HYDROLOGICAL CHARACTERISTICS OF SARAWAK, MALAYSIA

VOLUME III

TOSHIO TAKENOUCHI

JANUARY 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

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FOREWORD

The author has been working as a Colombo Plan Expert for the Drainage and Irrigation Department, Sarawak State, Malaysia, since April 1981. The job is mainly in the analysis of the Sarawak hydrological data available and the objective is to make available the useful hydrological information thus derived for the purpose of water resources planning, design and management in the State.

Recently, there are many occasions where Japanese river engineers have been invited to study on water resources in Southeast Asia. Generally speaking, most Japanese engineers have the experience and knowledge on hydrology obtained under the circumstances particular to Japan mostly. However, in cases when they are working in foreign countries, they should sometimes need to modify their knowledge previously obtained in their homeland to be adaptable to the different conditions in foreign countries.

As Sarawak is an equatorial country, it has its own unique hydrological characteristics which has not been fully studied in the past. In this last volume, six selected items related to the characteristics on rainfall in this State are studied. It is hoped that the information obtained from this study are useful to those interested in this field. For further reference, hydrological information on rainfall are illustrated in tables and figures as shown in the Appendix. It is quite regretted that the subjects related to discharge are not dealt in this volume due to the limited time of my appointment.

The author is very grateful to Mr. Foong Ka Nim, Director of Drainage and Irrigation Department, Sarawak State, Malaysia, for the permission to allow JICA to make a reproduction of the author's report presented to the Department. This publication which is the third volume of the author's work is also to be distributed to the river engineers and researchers concerned in Japan, with the hope that there will be future exchange of technical information between the two countries.

November 1983

Toshio Takenouchi

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REPORT 9 VARIATION IN THE VALUES OF 10-MINUTE RAINFALL MEASURED IN RAINY SEASON

Abstract

Pulsatory features of heavy rainfall observed during rainy season are studied by using the rainfall data obtained in Kuching, Sarawak.

Durations between successive peaks in the pulsation in Kuching range from one to two hours which are almost same as the ones obtained in Japan during the "Shuchu-gou (Torrential rainfall)".

It should be noted, however, that hourly rainfall determined through the records are not accurate if the clock contained in the recorder does not keep correct time. Variation of rainfall intensity caused by the abnormal running of the clock is also studied by checking the values of 10-minute rainfall determined tentatively under the assumptions that the clock has already lost certain minutes at the time of recording.

1. RAINFALL DATA USED FOR THE ANALYSIS

It is needless to say that detailed values of rainfall can be obtained only through the data which were recorded at relatively high speed of chart winding. The rain gauge installed at the Nurses' Home Experimental Basin, Kuching, Sarawak has been operating at a chart speed of 18 mm/hr. The rainfall records taken for four days from 23rd to 26th January 1983 are shown in Fig.–1. From these records, values of 10-minute rainfall were determined over four days. The values of 10-minute rainfall determined from the records on 24th Jan. 1983 are shown in Fig.–2. Here, it should be noted that 24th January was the heaviest rainy day among the four days mentioned above.

2. VARIATION OF HEAVY RAINFALL PATTERN

On 24th January 1983, heavy rain kept falling for about 6 hours, yielding total rainfall of 190 mm. Upper diagram of Fig.–2 shows the variation of hourly rainfall and the lower diagram shows the variation of 10-minute rainfall. Values of both hourly and 10-minute rainfall were determined from the records of that day. Hourly rainfall on that day ranged from 25 mm/hr to 43 mm/hr.

On the other hand, four peaks can be observed in the variation of 10-minute rainfall, although six peaks may be recognized in total if small peaks are also counted. Duration and intensity of rainfall determined from each variation diagram are listed as follows:

No.	Duration between Successive peaks	Total rainfall fallen within each duration (mm)
1	1 hr. 30 min.	44.5
2	30 min.	14
3	1 hr. 10 min.	51
4	20 min.	9
5	1 hr. 40 min.	49.5
6	50 min.	24
7	20 min.	3

3. FEATURES OF "SHUCHU-GOU (TORRENTIAL RAINFALL)" IN JAPAN

The region located between nearly 25° – 40° N in Japan is frequently hit by heavy rainfall during the end of "Bai-u (Rainy season)", although the area affected by it is limited.

