TABLE F-4-1 NUMBER OF RESIDENTIAL DWELLINGS IN THE FLOOD PRONE AREA BY FLOOD FREQUENCY (SG. KELUANG)

Flood Frequency: 50-Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (1000 m2)	1990				2010			
				Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings	Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings
Keluang	1	0<H<50	0.0	0.1	0	500	0	0.2	0	500	0
		50≤H<100	0.0	0.1	0	500	0	0.2	0	500	0
		100≤H<200	0.0	0.1	0	500	0	0.2	0	500	0
		200≤H<300	0.0	0.1	0	500	0	0.2	0	500	0
		300≤H	0.0	0.1	0	500	0	0.2	0	500	0
		Total	0.0		0		0		0		0
	2	0<H<50	0.0	0.1	0	500	0	0.2	0	500	0
		50≤H<100	0.0	0.1	0	500	0	0.2	0	500	0
		100≤H<200	0.0	0.1	0	500	0	0.2	0	500	0
		200≤H<300	0.0	0.1	0	500	0	0.2	0	500	0
		300≤H	0.0	0.1	0	500	0	0.2	0	500	0
		Total	0.0		0		0		0		0
	3	0<H<50	0.0	0.2	0	500	0	0.3	0	500	0
		50≤H<100	137.5	0.2	27.5	500	55	0.3	41.25	500	83
		100≤H<200	0.0	0.2	0	500	0	0.3	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.3	0	500	0
		300≤H	0.0	0.2	0	500	0	0.3	0	500	0
		Total	137.5		27.5		55		41.25		83
	4	0<H<50	0.0	0.2	0	500	0	0.4	0	500	0
		50≤H<100	242.0	0.2	48.4	500	97	0.4	96.8	500	194
		100≤H<200	0.0	0.2	0	500	0	0.4	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	242.0		48.4		97		96.8		194
	5	0<H<50	120.0	0.2	24	500	48	0.4	48	500	96
		50≤H<100	0.0	0.2	0	500	0	0.4	0	500	0
		100≤H<200	0.0	0.2	0	500	0	0.4	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	120.0		24		48		48		96
	6	0<H<50	125.0	0.2	25	500	50	0.4	50	500	100
		50≤H<100	0.0	0.2	0	500	0	0.4	0	500	0
		100≤H<200	0.0	0.2	0	500	0	0.4	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	125.0		25		50		50		100

TABLE F-4-2 NUMBER OF RESIDENTIAL DWELLINGS IN THE FLOOD PRONE AREA BY FLOOD FREQUENCY (SG. KELUANG)

Flood Frequency: 50 Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (1000 m2)	1990				2010			
				Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings	Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings
Keluang	7	0<H<50	0.0	0.2	0	500	0	0.5	0	500	0
		50≤H<100	17.5	0.2	3.5	500	7	0.5	8.75	500	18
		100≤H<200	0.0	0.2	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.5	0	500	0
		300≤H	0.0	0.2	0	500	0	0.5	0	500	0
		Total	17.5		3.5		7		8.75		18
	8	0<H<50	0.0	0.5	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.5	0	500	0	0.5	0	500	0
		100≤H<200	0.0	0.5	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.5	0	500	0	0.5	0	500	0
		300≤H	0.0	0.5	0	500	0	0.5	0	500	0
		Total	0.0		0		0		0		0
	9	0<H<50	0.0	0.5	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.5	0	500	0	0.5	0	500	0
		100≤H<200	0.0	0.5	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.5	0	500	0	0.5	0	500	0
		300≤H	0.0	0.5	0	500	0	0.5	0	500	0
		Total	0.0		0		0		0		0
	10	0<H<50	0.0	0.5	0	500	0	0.5	0	500	0
		50≤H<100	250.0	0.5	125	500	250	0.5	125	500	250
		100≤H<200	0.0	0.5	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.5	0	500	0	0.5	0	500	0
		300≤H	0.0	0.5	0	500	0	0.5	0	500	0
		Total	250.0		125		250		125		250
	11	0<H<50	0.0	0.2	0	500	0	0.4	0	500	0
		50≤H<100	250.0	0.2	50	500	100	0.4	100	500	200
		100≤H<200	0.0	0.2	0	500	0	0.4	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	250.0		50		100		100		200
	12	0<H<50	0.0	0.1	0	500	0	0.5	0	500	0
		50≤H<100	250.0	0.1	25	500	50	0.5	125	500	250
		100≤H<200	0.0	0.1	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.1	0	500	0	0.5	0	500	0
		300≤H	0.0	0.1	0	500	0	0.5	0	500	0
		Total	250.0		25		50		125		250

TABLE F-4-3 NUMBER OF RESIDENTIAL DWELLINGS IN THE FLOOD PRONE AREA BY FLOOD FREQUENCY (SG. KELUANG)

Flood Frequency: 50 Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (1000 m2)	1990				2010			
				Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings	Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings
Keluang	13	0<H<50	0.0	0.2	0	500	0	0.4	0	500	0
		50≤H<100	0.0	0.2	0	500	0	0.4	0	500	0
		100≤H<200	191.5	0.2	38.3	500	77	0.4	76.6	500	153
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	191.5		38.3		77		76.6		153
	14	0<H<50	0.0	0.2	0	500	0	0.4	0	500	0
		50≤H<100	0.0	0.2	0	500	0	0.4	0	500	0
		100≤H<200	5.0	0.2	1	500	2	0.4	2	500	4
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	5.0		1		2		2		4
	15	0<H<50	0.0	0.5	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.5	0	500	0	0.5	0	500	0
		100≤H<200	0.0	0.5	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.5	0	500	0	0.5	0	500	0
		300≤H	0.0	0.5	0	500	0	0.5	0	500	0
		Total	0.0		0		0		0		0
	16	0<H<50	0.0	0.5	0	500	0	0.6	0	500	0
		50≤H<100	0.0	0.5	0	500	0	0.6	0	500	0
		100≤H<200	140.5	0.5	70.25	500	141	0.6	84.3	500	169
		200≤H<300	0.0	0.5	0	500	0	0.6	0	500	0
		300≤H	0.0	0.5	0	500	0	0.6	0	500	0
		Total	140.5		70.25		141		84.3		169
	17	0<H<50	0.0	0.5	0	500	0	0.6	0	500	0
		50≤H<100	231.0	0.5	115.5	500	231	0.6	138.6	500	277
		100≤H<200	0.0	0.5	0	500	0	0.6	0	500	0
		200≤H<300	0.0	0.5	0	500	0	0.6	0	500	0
		300≤H	0.0	0.5	0	500	0	0.6	0	500	0
		Total	231.0		115.5		231		138.6		277
	18	0<H<50	0.0	0.2	0	500	0	0.5	0	500	0
		50≤H<100	250.0	0.2	50	500	100	0.5	125	500	250
		100≤H<200	0.0	0.2	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.2	0	500	0	0.5	0	500	0
		300≤H	0.0	0.2	0	500	0	0.5	0	500	0
		Total	250.0		50		100		125		250

TABLE F-4-4 NUMBER OF RESIDENTIAL DWELLINGS IN THE FLOOD PRONE AREA BY FLOOD FREQUENCY (SG. KELUANG)

Flood Frequency: 50 Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (1000 m2)	1990				2010			
				Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings	Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings
Keluang	19	0<H<50	0.0	0.3	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.3	0	500	0	0.5	0	500	0
		100≤H<200	250.0	0.3	75	500	150	0.5	125	500	250
		200≤H<300	0.0	0.3	0	500	0	0.5	0	500	0
		300≤H	0.0	0.3	0	500	0	0.5	0	500	0
		Total	250.0		75		150		125		250
	20	0<H<50	0.0	0.2	0	500	0	0.4	0	500	0
		50≤H<100	0.0	0.2	0	500	0	0.4	0	500	0
		100≤H<200	250.0	0.2	50	500	100	0.4	100	500	200
		200≤H<300	0.0	0.2	0	500	0	0.4	0	500	0
		300≤H	0.0	0.2	0	500	0	0.4	0	500	0
		Total	250.0		50		100		100		200
	21	0<H<50	0.0	0.01	0	500	0	0.4	0	500	0
		50≤H<100	0.0	0.01	0	500	0	0.4	0	500	0
		100≤H<200	125.0	0.01	1.25	500	3	0.4	50	500	100
		200≤H<300	0.0	0.01	0	500	0	0.4	0	500	0
		300≤H	0.0	0.01	0	500	0	0.4	0	500	0
		Total	125.0		1.25		3		50		100
	22	0<H<50	0.0	0.05	0	500	0	0.3	0	500	0
		50≤H<100	0.0	0.05	0	500	0	0.3	0	500	0
		100≤H<200	0.0	0.05	0	500	0	0.3	0	500	0
		200≤H<300	0.0	0.05	0	500	0	0.3	0	500	0
		300≤H	0.0	0.05	0	500	0	0.3	0	500	0
		Total	0.0		0		0		0		0
	23	0<H<50	0.0	0.15	0	500	0	0.3	0	500	0
		50≤H<100	72.0	0.15	10.8	500	22	0.3	21.6	500	43
		100≤H<200	0.0	0.15	0	500	0	0.3	0	500	0
		200≤H<300	0.0	0.15	0	500	0	0.3	0	500	0
		300≤H	0.0	0.15	0	500	0	0.3	0	500	0
		Total	72.0		10.8		22		21.6		43
	24	0<H<50	0.0	0.3	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.3	0	500	0	0.5	0	500	0
		100≤H<200	231.5	0.3	69.45	500	139	0.5	115.75	500	232
		200≤H<300	0.0	0.3	0	500	0	0.5	0	500	0
		300≤H	0.0	0.3	0	500	0	0.5	0	500	0
		Total	231.5		69.45		139		115.75		232

TABLE F-4-5 NUMBER OF RESIDENTIAL DWELLINGS IN THE FLOOD PRONE AREA BY FLOOD FREQUENCY (SG. KELUANG)

Flood Frequency: 50 Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (1000 m2)	1990				2010			
				Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings	Share of Residential Area (%)	Area of Residence (1000 m2)	Average Size of Residential Lot (m2)	Number of Residential Dwellings
Keluang	25	0<H<50	0.0	0.1	0	500	0	0.5	0	500	0
		50≤H<100	250.0	0.1	25	500	50	0.5	125	500	250
		100≤H<200	0.0	0.1	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.1	0	500	0	0.5	0	500	0
		300≤H	0.0	0.1	0	500	0	0.5	0	500	0
		Total	250.0		25		50		125		250
	26	0<H<50	0.0	0.1	0	500	0	0.5	0	500	0
		50≤H<100	162.5	0.1	16.25	500	33	0.5	81.25	500	163
		100≤H<200	0.0	0.1	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.1	0	500	0	0.5	0	500	0
		300≤H	0.0	0.1	0	500	0	0.5	0	500	0
		Total	162.5		16.25		33		81.25		163
	27	0<H<50	0.0	0.5	0	500	0	0.5	0	500	0
		50≤H<100	0.0	0.5	0	500	0	0.5	0	500	0
		100≤H<200	125.0	0.5	62.5	500	125	0.5	62.5	500	125
		200≤H<300	0.0	0.5	0	500	0	0.5	0	500	0
		300≤H	0.0	0.5	0	500	0	0.5	0	500	0
		Total	125.0		62.5		125		62.5		125
	28	0<H<50	0.0	0	0	500	0	0.5	0	500	0
		50≤H<100	125.0	0	0	500	0	0.5	62.5	500	125
		100≤H<200	0.0	0	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0	0	500	0	0.5	0	500	0
		300≤H	0.0	0	0	500	0	0.5	0	500	0
		Total	125.0		0		0		62.5		125
	29	0<H<50	0.0	0.05	0	500	0	0.5	0	500	0
		50≤H<100	17.0	0.05	0.85	500	2	0.5	8.5	500	17
		100≤H<200	0.0	0.05	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0.05	0	500	0	0.5	0	500	0
		300≤H	0.0	0.05	0	500	0	0.5	0	500	0
		Total	17.0		0.85		2		8.5		17
	30	0<H<50	0.0	0	0	500	0	0.5	0	500	0
		50≤H<100	15.5	0	0	500	0	0.5	7.75	500	16
		100≤H<200	0.0	0	0	500	0	0.5	0	500	0
		200≤H<300	0.0	0	0	500	0	0.5	0	500	0
		300≤H	0.0	0	0	500	0	0.5	0	500	0
		Total	15.5		0		0		7.75		16
Grand Total		0<H<50	245.0	-	49.0	-	98	-	98.0	-	196
		50≤H<100	2,270.0	-	497.8	-	995	-	1,067.0	-	2,134
		100≤H<200	1,318.5	-	367.8	-	736	-	616.2	-	1,232
		200≤H<300	0.0	-	0.0	-	0	-	0.0	-	0
		300≤H	0.0	-	0.0	-	0	-	0.0	-	0
		Total	3,833.5		914.6		1,829		1,781.2		3,562

TABLE F-5 NUMBER OF RESIDENTIAL DWELLING IN THE FLOOD PRONE AREA BY FLOOD FREQENCY (GEORGETOWN DRAINAGE)

Flood Frequency; 10-Year Return Flood

Name of Flood Prone Area	Sub Basin	Inundation Depth (cm)	Total Flood Prone Area (ha)	1990				2010			
				Population Density (person/ha)	Area per Person (m2/person)	No. of Persons per House (persons)	Number of Residential Dwellings	Population Density (person/ha)	Area per Person (m2/person)	No. of Persons per House (persons)	Number of Residential Dwellings
Georgetown	S-10	0<H<50	2.9	300	33	6.56	133	300	33	6.18	141
		50≤H<100	0.7	300	33	6.56	32	300	33	6.18	34
		100≤H<200	0.0	300	33	6.56	0	300	33	6.18	0
		200≤H<300	0.0	300	33	6.56	0	300	33	6.18	0
		300≤H	0.0	300	33	6.56	0	300	33	6.18	0
		Total	3.6				165				175
	S-18	0<H<50	14.4	220	45	6.56	483	220	45	6.18	513
		50≤H<100	11.7	220	45	6.56	392	220	45	6.18	417
		100≤H<200	0.8	220	45	6.56	27	220	45	6.18	28
		200≤H<300	0.0	220	45	6.56	0	220	45	6.18	0
		300≤H	0.0	220	45	6.56	0	220	45	6.18	0
		Total	26.9				902				958
	N-12	0<H<50	5.0	120	83	6.56	91	120	83	6.18	97
		50≤H<100	5.4	120	83	6.56	99	120	83	6.18	105
		100≤H<200	10.0	120	83	6.56	183	120	83	6.18	194
		200≤H<300	7.3	120	83	6.56	134	120	83	6.18	142
		300≤H	11.0	120	83	6.56	201	120	83	6.18	214
		Total	38.7				708				751
Total		0<H<50	22.3				707				750
		50≤H<100	17.8				523				555
		100≤H<200	10.8				210				223
		200≤H<300	7.3				134				142
		300≤H	11.0				201				214
		Total	69.2				1,775				1,884

TABLE F-6 TOTAL NUMBER OF HOUSES IN FLOOD PRONE AREA BY FLOOD RETURN YEAR

(SG. PINANG)

(unit; houses)

Year	Water Depth cm	5-year Return Flood	10-year Return Flood	30-year Return Flood	50-year Return Flood	100-year Return Flood
1990	0<H<50	3,341	2,888	1,612	1,522	621
	50≤H<100	1,575	6,726	3,740	1,606	1,514
	100≤H<200	371	8,033	13,719	12,121	6,735
	200≤H<300	0	358	9,237	11,138	9,756
	300≤H	0	13	1,212	7,033	16,669
	Total	5,288	18,019	29,520	33,421	35,296
2010	0<H<50	3,547	3,411	2,125	1,745	690
	50≤H<100	1,672	7,493	5,151	2,273	1,603
	100≤H<200	394	8,105	16,380	15,912	9,353
	200≤H<300	0	298	10,308	12,303	12,020
	300≤H	0	14	1,282	7,646	18,194
	Total	5,613	19,321	35,246	39,880	41,860

(SG. KELUANG)

(unit; houses)

Year	Water Depth cm	5-year Return Flood	10-year Return Flood	30-year Return Flood	50-year Return Flood	100-year Return Flood
1990	0<H<50	277	541	423	98	48
	50≤H<100	37	137	541	996	872
	100≤H<200	0	0	3	736	886
	200≤H<300	0	0	0	0	292
	300≤H	0	0	0	0	0
	Total	314	677	967	1,829	2,098
2010	0<H<50	579	1,010	1,097	196	96
	50≤H<100	420	620	1,049	2,134	1,936
	100≤H<200	0	0	100	1,232	1,354
	200≤H<300	0	0	0	0	445
	300≤H	0	0	0	0	0
	Total	999	1,630	2,246	3,562	3,831

(GEORGETOWN DRAINAGE)

Year	Water Depth	5-year Return Flood	10-year Return Flood
1990	0<H<50	525	707
	50≤H<100	277	523
	100≤H<200	70	210
	200≤H<300	0	134
	300≤H	0	201
	Total	872	1,775
2010	0<H<50	558	750
	50≤H<100	294	555
	100≤H<200	74	223
	200≤H<300	0	142
	300≤H	0	214
	Total	926	1,884

TABLE F-7 NUMBER OF HOUSES IN FLOOD PRONE AREA AND WATER DEPTH FOR 24 RIVER BASINS

Number & Name of River	Total Area	Number of Houses												Flood Water Level (m)					Ground Elevation (m)
		1990						2010											
		Flood Prone Area	Residential Area			Commercial	Industry	Flood Prone Area	Residential Area			Commercial	Industry	1/5	1/10	1/20	1/50	1/100	
			Town	Village	Sub-Total				Town	Village	Sub-Total								
1 Sg. Pinang																			
2 Sg. Teluk Awak		275	5	70	75	0	0	275	11	149	160	0	0	0.9	1.0	1.1	1.2	1.3	3.2
3 Sg. Teluk Bahang		331	18	308	326	0	0	331	18	308	326	15	0	0.7	0.9	1.0	1.1	1.2	2.1
4 Sg. Batu Ferringghi		29	0	0	0	0	0	29	26	0	26	0	0	0.9	1.0	1.2	1.3	1.4	2.4
5 Sg. Satu		81	0	13	13	0	0	81	0	81	81	0	0	0.2	0.3	0.3	0.4	0.4	2.9
6 Sg. Mas		119	0	100	100	0	0	119	0	100	100	9	0	0.2	0.2	0.3	0.4	0.4	2.3
7 Sg. Kecil		106	13	69	82	3	0	106	16	86	102	0	0	0.6	0.7	0.7	0.8	0.9	1.9
8 Sg. Kerian		350	8	342	350	0	0	350	8	342	350	0	0	0.4	0.5	0.6	0.6	0.7	2.3
9 Sg. Balik Batu		81	67	14	81	0	0	81	67	14	81	14	0	0.7	0.7	0.8	0.9	0.9	1.3
10 Sg. Fettes		125	87	30	117	6	0	125	87	30	117	48	0	0.6	0.7	0.7	0.8	0.8	2.5
11 Sg. Bagan Jermal		52	8	29	37	0	0	52	8	29	37	0	0	0.3	0.4	0.5	6.0	0.7	1.8
12 Sg. Babi		156	15	81	96	0	0	256	15	81	96	0	0	0.5	0.6	0.7	0.7	0.8	2.7
13 Sg. Gelugor																			
13-1		94	94	0	94	0	0	94	94	0	94	0	0	1.3	1.5	1.6	1.7	1.8	1.2
13-2		350	250	0	250	0	0	350	333	0	333	0	0	1.0	1.3	1.5	1.7	1.8	4.2
Sub-total		444	344	0	344	0	0	444	427	0	427	0	0	-	-	-	-	-	-
14 Sg. Dua Besar																			
14-1		163	69	94	163	0	0	144	69	94	163	0	0	1.1	1.2	1.4	1.5	1.6	1.7
14-2		450	0	369	369	0	0	425	0	369	369	0	0	0.8	0.9	1.1	1.2	1.3	2.8
14-3		969	63	171	234	0	0	969	125	339	464	0	0	0.6	0.7	0.7	0.8	0.8	4.1
Sub-total		1582	132	634	766	0	0	1538	194	802	996	0	0	-	-	-	-	-	-
15 Sg. Nibong Besar		519	134	193	327	0	0	519	115	166	281	0	94	1.0	1.2	1.3	1.5	1.6	2.3
16 Sg. Nibong Kecil		-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-
17 Sg. Keluang		-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-
18 Sg. Nipah		938	88	84	172	0	0	938	345	330	676	0	0	0.4	0.5	0.6	0.6	0.7	0.3
19 Sg. Kampumg Masjid		456	0	325	325	0	0	456	0	288	288	43	0	0.5	0.5	5.0	0.6	0.6	1.4
20 Sg. Ikan Mati		169	0	88	88	0	0	169	0	163	163	0	0	0.9	1.0	1.2	1.3	1.4	2.8
21 Sg. Bayan Lepas		694	0	431	431	1	0	694	0	500	500	19	0	1.4	1.5	1.6	1.7	1.8	1.1
22 Sg. Batu		256	0	100	100	0	0	256	0	225	225	0	0	0.8	0.9	0.9	1.0	1.1	1.3
23 Sg. Mati		481	25	250	275	0	0	481	36	356	392	0	0	0.0	0.0	0.1	0.1	0.1	2.1
24 Sg. Teluk Kumbar																			
24-1		769	0	363	363	0	0	769	0	363	363	0	0	1.2	1.3	1.4	1.5	1.5	1.3
24-2		719	0	156	156	0	0	719	0	156	156	0	0	1.1	1.1	1.2	1.2	1.3	2.8
Sub-total		1488	0	519	519	0	0	1488	0	519	519	0	0	-	-	-	-	-	-
25 Sg. Gemuroh		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26 Sg. Gertak Sanggul		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE F-8 FLOOD DAMAGE RATIO (FOR SG. PINANG, SG. KELUANG AND GEORGETOWN)

Water Depth (cm)	Flood Damage Ratios			
	House	Household Articles	Commercial Assets*	Commercial Stocks*
0<H<50	0.004	0.057	0.052	0.127
50≤H<100	0.030	0.096	0.121	0.276
100≤H<200	0.068	0.135	0.161	0.379
200≤H<300	0.112	0.336	0.208	0.479
300≤H	0.170	0.687	0.243	0.562

Remarks; * Figures are the same as those used in "The Study on the Flood Mitigation of the Klang River Basin."

TABLE F-9 ESTIMATION PROCEDURE OF FLOOD DAMAGE POTENTIAL FOR HOUSE AND COMMERCIAL ASSETS (50 YEAR FLOOD)

Water depth (cm)	No. of houses in flood prone area	House value (M$)	Depreciation ratio	Average value of house (M$)	Damage ratio	Flood damage potential (Million M$)
0<H<50	1,522	69,800	0.2	13,960	0.004	0.1
50≤H<100	1,606	69,800	0.2	13,960	0.030	0.7
100≤H<200	12,121	69,800	0.2	13,960	0.068	11.5
200≤H<300	11,138	69,800	0.2	13,960	0.112	17.4
300≤H	7,033	69,800	0.2	13,960	0.170	16.7
Total	33,420					46.4

Water depth (cm)	No. of houses in flood prone area	Share of commercial house	Share of commercial shop	No. of commercial houses in flood prone area	Assets value (M$)	Depreciation ratio	Average aseets value (M$)	Damage ratio	Flood damage potential (Million M$)
0<H<50	1,522	0.21	0.43	137	165,000	0.2	33,000	0.052	0.2
50≤H<100	1,606	0.21	0.43	145	165,000	0.2	33,000	0.121	0.6
100≤H<200	12,121	0.21	0.43	1,094	165,000	0.2	33,000	0.161	5.8
200≤H<300	11,138	0.21	0.43	1,005	165,000	0.2	33,000	0.208	6.9
300≤H	7,033	0.21	0.43	635	165,000	0.2	33,000	0.243	5.1
Total	33,420			3,017					18.6

TABLE F-10 ANNUAL COST OF ROAD RESURFACING BY MPPP, 1985 - 1989

Items		Road Length (yard)	Width (yard)	Road Area (sq. yd)	Unit Cost of Resurfacing (M$/sq.yd)	Total Cost of Resurfacing (1000 M$)
1985	Jn. Jelutong	8622	35	301,770		
	Jn. Patani	2656	26	74,256		
	Jn. Burmah	11901	33	392,733		
	Jn. Macallum	1114	30	33,420		
	Jn. Argyll	2450	34	83,300		
	Total			885,479	7.70	6,818
1986	Jn. Cacalister	9905	37	366,485		
	Tek Soon Street	1779	33	58,707		
	Gurney Drive	8807	44	387,508		
	Total			812,700	7.70	6,258
1987	MacNair Street	3057	36	110,052		
	Chin Ho Square	412	34	14,008		
	Jn. Lim Chwee Leong	2212	42	92,904		
	Jn. Air Itam	10867	37	402,079		
	Total			619,043	7.70	4,767
1988	Jn. Asson	4082	37	151,034		
	Jn. Sato Kramat	5998	44	263,912		
	Jn. Perak	21051	29	610,479		
	Jn. Ross	771	20	15,420		
	Jn. Ria	818	25	20,450		
	Jn. Magazine	1901	48	91,248		
	Jn. Transfer	2313	35	80,955		
	Jn. Bagan Jermal	2772	30	83,160		
	Total			1,316,658	7.70	10,138
1989	Jn. Birch	671	18	12,078		
	Jn. Ibbeston	1104	15	16,560		
	Jn. Jesselton	2983	18	53,694		
	Lebuh Raya Kesselton	871	18	15,678		
	Jn. Burmah	11901	32	380,832		
	Jn. Chowrasta	401	35	14,035		
	Kuala Kangsar Road	999	32	31,968		
	Lebuh King	1600	45	72,000		
	Total			596,845	7.70	4,596
Average Expenditure for Resurfacing of Road				846,145		6,515

Source : MPPP

TABLE F-11 LOSS OF EARNING OPPORTUNITY -- BUS COMPANY

Bus Company	Operation									Revenue	Flood Damage			Average Period of Service Failure	Estimated Reduction of Revenue due to Flood (Habitual Flood)
	No. of Bus Route	Total Length of Bus Route	No. of Bus Fleet	No. of Trips per Day		Operation Days per Year	Operating Hour	Peak Hour	Peak Hour Ratio	Average of Daily Revenue	Revenue Reduction due to Flood (% of Daily Earning)				
				One Bus	Total						Rainy Day	Habitual Flood	1984 Flood		
1 Lim Seng Seng Bus Com.	1	-	10	12	-	365	06:00-22:30	15:00-16:00	-	2300	15%	40%	n.a.	2-3hrs/flood	5,750
2 Hin Bus Com.	1	9	26	-	230	365	05:15-01:00	06:00-08:00 12:00-14:00 17:00-19:30	-	8000	-	10%	more than 20%	-	8,000
3 Sri Negara Bus Com.	-	-	39	8	-	365	05:30-24:00	06:30-10:00 15:30-19:30	60%	3500	5%	30%	100% 1.5 days	-	8,750
4 Penang Yellow Bus Comp.	-	-	-	60	-	365	06:30-24:00	06:30-08:00 12:00-14:30 16:00-18:30	70-75%	8000	-	5%	100% 2-3 days	-	4,000
5 MPPPs	13	107.64	82	-	701	365	-	07:00-09:00 12:00-14:30	60%	11800	-	25%	-	100 hrs/year	29,500
Total	-	-	-	-	-	-	-	16:30-20:00	-	33,600	-	-	-	-	56,000

Source ; Interview Survey, the Study Team, July 1990.

TABLE F-12 LOSS OF INCOME OPPORTUNITY -- TAXI AND TRISHAW

Items		Unit	Habitual Flood	
			Taxi	Trishaw
No. of Vehicles		(vehicles)	524	1,728
Per One Vehicle	Average Daily Earning	(M$/day)	70	30
	Reduction Rate in Earning due to Flood	(%)	15	15
	Reduction in Daily Earning due to Flood	(M$)	10.5	4.5
	No Working Days per Year due to Flood	(days/year)	10	10
	Yearly Loss of Earning due to Flood	(M$/year)	105	45
Loss of Earning Opportunity		(M$/year)	55,020	77,760

Source: Taxi Association of Penang,
Trishaw Association of Penang

TABLE F-13 VEHICLE OPERATING COST BY TRAVEL SPEED, 1990

(unit; cent/vehicle-kilometer)

Travel Speed (kph)	Motor-cycle	Sedan	Bus	Lorry
5	8.7	28.2	140.8	184.4
10	8.2	26.9	112.1	147.1
15	7.6	25.9	88.6	116.2
20	7.0	24.6	73.0	95.7
25	6.7	23.8	62.6	82.1
30	6.3	23.3	54.7	71.8
35	6.1	22.3	50.9	66.7
40	5.9	21.9	48.3	63.4
45	5.9	21.5	45.7	59.9
50	6.1	21.5	43.0	56.4
55	6.1	21.9	41.7	54.7
60	6.2	22.3	43.1	56.5
65	6.3	23.3	44.3	58.1
70	6.6	24.2	45.7	59.9
75	6.9	25.0	46.9	61.5
80	7.2	25.9	48.3	63.4

TABLE F-14 REGISTERED VEHICLE NUMBER IN PENANG STATE, 1985

Item	Motor-cycle	Sedan	Bus	Lorry
Registered Vehicle Number in Penang State 1985	251000	116000	19400	1600
Composition Share (%)	64.7	29.9	5.0	0.4

Source: Feasibility Study of Computerized Area Traffic Control System in Penang, Malaysia, Final Report, Supplementary Volume, January 1988, 1988, JICA, p.3-11.

