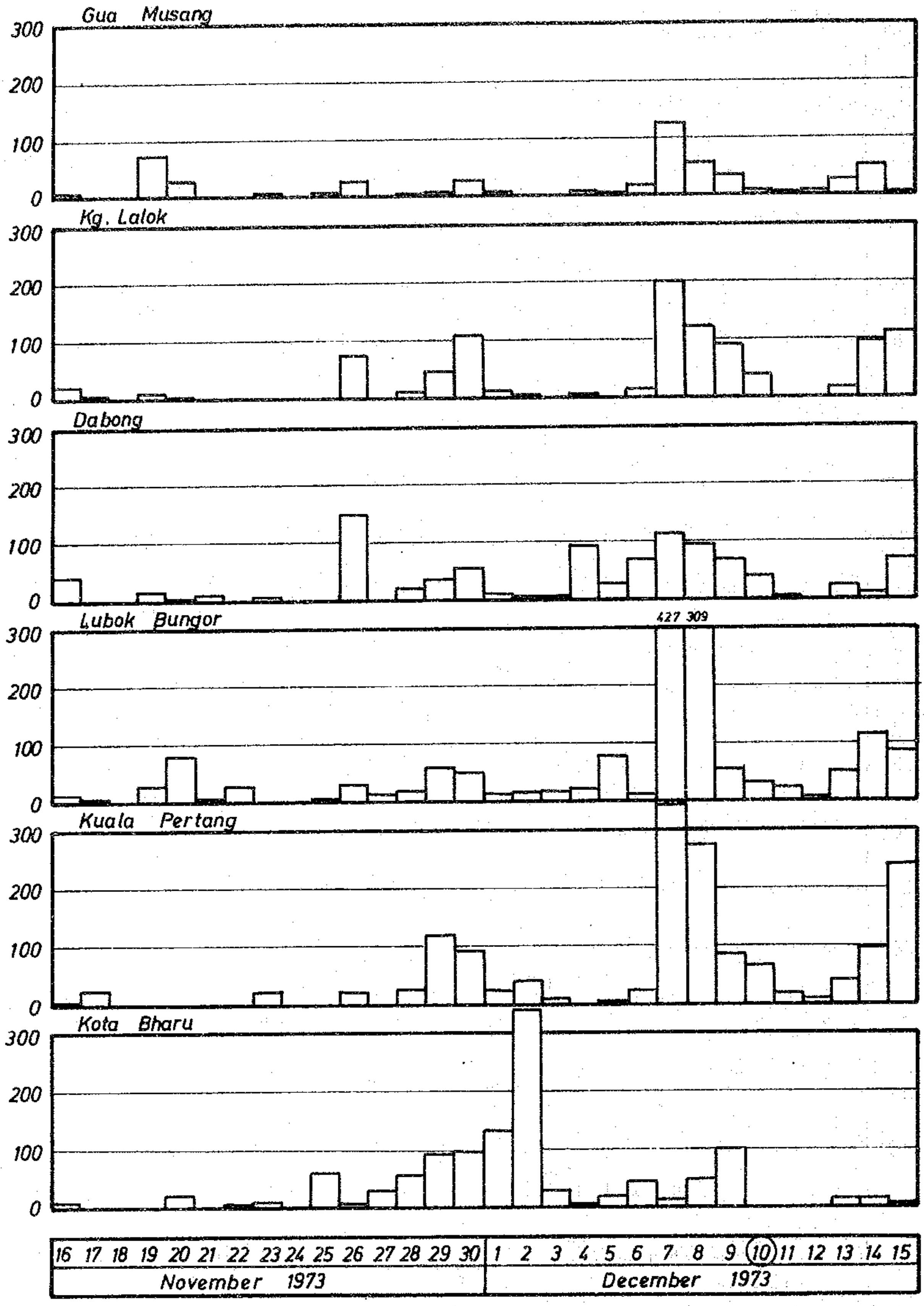

Daily Rainfall During 1973 Flood
(Qpeak = 11,130 m^3/sec on Dec.10 at G/Bridge)