Fig.–3 shows one of the rainfall records obtained during Shuchu-gou. The rain gauge used here has a recorder which prints out digital values of 1-minute rainfall in the unit of milimeter. The heavy rain kept falling for about 8 hours on that day. Within this period, 4 large peaks were observed whose duration ranged from one to two hours respectively. Careful observation of each peak further reveals that there exist minor pulsation whose durations range from 10 to 20 minutes.

4. COMPARISON OF RAINFALL PATTERNS OBTAINED IN KUCHING AND JAPAN

The records of rainfall obtained in Japan by a rain gauge which can give the values of 1-minute rainfall provide more detailed information on heavy rainfall data recorded in Kuching by a analogue recorder at a chart speed of 18 mm/hr.

The Shuchu-gou during Bai-u season in Japan is caused by the intensive activity of convection in the front. In general, many groups of cumlonimbus bring heavy rainfall periodically.

It seems that the heavy rainfall in the tropical area may be caused by similar mechanism to that of Shuchu-gou in Japan, although frequency of heavy rainfall in the tropical area is much higher. In these two cases, duration of heavy rainfall is about 10 hours, and several peaks appear within this period whose durations range from one to two hours respectively. In rainy season (or Bai-u), Shuchu-gou may occurr in any place within the region between nearly 25° – 40° N in Japan. Similarly, heavy rainfall such as the one observed in January 1983 in Kuching can possibly occurr in any place in Sarawak, if the meteorological conditions of producing such an intensive convection are satisfied.

5. EFFECTS OF THE TIMER'S DELAY TO THE VALUES OF RAINFALL INTENSITY

It may be impossible to get accurate time variations of rainfall from the rainfall recorders as long as a spring driven clock is used as a timer in a rain gauge. Thus, hydrologists cannot get rid of this problem whenever they analyse the records of rainfall obtained by rain gauges in which spring driven clocks are used as their timer. However, this problem is going to be solved by using a quartz clock in recorder as a timer.

It is pointed out that the values of hourly rainfall determined from the records which were obtained by ordinary rain gauge is somehow different from the one determined from the records which were obtained by new type of rain gauge with quartz clock.

In order to estimate how much difference is yielded between the values of hourly rainfall in these two cases, the following calculation was made in trial by using the records of heavy rainfall recorded from 23rd January to 26th January 1983 in Kuching.

Five values of hourly rainfall were determined from these records by assuming that clock had lost 10 minutes at each case of the determination.

Fig.–4 shows the comparison of these calculation results with the ones determined from the records without assuming any delay of time. Calculation was made for 5 cases assuming that timer in the recorder had been delayed from 10 to 50 minutes, 10 minutes at each time respectively, when the records were obtained. From these comparisons, it can be noticed clearly that abnormal running of the clock will give a vital difference to the values of hourly rainfall. Clear difference is found especially in the variation pattern of hourly rainfall determined from the records on 24th January 1983, in which the number of peaks of hourly rainfall varies due to the length of delayed time.

The maximum value of hourly rainfall in each day was picked up from the daily distribution of hourly rainfall in Fig.–1. To evaluate the error which is possibly caused by the abnormal running of clock quantitatively, the following formula was used.

$$r_e = \frac{r_d - r_o}{r_o} \times 100\%$$

where r_d is the maximum value of hourly rainfall in one day determined by assuming that the clock had delayed for certain minutes, and r_o is the corresponding value determined by assuming that the clock ran without any delay. Thus, r_e means the relative ratio of r_d to r_o.

The extreme values of r_e in each day are listed in Table–2. The ratio ranges from +89% to -25% within 4 days. However, the ratio is reduced to the range from +13% to -10% in case of the second day in which the heaviest daily rainfall was recorded among four days. Judging from this fact, it may be concluded that abnormal running of a clock possibly causes the error of 20% at most in the peak values of hourly rainfall in case of heavy rainfall. In Japan, similar range of error was also obtained.