TABLE F-15 WEIGHTED VEHICLE OPERATING COST

Travel Speed (kph)	Weighted VOC (cent/CPU-km)
10	15.09
40	9.84

TABLE F-16 LOSS IN TRAFFIC ECONOMY

	Name of Road	Length of Road (m)	CPU (1000/day)		Loss in Time Value					Loss in Vehicle Operating Cost (VOC)			
					Runnig Speed (km/h)		Time Value (M$/	Loss in Travel Time (1000 M$/year)		VOC (M$/1000 km)		Loss in VOC (1000 M$)	
			1990	2000	40	10		1990	2000	40 km/h	10 km/h	1990	2000
1	Leboh Carnarvon	200	38.2	46.7	40	10	0.57	3.3	4.0	9.84	15.09	0.4	0.5
2	Transfer Road	600	18.8	20.4	40	10	0.57	4.8	5.2	9.84	15.09	0.6	0.6
3	Burma	210	30.4	32.3	40	10	0.57	2.7	2.9	9.84	15.09	0.3	0.4
4	Jn. Zainal Abidin	270	17.3	22.6	40	10	0.57	2.0	2.6	9.84	15.09	0.2	0.3
5	Jn. Macalister 1	420	30.4	30.2	40	10	0.57	5.5	5.4	9.84	15.09	0.7	0.7
6	2	280	22.2	44.9	40	10	0.57	2.7	5.4	9.84	15.09	0.3	0.7
7	Jn. Anson 1	260	30.5	44.1	40	10	0.57	3.4	4.9	9.84	15.09	0.4	0.6
8	2	260	30.8	39.7	40	10	0.57	3.4	4.4	9.84	15.09	0.4	0.5
9	Jn. C. Y. Choy	730	38.0	53.5	40	10	0.57	11.9	16.7	9.84	15.09	1.5	2.1
10	Brick Kiln Road	700	18.9	28.0	40	10	0.57	5.7	8.4	9.84	15.09	0.7	1.0
11	Jn. Dato Keramat 1	590	53.6	75.2	40	10	0.57	13.5	19.0	9.84	15.09	1.7	2.3
12	2	750	42.7	52.3	40	10	0.57	13.7	16.8	9.84	15.09	1.7	2.1
13	Jn. Ayer Itam 1	610	46.9	85.0	40	10	0.57	12.2	22.2	9.84	15.09	1.5	2.7
14	2	380	46.9	85.0	40	10	0.57	7.6	13.8	9.84	15.09	0.9	1.7
15	3	720	41.1	67.9	40	10	0.57	12.7	20.9	9.84	15.09	1.6	2.6
16	4	350	52.4	79.5	40	10	0.57	7.8	11.9	9.84	15.09	1.0	1.5
17	Jn. Ross	580	11.0	22.6	40	10	0.57	2.7	5.6	9.84	15.09	0.3	0.7
18	Jn. Perak 1	550	38.7	67.8	40	10	0.57	9.1	15.9	9.84	15.09	1.1	2.0
19	2	230	31.9	50.5	40	10	0.57	3.1	5.0	9.84	15.09	0.4	0.6
20	Jn. Sungai Pinang 1	700	11.9	23.9	40	10	0.57	3.6	7.2	9.84	15.09	0.4	0.9
21	2	500	17.5	33.2	40	10	0.57	3.7	7.1	9.84	15.09	0.5	0.9
22	Jn. Patani	850	16.9	25.0	40	10	0.57	6.1	9.1	9.84	15.09	0.8	1.1
23	Jn. Jelutong	470	46.0	82.6	40	10	0.57	9.2	16.6	9.84	15.09	1.1	2.0
24	Jn. Free School 1	690	17.1	41.3	40	10	0.57	5.0	12.2	9.84	15.09	0.6	1.5
25	2	570	18.7	30.6	40	10	0.57	4.6	7.5	9.84	15.09	0.6	0.9
26	Jn. Trengganu	960	17.6	23.0	40	10	0.57	7.2	9.4	9.84	15.09	0.9	1.2
27	Jn. Hamilton	620	19.3	31.7	40	10	0.57	5.1	8.4	9.84	15.09	0.6	1.0
28	Lorong	440	15.5	19.8	40	10	0.57	2.9	3.7	9.84	15.09	0.4	0.5
29	Jasjid Negeri	400	57.7	86.7	40	10	0.57	9.9	14.8	9.84	15.09	1.2	1.8
30	Jn. Scottland 1	320	58.5	71.8	40	10	0.57	8.0	9.8	9.84	15.09	1.0	1.2
	2	330	57.1	64.3	40	10	0.57	8.1	9.1	9.84	15.09	1.0	1.1
	Total	-	-	-	-	-	-	201.2	305.8	-	-	24.7	37.6

Note ; (1) Flooded day is set to be 10 days/year.
(2) Average running speed of the vehicles is set to be 40 km/h at non-flood day, while 20 km/h at flood days.

TABLE F-17 SUMMARY OF DIRECT DAMAGE AND INDIRECT FLOOD DAMAGE

(unit : M$)

NO.	Items	Habitual Flood	1984 Flood	Authority Related
1	Flood Damage of Road	0	0	JKR, MPPP
2	Deterioration of Road Structure	3,722,000	3,722,000	MPPP
3	Flood Damage of Bridge	0	0	JKR
4	Flood Damage of Electric Facilities	0	-	LLN
5	Revenue Loss of Electricity	0	0	LLN
6	Flood Damage of Gov. Buildings' Facilitie	0	0	MPPP
7	Flood Damage of School Facilities	0	0	MPPP
8	Flood Damage of Hospital Facilities	0	0	MPPP
9	Revenue Loss of Bus Service	56,000	-	Bus Companies
10	Revenue Loss of Taxi	55,020	-	Taxi Association
11	Revenue Loss of Trishaw	77,760	-	Trishaw Association
12	Traffic Loss (Time Loss)	201,000	-	MPPP
13	Traffic Loss (VOC Loss)	24,000	-	
14	Sales Loss of Shop	0	0	Interview Survey
15	Sales/Production Loss of Factory	0	0	PDC

TABLE F-18-1 FLOOD DAMAGE POTENTIAL BY DAMAGE ITEM AND FLOOD FREQUENCY (SG. PINANG)

(unit: million M$ in 1990 Prices)

Damage Item	1990						2010					
	1/1.1	1/5	1/10	1/30	1/50	1/100	1/1.1	1/5	1/10	1/30	1/50	1/100
A. General Property												
(1) Houses	0.4	1.2	11.6	33.0	47.9	63.9	0.4	1.3	11.9	38.2	55.2	73.9
(2) Household Articles	0.6	1.8	8.9	27.3	45.7	69.2	0.6	1.9	9.3	31.4	51.9	78.7
(3) Commercial Assets	0.4	1.3	7.2	15.3	19.2	22.7	0.4	1.3	13.2	18.0	22.6	26.6
(4) Commercial Stocks	0.6	2.0	10.6	22.4	28.2	33.2	0.7	2.1	11.1	26.3	33.1	39.0
Sub-total	2.1	6.2	38.2	98.0	141.1	189.1	2.2	6.6	45.5	113.8	163.0	218.3
B. Public Property												
(1) Road	3.8	11.6	50.6	89.7	105.3	113.2	3.8	11.6	50.6	89.7	105.3	113.2
(2) Bridge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(3) Electricity Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(4) Telecomm. Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(5) School,Hospital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(6) Gov. Building Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	3.8	11.6	50.6	89.7	105.3	113.2	3.8	11.6	50.6	89.7	105.3	113.2
C. Agricultural Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D. Income/Sale Loss												
(1) Shop Revenue	0.0	0.1	0.5	0.9	1.1	1.2	0.1	0.2	0.8	1.4	1.7	1.8
(2) Factory Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(3) Bus Services	0.1	0.2	0.7	1.3	1.5	1.7	0.1	0.2	1.1	2.0	2.4	2.6
(4) Taxi Services	0.1	0.2	0.7	1.3	1.5	1.7	0.1	0.2	1.1	2.0	2.3	2.5
(5) Trishaw Services	0.1	0.2	1.0	1.9	2.2	2.4	0.1	0.3	1.5	2.8	3.3	3.5
Sub-total	0.2	0.7	3.1	5.5	6.5	6.9	0.3	1.0	4.6	8.2	9.6	10.3
E. Vehicle's Running Cost												
(1) Operating Cost	0.0	0.1	0.3	0.6	0.7	0.7	0.0	0.1	0.5	0.9	1.0	1.1
(2) Time Cost	0.2	0.6	2.7	4.9	5.7	6.1	0.3	0.9	4.1	7.3	8.7	9.3
Sub-total	0.2	0.7	3.1	5.5	6.4	6.9	0.3	1.0	4.6	8.3	9.7	10.4
Grand Total	6.4	19.1	94.9	198.7	259.1	316.1	6.7	20.2	105.4	219.9	287.4	352.2

Remarks; Flood damage potentials of 'General Property' for 1.1-year return flood are estimated based on flood prone area in proportion with that for 5-year return flood.

TABLE F-18-2 FLOOD DAMAGE POTENTIAL BY DAMAGE ITEM AND FLOOD FREQUENCY (SG. KELUANG)

(unit: million M$ in 1990 Prices)

Damage Item	1990						2010					
	1/1.1	1/5	1/10	1/30	1/50	1/100	1/1.1	1/5	1/10	1/30	1/50	1/100
A. General Property												
(1) Houses	0.0	0.0	0.1	0.3	1.4	2.2	1.0	3.1	5.1	7.0	11.8	13.1
(2) Household Articles	0.1	0.2	0.5	0.8	2.2	3.3	2.6	7.7	12.7	17.6	29.4	32.1
(3) Commercial Assets	0.0	0.1	0.2	0.4	1.0	1.3	0.4	1.1	3.8	2.6	4.7	5.4
(4) Commercial Stocks	0.0	0.1	0.2	0.3	0.8	1.0	0.3	0.9	1.4	2.2	3.9	4.3
Sub-total	0.1	0.4	0.9	1.9	5.6	7.8	4.3	12.9	23.0	29.4	49.8	55.0
B. Public Property												
(1) Road	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	4.4	7.7	9.1	9.8
(2) Bridge	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(3) Electricity Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(4) Telecomm. Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(5) School,Hospital	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(6) Gov. Building Facility	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.0	4.4	7.7	9.1	9.8
C. Agricultural Products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D. Income/Sale Loss												
(1) Shop Revenue	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2) Factory Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(3) Bus Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(4) Taxi Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(5) Trishaw Services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. Vehicle's Running Cost												
(1) Operating Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
(2) Time Cost	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grand Total	0.1	0.4	0.9	1.9	5.6	7.8	4.7	13.9	27.4	37.2	58.9	64.8

Remarks; Flood damage potentials of 'General Property' for 1.1-year return flood are estimated based on flood prone area in proportion with that for 5-year return flood.

TABLE F-18-3 FLOOD DAMAGE POTENTIAL BY DAMAGE ITEM AND FLOOD FREQUENCY
(GEORGETOWN DRAINAGE)

(unit: sillion M$ in 1990 Prices)

Damage Item	1990			2010		
	1/1.1	1/5	1/10	1/1.1	1/5	1/10
A. General Property						
(1) Houses	0.1	0.4	2.4	0.1	0.4	2.5
(2) Household Articles	0.2	0.6	2.7	0.2	0.6	2.8
(3) Commercial Assets	0.1	0.4	1.3	0.2	0.5	1.0
(4) Commercial Stocks	0.2	0.6	1.9	0.2	0.7	2.1
Sub-total	0.7	2.2	8.3	0.7	2.3	8.4
B. Public Property						
(1) Road	0.4	1.1	5.1	0.4	1.1	5.1
(2) Bridge	0.0	0.0	0.0	0.0	0.0	0.0
(3) Electricity Facility	0.0	0.0	0.0	0.0	0.0	0.0
(4) Telecomm. Facility	0.0	0.0	0.0	0.0	0.0	0.0
(5) School.Hospital	0.0	0.0	0.0	0.0	0.0	0.0
(6) Gov. Building Facility	0.0	0.0	0.0	0.0	0.0	0.0
Sub-total	0.4	1.1	5.1	0.4	1.1	5.1
C. Agricultural Products	0.0	0.0	0.0	0.0	0.0	0.0
D. Income/Sale Loss						
(1) Shop Revenue	0.0	0.0	0.2	0.0	0.1	0.3
(2) Factory Production	0.0	0.0	0.0	0.0	0.0	0.0
(3) Bus Services	0.1	0.2	0.7	0.1	0.2	1.1
(4) Taxi Services	0.1	0.2	0.7	0.1	0.2	1.1
(5) Trishaw Services	0.1	0.2	1.0	0.1	0.3	1.5
Sub-total	0.2	0.6	2.8	0.3	0.9	4.1
E. Vehicle's Running Cost						
(1) Operating Cost	0.0	0.1	0.3	0.0	0.1	0.5
(2) Time Cost	0.2	0.6	2.7	0.3	0.9	4.1
Sub-total	0.2	0.7	3.1	0.3	1.0	4.6
Grand Total	1.5	4.6	19.1	1.8	5.4	22.2

Remarks; Flood damage potentials of 'General Property' for 1.1-year return flood are estimated based on flood prone area in proportion with that for 5-year return flood.

TABLE F-19 FLOOD DAMAGE POTENTIAL BY FLOOD FREQUENCY

(Sg. Pinang)
(unit: million M$ in 1990 Prices)

Year	1.1-year Return Flood	5-year Return Flood	10-year Return Flood	30-year Return Flood	50-year Return Flood	Annual Average Flood Damage Potential
1990	6.4	19.1	94.9	198.7	259.1	27.6
2010	6.7	20.2	105.4	219.9	287.4	30.1

((Sg. Keluang)
(unit; million M$ in 1990 Prices)

Year	1.1-year Return Flood	5-year Return Flood	10-year Return Flood	30-year Return Flood	50-year Return Flood	Annual Average Flood Damage Potential
1990	0.1	0.4	0.9	1.9	5.6	0.4
2010	4.7	13.9	27.4	37.2	58.9	11.4

(Georgetown Drainage)
(unit; million M$ in 1990 Prices)

Year	1.1-year Return Flood	5-year Return Flood	10-year Return Flood	Annual Average Flood Damage Potential
1990	1.5	4.6	19.1	3.4
2010	1.8	5.4	22.2	3.9

TABLE F-20 RESULT OF INTERVIEW SURVEY--CAUSE OF FLOOD BY ZONE

Zone	High Tidal Level	Narrow River	Low Clearance of Bridge	Floating Debris	High Water Level of River Causes Reverse Flow of Drainage	Floating Debris	High Tidal Level	Narrow River	Low Clearance of Bridge	Floating Debris	High Water Level of River Causes Reverse Flow of Drainage
	1-A	1-B	1-C	1-D	2-A	2-B	3-A	3-B	3-C	3-D	3-E
1-1	18	36	4	26	3	8	2	0	1	4	2
1-2	13	9	0	10	4	2	0	3	1	3	3
1-3	17	23	1	18	20	9	4	10	2	6	9
1-4	30	35	2	7	9	4	3	6	0	8	2
1-5	9	32	0	22	42	26	4	20	0	15	8
1-6	19	18	0	6	19	14	4	5	1	6	2
1-7	43	36	5	36	3	2	11	11	4	10	8
1-8	19	20	1	5	29	25	21	23	0	13	19
1-9	47	32	1	34	57	53	29	23	0	31	24
1-10	10	19	2	14	56	45	3	8	1	4	2
TOTAL	223	258	16	176	242	188	81	108	10	99	79

Figures

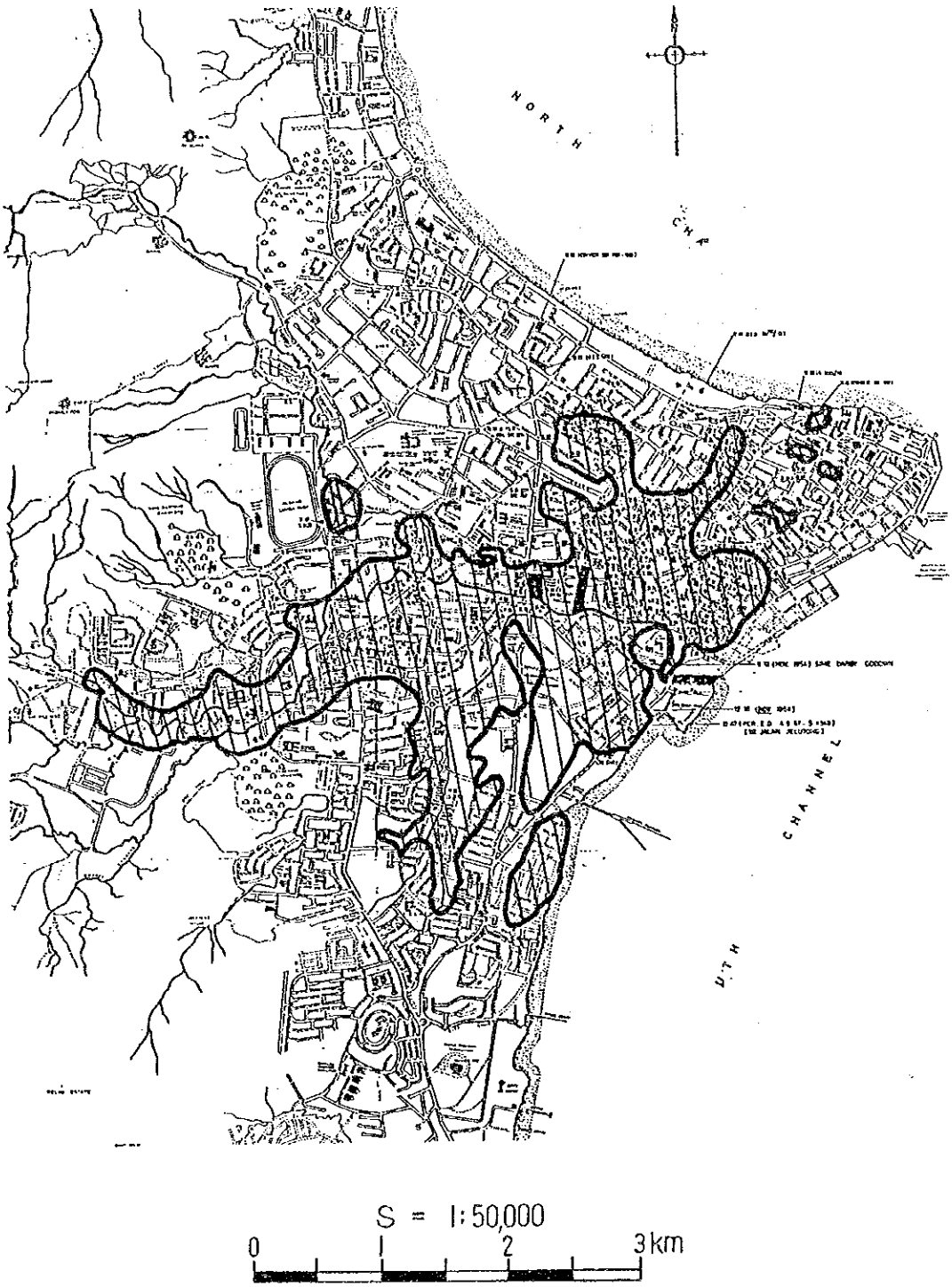
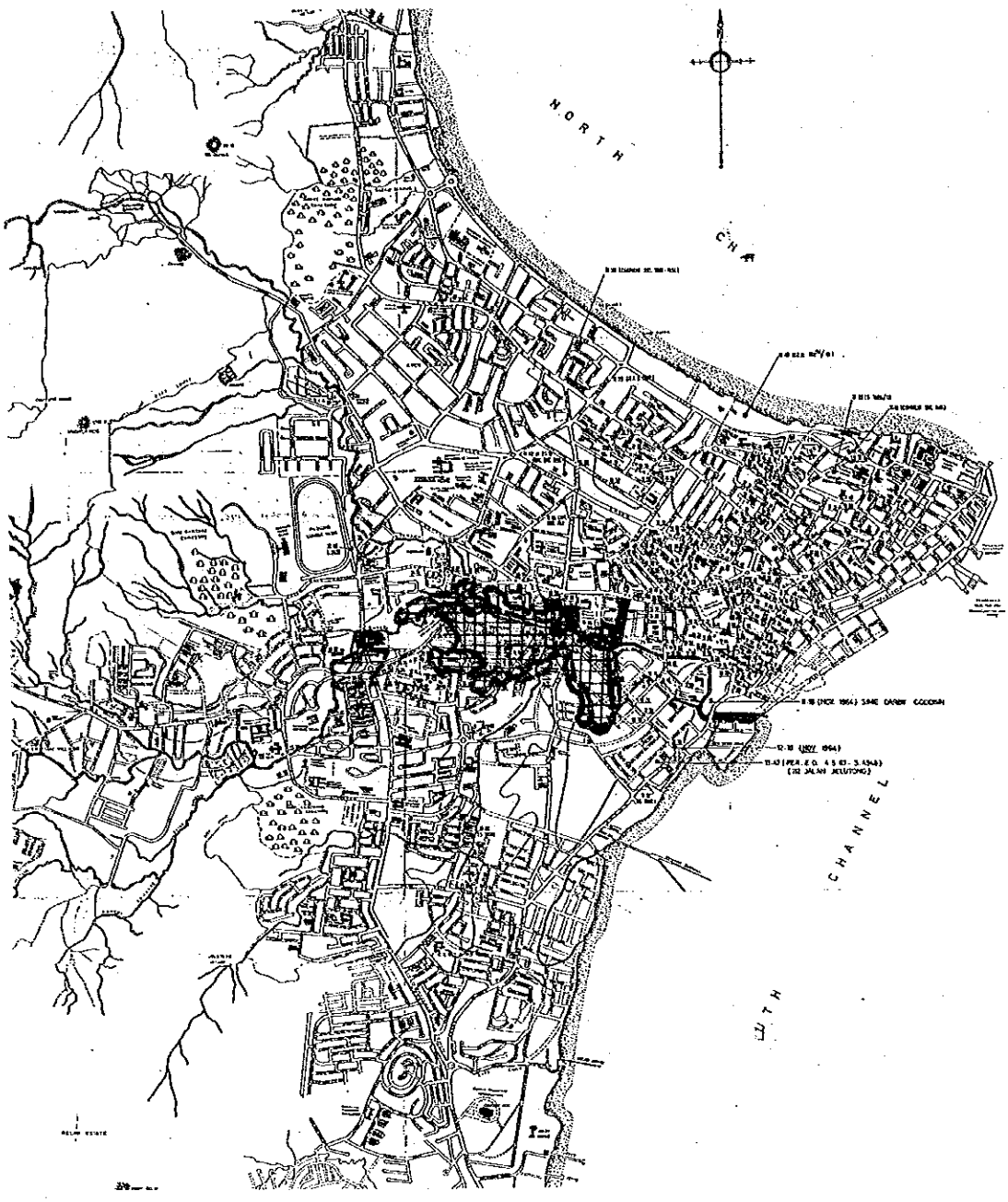


FIG. F-1	EXPERIENCED FLOOD AREAS IN THE CITY OF GEORGETOWN

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



S = 1 : 50,000

0 1 2 3km

LEGEND	
	Apr. 19, 1984 Flood
	Sep. 20, 1986 Flood

FIG. F-2 FLOOD AREAS IN GEORGETOWN IN 1984 AND 1986

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

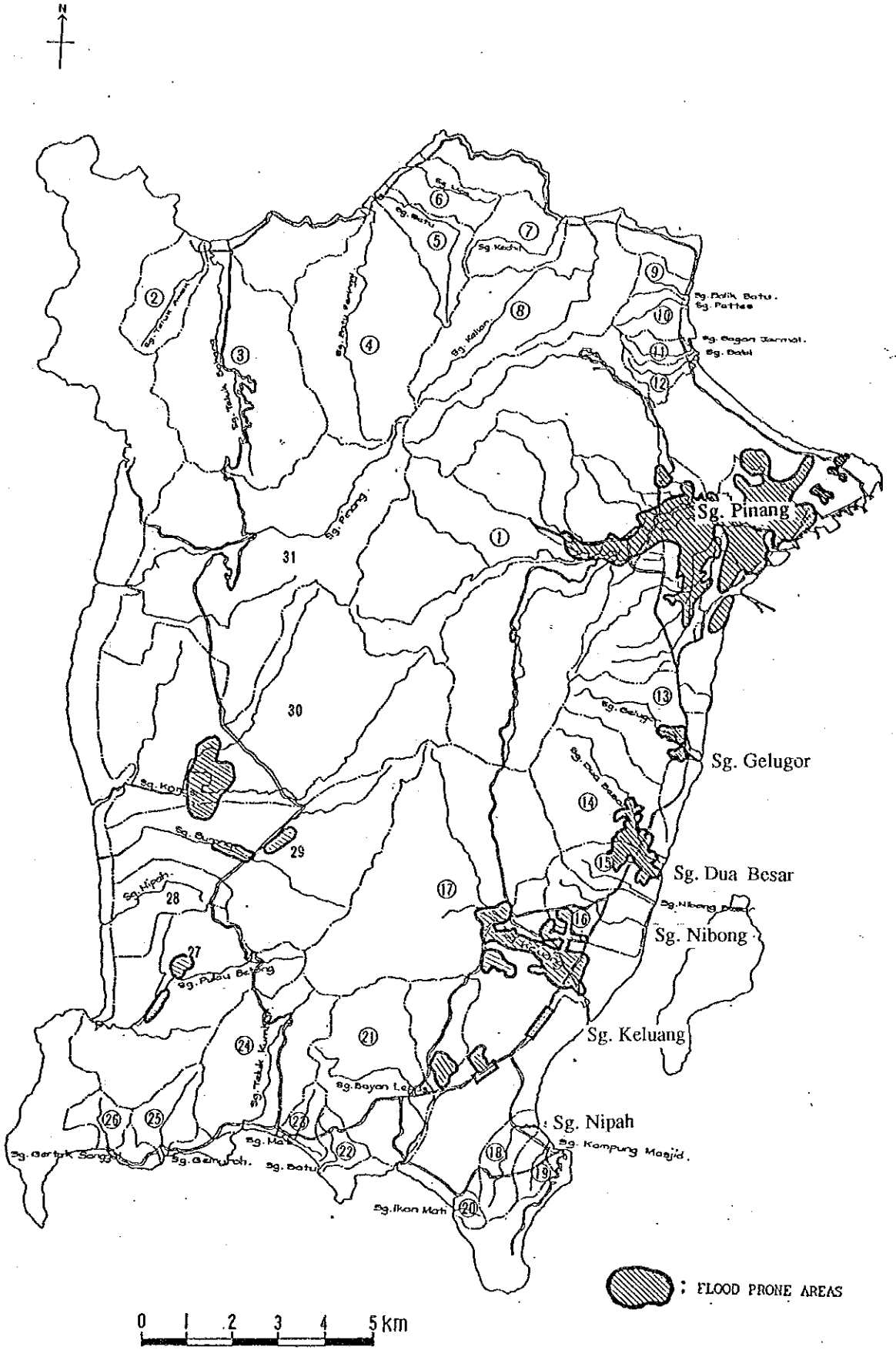


FIG. F-3	FLOOD PRONE AREAS IN WHOLE PENANG ISLAND

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

(APPENDIX 1 : INTERVIEW SHEET-1)

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN THE PENANG ISLAND

Subject: Flood/Inundation Damage in the Penang Island

Date; Sep.,1989

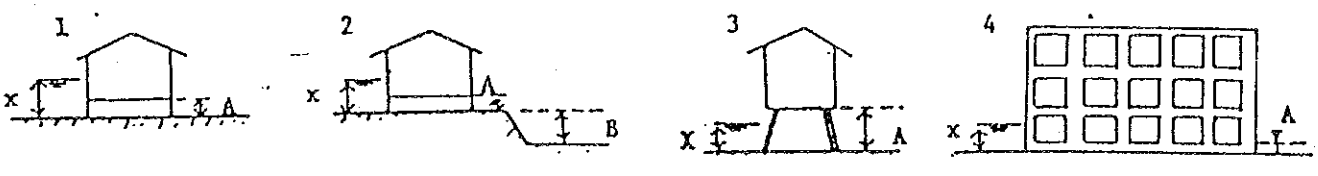
Executive Agency: **JICA STUDY TEAM** in cooperation with **SDID, Penang**

Area Code ; _____

Name and Reg.No of Interviewer ; _____

Interviewee's Address and Signature: _____

		Annual Flood	Severest Flood
A. Water Depth			
A-1	Is your house inundated annually? And is submurged in the severest flood year?	Yes, No	Yes, No
A-2	Check the items below;		
	H. Type of house/building	1, 2, 3, 4	-
	A. Height of the Floor from the ground	A. cm	A. cm
	B. Height of the elevated ground	B. cm	B. cm
	X. Maximum water depth	X. cm	X. cm
	(Calculate!)	X-A cm	X-A cm
A-3	Duration (on the floor)	hours days	hours days
A-4	How many times is your house inundated annually?	times /year	-



A-5-1 What do you think causes the flood/inundation so severer, or makes the flood/inundation occur so frequently? Please encircle only one alternative appropriate.

1. Caused by overflow of river
2. Caused by overflow of drainage
3. Caused by overflow both of 1. and 2.
4. Others (specify _____)

1, 2, 3, 4

A-5-2 If interviewee has clear idea about the questions below, identify the appropriate cause?

- If 1 in A-5 is selected, what is its cause?
  - 1-a high tidal level (which prevents river water from flowing into the sea)
  - 1-b river is too narrow
  - 1-c bridge prevents the water flow into the sea smoothly
  - 1-d so many floating debris

1-a, 1-b, 1-c, 1-d

- If 2 in A-5 is selected, what is its cause?
  - 2-a high level of river causes the reverse flow of the drainage channel
  - 2-b so many floating debris

2-a, 2-b

- If 3 in A-5 is selected, what is its cause?
  - 3-a high tidal level which prevents river water from flowing into the sea
  - 3-b river is too narrow
  - 3-c bridge is the obstacle to let the water flow smoothly
  - 3-d so many floating debris
  - 3-e high level of river causes the reverse flow of the drainage channel

3-a, 3-b, 3-c, 3-d, 3-e

B. House & Value

B-1	How wide is the area concerned?	Housing/ground floor (excluding garden)
B-2	What is main material of your house's walls?	
B-3-1	How many years ago was this house constructed?	
B-3-2	Can you remember how much was the constructin cost of this house? (or) If you re-construct this house now, how much does it cost (at present)?	
B-3-3	Can you estimate the present value of this house at present?	