Fig.A.2

Daily Rainfall during 1973 Flood

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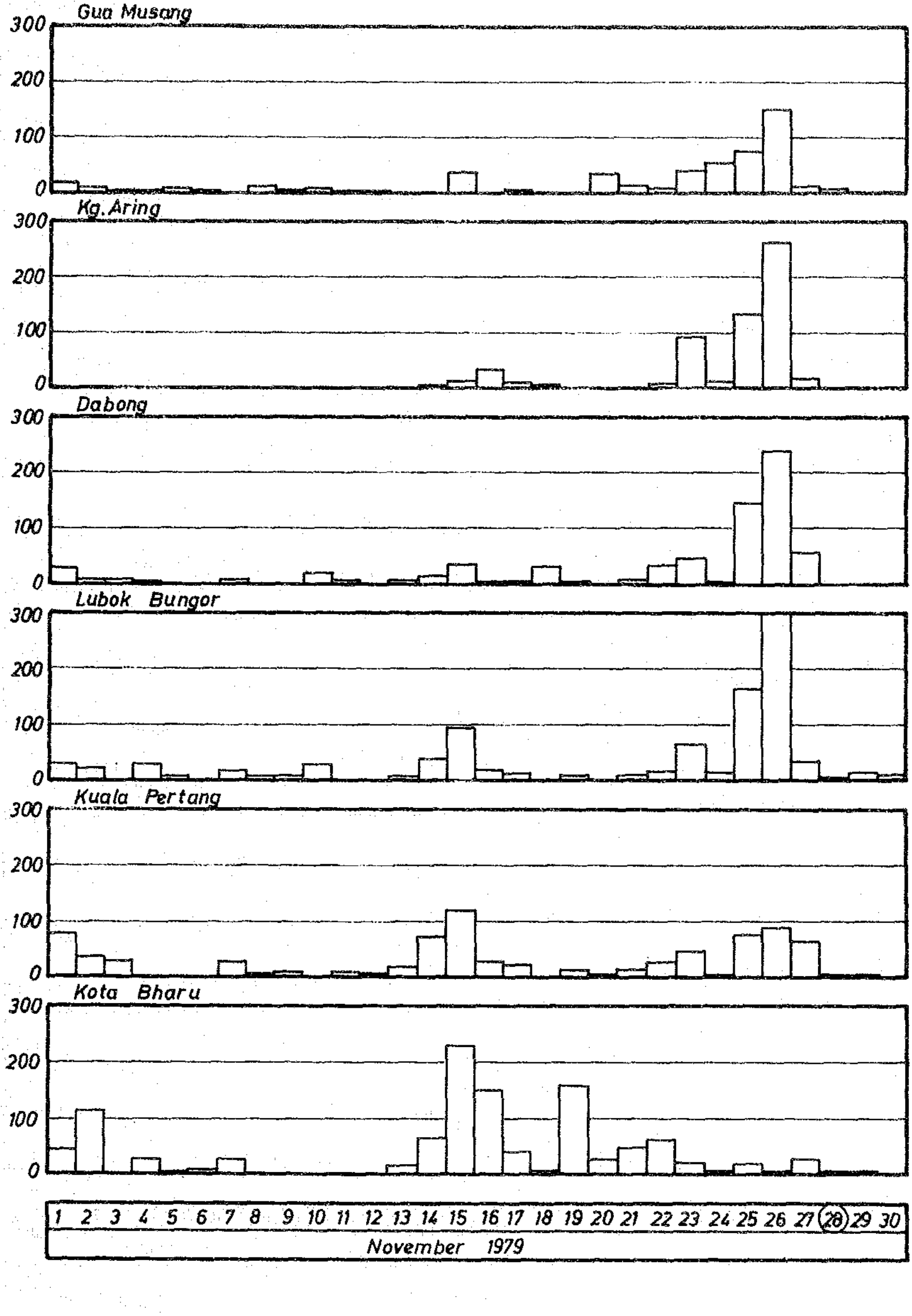

Daily Rainfall During 1979 Flood
(Qpeak = 10,400 m³/sec on Nov. 28 at G/Bridge)