6. CONCLUSIONS

Through the analyses of heavy rainfall data recorded in both Kuching and Japan, the following facts were revealed:

(1) Durations between successive peaks appeared in the distribution of heavy rainfall range from one to two hours in both Kuching and Japan.

(2) Abnormal running of clock used in a rain gauge will cause an error of ±20% at most in the peak values of hourly rainfall if the length of delayed time is less than 50 minutes.

REFERENCE

S. Matsumoto: "Forecast on heavy rainfall" P. 30, June 1983 Monthly Bulletin of Public Works (in Japanese)

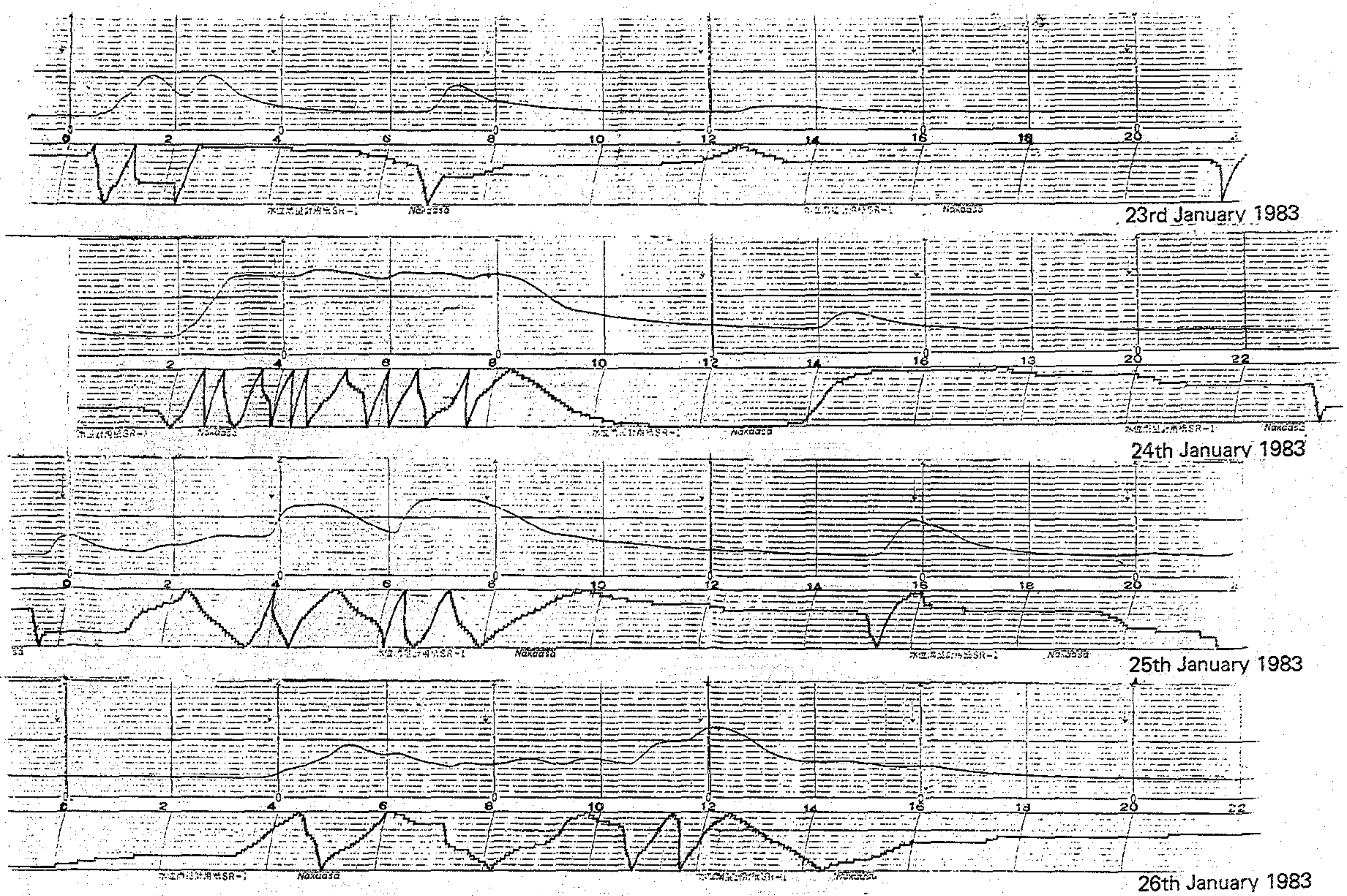


FIG.–1 RECORDS OF HEAVY RAINFALL OBTAINED IN THE PERIOD OF 23RD JANUARY TO 26TH JANUARY 1983 IN KUCHING

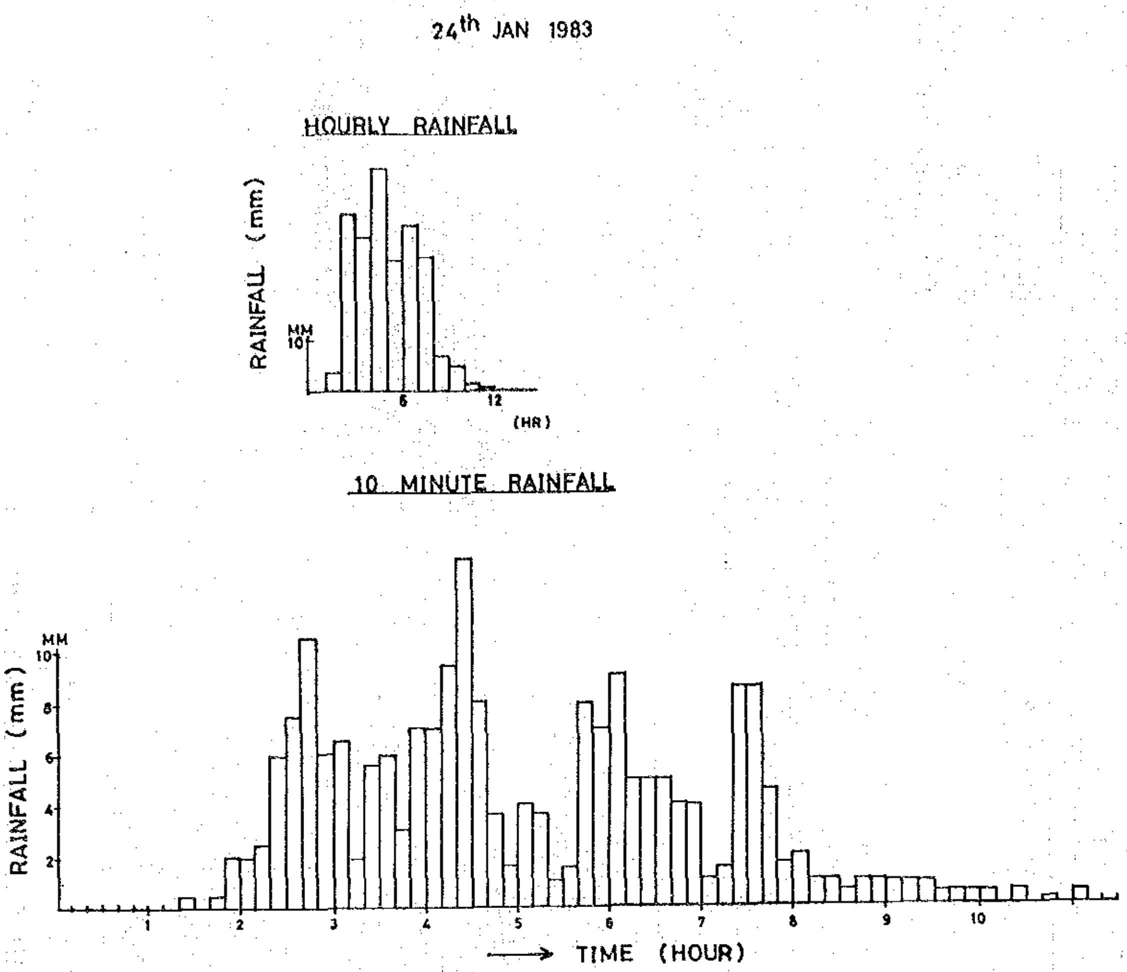


FIG.–2 TIME VARIATION OF 10-MINUTE RAINFALL AND HOURLY RAINFALL DETERMINED FROM THE RECORDS ON 24TH JANUARY 1983, IN KUCHING