( ) M.x( ) M =( ) sq M.
1. Wood 2. Brick/Cement/Stone
years ago
(original cost) M$ (or) M$
M$

C. Assets Value and Flood/Inundation Damage

C-1 Please estimate present value of the property in this house? (How much does it cost?) Was any item below damaged by flood/inundation? If so, please check the damaged items and estimate their damage value;

	Value	Flood Damage	
	Whole Property Value	Annual Flood	Severest Flood
Furniture (Desk, table,sofa,chair, word robe, buffet, carpet etc.)	M$	M$	M$
Clothes, dresses	M$	M$	M$
Kitchen commodities	M$	M$	M$
Electric equipments (TV, Video, Radio, Washing Machine, Refrigirator etc.)	M$	M$	M$
Car, Motorcycle Bycicle	M$	M$	M$
Others	M$	M$	M$
Total (calculate!)	M$	M$	M$

C-1-b House

Which actions was required for your house maintenance, repair or new construction?

How much did it cost?

Annual Flood	Severest Flood
Nothing Repair New const.	Nothing Repair New const.
M$	M$

D. Wage Lost

D1: How many families and persons are living in this house?

D2: How many members of your family are getting incomes?

D3: How much is their income per month or per day (household income)?

D4: How many days do you work per month?

D5: How many days couldn't you work due to flood or inundation?

D-6: How much was your income reduced owing to flood/inundation?

D1		D2	D3		D4	D5		D6	
No of Family	Persons	Persons	Average Income per Month	Average Income per Day	Total Working Days per Month /inundation	Total days which you cannot work due to flood		Income Loss due to flood /inundation	
	persons	Persons	M$/m	M$/d	day::/m	days/year		M$/year	
						Annually	Severest Flood	Annually	Severest Flood
1	1 8	1 8							
2	2 9	2 9							
3	3 10	3 10							
4	4 11	4 11							
5	5 12	5 12							
6	6 13	6 13							
7	7more	7more							
Total	—	—	—	—	—	—			

E. Policy Preference

Question:
I will refer two policy alternatives. Question is, "Which of the two policies you think the Government should give the higher priority?"

Recording Sample:
In case of comparison between (A1) and (B2),
if (A1) is given priority, write "A" in the cell, and
if (B2) is given priority, write "B" in the cell.

policy	B-1 Housing Develop-ment	B-2 Drainage System Improve-ment (no flood)	B-3 Public Transport Improve-ment (more bus) (and taxi) (services)	B-4 River/Sea Water Purifi-cation	B-5 Road Network & Traffic Improve-ment (no traffic) (jam)	B-6 Sewage System Improve-ment
A1 Housing Development						
A2 Drainage System (no flood)	—					
A3 Public Transport System (more bus services)	—	—				
A4 River/Sea Water Purifi-cation	—	—	—			
A5 Road Network & Traffic Improvement (no traffic jam)	—	—	—	—		
A6 Sewage System Improvement	—	—	—	—	—	

[APENDIX 2; INTERVIEW SHEET-2]

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN THE PENANG ISLAND

Subject: Flood/Inundation Damage in the Penang Island

Date: 13 ~~Aug.~~ Sep., 1989

Executive Agency: **JICA STUDY TEAM** in cooperation with **SDID**, Penang

Jalan Name: Kampung Jawa Baru

Name and Reg. No of Interviewer: AZHAR (16)

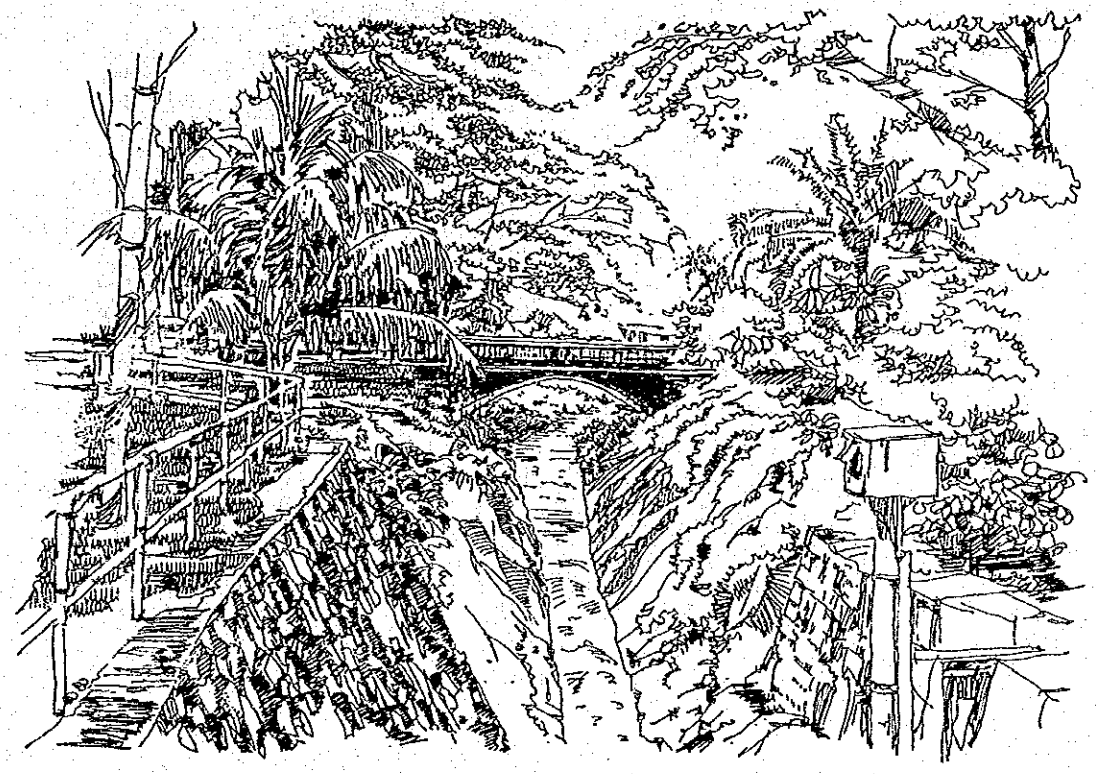
Shop/factory address & name Jaya Store, 170 Jalan Kampung Jawa Baru

A. Water Depth

		annual flood	severest year
A-1	Was your shop/factory submerged in the severest flood? If so, check the items below;		
A-1-1	Maximum water depth	cm	cm
A-1-2	Duration day/hours	4 (hour) days	4 (hour) days
A-1-3	How many times is your shop/factory inundated annually?	4 times	5 times
A-2-1	Did the flood/inundation affect the commuting of employees? If so, how many minutes of extra commuting time was required?	70 cm	70 cm
A-2-2	Did the flood/inundation affect the supply of the materials/products? If so, how large is the loss? (time, sales)	0 M$	0 M$
A-2-3	Was the operation time shortened? If so, how many hours was it?	0 hrs	0 hrs
A-2-4	Was the shop/factory closed because of the flood/inundation? If so, how many days per year?	0 hrs days	1 hrs (days)
B. Total Assets			
B-1	Total value of facilities of your shop/factory? (excluding the building)	4000 M$	4000 M$
B-2	Total value of constant stock in the shop/factory?	6000 M$	6000 M$
B-3	Is there any part of this shop/factory damaged by the flood/inundation? If so, how much is the damage?	0 M$	4000 M$
B-4	Total sales/production value per year?	24000 M$	24000 M$

APPENDIX G

METEO-HYDROLOGICAL CONDITIONS AND FLOOD RUN-OFF ANALYSIS



APPENDIX G METEO-HYDROLOGICAL CONDITIONS AND FLOOD RUN-OFF ANALYSIS

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APPENDIX G METEO-HYDROLOGICAL CONDITIONS AND FLOOD RUN-OFF ANALYSIS

1. INTRODUCTION

The objectives of the hydrological study is to grasp the hydrological characteristics of the 26 river basins (Fig.G-1), to provide useful information necessary for the formulation of the flood mitigation and drainage plan. The hydrological study includes the following activities:

- Collection of existing hydrological data
- Installation of 3 water level gauging stations
- Assessment of the rainfall and run-off characteristics
- Hydrological analysis for an estimation of probable rainfall
- Flood run-off analysis using the mathematical model
- Hydraulic analysis of flooding area
- Hydrological and hydraulic evaluation for flood mitigation works and drainage works.

The catchment areas of the rivers in the study area and sub catchment areas of Sg. Pinang basin are shown in Table G-1 and Fig. G-1.

2. METEO-HYDROLOGICAL DATA

2.1 Meteorological Data

Meteorological data in Penang Island are recorded by *Drainage and Irrigation Department, Penang Water Authority and* Malaysian Meteorological Service.

Table G-2 shows monthly meteorological data in Penang Island.

There exist seven rainfall gauging stations in the Island as shown in the Table G-3, G-4 and Fig. G-2.

Most of these rain gauges are automatic rain gauges. These stations are densely distributed in the Island. Hourly rainfall observation at Kajicuaca Bayan Lepas were commenced in 1934.

Daily and hourly data are compiled and stored in the Data Bank of D.I.D. For discussion of storm pattern, hourly rainfall data exceeding 100 mm of daily depth were collected. They are listed in Table G-5.

2.2 Water level And Discharge

The 4 gauging stations of D.I.D, installed before 1982 are listed in Table G-6. At present, for this study 3 gauging

stations as shown in Fig. G-3 were set up in the Sg.Pinang at Jalan Perak, Sg.Air Itam at Jalan Scotland, and Sg. Air Terjun at Brook Road. Rating-Curve at each station was compiled for run-off analysis.

2.3 Tidal Data

The tide water level fluctuation is recorded at Kedah Pier by Port Authority since 1985.

In addition, 4 tide poles were set up to check the tidal fluctuation along Penang Island for this Study. Fig. G-4 shows location and site pictures.

3. METEO-HYDROLOGICAL CONDITION

3.1 Climate

Penang has an equatorial climate which is quite uniform throughout the year. The climate is warm and humid. The maximum average temperature is 23.2°C. There are no recognizable hot or cold seasons and the mean annual rainfall of approximately 2600mm is unevenly distributed throughout the year. Table G-7 and Fig. G-5 shows the monthly rainfall distribution at seven gauging stations. September to November may be considered as the wettest months with heavy showers.

Fig. G-6 shows mean annual rainfall isohyets in Penang Island.

3.2 Rainfall

A storm rainfall study over Peninsular Malaysia has been published by D.I.D in 1982. The study was based on relatively short term data of 104 rainfall gauges. The rainfall-depth-duration relation was derived by applying the Gumbell distribution, and the conversion factor from point rainfall to a real average rainfall was given based on U.S.Weather Bureau recommendations. Probable rainfall at Taliair Besar in Sg. Pinang (Stn.5302001) was listed in Table G-8.

3.3 Storm Pattern

Temporal distribution of annual maximum rainstorms in Peninsular Malaysia has been estimated for selected durations, namely 1/2,3,6,12,24 and 72 hours, in Hydrological Procedure 1 (Revised and Updated in 1982) based on the data from July 1970 to June 1979. Temporal rainfall distribution in West Coast Region are illustrated in Fig. G-7. As can be seen from the Figure;

i) 75 percent of 6 hours depth is concentrated in 2 hours,

ii) 70 percent of 24 hours depth is concentrated in 6 hours,

iii) 50 percent of 72 hours depth is concentrated in 24 hours.

3.4 Rainfall Intensity

Rainfall intensity curves for Penang Island were estimated by D.I.D and M.P.P.P as shown in Fig.G-8. Intensity curve by

D.I.D was based on records during 1951- 1983 at Kajicuaca Bayan Lepas. The curve by M.P.P.P was adjusted by Kajicuaca Bayan Lepas and Butterworth values.

3.5 Floods

Experienced floods in the Island from 1963 to 1985 are summarized below.

Date	Flooding Area
1964	Built-up Lowlying Area in Georgetown
1974	Air Terjun
1976	Lowlying Area in Georgetown
1977	Lowlying Area in Georgetown
1978	Local Lowlying Area in Penang Island
1979	Lowlying Area in Georgetown
1980	Georgetown
1984	Built-up Lowlying Area along the Sg.Pinang. Lowlying Area of the Sg.Gelugor, Sg.Dua Besar, Sg.Nibong Kecil, Sg.Relau, Sg. Ara and Sg.Tiram
1985	Built-up Lowlying Area along the Sg.Pinang

Features of flooding in the Island are ;

(1) Flooding occurs frequently during the heavy rainfall of flash storms coming with high tides.

(2) Flooding occurs along the lowlying and built-up areas during spring high tide affecting.

3.6 Flood Hydrograph

Flood hydrographs are available for Sg.Pinang at Jalan Perak/Jalan Sg.Pinang and Paras Air Pasang for the days listed below;

5th June, 1987

25th October, 1987

13th - 15th September, 1987

2nd December, 1987

3.7 Tidal Water level

Data on tide level of Penang Island are available in "Record Cerapan Air Pasang Surut 1985" which was published by Director General of Survey and Mapping, Dept. of Survey and Mapping. The data were observed at Kedah Pier in Penang Island.

The tide level data obtained from this record is given below.

		RL
EHW		+1.615
MHWS	+2.5 A.C.D	+1.08
NHWN	+1.8 A.C.D	+0.38
MSL	+1.6 A.C.D	+0.18

MLWN	+1.3 A.C.D	-0.12
MLWS	+0.6 A.C.D	-0.82
LAT	+0.2 A.C.D	-1.22

R.L : Reduced Level
A.C.D : Admiralty Chart Datum

Mostly these values have been used by DID for hydraulic analysis of the river.

In addition, 4 tide poles were set up to check the tidal fluctuation along Penang Island for this Study. A slight difference (about 10 cm) in tide level was observed between the two points in the northern and southern part of the Island.

While, the tide level is also recorded at Kedah pier by Port Authority for three years since 1985. MHWS of this station is +1.095 (R.L.) and EHW is +1.615 (R.L.).

4. HYDROLOGICAL ANALYSIS

4.1 Flood Run-off Analysis

4.1.1 General Procedure

In order to calculate the flood discharges and design flood discharge of the objective rivers for flood control, run-off analysis was conducted based on the rainfall data with proposed safety factor. The results of this analysis are the most fundamental information for formulating the flood mitigation plan.

For establishing the above objectives, the following study on flood run-off analysis is needed so as to simulate flood hydrograph at major sites in the basin;

- Modelling of the river basin and channel,
- Construction of a river system model in which the existing dams and proposed flood mitigation works are linked,
- Rainfall analysis for determining the design rainfall duration, rainfall amount and pattern,
- Run-off calculation for the present river condition and with proposed flood control works using results of rainfall analysis, and
- Prediction of inundated area and depth in the target year.

In the flood run-off analysis for the 25 rivers in the Island, following methods were used.

As for the Sg. Pinang and Sg. Keluang, storage function method was adopted. This is because their catchment areas are large and retention ponds are considered for flood control.

As for the other rivers, rational formula method was adopted. This is because their catchment areas are small and flood inflow time is short.

In addition to this, inundation analysis to calculate the inundation area and depth was conducted for the Sg. Pinang and Sg. Keluang.

Fig. G-9 shows the general procedures of flood run-off analysis.

4.1.2 Simulation Model

As mentioned earlier, it is required to calculate the flood hydrograph in order to evaluate the effects for flood mitigation works.

1) Storage Function Method (For Sg. Pinang and Sg. Keluang)

In this Study, the Storage Function Method proposed by Dr. Kimura was applied for the conversion of areal rainfall to flood hydrograph.

(1) Basic Equation

$$S_1 = K*Q_1^P$$

where, K, P : Constants for a basin or a channel

This equation of motion is combined with the following continuous equation for a river basin or a river channel.

a) For Basin

$$ds/dt=1/3.6 * f * r_{ave} * A - Q_1$$

where,
- f : Inflow coefficient
- Rave : Average rainfall in the basin (mm/hr)
- A : Catchment area at the calculated point (km^2)
- T_1 : lag time (hr)
- $Q_1(t) = q(t+T_1)$ (m^3/sec)

constants K, P and lag-time in the equation are initially estimated by means of the following empirical formulas which are described by average river bed slope in sub-basin. These are then calibrated using the flood records.

$$K = 118.84 \cdot i^{0.3}$$

$$P = 0.175 \cdot i^{-0.235}$$

where, i : Average river bed slope

In the study, lag-time in sub-basin is roughly estimated by following empirical formula.

$$T_1 = 0.047 * L = 0.56 \qquad (L>11.9 \text{ km})$$

$$T_1 = 0 \qquad (L<11.9 \text{ km})$$

where, T_1 : Basin lag-time (hour)
L : River length (km)

b) For River Channel

$$\sum_{j=1}^{n} fjIj - Q_1 = d/dtS_1$$

where, Ij : Inflow discharge into the basin, tributaries and/or upper boundary of the channel (m^3)
fj : Inflow coefficient
T_1 : L Lag time (hr)

$Q_1(t) = Q(t + T_1)$ (m^3/sec)

Discharge at lower boundary of channel after lag time

S_1 : Apparent storage in channel

(2) Basin Division and River System Model

a) Sg. Pinang Basin

Fig. G-10, G-11 shows division of catchment area and the river system model of the Sg. Pinang for flood analysis. The river system model of the Sg. Pinang is modelled by 16 sub-basins, 5 river channels. In addition, the proposed retention ponds, and diversion channel are linked to the river system model.

Base points are set at river mouth of the Sg. Pinang.

b) Sg. Keluang Basin

Fig. G-12 shows the river system model for flood analysis. The river system model of Sg. Keluang is modelled by 8 sub-basins, and 3 river channels.

(3) Run-off Coefficient

The coefficients used for various types of land use are listed in Table G-9.

Preliminary run-off coefficients for the sub-basins of Sg. Pinang are listed in Table G-10, based on run-off coefficient under various land use condition.

(4) Base Flow

The specific discharge of 0.05 $m^3/sec/km^2$, which corresponds to the average discharge, is distributed into sub-basins.

2) Rational Formula Method (For Other Rivers)

(1) Basic Equation

The Rational formula method is generally considered to be one of the best available flood estimation for small urban and rural catchment areas. In this Study, the peak discharge is obtained from the Rational formula shown below:

Peak Discharge

$$Qp = 1/3.6\ f \cdot r \cdot A$$

where,
- Qp : Peak discharge
- f : Run-off coefficient
- r : Rainfall Intensity (mm/hr)
- A : Catchment area (km^2)

(2) Rainfall Intensity

The rainfall intensity curve for the probable discharge estimation in this Study is based on the curve prepared by D.I.D, because D.I.D's values are bigger than MPPP's ones and considered as the conservative values given for the safety side to the planning.

(3) Run-off Coefficient

The run-off coefficient for the 24 catchments is listed in Table G-11, based on run-off coefficients under various land use condition.

These run-off coefficients for the probable discharge estimation were accounted for the future land use condition in the target year 2010.

(4) Time of Concentration

The time of concentration is estimated from the sum of overland flow time (t_o), and the time of flow in the watercourse (t_d).

$$t_c = t_o + t_d$$

where,
- t_c : concentration time
- t_o : overland flow time
- t_d : flow time in the watercourse

Kraven's formula incorporating the length of water course and slope was used for estimating the flow time in the course.

Kraven's Formula

I	over 1/100	1/100-1/200	below 1/200
W	3.5 m/s	3.0 m/s	2.1 m/s

$T = L/W$

where, I : Slope of watercourse
W : Flood run-off velocity
L : Length of watercourse
T : Time

4.1.3 Rainfall Analysis

1) Probable Areal rainfall

Daily rainfall data observed at 7 stations in Penang Island for 35 years (4 stations in Sg. Pinang Basin for 13 years) have been obtained.

A regression and correlation analysis for 7 stations were carried out to fill up the values of the missing data. The result of analysis is listed in Table G-13.

Probable areal rainfall is estimated by means of log-normal method, Iwai method, Ishihara-Takase method and Gumbel method. Among all results, the rainfall estimated by Gumbel method was adopted, because the value was comparatively higher than others and Gumbel method was widely used in Malaysia. Probable daily rainfall at these stations are shown in Table G-14.

Frequency curves of annual maximum daily rainfall are plotted in Fig. G-13.

2) Duration Time and Pattern of Probable Rainfall

The design rainfall at typical station was adopted for run-off analysis, because catchment area was comparatively small in all river basins except Sg. Pinang. There are 4 stations in Sg. Pinang basin, and average probable daily rainfall was adopted for runoff analysis as a design rainfall. The average probable rainfall in Sg.Pinang basin is as follow:-

Return Periods(Year)	2	5	10	20	30	50	100
Average probable Rainfall of the Basin (mm/day)	124	178	213	247	266	291	423

As a design rainfall, daily rainfall was used for Sg. Pinang and Sg. Keluang which have comparatively large catchment areas, and rainfall intensity-duration curve by D.I.D. was used for other rivers which have small catchments. Rainfall intensity-duration curve by M.P.P.P. was used for the drainage plan.

Rainfall pattern data recorded in the Sg. Pinang and other basins from 1975 until 1987 have been obtained. Among

them, the rainfall pattern which caused the highest peak discharge was adopted as a design rainfall model, taking into account the conditions given below.

a) Enlargement ratio for design probable rainfall (291 mm in average) must be 2.0 and under.

b) The enlarged values of 1-hour, 3-hour and 6-hour rainfall must not be extremely beyond the values of rainfall intensity-duration curve by D.I.D.

Thus rainfall pattern observed on September 17, 1976 at Air Itam station was adopted as a design rainfall model. The 24-hour rainfall is 231.8 mm and enlargement ratio is 1.25. Typical three rainfall patterns are shown in Fig. G-14.

4.1.4 Flood Run-off Calculation

1) Calibration of Run-off Model

Run-off simulation of actual flood discharge was carried out, in order to establish a simulation model for run-off analysis of the Sg. Pinang and other rivers. The model was calibrated by using the actual data for the Sg. Pinang.

Flood discharges were observed twice during the study period. The floods on August 25 was adopted as the actual flood discharge, because the discharge was comparatively big.

Hourly hydrographs in August and September 1989 floods are shown in Fig. G-15 and their hydrographs are shown in Fig. 16.

The rating-curves estimated based on these observed data at two gauging stations are shown in Fig. 17.

Calibration was done through trial and error in comparison between the calculated flood hydrogragh and the hydrogragh observed in Sg. Air Itam at Jln. Scotland and Sg. Air Terjun at Brook Road on August 25, 1989.

The flood hydrogragh describing both actual and calculated discharge are shown in Fig. G-18.

The coefficients of the river courses and basins used in a simulation model for run-off analysis of Sg. Pinang are shown in Table G-12.

2) Probable Flood Discharge

<u>For Sg. Pinang</u>

Probable Flood discharges were calculated by using the established simulation model. The conditions assumed in the calculation are as follows:

a) Landuse in 2010 was considered as a landuse of the basin.

b) The existing Air Itam Dam cannot have effective flood control potential even if improved, and

control effect of this dam was not taken into account.

c) The discharge of Sg. Jelutong was only due to run-off from the catchment downstream of the Jelutong Diversion Channel, as the discharge from the upper catchment is diverted to the Jelutong Diversion Channel.

d) The discharge corresponding to a rainfall reform period of 50 years at the river mouth of Sg. Pinang is assumed to be 270 m^3/sec.

The determined probable flood discharge distribution of Sg. Pinang is shown in Fig. G-19.

For Other Rivers

All other rivers except Sg. Keluang have comparatively small catchment areas and short time of concentration, the Rational formula was adopted for discharge determination.

Target points for the diversion were considered at the river mouth of the individual catchment. In addition, the probable discharge was put out at the important sub-target points for the river planning. The determined probable flood discharge of all the other 25 rivers are given in Table G-15.

3) Design Flood Discharge Distribution (for Sg. Pinang)

Based on the alternative study, the design discharge distribution was determined as following conditions:-

a) 2010 year for the target.

b) With a diversion and retention pond.

Fig. G-20 and Fig. G-21 show the design flood discharge distribution and probable flood hydrograph at river mouth formulated by the Master Plan Study.

4.2 Inundation Analysis

Inundation analysis was carried out to identify flood areas and inundation depth (or flood water level) under the existing river conditions for the estimation of annual flood damage potential.

4.2.1 Hydraulic Calculation of the Flooding Area

The inundation area-depth is worked out by hydraulic flooding calculation.

Hydraulic flooding calculation in Sg. Pinang basin is composed by non-uniform flow computation methods under the assumption of the existing river conditions with a Manning's roughness coefficient of 0.03, for the 2 cases of with and without retention pond and diversion channel.

4.2.2 Flooding Analysis

Flooding analysis was carried out for 5 numbers frequency floods, ranging from 5 year to 100 year (5, 10, 30, 50 and 100 year frequency floods), under the following conditions that remained unchanged:-

- River under the existing conditions.
- Catchment area under the future (2010) land use conditions.
- With and without considering the proposed retention pond and diversion channel.

The results of the analysis are shown in Fig. G-22.

Tables

TABLE G-1-1 CATCHMENT AREA OF THE 26 RIVER BASINS

River No.	River Name	Catchment Area(km2)
1	Sg. Pinang	50.97
2	Sg. Teluk Awak	2.95
3	Sg. Teluk Bahang	12.30
4	Sg. Batu Ferringghi	11.27
5	Sg. Satu	2.58
6	Sg. Mas	2.11
7	Sg. kecil	2.75
8	Sg. Kelian	9.04
9	Sg. Balik Batu	0.80
10	Sg. Fettes	1.36
11	Sg. Bagan Jermal	0.83
12	Sg. Babi	0.84
13	Sg. Gelugor	4.07

River No.	River Name	Catchment Area(km2)
14	Sg. Dua Besar	6.19
15	Sg. Nibong Besar	1.50
16	Sg. Nibong Kecil	2.77
17	Sg. Keluang	22.17
18	Sg. Nipah	1.69
19	Sg. Kampung Masjid	0.84
20	Sg. Ikan Mati	0.38
21	Sg. Bayan Lepas	7.04
22	Sg. Batu	0.90
23	Sg. Mati	0.95
24	Sg. Teluk Kumbar	7.06
25	Sg. Gemuroh	1.91
26	Sg. Gertak Sanggul	1.03

TABLE G-1-2 DIVISION OF CATCHMENT AREA IN SG. PINANG BASIN

Catchment No.	River Name	Catchment Area(km2)
①-1	Sg. Air Itam (upper reach)	10.64
①-2	Sg. Air Putih	4.56
①-3	Sg. Dondang	11.33
①-4	Sg. Air Itam (lower reach)	1.05
①-5	Tributary Sg. Air Itam	2.42
①-6	Sg. Terjun	10.76
①-7	Sg. Pinang (upper reach)	0.73
①-8	Sg. Jelutong (lower reach)	1.69
①-9	Sg. Pinang (lower reach)	2.89
①-10	Sg. Jelutong (lower reach)	4.90
Total		50.97

TABLE G-2 MONTHLY METEOROLOGICAL DATA

Item / Month	Temperature							Humidity		Precipitation		
	Highest Recorded (°C)	Ave. of Monthly Highest (°C)	Ave. of Daily Highest (°C)	Ave. (°C)	Ave. of Daily Lowest (°C)	Ave. of Monthly Lowest (°C)	Lowest Recorded (°C)	9 o'clock (%)	15 o'clock (%)	Monthly (mm)	Max. of 24 hrs. (mm)	Nos. of Date (>0.25mm)
Jan.	36.6	33.9	32.2	27.5	22.8	21.6	18.9	75	68	94	69	8
Feb.	36.1	33.9	32.8	27.8	22.8	21.6	18.9	74	64	76	142	7
Mar.	36.6	34.4	33.3	28.3	23.3	21.6	19.4	75	64	142	132	11
Apr.	36.6	33.9	32.8	28.9	23.9	22.2	19.4	79	66	188	158	14
May.	35.5	33.9	32.2	27.8	23.3	22.2	20.0	78	66	272	135	16
Jun.	36.1	33.9	32.2	27.8	23.3	21.6	20.5	77	67	196	145	12
July	35.0	33.3	32.2	27.8	23.3	21.6	20.5	77	67	191	158	12
Aug.	35.5	33.3	31.6	27.2	22.8	21.6	20.5	78	67	295	168	15
Sep.	36.6	32.8	31.1	27.0	22.8	21.6	20.0	80	69	401	221	18
Oct.	34.4	32.8	31.6	27.2	22.8	21.6	19.4	81	70	429	241	21
Nov.	35.0	32.8	31.1	27.0	22.8	21.6	18.3	79	71	302	183	19
Dec.	35.0	32.8	31.6	27.2	22.8	21.6	19.4	76	68	147	196	11

Notes: (1) Average temperature is that of average temperature of daily highest and lowest.

(2) Data source is "Climate of Asia" written by Hisataka Hatakeyama.