Fig.A.3

Daily Rainfall during 1979 Flood

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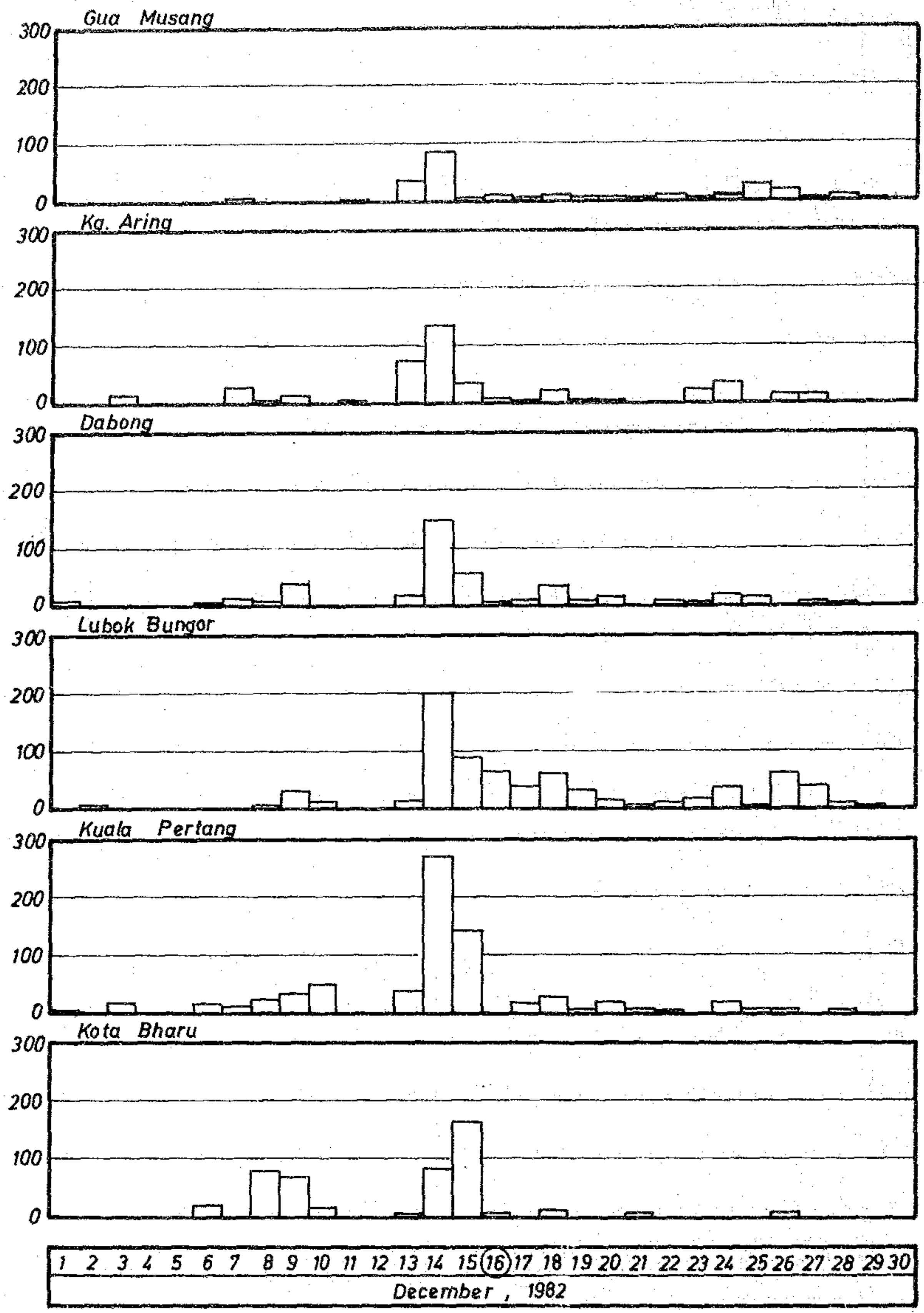

Daily Rainfall During 1982 Flood
(Qpeak = 7,172 m³/sec on Dec. 16 at G/Bridge)