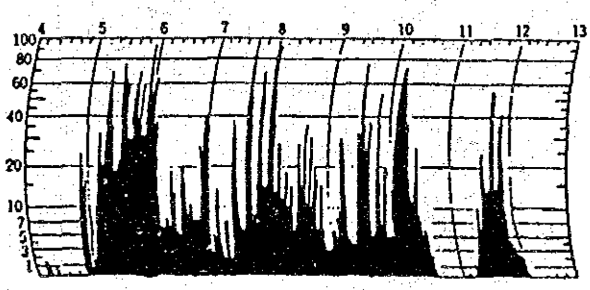


FIG.–3 AN EXAMPLE OF THE RECORDS OF "SHUCHU-GOU (TORRENTIAL RAINFALL)" IN JAPAN

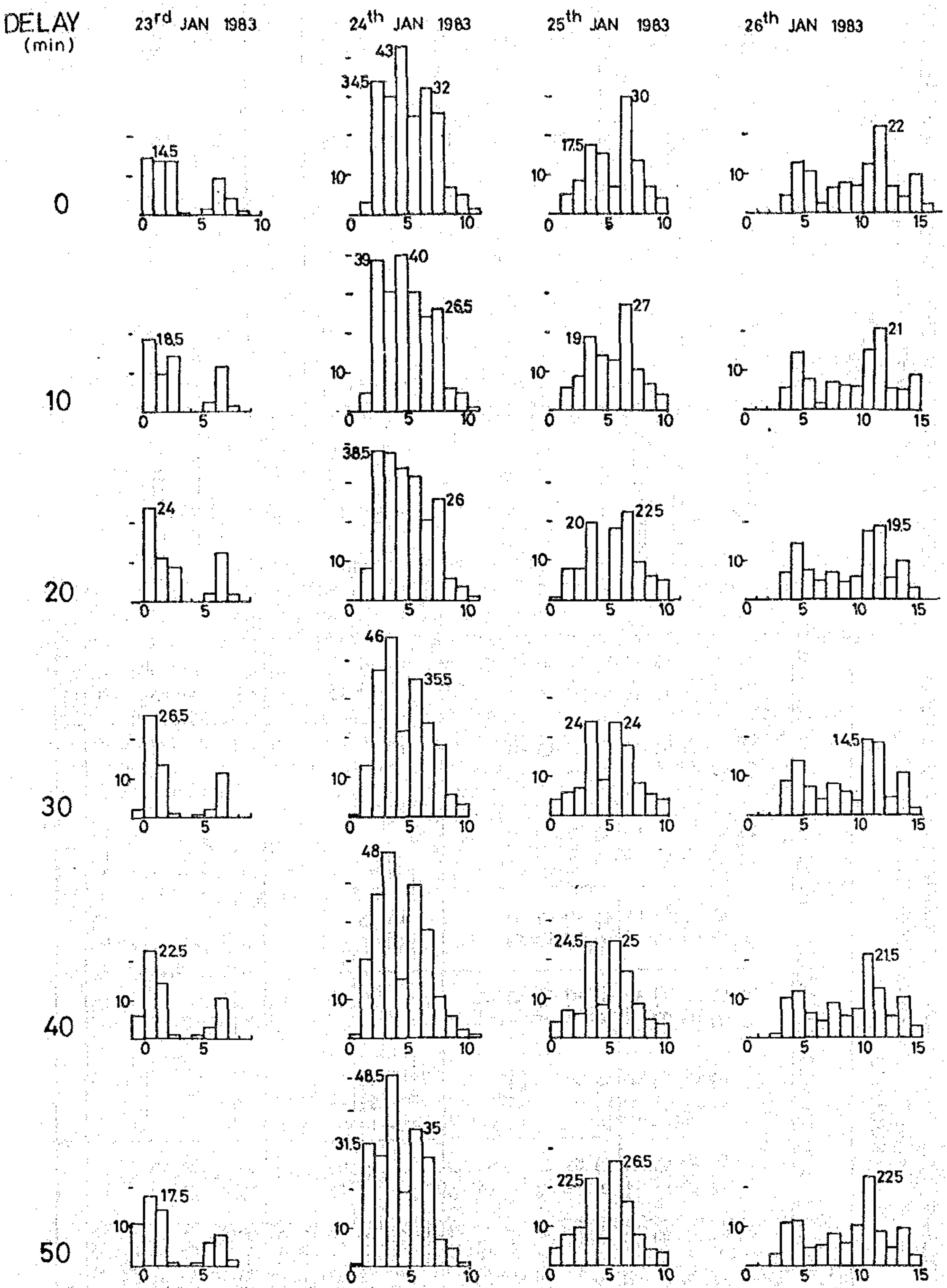


FIG.–4 INFLUENCE OF THE TIMER'S DELAY TO THE VALUES OF HOURLY RAINFALL

TABLE–1 VALUES OF 10-MINUTE RAINFALL DETERMINED FROM THE RECORDS ON 24TH JANUARY 1983, IN KUCHING

HOUR \ MINUTE	0~10	10~20	20~30	30~40	40~50	50~60	0~60
0~1							
1~2			0.5		0.5	2.0	3.0
2~3	2.0	2.5	6.0	7.5	10.5	6.0	34.5
3~4	6.5	2.0	5.5	6.0	3.0	7.0	30.0
4~5	7.0	9.5	13.5	8.0	3.5	1.5	43.0
5~6	4.0	3.5	1.0	1.5	8.0	7.0	25.0
6~7	9.0	5.0	5.0	5.0	4.0	4.0	32.0
7~8	1.0	1.5	8.5	8.5	4.5	1.5	25.5
8~9	2.0	1.0	1.0	0.5	1.0	1.0	6.5
9~10	1.0	1.0	1.0	0.5	0.5	0.5	4.5
10~11	0.5		0.5				1.0
11~12	0.5						0.5
12~13							
13~14				0.5		1.0	1.5
14~15	2.5	2.5	1.0	1.0			7.0
15~16	0.5						0.5
16~17							
17~18			0.5		1.0		1.5
18~19	0.5						0.5
19~20							
20~21	0.5		1				1.5
21~22	0.5						0.5