TABLE G-3 INVENTORY OF RAINFALL GAUGING STATIONS

STATION NUMBER	STATION INDEX	STATION NAME	GRID REFERENCE	LATITUDE (D, M, S)	LONGITUDE (D, M, S)	DATE EQUIP. INSTALLED MAN./AUTO.	CURRENT EQUIP.	OPER. AUTH.	ELEV. (m)	DATE CLOSED
5202021	25M	STN. KAJICUACA BAYAN LEPAS	QX539867	05 17 50	100 16 20	05/34	M5	PKM.	3	
5302001	2PA	TALIAIR BESAR SG. PINANG	QX472972	05 23 30	100 12 45	01/52 09/66	M8 OTAW	JPT.	30	
5302002	25M	PINTU AIR BAGAN, AIR ITAM	QX460929	05 21 15	100 12 00	01/46	M8	JPT.	2	
5302003	25A	KOLAM TAKONGAN AIR ITAM	QX531974	05 23 45	100 15 55	C8/75 C8/75	M8 HW	JPT.	210	
5303001	25A	RUMAH KEBAJIKAN, PULAU PINANG	QX575970	05 23 30	100 18 15	C8/75 08/75	M8 HW	JPT.	10	
5402001	25A	KLINIK BKT. BENDERA	QS539006	05 25 25	100 16 15	08/75 08/75	M8 HW	JPT.	690	
5402002	25A	KOLAN BERSIN PULAU PINANG	QS555024	05 26 25	100 17 10	08/75 08/75	M8 HW	JPT.	80	

TABLE G-4 AVAILABLE DAILY RAINFALL RECORDS

STATION NUMBER	STATION NAME	1950 1960 1970 1980 51 52 53 54 55 56 57 58 59 | 61 62 63 64 65 66 67 68 69 | 71 72 73 74 75 76 77 78 79 | 81 82 83 84 85 86 87 88 89 90
5202021	STN. KAJIKUACA BAYAN LEPAS	'53 ▨ '87
5302001	TALIAIR BESAR SG. PINANG	▨
5302002	PINTU AIR BAGAN, AIR ITAM	▨
5302003	KOLAM TAKONGAN AIR ITAM	'75 ▨
5303001	RUMAH KEBAJIKAN, PULAU PINANG	▨
5402001	KLINIK BKT. BENDERA	▨
5402002	KOLAN BERSIN PULAU PINANG	▨

TABLE G-5 LIST OF COLLECTED HOURLY RAINFALL DATA

Station No.	5302001	5302003	5303001	5402001	5402002
Date (day/month/year)	22/8 1976	17/9 1976	17/9 1976	1/9 1975	28/2 1976
	17/9 1976	5/9 1980	3/11 1978	9/10 1975	17/9 1976
	29/6 1978	28/9 1980	27/11 1979	17/9 1976	8/10 1976
	5/9 1978	6/9 1981	5/9 1980	22/10 1976	5/9 1978
	7/9 1978	14/10 1981	16/10 1983	23/9 1977	7/8 1980
	7/4 1981	18/4 1984	18/4 1984	28/6 1978	28/9 1980
	2/9 1982	28/4 1984	16/7 1984	5/9 1978	20/10 1980
	1/10 1983	11/10 1985	11/10 1985	19/8 1979	9/9 1983
	16/10 1983	7/12 1985		7/8 1980	16/10 1983
	18/4 1984	19/9 1986		5/9 1980	18/4 1984
	28/4 1984	5/10 1986			14/7 1984
	15/7 1984	12/11 1986		17/5 1983	16/4 1985
	3/10 1984	4/6 1987		9/9 1983	11/10 1985
	25/9 1985	15/8 1987		16/10 1983	21/9 1986
	26/9 1985	15/9 1987		18/4 1984	4/6 1987
	11/10 1985			28/4 1984	21/7 1987
	1/8 1986			16/5 1984	8/11 1987
	11/10 1986			15/7 1984	13/11 1987
	15/8 1987			25/9 1985	
	8/11 1987			11/10 1985	
				1/8 1986	
				5/10 1986	
				18/3 1987	
				4/6 1987	
				8/11 1987	
				13/11 1987	

TABLE G-6 LIST OF WATER LEVEL GAUGING STATIONS

Station No.	Station Name	River Name	Catchment Area (km^2)	Latitude (D, M, S)	Longitude (D, M, S)	Observation Period
5204422	Jam. Jln. Raya	Sg. Jawi	41.4	05° 12' 10"	100° 29' 55"	1970 - 1971
5303401	Jln. Kurau	Sg. Jelutong	2.8	05° 23' 40"	100° 18' 40"	1975 - Nov/1980
5403401	Jam. Jln. Scotland	Sg. Air Itam	33.0	05° 24' 40"	100° 18' 10"	1975 - 1982
5403402	Western Road	Sg. Terjun	9.2	05° 25' 35"	100° 18' 10"	1975 - 1980

TABLE G-7 ANNUAL MEAN MONTHLY RAINFALL DATA

STATION NUMBER	STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL	NOTE
5202021	STN. KAJICUACA BAYAN LEPAS	66.7	81.5	137.3	211.3	241.1	172.2	199.7	238.8	350.3	366.8	217.6	100.7	2411.4	1953 - 1987
5302001	TALIAIR BESAR SG. PINANG	70.0	78.7	177.5	268.2	278.1	215.2	248.6	272.5	378.3	454.4	392.3	111.8	2945.6	1953 - 1987
5302002	PINTU AIR BAGAN, AIR ITAM	73.5	74.5	168.6	243.3	270.2	170.4	227.4	242.5	383.4	452.2	273.1	117.7	2778.8	1953 - 1987
5302003	KOLAM TAKONGAN AIR ITAM	33.4	63.2	105.4	216.7	224.5	107.3	184.1	220.2	371.0	384.0	247.2	100.4	2261.4	1975 - 1987
5303001	RUMAH KEBAJIKAN, PULAU PINANG	30.5	62.8	89.0	173.8	186.8	106.0	162.6	201.1	372.6	275.7	197.3	06.4	1911.6	1975 - 1987
5402001	KLINIK BKT. BENDERA	54.0	73.7	147.4	237.3	276.1	183.4	271.8	271.7	455.2	464.7	276.7	116.0	2873.0	1975 - 1987
5402002	KOLAN BERSIN PULAU PINANG	43.0	57.7	124.7	204.0	268.6	132.7	178.5	229.9	414.7	410.2	253.2	76.0	2443.4	1975 - 1987

TABLE G-8 PROBABLE RAINFALL DEPTH DURATION AT STATION NUMBER 5302001

Return Period	Duration (Hrs)		
(Yrs)	24	48	72
2	168 mm	210 mm	239 mm
5	243	285	315
10	292	335	365
20	339	382	414
50	400	444	476

*Station No. 5302001 (Talair Besar Sg. Pinang)
Years Used 24 (1954 - 1978)

TABLE G-9 RUN-OFF COEFFICIENT FOR URBAN AREAS

Type of Drainage Area	Coefficient (C)
Business Areas	0.70 - 0.95
Residential Areas	0.25 - 0.50
Light Industrial Areas	0.50 - 0.80
Unimproved Areas	0.10 - 0.30
Streets	0.70 - 0.95
Lawns:	
Sandy soil, flat 2%	0.50 - 0.10
Sandy soil, av. 2 - 7%	0.10 - 0.15
Sandy soil, steep 7%	0.15 - 0.20
Heavy soil, flat 2%	0.13 - 0.17
Heavy soil, av. 2 - 7%	0.18 - 0.22
Heavy soil, steep 7%	0.25 - 0.35

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TABLE G-10 ESTIMATED RUN-OFF COEFFICIENTS FOR SG. PINANG SUB-BASINS

No.	C.A. (Km^2)	Run-Off Coefficients	
		1988	2010
1.	5.75	0.14	0.20
2.	4.59		0.24
3.	4.56	0.18	0.23
4.	0.30	0.38	0.38
5.	6.15	0.23	0.27
6.	5.18		0.28
7.	0.70	0.29	0.29
8.	2.42	0.31	0.30
9.	0.35	-	0.30
10.	7.74	-	0.21
11.	3.02	-	0.30
12.	0.73	-	0.30
13.	1.69	-	0.35
14.	0.88	-	0.61
15.	1.20	-	0.54
16.	0.81	-	0.50

TABLE G-11 **ESTIMATED RUN-OFF COEFFICIENTS OF 25 RIVER BASINS**

NO	RIVER NAME	Existing	Future
2	Sg.Teluk Awak	0.21	0.22
3	Sg.Teluk Bahang	0.21	0.22
4	Sg. Batu Ferringghi	0.20	0.21
5	Sg.Satu	0.21	0.23
6	Sg.Mas	0.26	0.33
7	Sg.Kechil	0.25	0.25
8	Sg.Kelian	0.25	0.25
9	Sg.Balik Batu	0.36	0.37
10	Sg.Fettes	0.30	0.34
11	Sg.Bagan Jermal	0.26	0.26
12	Sg.Babi	0.26	0.29
13	Sg.Gelugor	0.31	0.31
14	Sg.Dua Besar	0.28	0.29
15	Sg.Nibong Besar	0.35	0.36
16	Sg.Nibong Kechil	0.39	0.41
17	Sg.Keluang	0.25	0.28
18	Sg.Nipah	0.24	0.35
19	Sg.Kampung Masjid	0.29	0.35
20	Sg.Ikan Mati	0.26	0.37
21	Sg.Bayan Lepas	0.22	0.24
21	BY-PASS OF NO.21	0.25	0.30
22	Sg.Batu	0.25	0.26
23	Sg.Mati	0.27	0.29
24	Sg.Teluk Kumbar	0.23	0.23
25	Sg.Gemroh	0.20	0.20
26	Sg.Gertak Sanggul	0.22	0.22

TABLE G-12-1 COEFFICIENT OF BASIN (EXISTING)

Check Point	Catchment No.	Catchment Area A (km^2)	Inflow Coefficient f_1	K	P	Lag Time Tl (min.)	Base Flow Q_B (m^3/s) (=0.05$m^3/s/km^2$)	Saturation Rainfall Rsa (mm)
(1) Brook Road	8	9.62	0.26	23	0.33	0.0	0.48	120
(2) Jln. Scotland	1	10.34	0.14	36	0.33	0.0	0.52	120
	2	4.56	0.18	36	0.33	0.0	0.23	120
	3	0.30	0.38	30	0.33	0.0	0.02	120
	4	11.33	0.23	30	0.33	0.0	0.57	120
	5	0.70	0.29	23	0.33	0.0	0.04	120
	6	2.42	0.31	36	0.33	0.0	0.12	120

COEFFICIENT OF RIVER (EXISTING)

Check Point	River No.	K	P	Lag Time Tl (min)
(1) Brook Road	D	2.1	0.70	5
(2) Jln. Scotland	A	0.9	0.68	5
	B	2.2	0.72	5

TABLE G-12-2 **COEFFICIENT OF BASIN (FUTURE)**

Catchment No.	Catchment Area A (km2)	Inflow Coefficient f_1	K	P	Lag Time Tl (min.)	Base Flow Q_B (m^3/s) (=0.05$m^3/s/km^2$)	Saturation Rainfall Rsa (mm)
1	5.75	0.20	36	0.33	0.0	0.29	120
2	4.59	0.24	36	0.33	0.0	0.23	120
3	4.56	0.23	36	0.33	0.0	0.23	120
4	0.30	0.38	30	0.33	0.0	0.02	120
5	6.15	0.27	30	0.33	0.0	0.31	120
6	5.18	0.28	30	0.33	0.0	0.26	120
7	0.70	0.29	23	0.33	0.0	0.04	120
8	2.42	0.30	36	0.33	0.0	0.12	120
9	0.35	0.30	23	0.33	0.0	0.02	120
10	7.74	0.21	23	0.33	0.0	0.39	120
11	3.02	0.30	27	0.33	0.0	0.15	120
12	0.73	0.30	30	0.33	0.0	0.04	120
13	1.69	0.35	18	0.33	0.0	0.08	120
14	0.88	0.61	18	0.33	0.0	0.04	120
15	1.20	0.54	18	0.33	0.0	0.06	120
16	0.81	0.50	18	0.33	0.0	0.04	120

COEFFICIENT OF RIVER (FUTURE)

River No.	K	P	Lag Time Tl (min)
A	0.9	0.68	5
B	2.2	0.72	5
C	1.8	0.69	5
D	2.1	0.70	5
E	5.5	0.46	5

TABLE G-13 CORRELATION COEFFICIENT FOR 7 STATIONS

Station Number	5303001			
5303001		5302003		
5302003	0.807		5402001	
5402001	0.758	0.793		5402002
5402002	0.725	0.753	0.843	
5202021	0.624	0.633	0.558	0.554
5302001	0.595	0.674	0.640	0.613
5302002	0.577	0.664	0.620	0.579

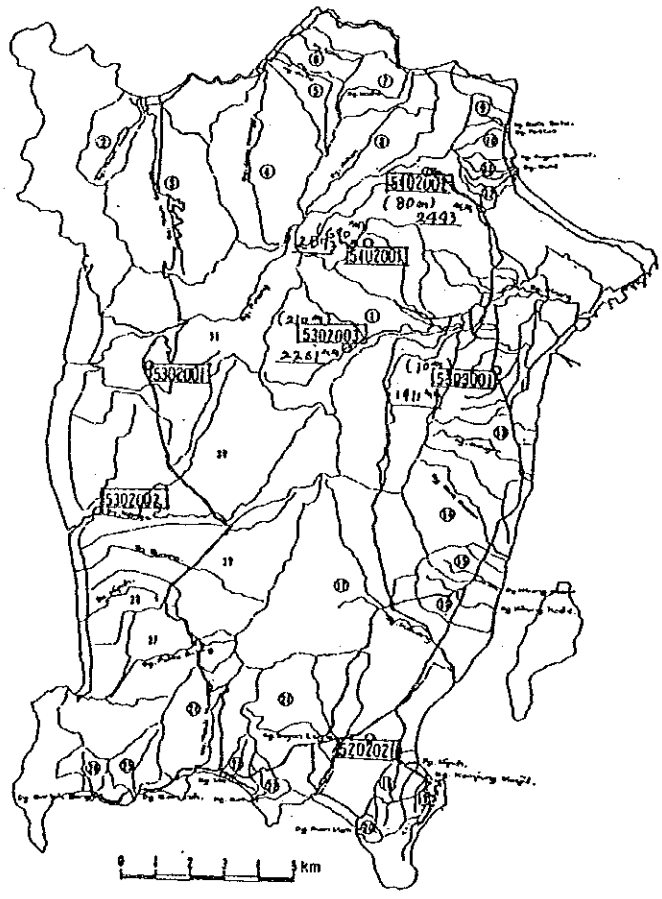
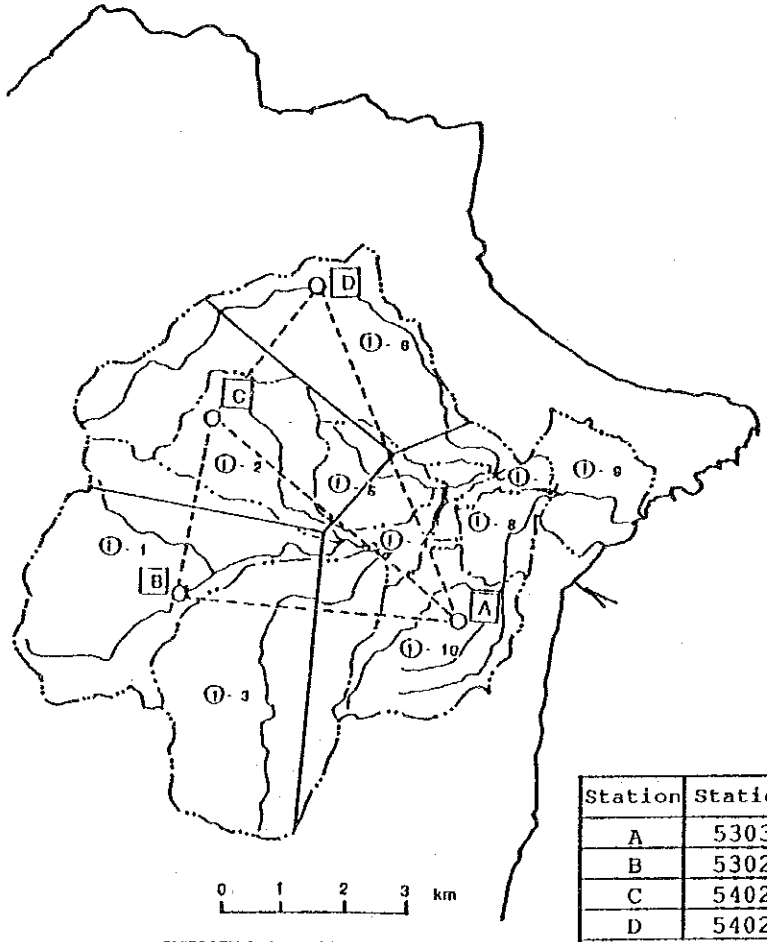


TABLE G-14 PROBABLE AREAL RAINFALL BY GUMBEL METHOD (1 DAY)

Unit : mm

Station / Return Period	A	B	C	D	*Mean Probable Areal Rainfall in Penang Basin
1/2	112	124	142	126	124
1/5	163	179	188	193	178
1/10	197	216	218	237	213
1/20	229	251	247	279	247
1/30	248	271	264	303	266
1/50	271	296	285	334	291
1/70	286	312	298	354	306
1/100	302	330	313	375	323

* Mean Probable Areal Rainfall is Calculated by Thiessen Method



THIESSEN POLYGON NETWORK

Station	Station No.	Area(km²)	Coefficient
A	5303001	16.37	0.32
B	5302003	17.45	0.34
C	5402001	10.85	0.21
D	5402002	6.30	0.13
Total		50.97	1.00

TABLE G-15 PROBABLE DISCHAGE FOR 25 RIVERS

Land Use Condition in 2010

NO.	River Name	Catchment Area (km^2)	Run-off Coefficient	Time of Concentration (minute)	Probable Flood Discharge (m^3/s)				
					5 year	10 year	20 year	50 year	100 year
2	Sg.Teluk Awak	2.95	0.22	37	16	17	19	21	22
3	Sg.Teluk Bahang	12.30	0.22	56	39	44	48	52	56
4	Sg.Batu Ferringghi	11.27	0.21	49	40	45	49	53	57
5	Sg.Satu	2.58	0.23	35	15	17	19	20	22
6	Sg.Mas	2.11	0.33	32	20	22	25	27	29
7	Sg.Kechil	2.75	0.25	33	19	21	23	26	27
8	Sg.Kelian	9.04	0.25	56	33	37	40	44	47
9	Sg.Balik Batu	0.80	0.37	23	14	15	17	18	20
10	Sg.Fettes	1.36	0.34	24	20	22	24	27	29
11	Sg.Bagan Jermal	0.83	0.26	24	9	10	11	13	14
12	Sg.Babi	0.84	0.29	28	8	9	10	11	12
13	Sg.Gelugor	4.07	0.31	39	28	32	35	38	40
14	Sg.Dua Besar	6.19	0.29	42	37	41	45	49	52
15	Sg.Nibong Besar	1.50	0.36	29	18	20	22	24	26
16	Sg.Nibong Kechil	2.77	0.41	33	32	35	38	42	45
17	Sg.Keluang	22.17	0.28	63	36	61	81	130	157
18	Sg.Nipah	1.69	0.35	25	24	27	29	32	35
19	Sg.Kampung Masjid	0.84	0.35	23	14	15	16	18	20
20	Sg.Ikan Mati	0.38	0.37	19	9	10	11	12	13
21	Sg.Bayan Lepas	7.04	0.24	47	30	34	37	40	43
	Sg.Tiram Diversion	2.59	0.30	35	20	22	24	26	29
22	Sg.Batu	0.90	0.26	26	9	10	11	12	13
23	Sg.Mati	0.95	0.29	25	11	12	14	15	16
24	Sg.Teluk Kumbar	7.06	0.23	40	35	39	43	46	50
25	Sg.Gemuroh	1.91	0.20	25	16	17	19	21	22
26	Sg.Gertak Sanggul	1.03	0.22	22	11	12	14	15	16

Catchments of each river are shown in Fig.G-23 to Fig.G-35

Figures

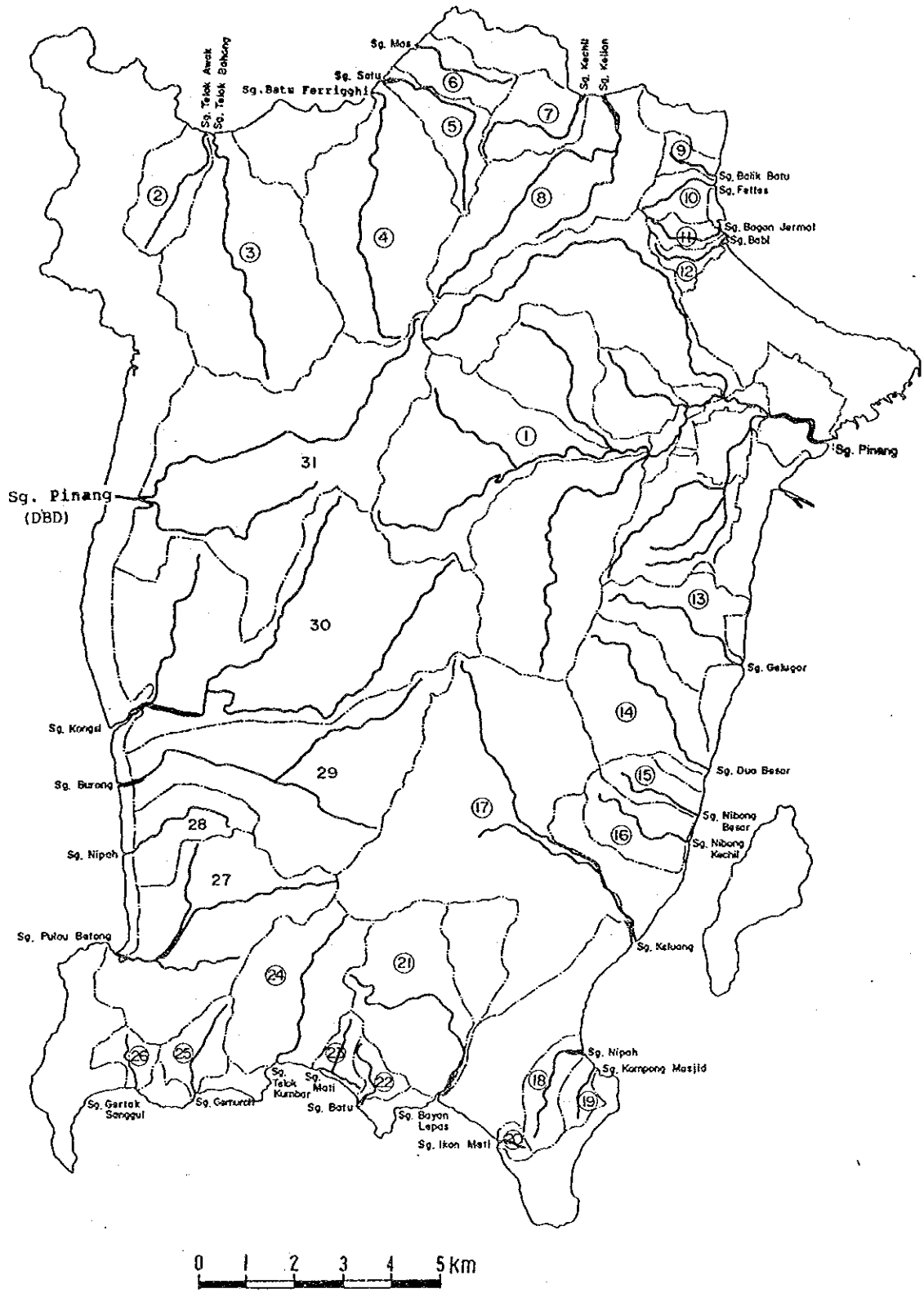


FIG. G-1-1 **GENERAL AREA MAP OF THE 26 RIVER BASINS**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

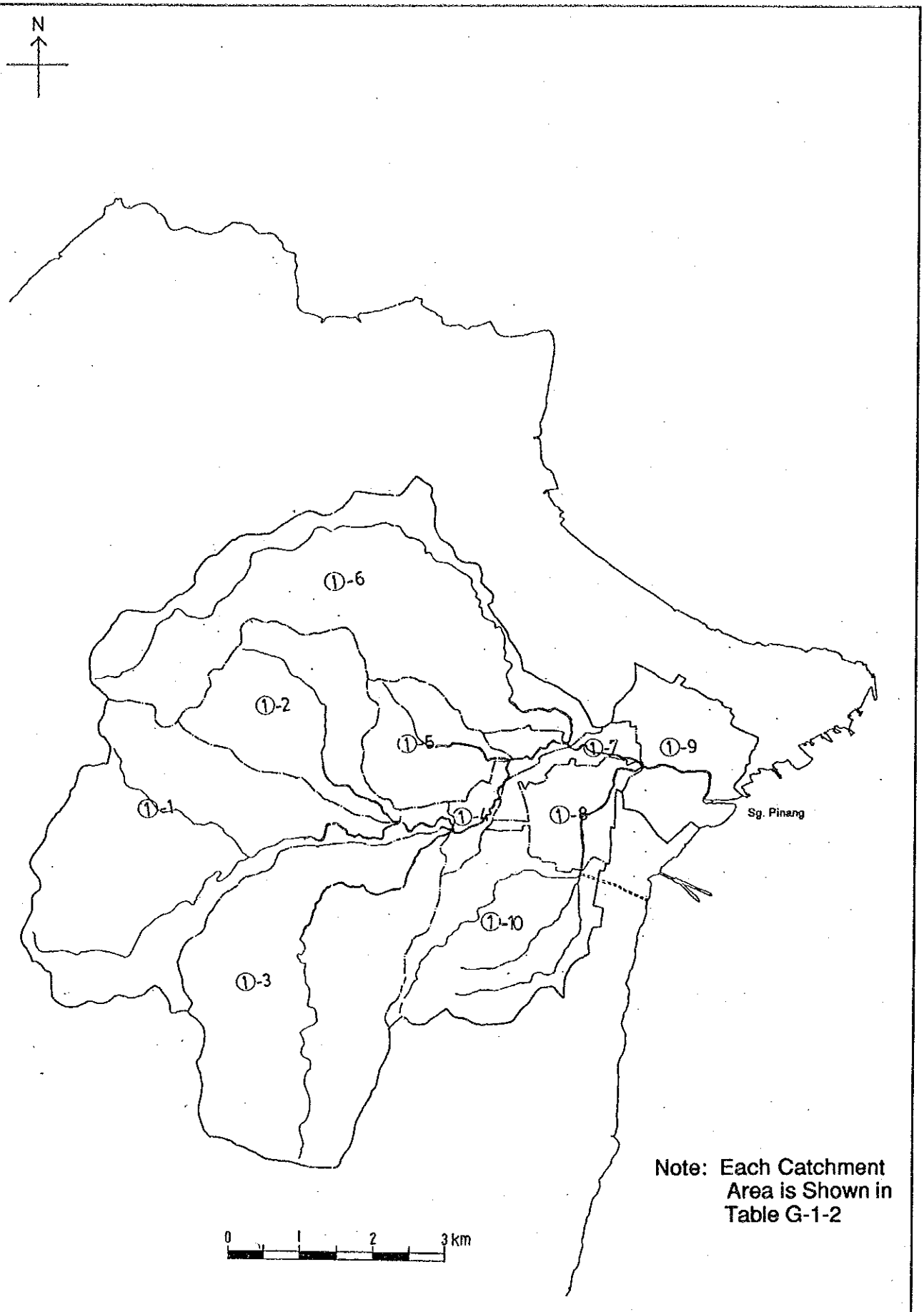


FIG. G-1-2 **DIVISION OF CATCHMENT AREA IN SG. PINANG BASIN**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

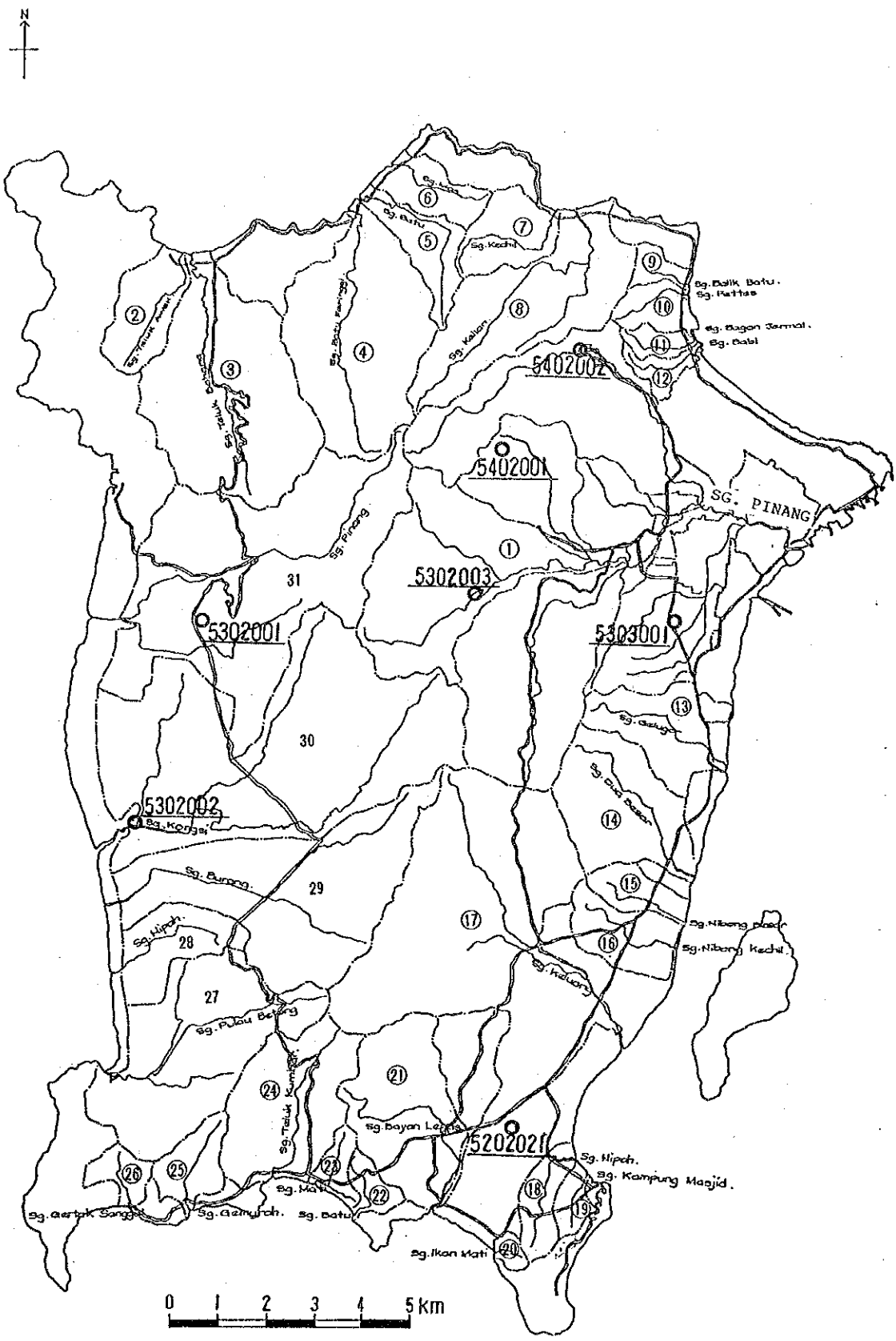
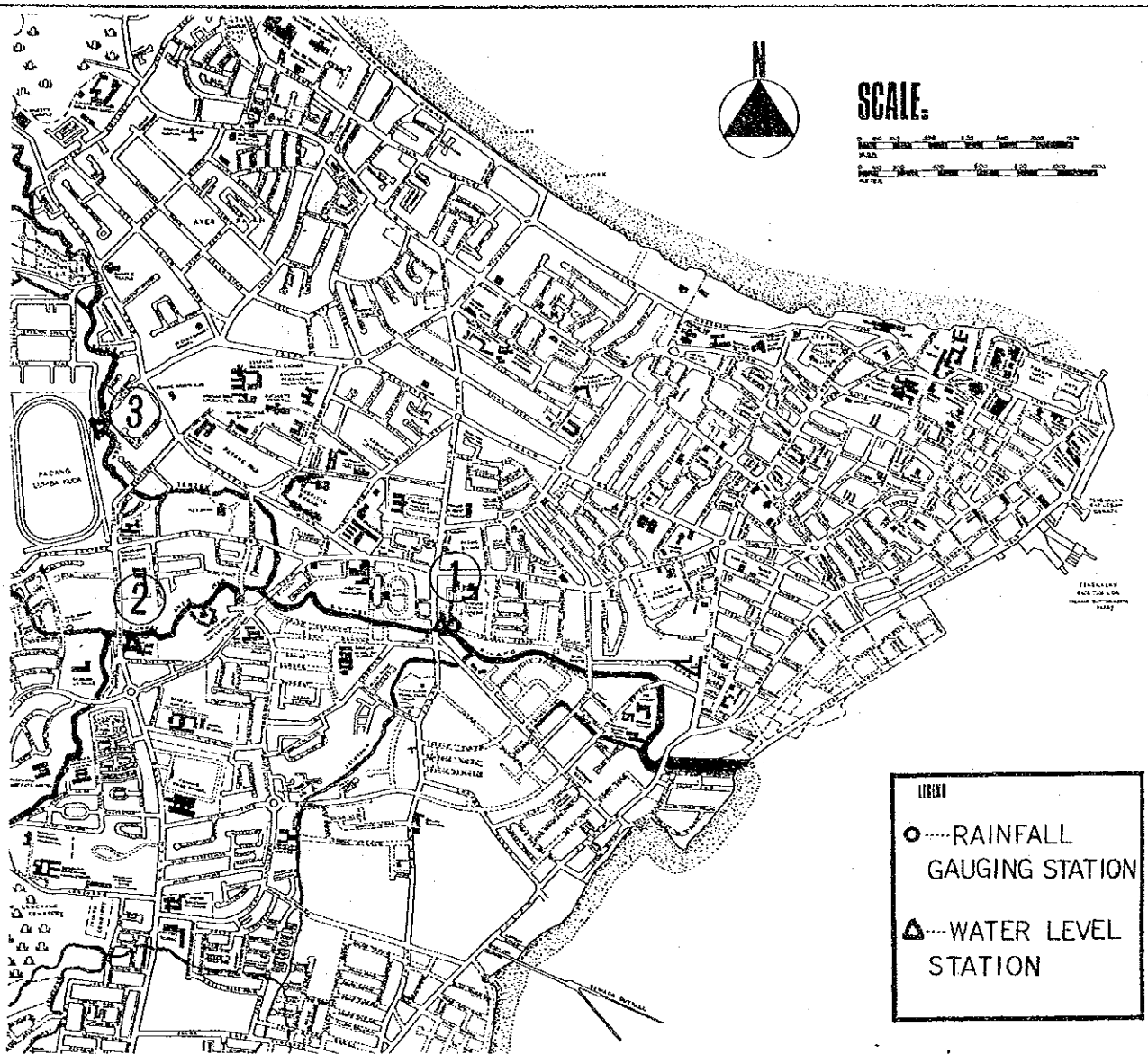
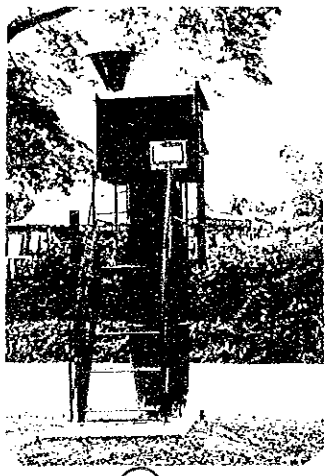