Fig.A.4

Daily Rainfall during 1982 Flood

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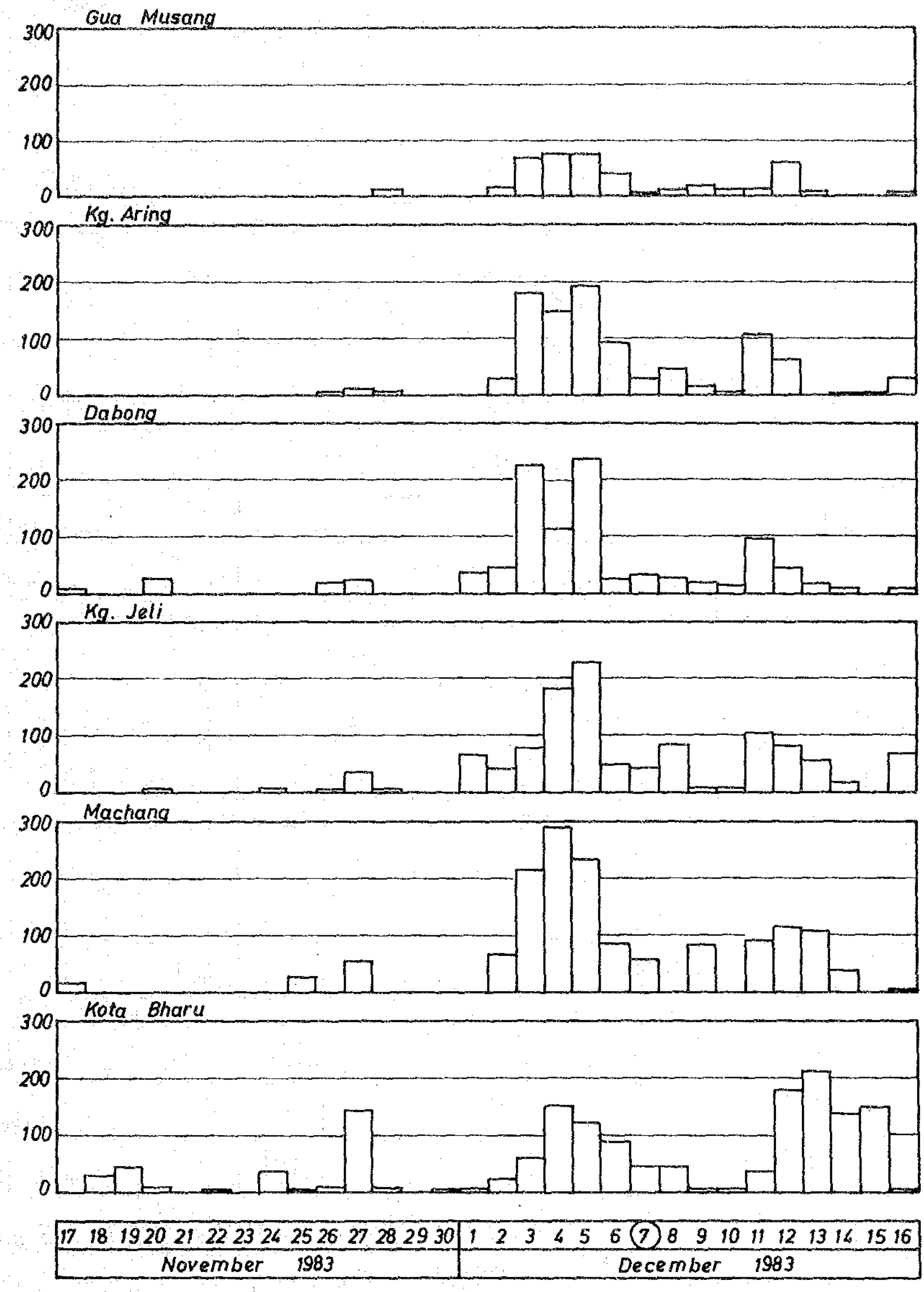

Daily Rainfall During 1983 Flood
(Qpeak = 12,007 m^3/sec on Dec. 7 at G/Bridge)