FIG. G-2 | LOCATION MAP OF RAINFALL STATIONS

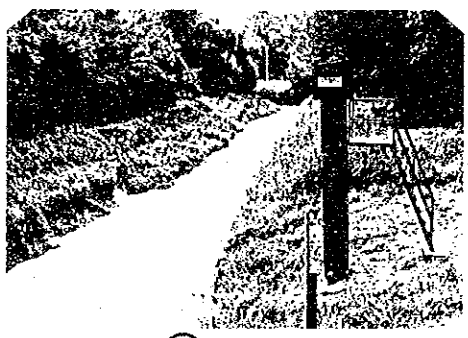
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

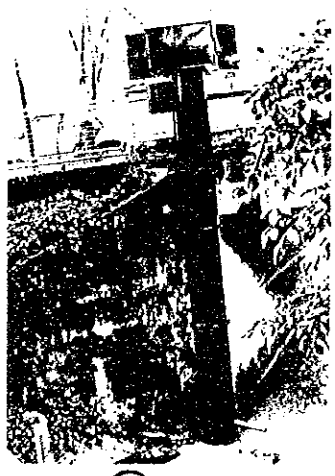




① JL. PERAK
(RAINFALL AND WATER LEVEL STATION)

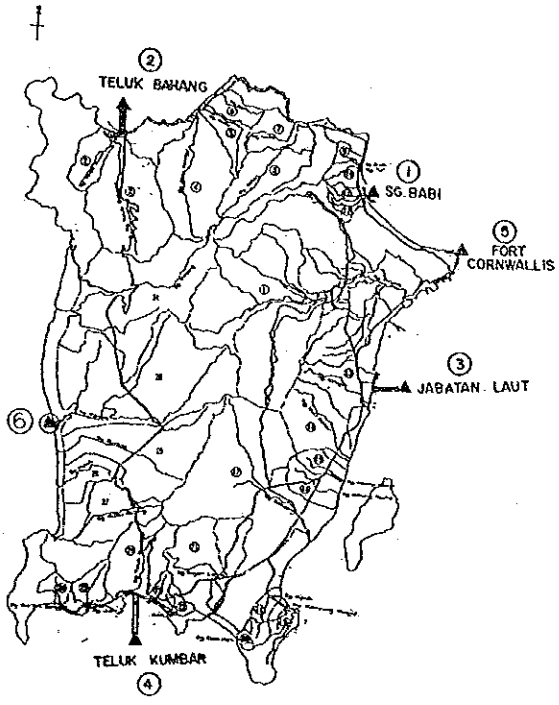


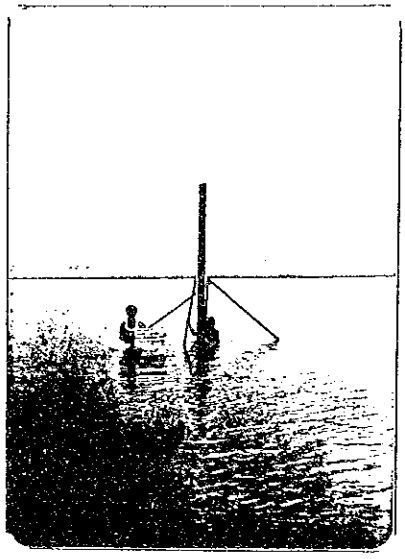
② JL. SCOTLAND
(WATER LEVEL STATION)



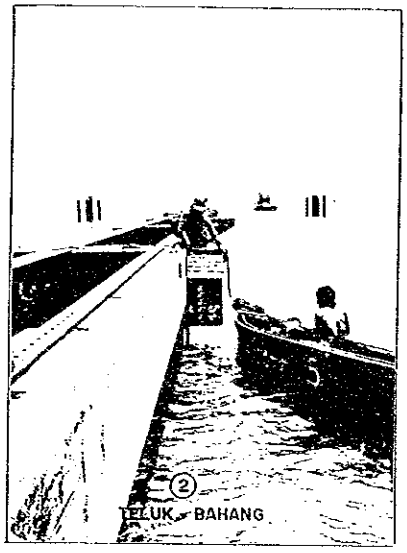
③ BROOK ROAD
(WATER LEVEL STATION)

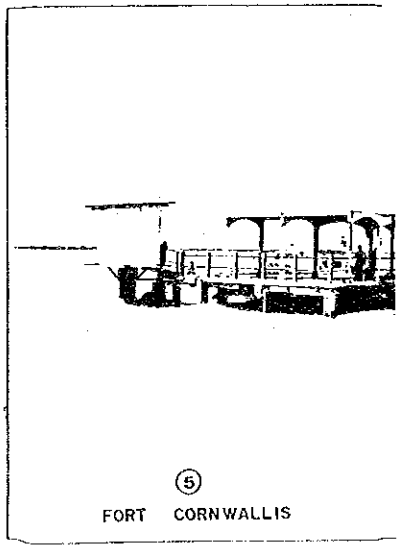
FIG. G-3 LOCATION MAP OF WATER LEVEL STATIONS AND RAINFALL GAUGING STATIONS

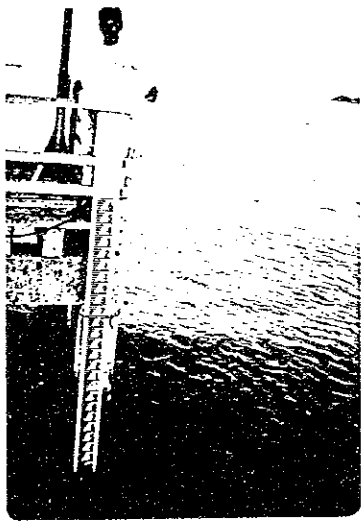




① Sg. BABI







④ TELUK KUMBAR

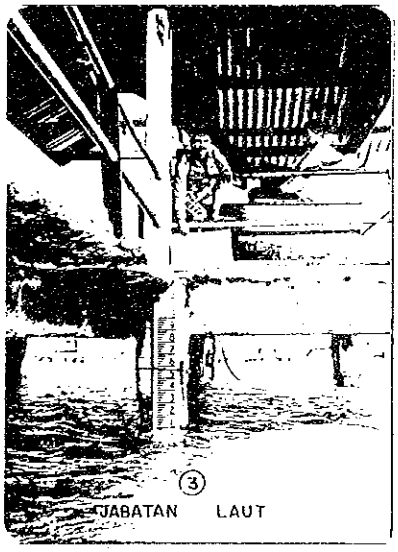


FIG. G-4	LOCATION OF TIDE POLES

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

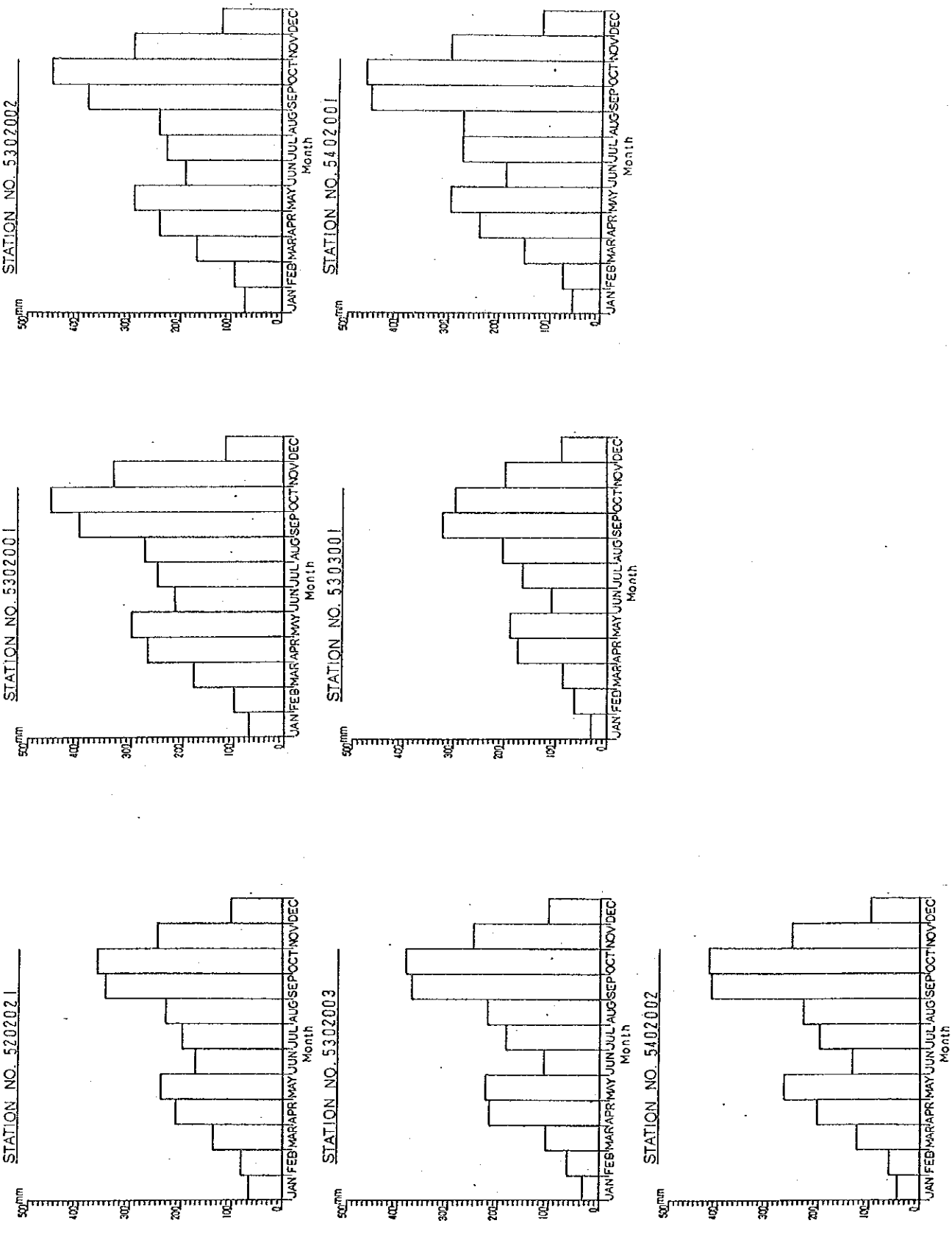


FIG. G-5 MONTHLY MEAN RAINFALL HYETOGRAPH

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

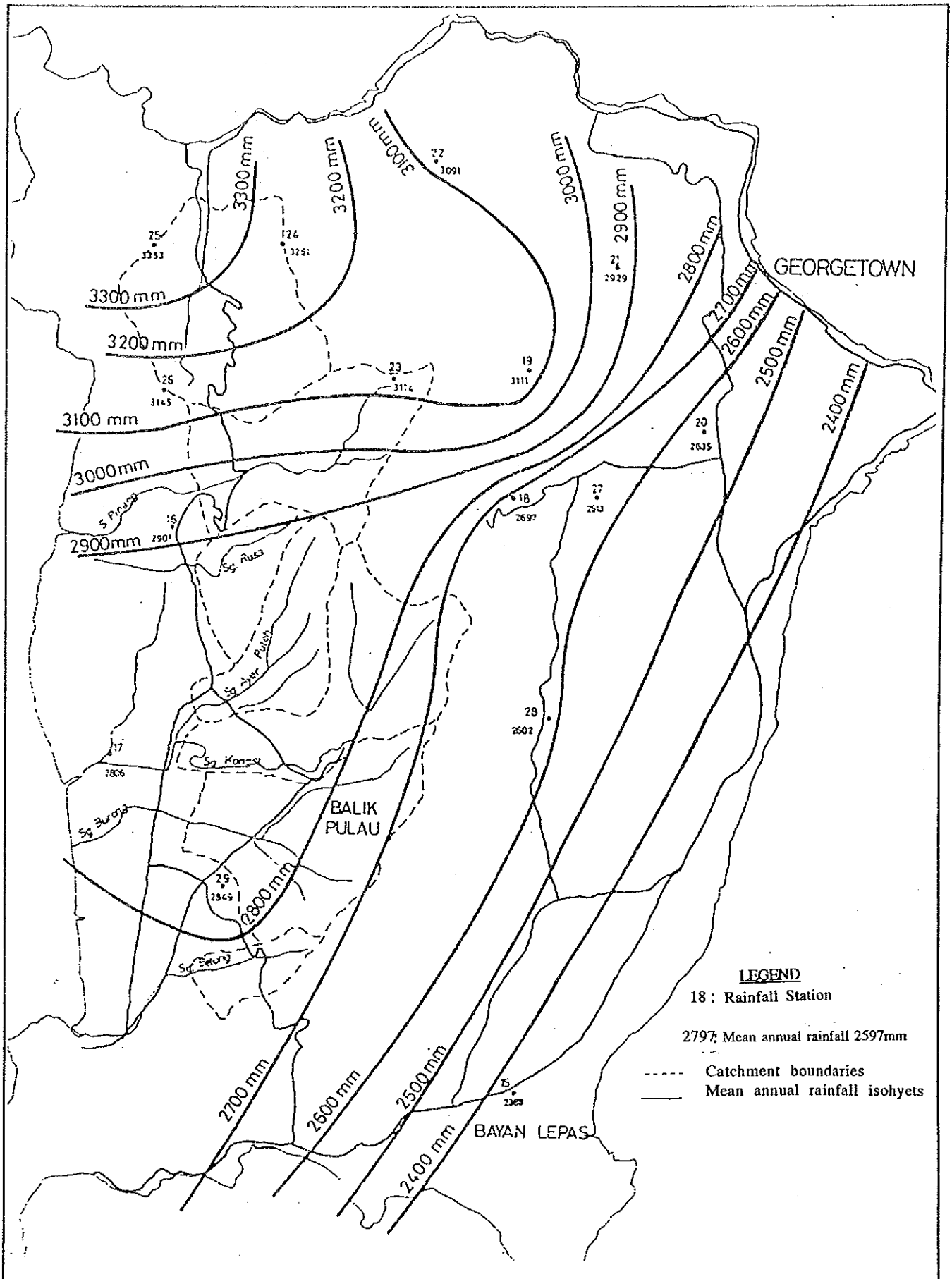
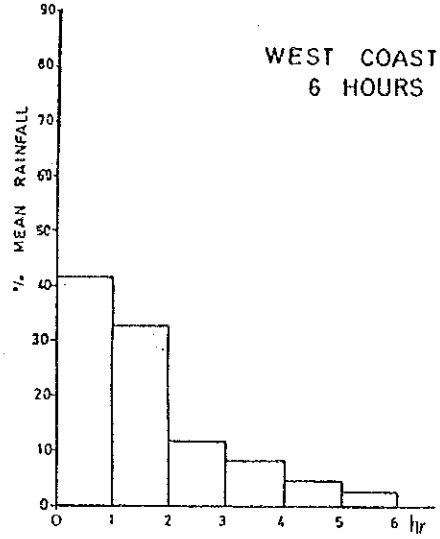
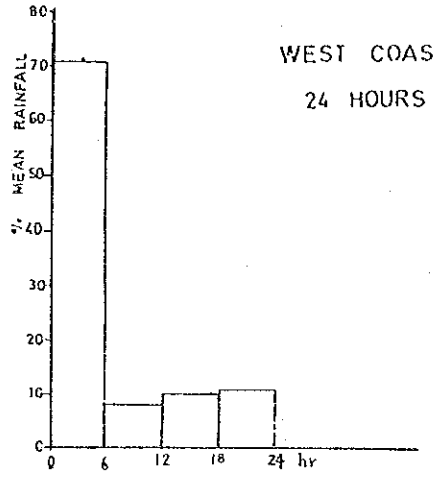


FIG. G-6 MEAN ANNUAL RAINFALL ISOHYETS

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND





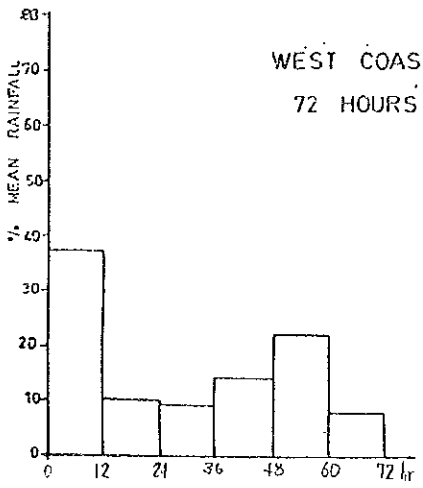
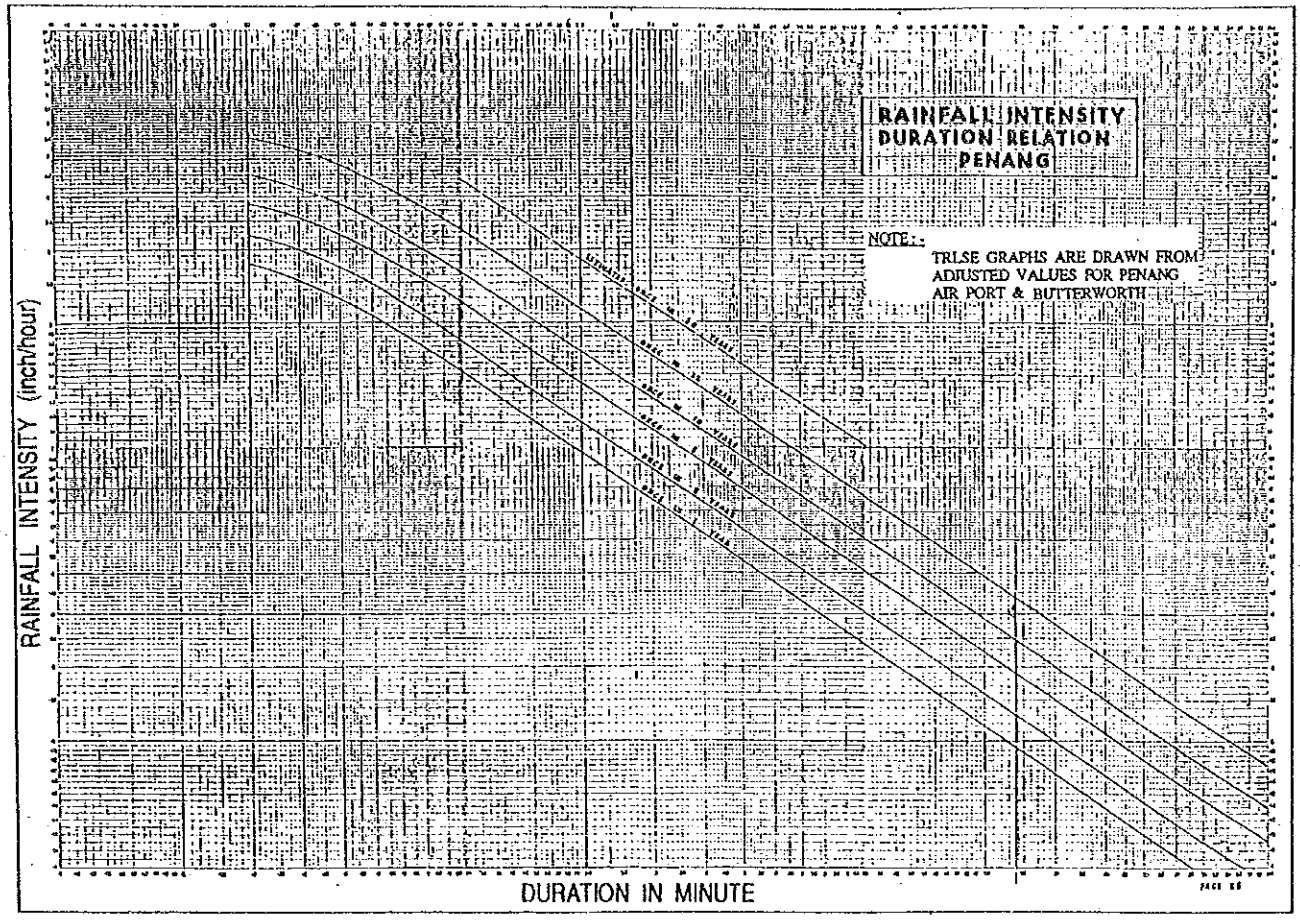
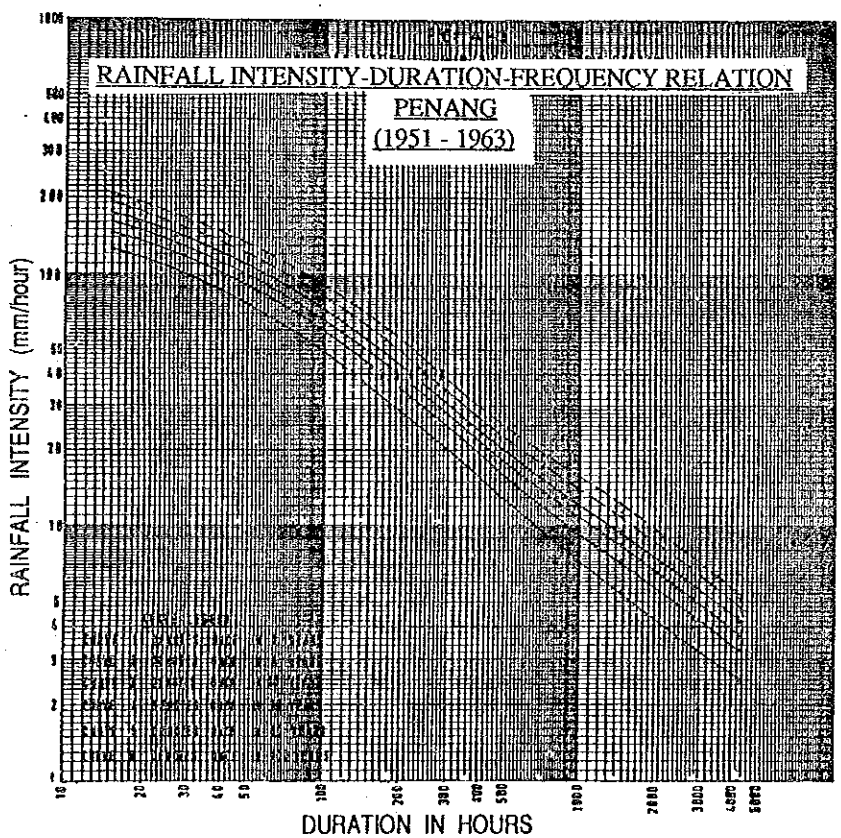


FIG. G-7	**TEMPORAL RAINFALL DISTRIBUTION IN WEST COAST REGION**



by MPPP



by DID

FIG. G-8 **RAINFALL INTENSITY CURVES**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

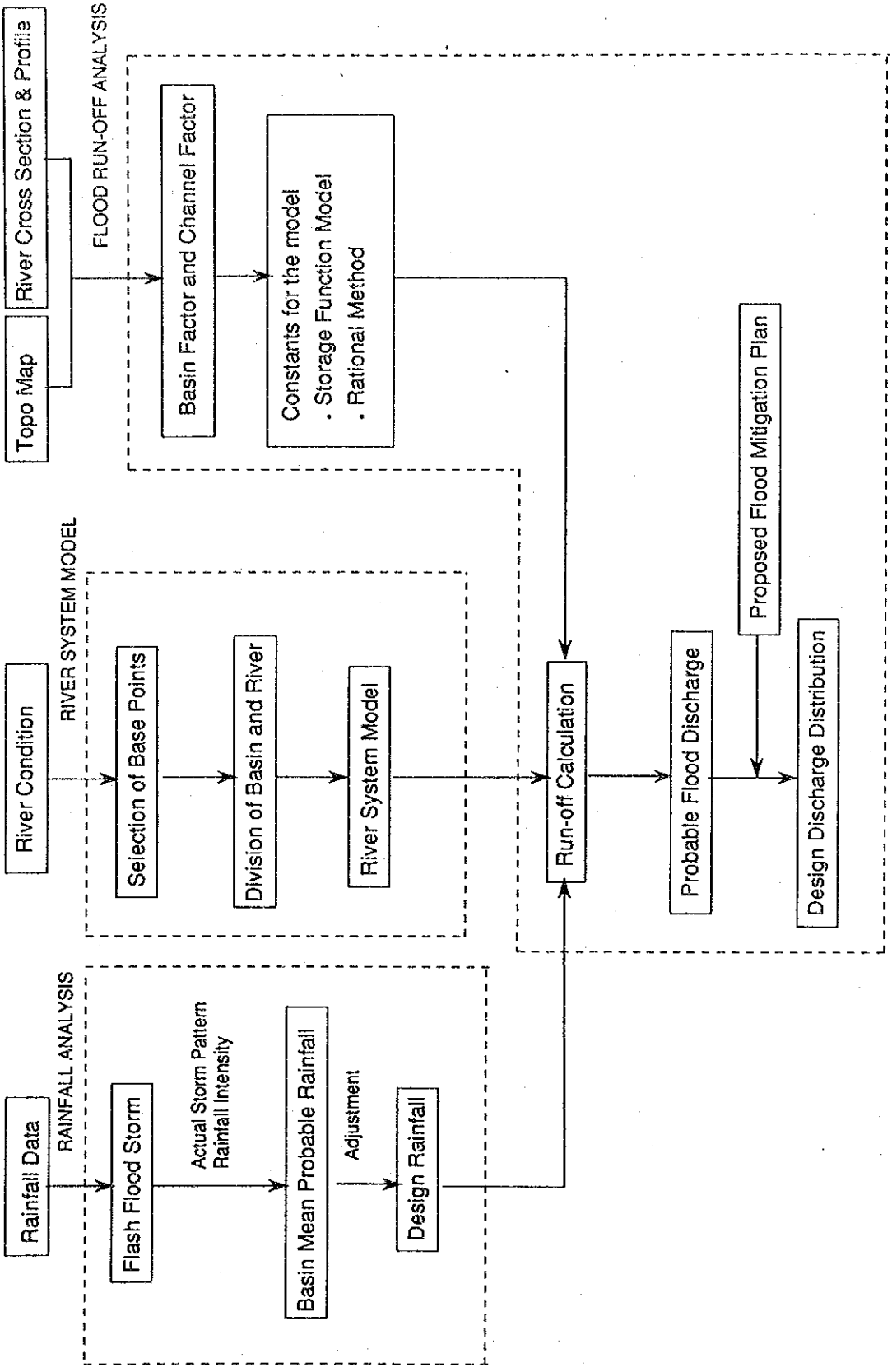


FIG. G-9 **GENERAL FLOW CHART OF FLOOD RUN-OFF ANALYSIS**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

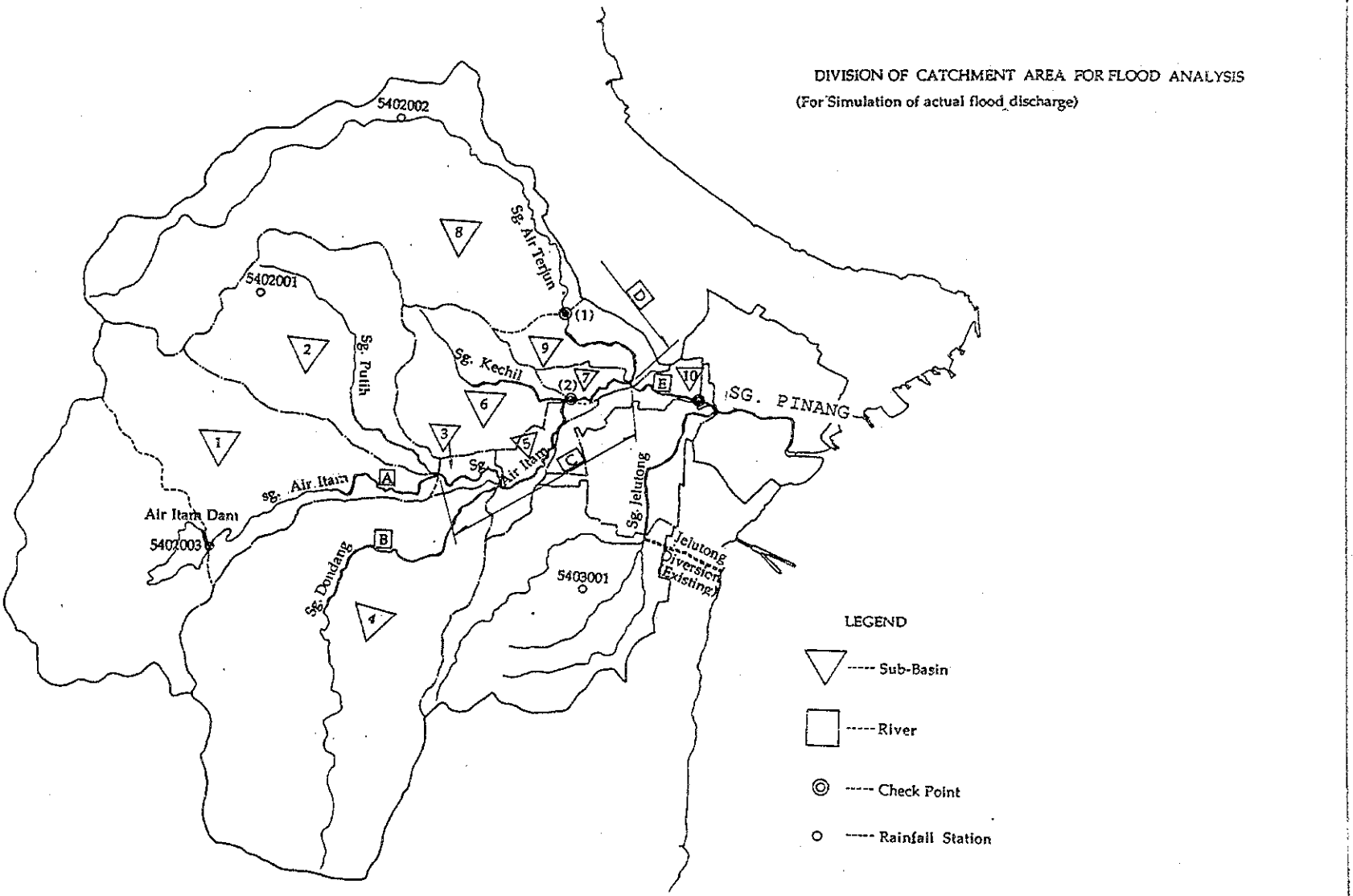


FIG. G-10-1	**DIVISION OF CATCHMENT AREA FOR FLOOD ANALYSIS (FOR SIMULATION OF ACTUAL FLOOD DISCHARGE)**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

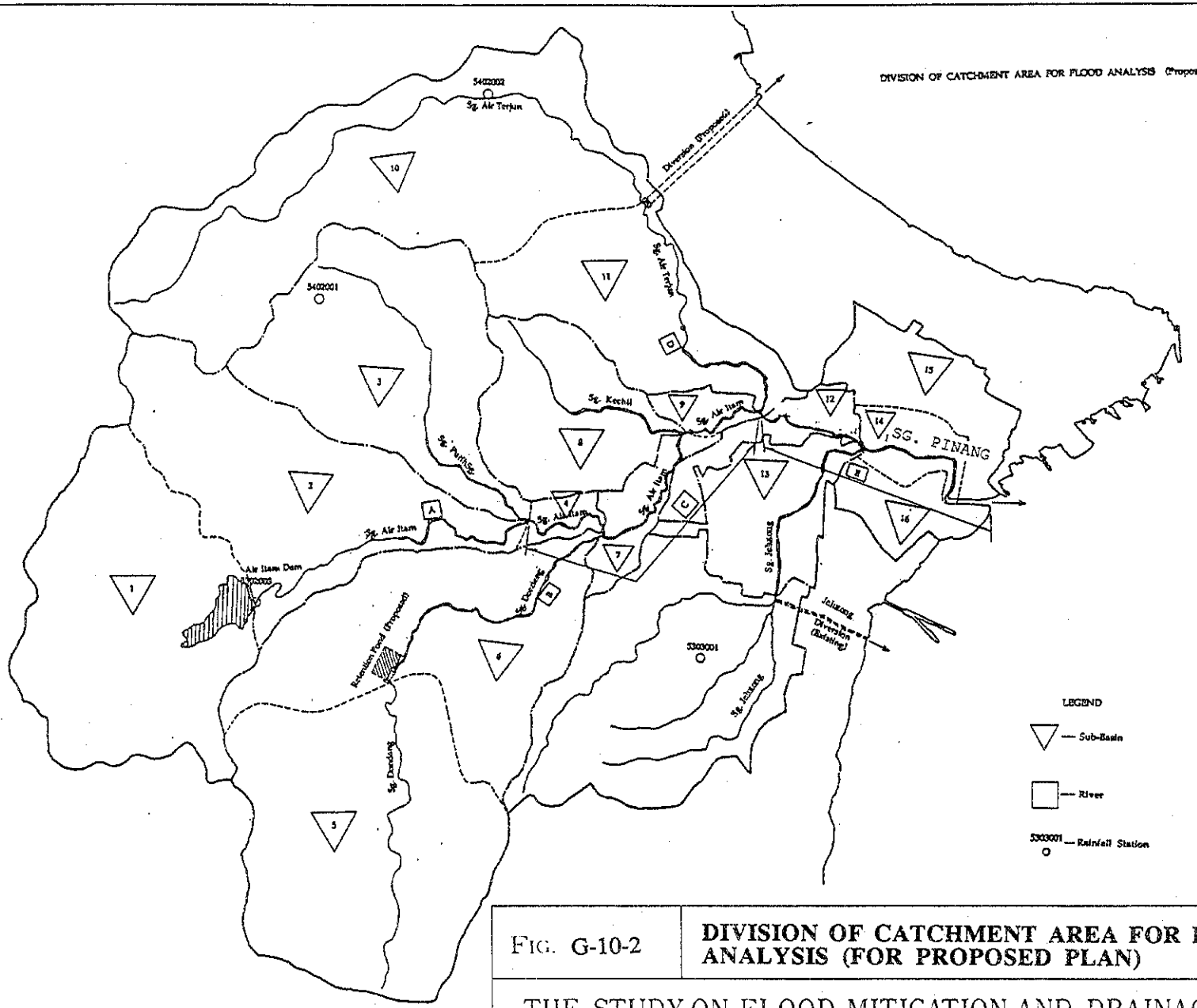


FIG. G-10-2 **DIVISION OF CATCHMENT AREA FOR FLOOD RUN-OFF ANALYSIS (FOR PROPOSED PLAN)**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

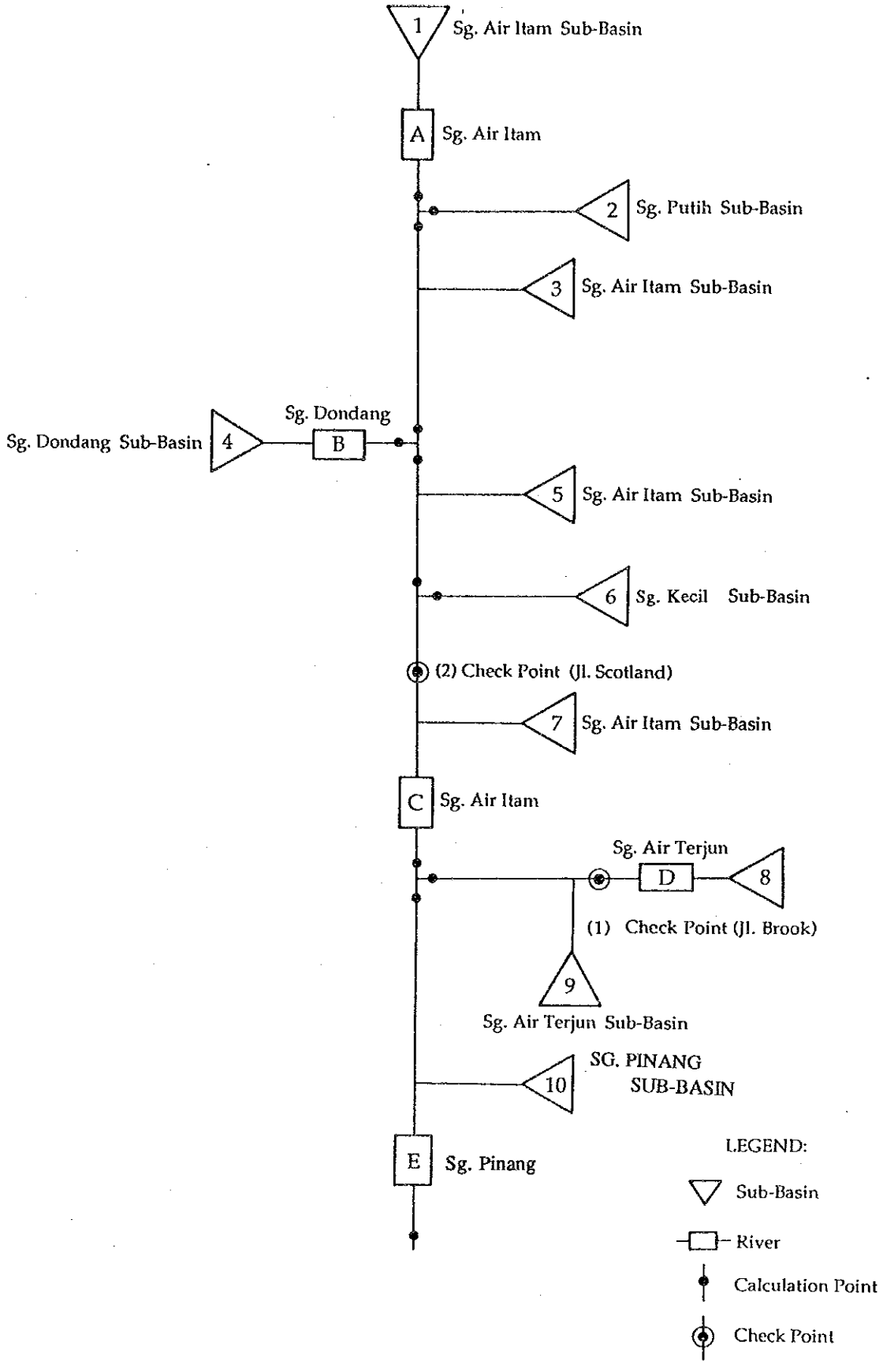


FIG. G-11-1 RIVER SYSTEM MODEL FOR FLOOD ANALYSIS (FOR SIMULATION OF ACTUAL FLOOD DISCHARGE)

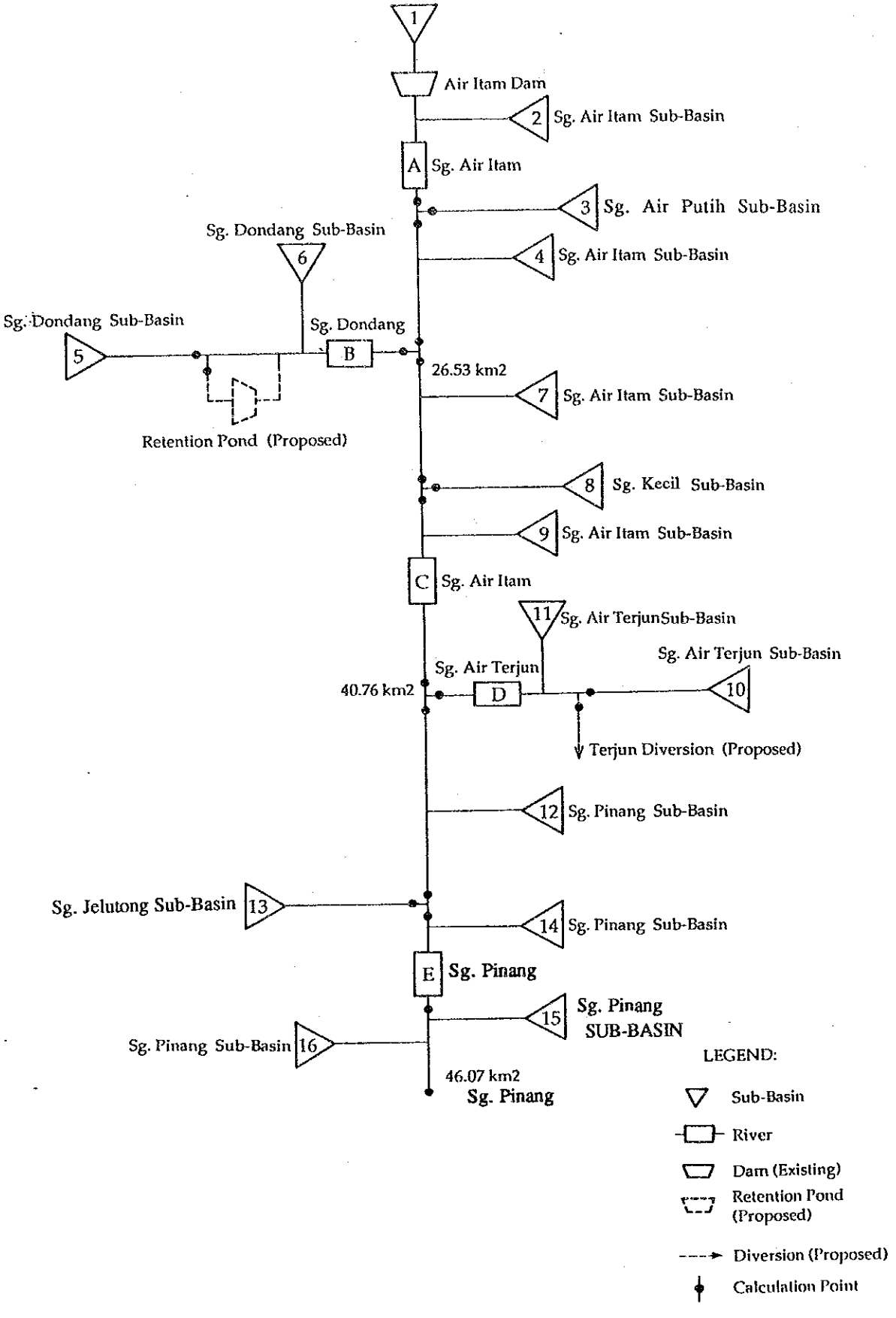


FIG. G-11-2 **RIVER SYSTEM MODEL FOR FLOOD RUN-OFF ANALYSIS (FOR PROPOSED PLAN)**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

Sg. Keluang River System Model

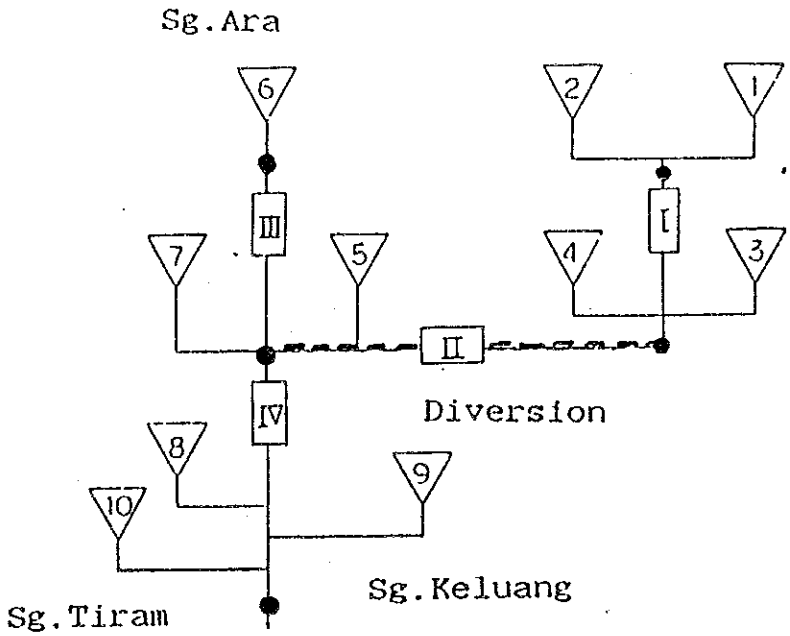
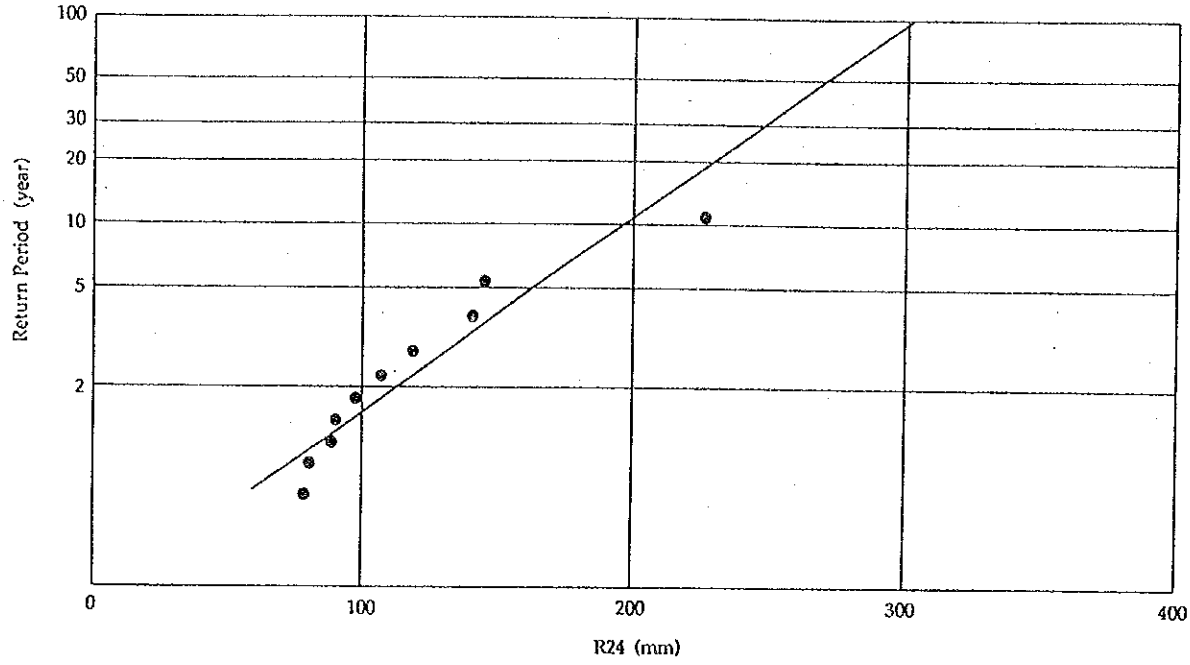


FIG. G-12	SG. KELUANG RIVER SYSTEM MODEL

Station No. 5303001
Gumbel Method
Data : 10 (1976 - 1987)



Station No. 5302003
Gumbel Method
Data ; 13 (1975 - 1987)

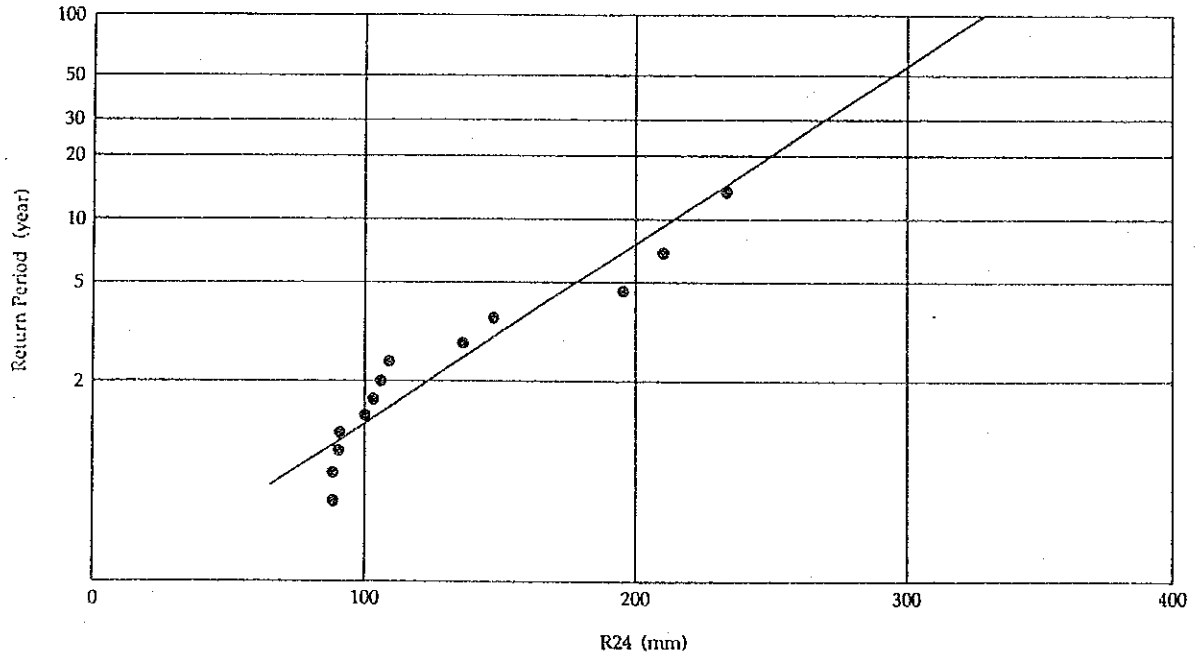
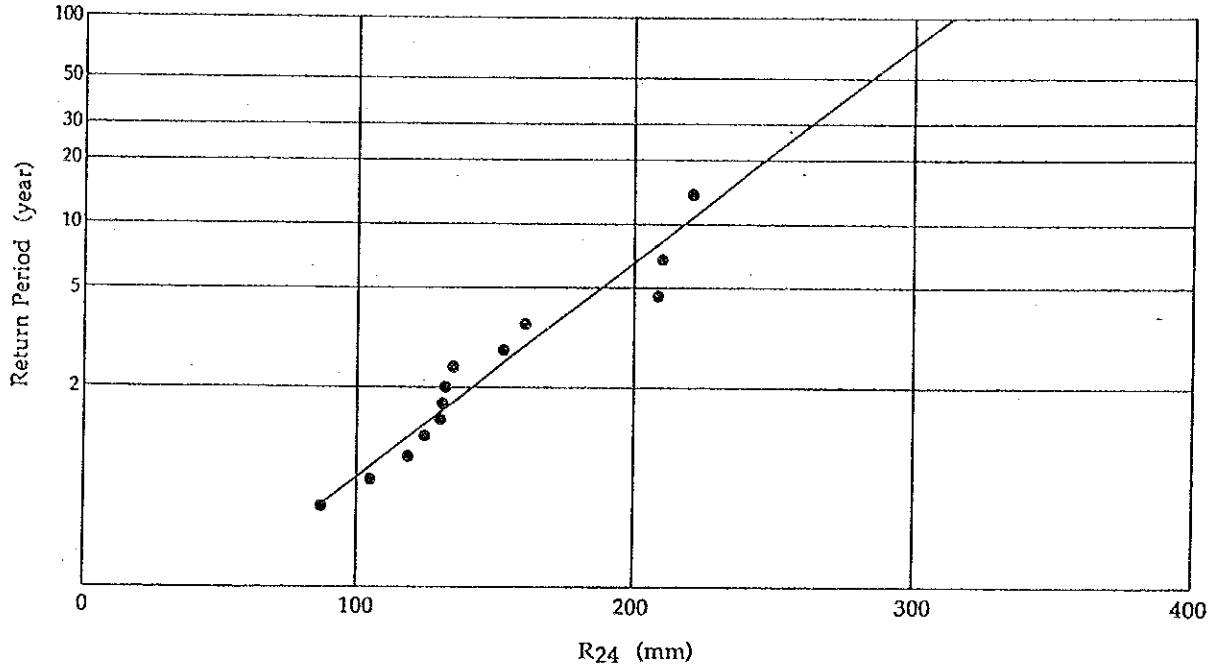


FIG. G-13 FREQUENCY CURVE OF 1 DAY RAINFALL (1)

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

Station No. 5402001
Gumbel Method
Data ; 13 (1975 - 1987)



Station No. 5402002
Gumbel Method
Data ; 13 (1975 - 1987)

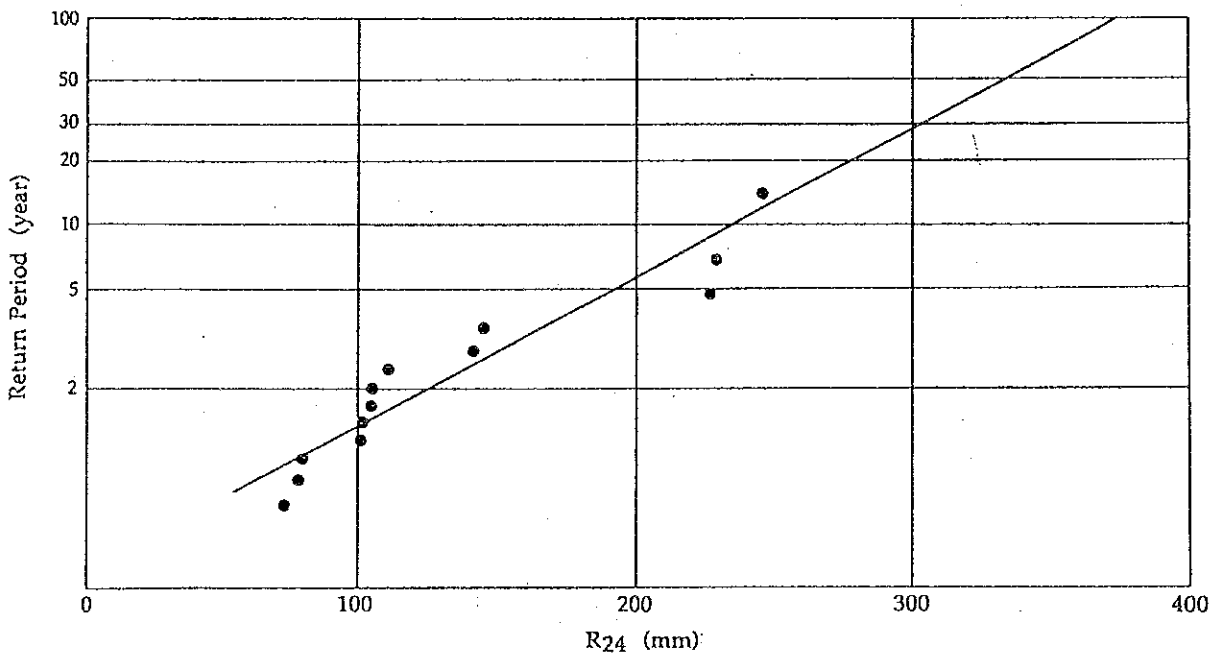


FIG. G-13 FREQUENCY CURVE OF 1 DAY RAINFALL (2)