Fig.A.5

Daily Rainfall during 1983 Flood

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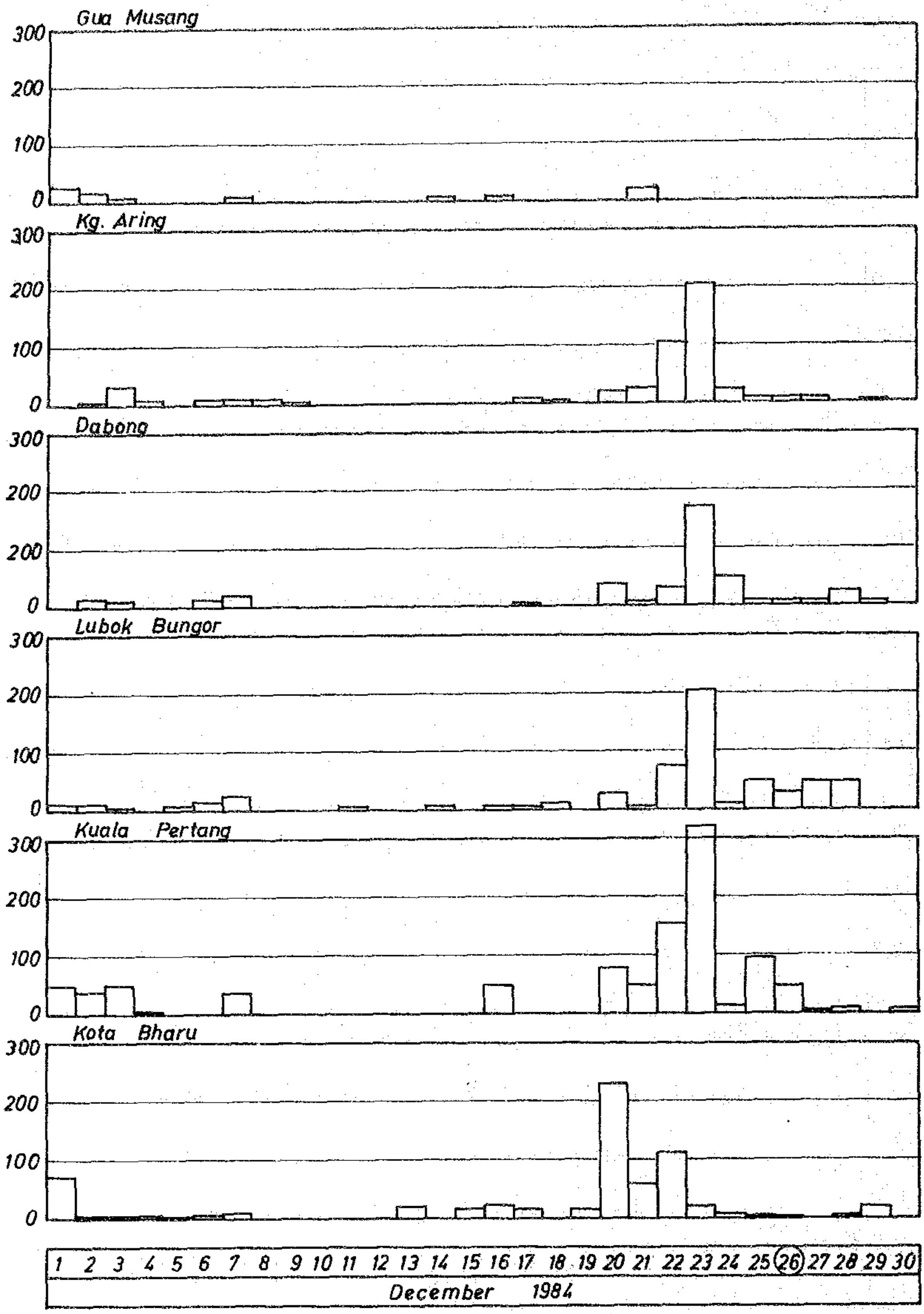

Daily Rainfall During 1984 Flood
(Qpeak = 7,744 m³/sec on Dec. 26 at G/Bridge)

Fig.A.6

Daily Rainfall during 1984 Flood

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KELANTAN RIVER BASIN - WIDE FLOOD MITIGATION
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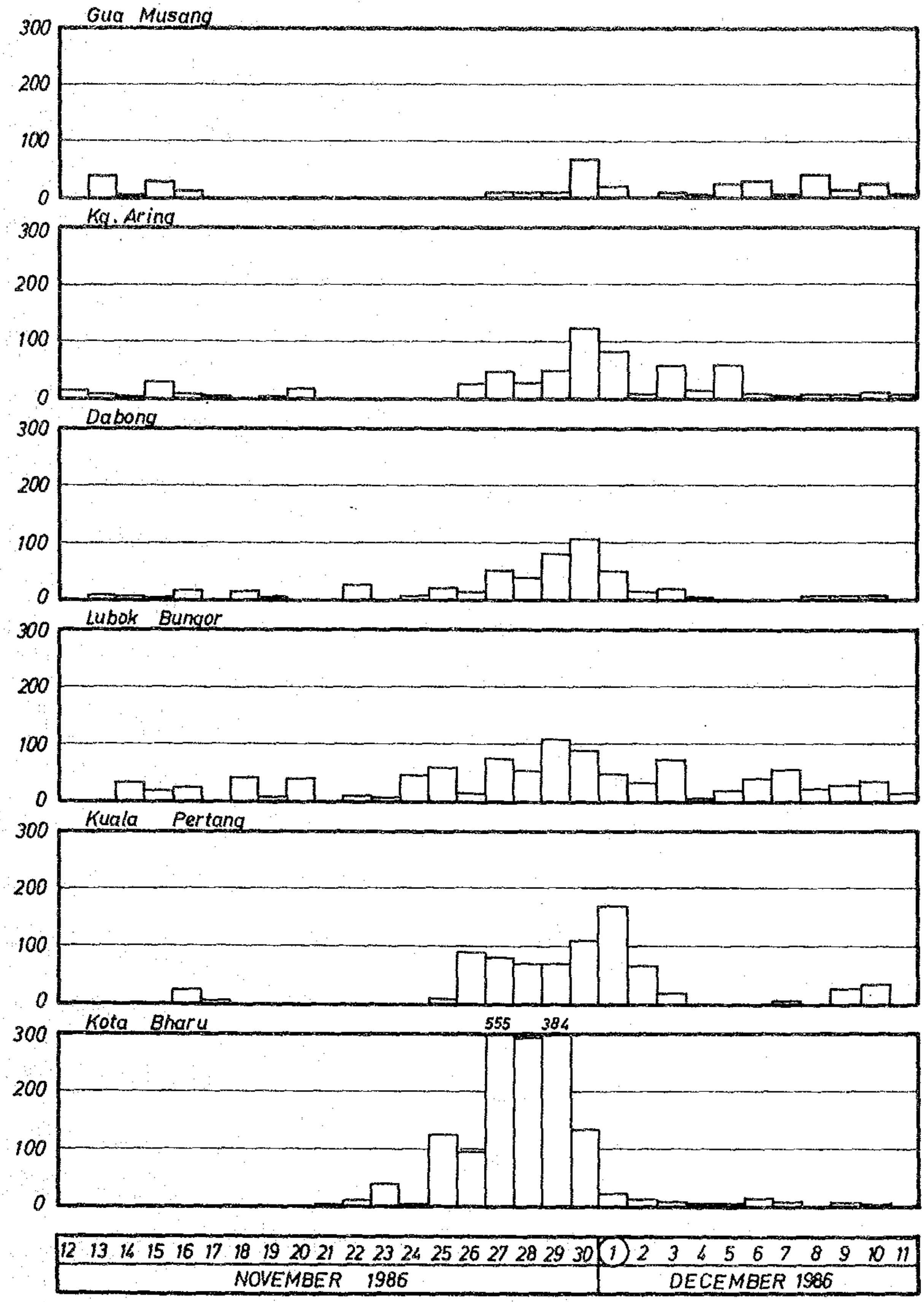