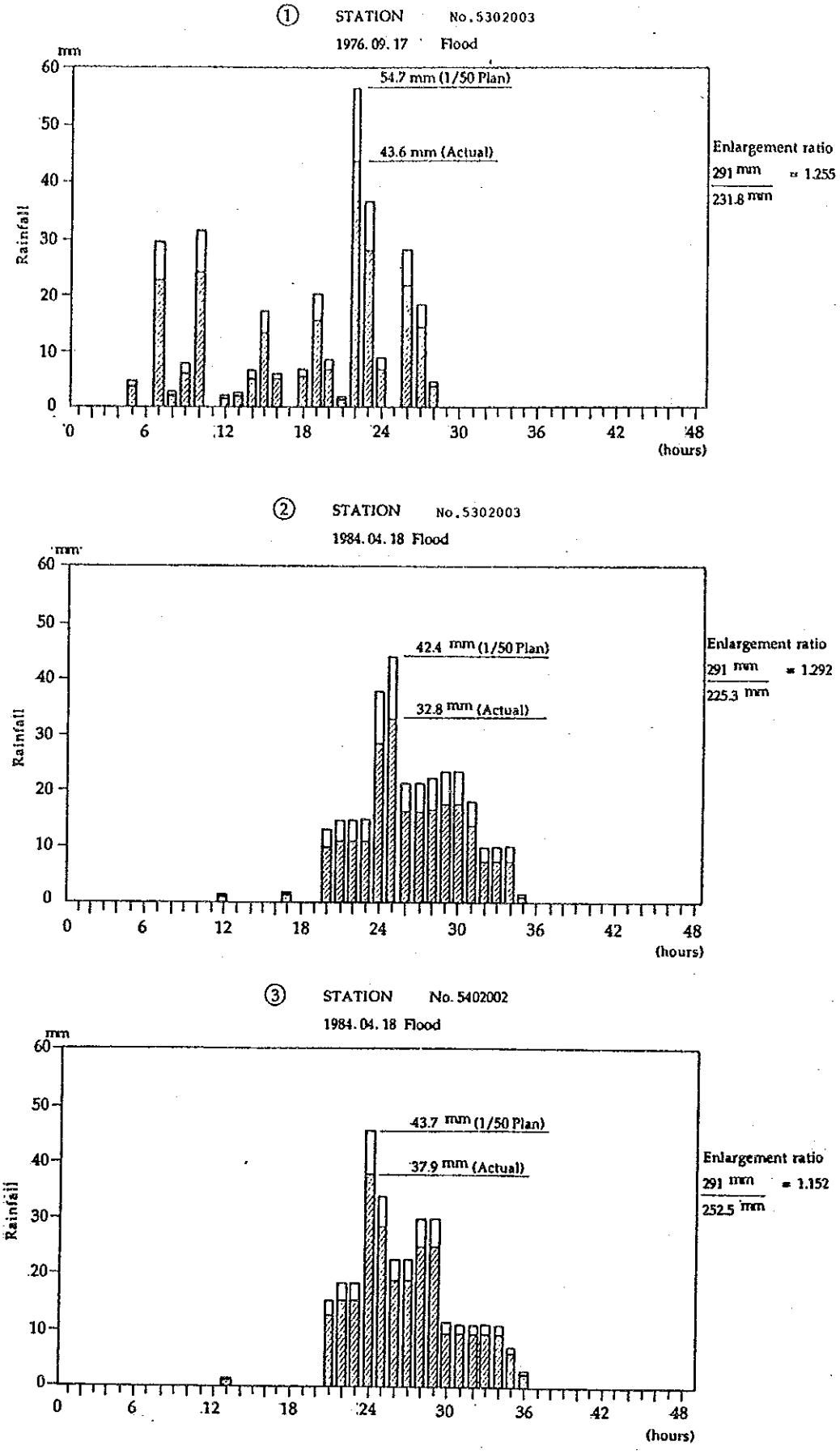


FIG. G-14 ACTUAL HYETOGRAPH IN 1976 AND 1984 FLOODS

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

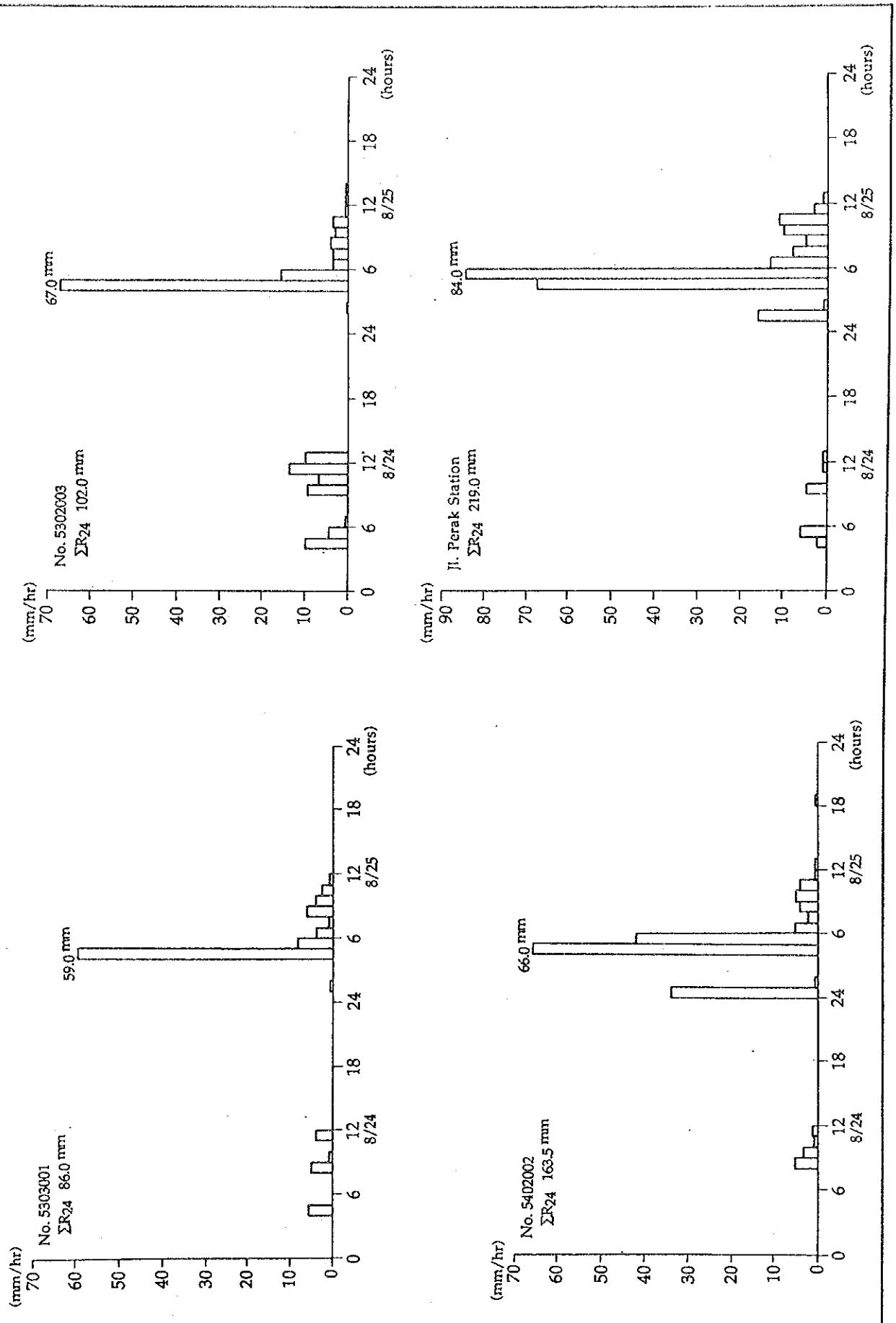


FIG. G-15-1 HOURLY HYETOGRAPH IN AUGUST 1989

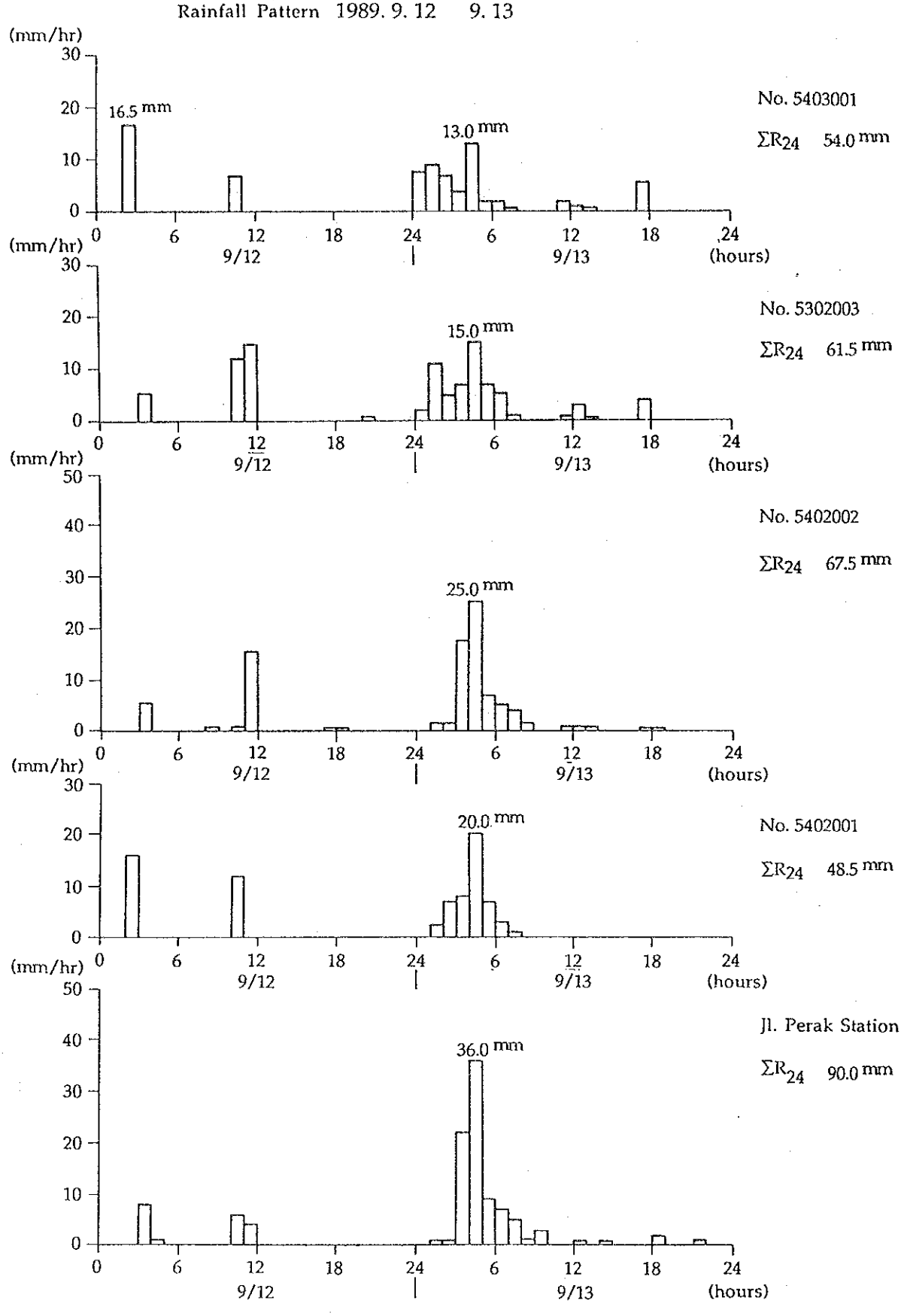


FIG. G-15-2 HOURLY HYETOGRAPH IN SEPTEMBER 1989

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

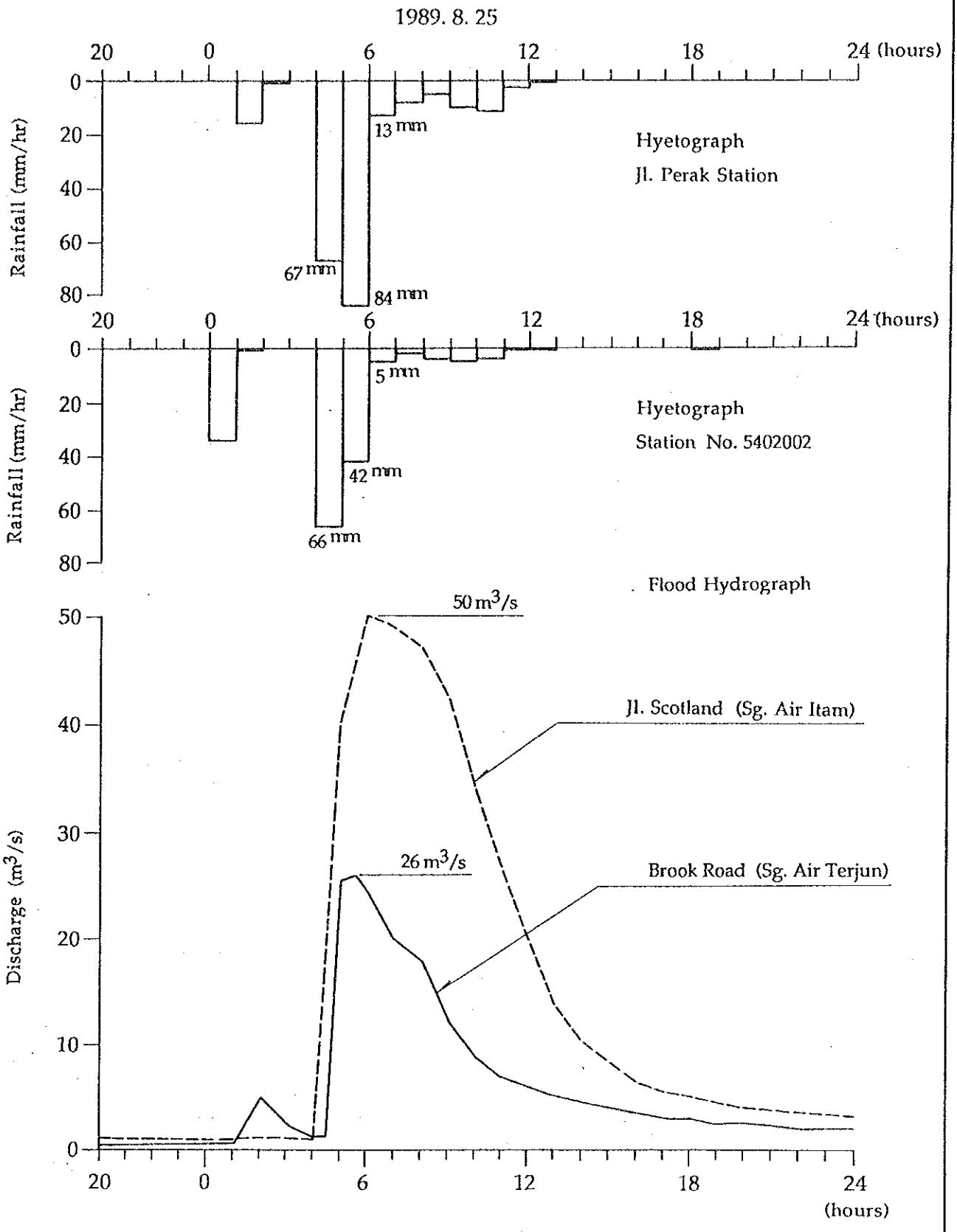


FIG. G-16-1 OBSERVED FLOOD HYDROGRAPH IN AUGUST 1989

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

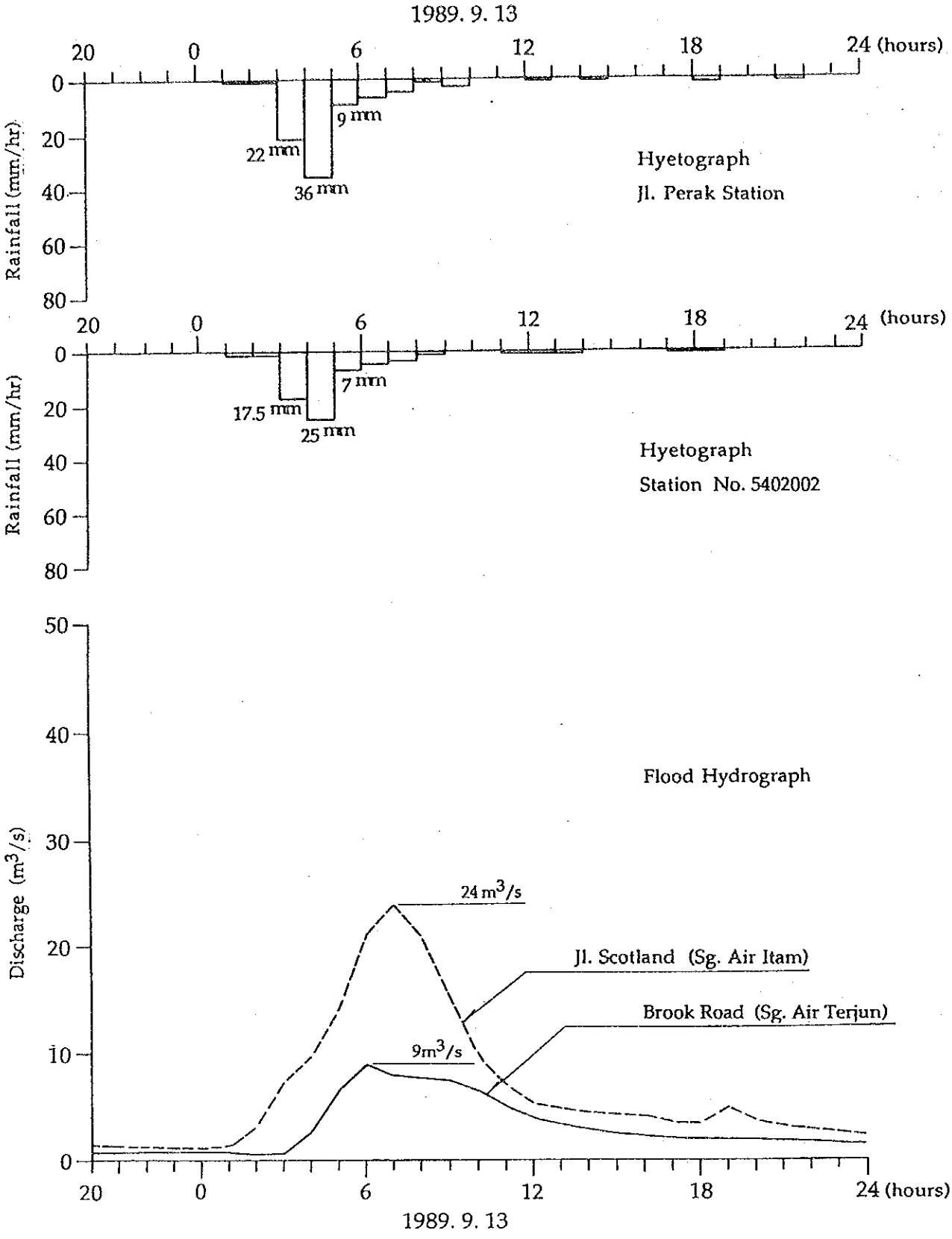
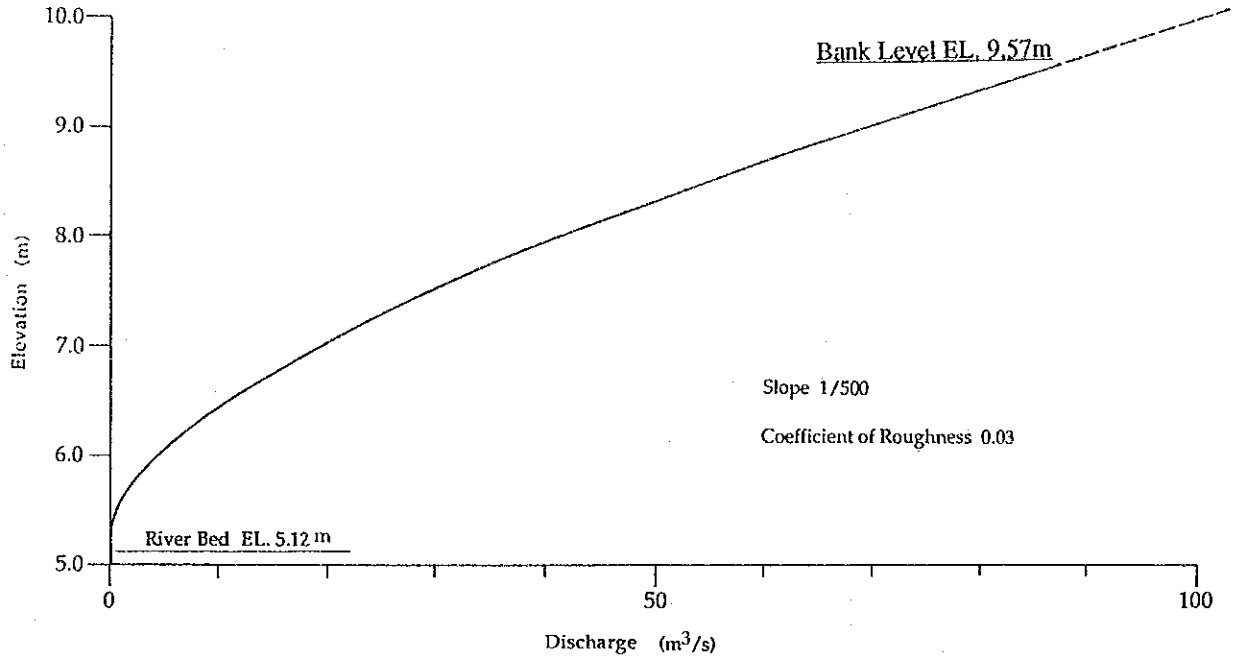


FIG. G-16-2 OBSERVED FLOOD HYDROGRAPH IN SEPTEMBER 1989

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

Sg. Air Terjun [Brook Road] CH. 1657



Sg. Air Itam [Jln. Scotland] CH. 900, (CHR 1025)

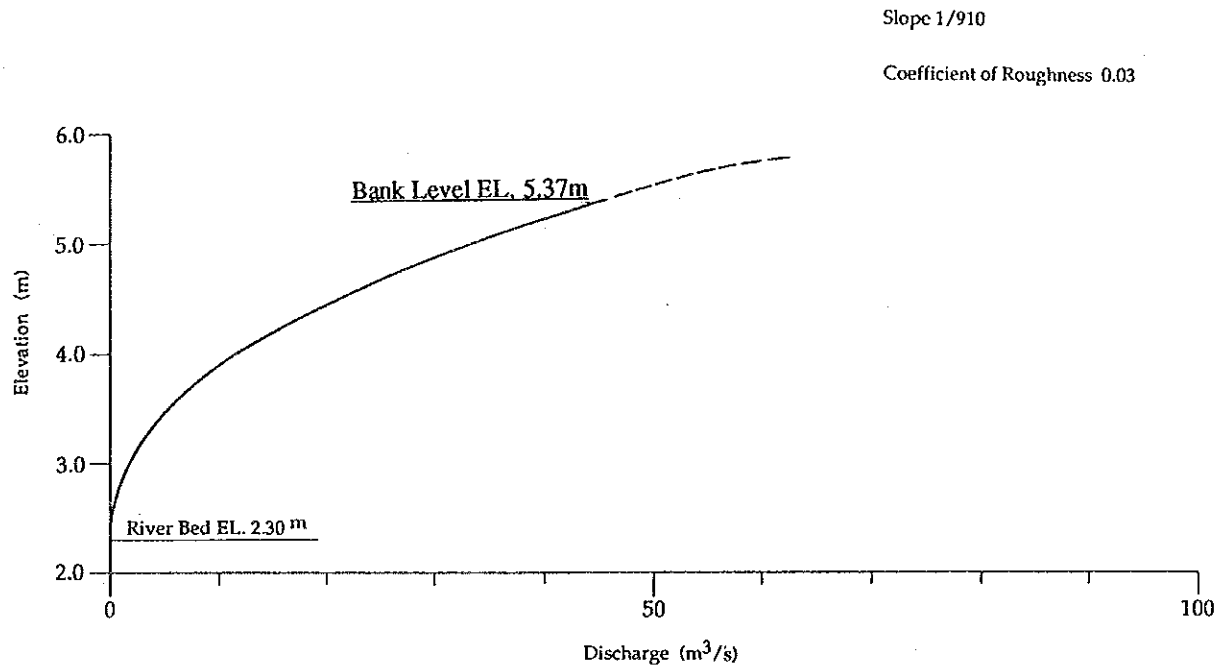
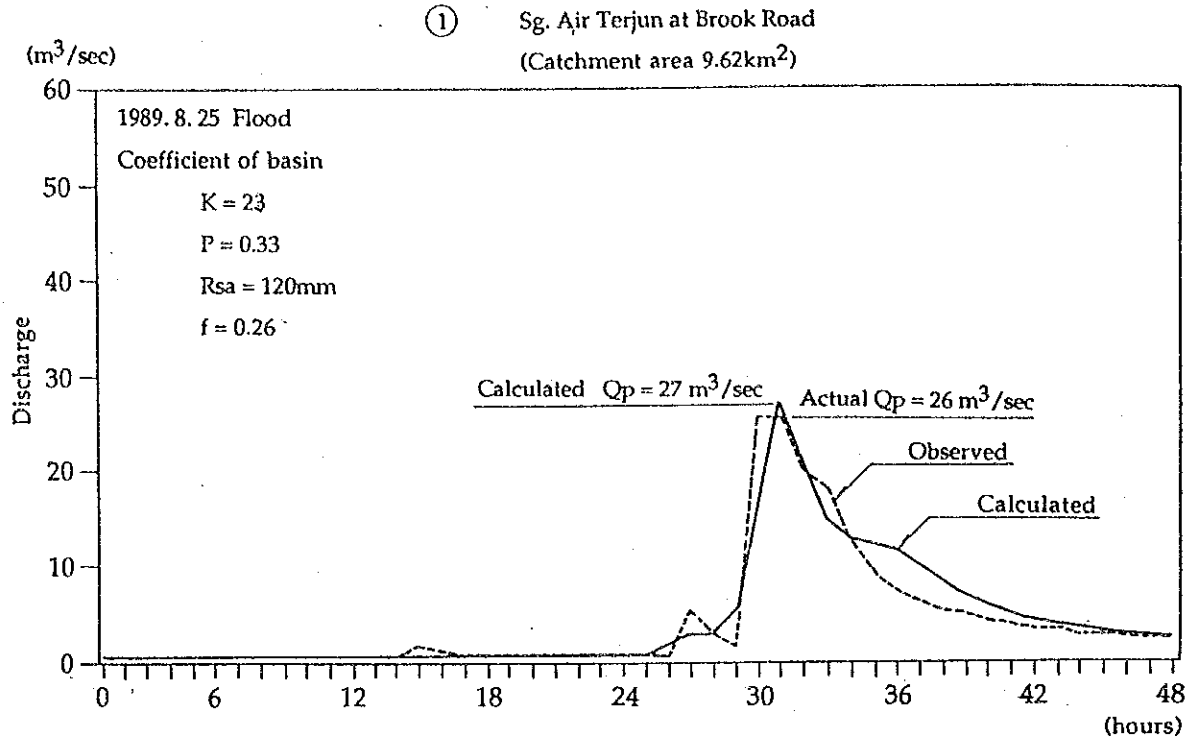


FIG. G-17 **RATING-CURVE AT JLN. SCOTLAND AND BROOK ROAD**



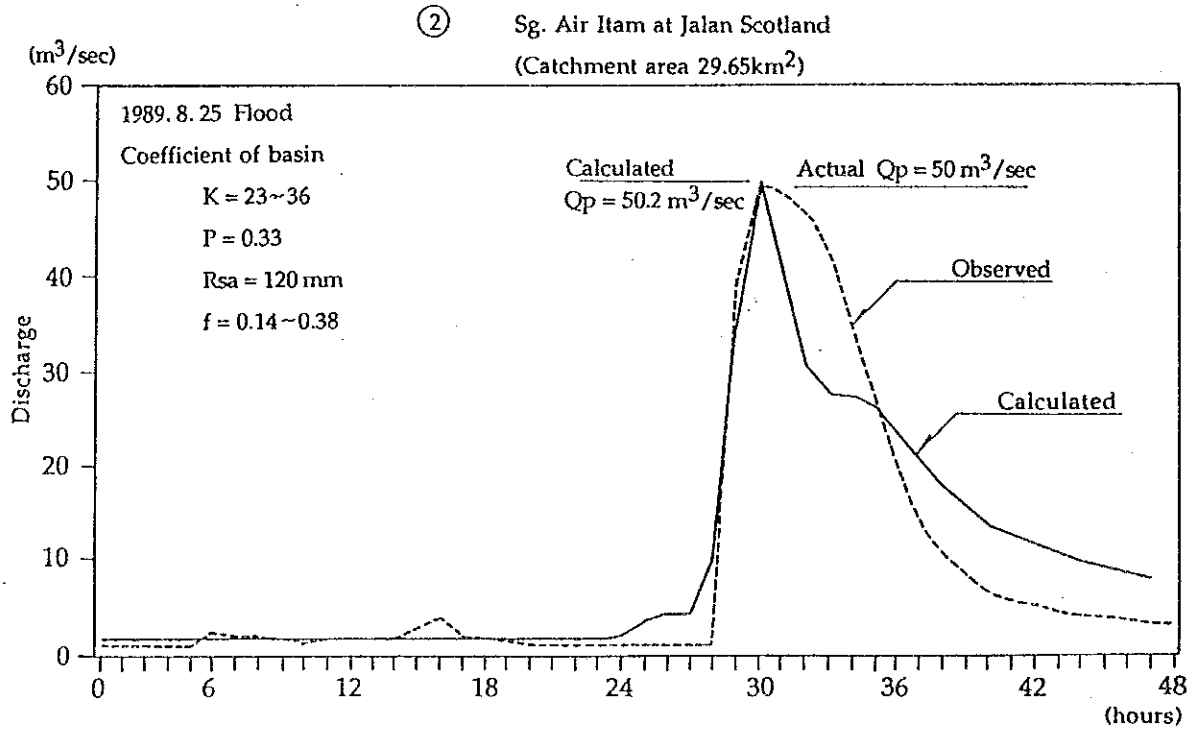


FIG. G-18 OBSERVED AND SIMULATED FLOOD HYDROGRAPH

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

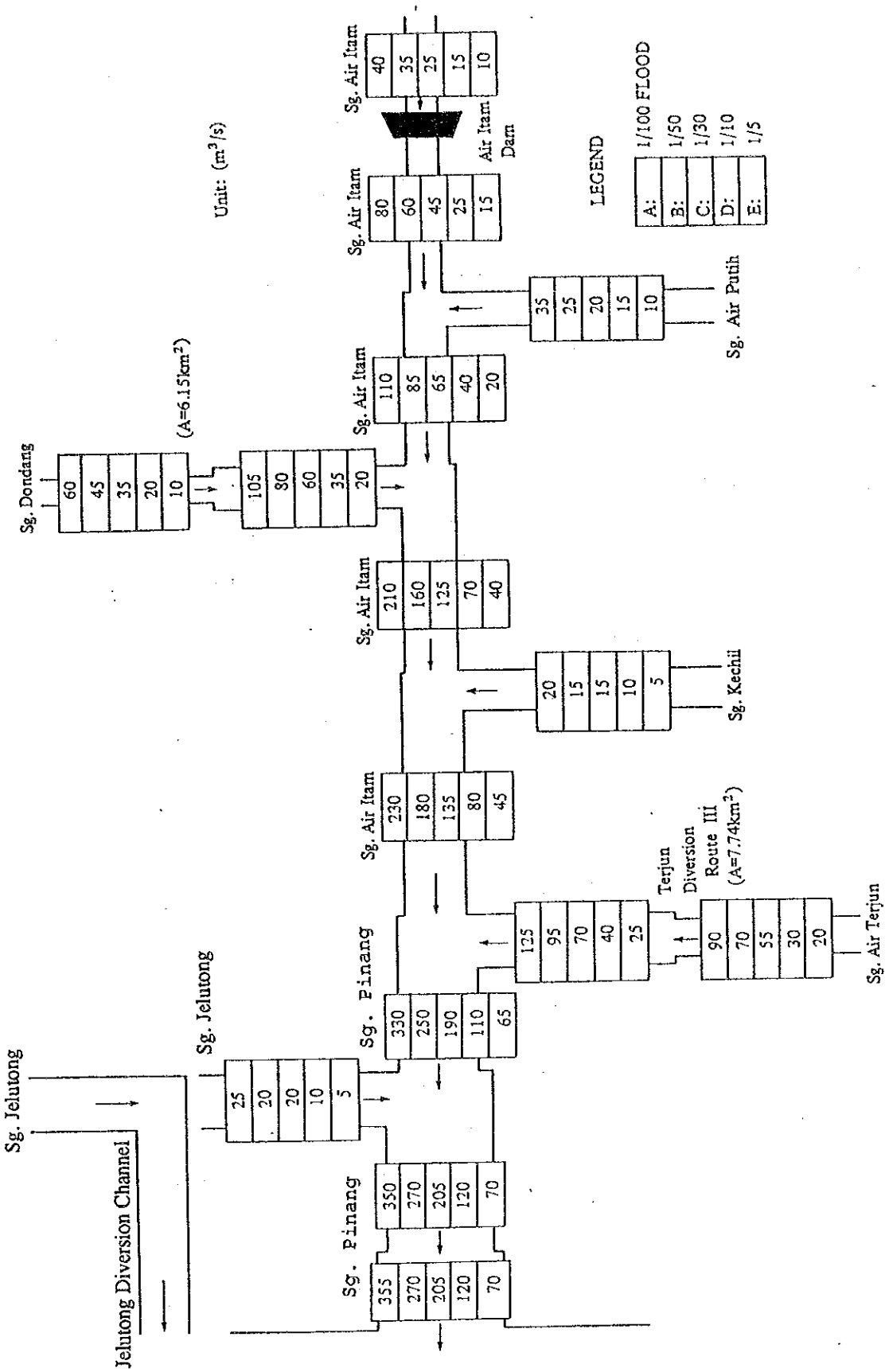


FIG. G-19 PROBABLE FLOOD DISCHARGE DISTRIBUTION

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

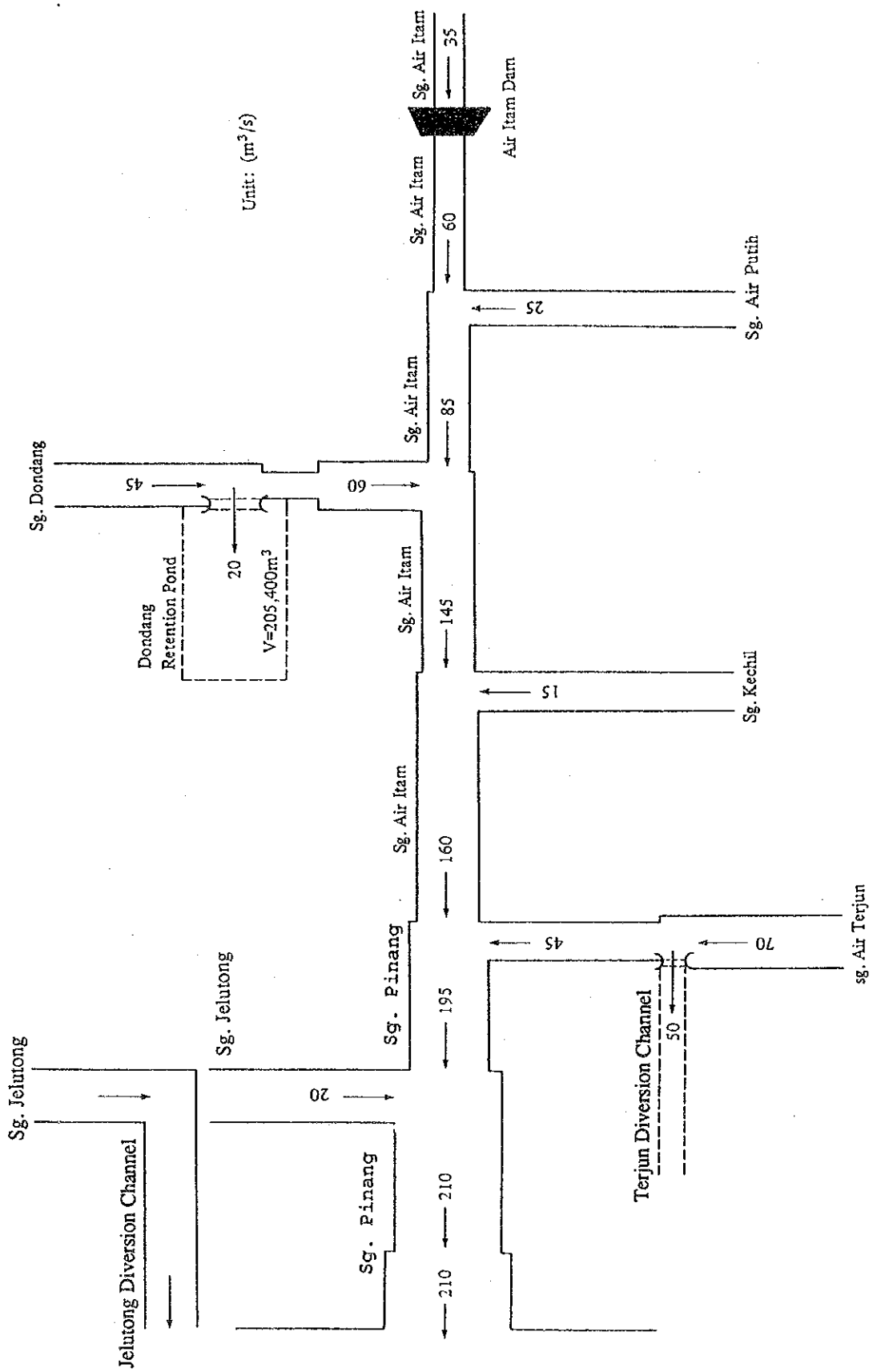
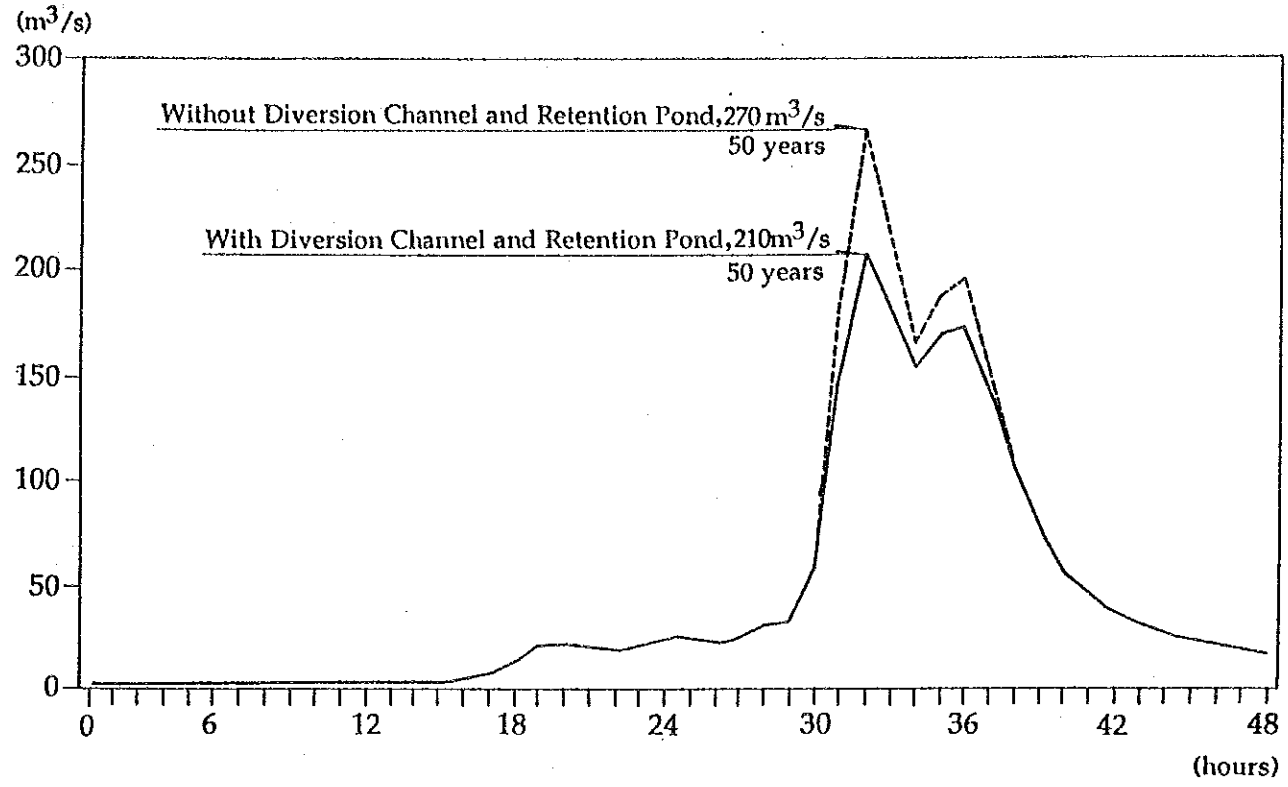


FIG. G-20 DESIGN FLOOD DISCHARGE DISTRIBUTION

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



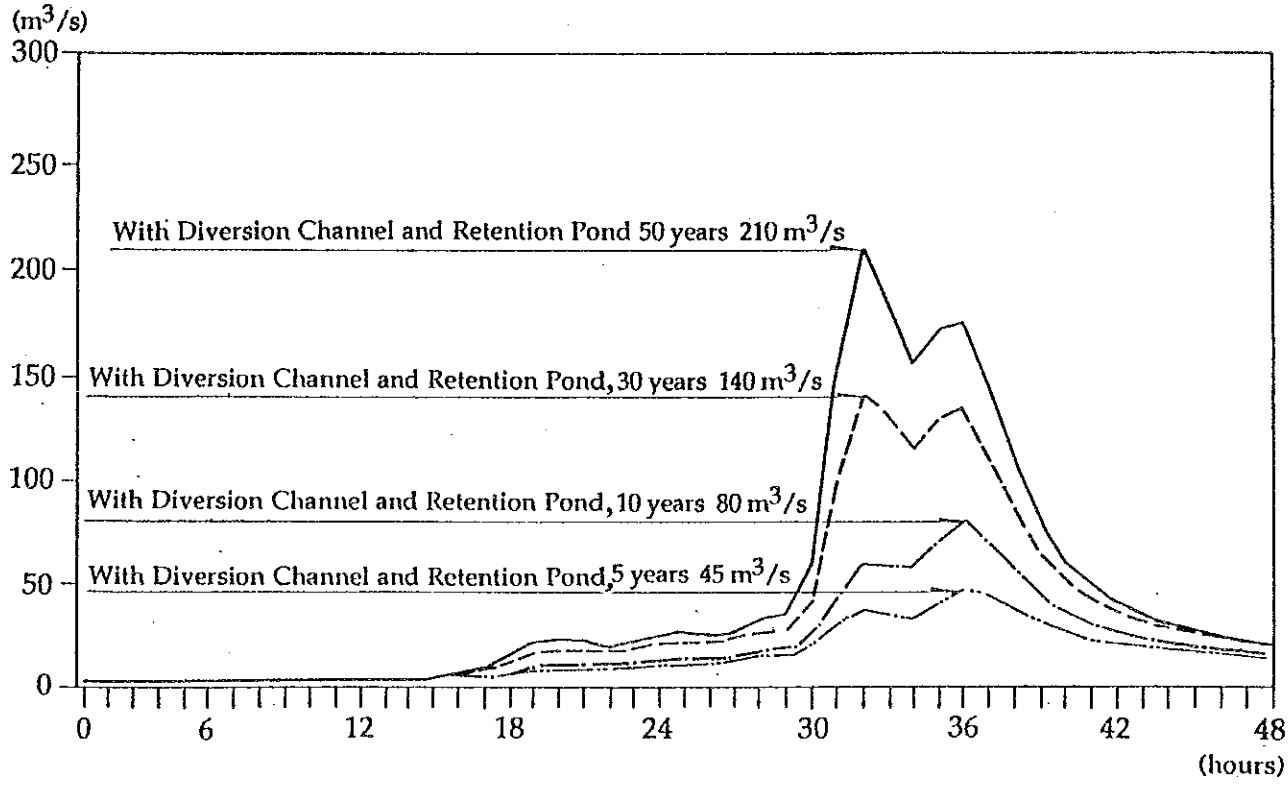


FIG. G-21	PROBABLE FLOOD HYDROGRAPH AT RIVER MOUTH

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

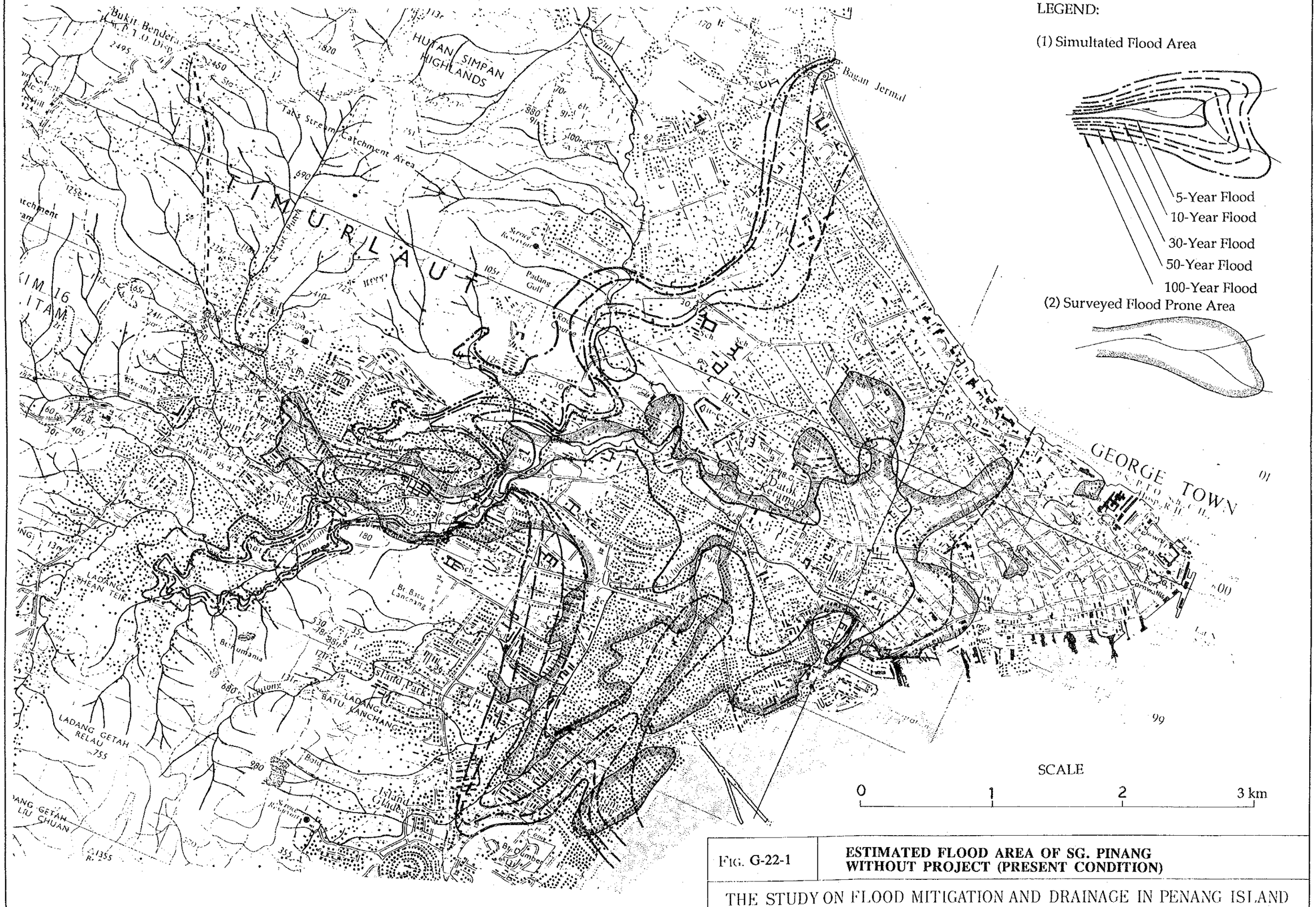


FIG. G-22-1	**ESTIMATED FLOOD AREA OF SG. PINANG WITHOUT PROJECT (PRESENT CONDITION)**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

JICA

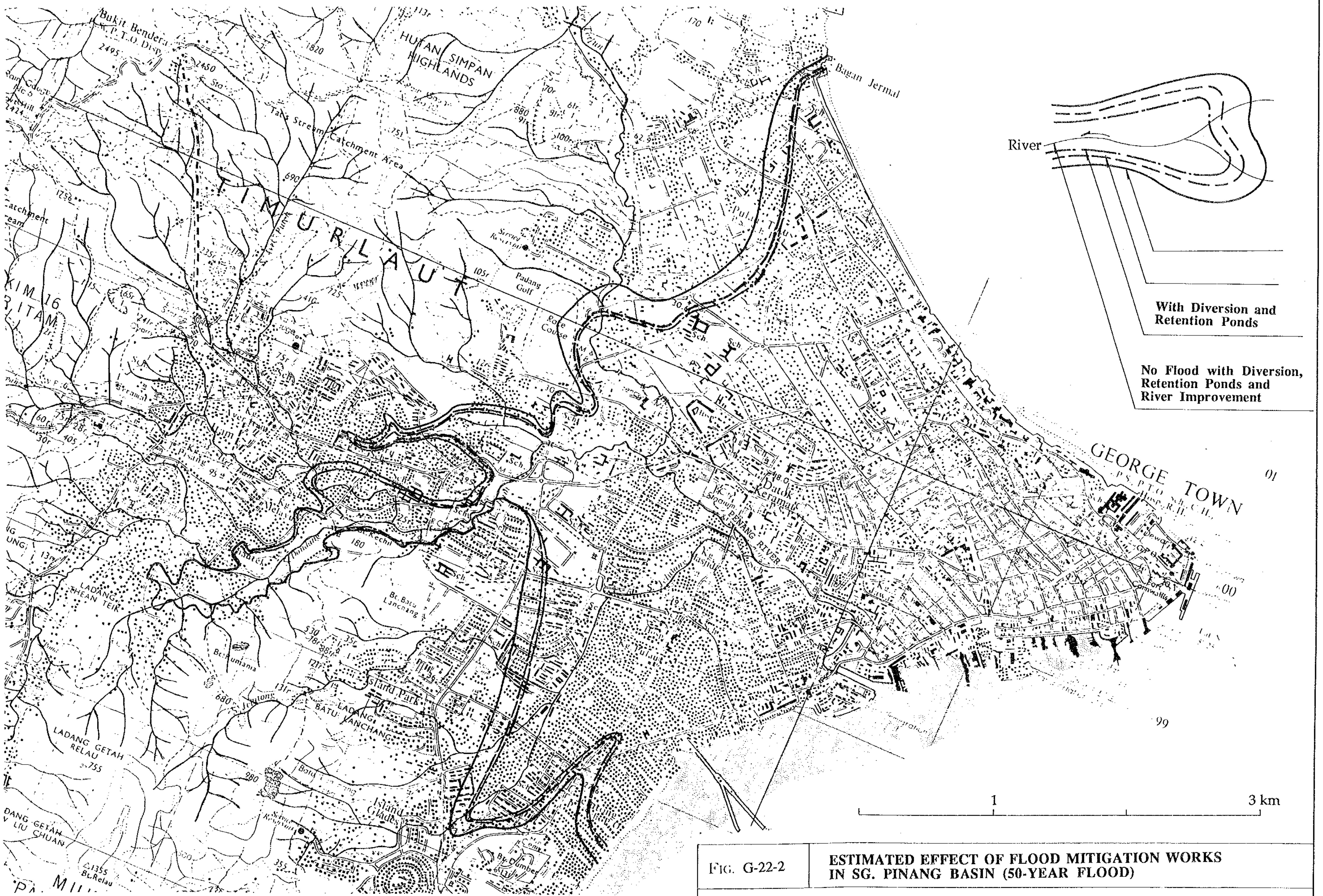
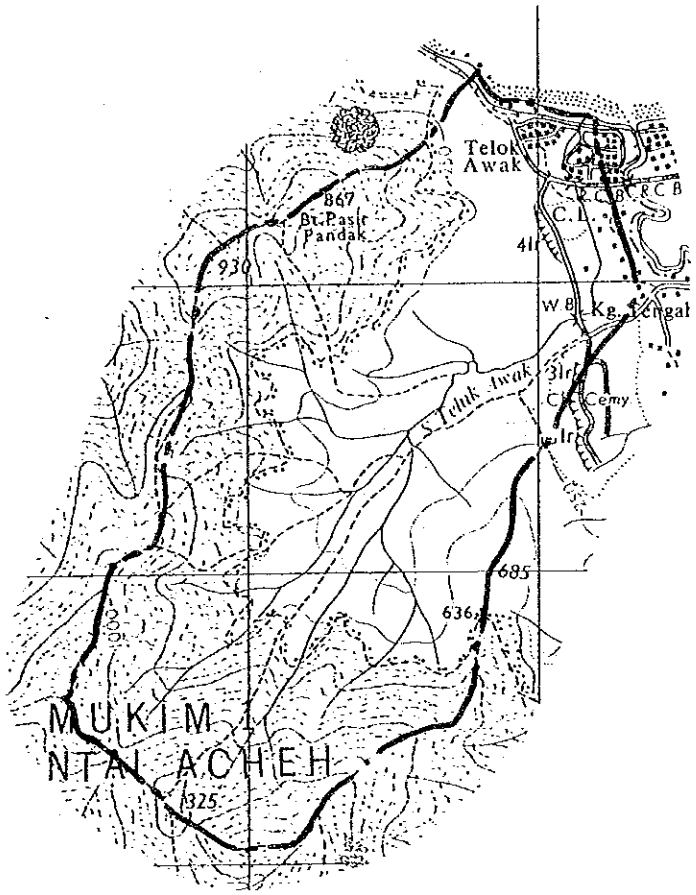


FIG. G-22-2 **ESTIMATED EFFECT OF FLOOD MITIGATION WORKS IN SG. PINANG BASIN (50-YEAR FLOOD)**

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND

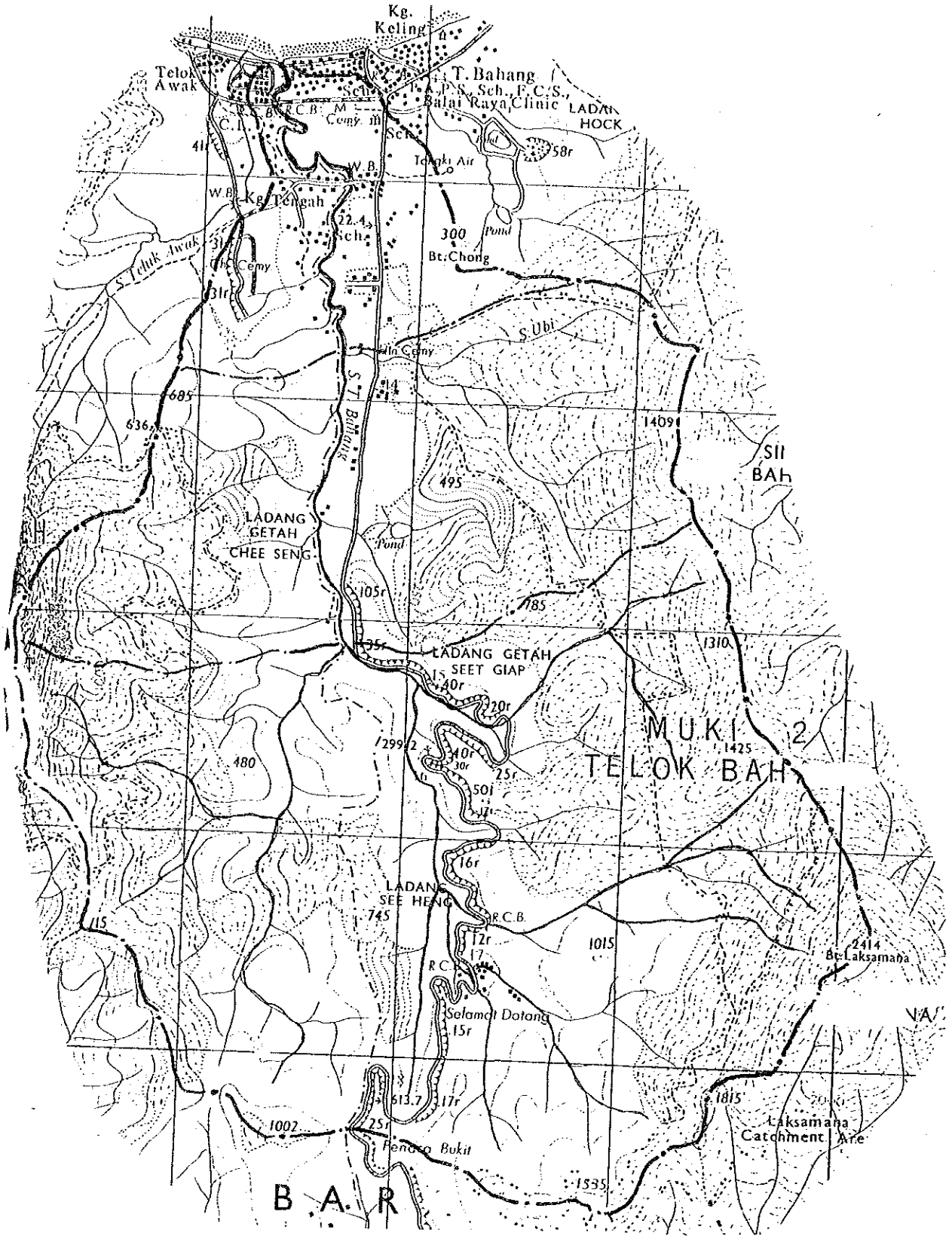
JICA



NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
2	Sg.Teluk Awak	: 295	: 16	: 17	: 19	: 21	: 22

FIG. G-23	CATCHMENT OF SG. TELUK AWAK

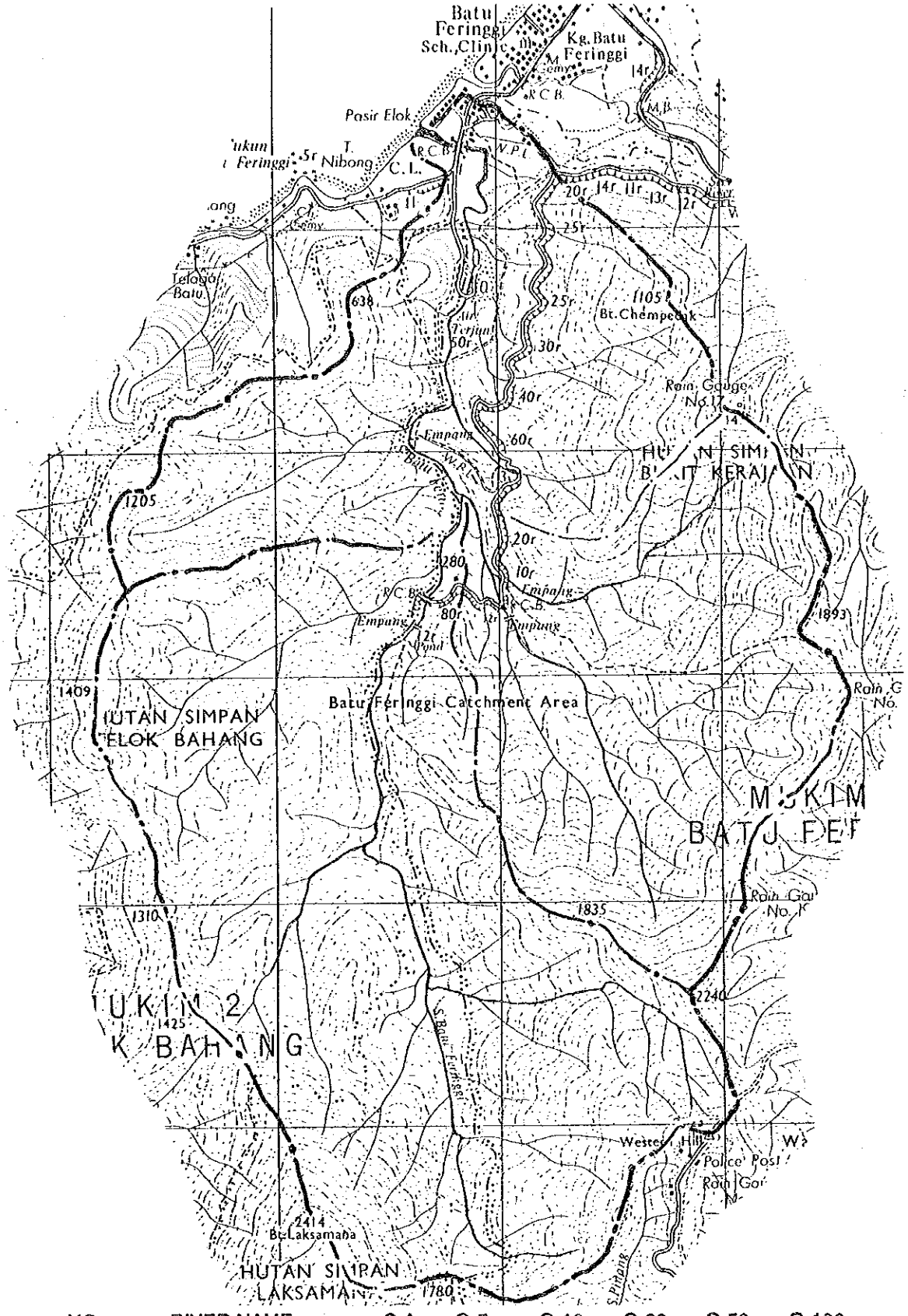
THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
3	Sg.Teluk Bahang	: 1230	: 39	: 44	: 48	: 52	: 56

FIG. G-24 CATCHMENT OF SG. TELUK BAHANG

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND



NO	RIVER NAME	: C.A	: Q-5	: Q-10	: Q-20	: Q-50	: Q-100
4	Sg.Batu Ferringghi	: 1127	: 40	: 45	: 49	: 53	: 57

FIG. G-25 CATCHMENT OF SG. BATU FERRINGGHI

THE STUDY ON FLOOD MITIGATION AND DRAINAGE IN PENANG ISLAND