Daily Rainfall During 1986 Flood
(Qpeak = 6,901 m³/sec on Dec. 1)

Fig.A.7

Daily Rainfall during 1986 Flood

GOVERNMENT OF MALAYSIA STUDY ON KELANTAN RIVER BASIN - WIDE FLOOD MITIGATION
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ANNEX III

GEOTECHNICAL INVESTIGATION

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III. GEOTECHNICAL INVESTIGATION

1. INTRODUCTION

This Annex III, Geotechnical Investigation, deals with the results of geotechnical investigation on the Kelantan River Basin-wide Flood Mitigation Study performed at the study level of master plan. Major work carried out in this study is as follows:

(1) Analysis of geological data collected from DID and GSD,

(2) Field survey at and around the conceivable damsites, i.e. Lebir, Dabong, Lower Pergau, Kemubu and Nenggiri dams, and along the downstream reaches of the Kelantan River, and

(3) Geotechnical consideration for the conceivable damsites and river improvement works of the downstream reaches.

2. GEOLOGY IN THE KELANTAN RIVER BASIN

2.1 General

The Kelantan River is located in the north-eastern part of Peninsular Malaysia and originates from the mountain ridge which is the border with the State of Perak. Meandering the hilly areas in the middle reaches and flat plains in the downstream reaches northwardly, the Kelantan River drains into the South China Sea. A total catchment area of the Kelantan River basin is 13,100 km^2, which is 85% of the Kelantan State. A location map of the Kelantan River basin is shown in Fig.III.2.1.

The topographic features of the Kelantan River basin are characterized by geological strata running from the south to the north direction as shown in Fig. III.2.2. High mountain ranges located at the eastern, western and southern sides of the basin make a border with the State of Terengganu and the State of Perak and Thailand, respectively.

A geological map of the Kelantan River basin is given in Fig. III.2.3. High mountains running from east to west through the southern part of the basin consist mainly of granites which are intruded at the Palaeozoic-Tertiary age. The granites, being massive and sound, shape the steep mountain slopes.

The hilly areas extended in the middle reaches are predominated by the Palaeozoic-Mesozoic rocks comprising sandstones, shales, limestones, tuffs and volcanics, which are very often metamorphosed regionally into phyllites and slates and further into crystalline schists. Thermal metamorphism due to the granite intrusion is often observed in the formation of hornfels. Particularly, phyllites, slates and schists are deeply weathered because of plenty of cracks and foliations.

Limestones having strong resistance to weathering form the high pinnacles with some caves in these bodies. Granitic masses intruded sporadically in the hilly areas are generally small in size and without tendency to expand.

Geological structure runs north-south or northwest-southeast. The axes of folding and major faults also orient these directions, but are sometimes intersected by other groups of faults tending northeast to southwest.

The flat areas of downstream reaches situated in about 40 km long endmost river stretches consist of the alluvial deposits comprising mainly sand, silt and clayey soil, and form the soft ground. Dunes formed with coarse sands carried by the westward littoral current are developed with the 10 km wide band from the coastline, especially at the estuary of the Kelantan River.

2.2 Upstream Reaches

Most parts of the upstream reaches forming high mountainous ranges (refer to Figs. III.2.2 and 2.3) consist mainly of granites except for the southern part dominated by the Palaeozoic-Mesozoic rocks. These granites are massive and sound, shaping the steep mountain slopes with waterfalls and rapids.

Granitic activities have been indicated in four periods at least by Rb/Sr radiometric datings. The earliest one is in the Late Carboniferous (300-285 million years), followed by two granite emplacements occurred in the Triassic; the Early Triassic (230 ± 6 million years) and Late Triassic (199 ± 2 million years). The latest granites intruded at the beginning of the Tertiary (75 ± 1 million years) occur as isolated stocks and dykes.

The granite is often sheared and gneissic, particularly near its contact with the adjoining rocks. Sheared planes generally strike in a northerly direction. On the other hand, weathering of the granites is not supposed to develop intensively except for the gentle slopes around the border with the hilly areas.

2.3 Mid-stream Reaches

Out of five conceivable damsites, Dabong, Lower Pergau, Kemubu and Lebir damsites are located in the hilly area as shown in Figs. III.2.2 and 2.3. The Nenggiri damsite is, on the other hand, situated at the border between the mountainous and hilly areas.

The hilly area consists mainly of the Permian and Triassic rocks, comprising phyllite, slate, shale, limestone, tuff, volcanics and metamorphic rocks. Due to metamorphism widely spread in the region, most of the Permian and Triassic rocks are deformed slightly to moderately. In general, the older rocks show a greater degree of metamorphism than the younger ones.

The distribution of Permian and Triassic rocks is complicated. These strata, however, have almost same direction of north-south or northwest-southeast.

The Permian rocks are classified into four groups; arenaceous rocks, argillaceous rocks, volcanic rocks, and metamorphic rocks. Metamorphic rocks consisting mainly of schists with developed foliation are distributed in the strip area from the vicinity of Terowong 20 km southeast of Dabong to Tanah Merah 30 km downstream of Kuala Krai. These schists named "Taku schists" comprise mica-garnet schist, quartz schists and amphibole schists.

Volcanics consist of acid volcanics and basic volcanics. Acid volcanics comprising tuffs, agglomerates and rhyolites together with subordinately intercalated shale and quartzite predominate in the southeastern part of mid-stream reaches. Basic volcanics consisting mainly of tuffs, andesite and agglomerate with minor interbedded shale are distributed in the western part of hilly area and form long and narrow strips.

Argillaceous and arenaceous rocks occur mainly in the centre of hilly areas with limestones. These rocks due to metamorphism develop many foliations.

Limestones predominating in the area between the Lebir and Galas rivers form spectacular cliffs standing vertically or overhanged. Near the contact with granite masses, limestones are changed to crystalline marbles showing considerable variation in the grain size.

On the other hand, the Triassic rocks consist mainly of shales with mudstones. Sandstones/metasandstones, conglomerates, tuffaceous varieties and limestones are sporadically included in these Triassic rocks. The shales with grey to black colour are generally thinly laminated and strongly fissile.

Dykes formed from quartz porphry, aplite, pegmatite and microgranite sporadically occur in the schists and sedimentary rocks, being massive and sound in general. Faulting is common in all rocks.

Major faults strongly trend in the north-south or northwest-southeast direction, but are sometimes intersected by other groups of faults trending in the northwest to southwest direction. One of long-ranged major faults with a north-northwesterly trend is located on the right bank of the Lebir River, running parallel to the river course. Minor faults are commonly found in association with foldings.

2.4 Downstream Reaches

The downstream reaches shown in Figs. III.2.2 and 2.3 are characterized by lower hilly area from Kuala Krai to Kg. Kemubu and flat alluvial plain area from Kg. Kemubu to the river mouth. The lower hilly area consists of Permian-Triassic sedimentary rocks and granites which have same geological conditions as the rocks distributed in the mid-stream reaches.

Flat alluvial plain area consists of alluvial deposits classified into marine deposits and fluviatile deposits, although it is not always possible to demarcate two types of deposits. The underlying bed rock consists mainly of the Permian sedimentary rocks and granites. The depth from the ground surface to the bed rocks is in 100 to 200 m at the estuary of the Kelantan River and gradually shallow towards the upstream area of the river.

Marine deposits are composed of coarse sand containing shell fragments. Rised beaches and dunes, which are one of marine deposits and characterize the coastline, are formed by the westward littoral current. Around the mouth of the Kelantan River, many swamps are formed behind the ranging dunes due to poor drainage. Clayey soils with soft ground are predominant as the top soil of swamp areas.

On the other hand, fluvial deposits are composed of gravel, sand, silt, clay and their alternation. Medium-coarse sand with gravel is occasionally observed at the dunes in the river bed or at the inner bank where the Kelantan River largely bends, but the river alluvium is more commonly represented by bands of stiff clay, thinner bands of silt and irregular beds of decayed vegetation. The change of river courses due to flooding causes the considerable complication in the river alluvium.