22~23							
23~24			3.5	5.0	0.5		9.0
TOTAL							227.5

TABLE–2 ERRORS IN THE VALUES OF RAINFALL INTENSITY CAUSED BY THE TIMER'S DELAY

TIME OF DELAY (mm) \ DATE	23 JAN. 1983	24 JAN. 1983	25 JAN. 1983	26 JAN. 1983
10	+ 32	- 7	- 10	- 5
20	+ 71	- 10	- 25	- 11
30	+ 89	+ 7	- 20	- 11
40	+ 61	+ 12	- 17	- 2
50	+ 25	+ 13	- 12	+ 2
MAX. (+)	+ 89	+ 13		+ 2
MIN. (-)		- 10	- 25	- 11
DAILY RAINFALL (mm)	91	228	138	107

REPORT 10 DISTRIBUTION MAP OF THE MAXIMUM 1-HOUR RAINFALL IN THE 1ST DIVISION, SARAWAK

Abstract

Rainfall records obtained by the Drainage and Irrigation Department, Sarawak are checked to determine the clock maximum and the moving maximum values of hourly rainfall from them. Areal distribution maps of these values are also prepared.

1. BASIC DATA USED FOR THE ANALYSIS

Twenty nine self-recording rain gauges are installed in the 1st Division in which 6 gauges are installed in the limited area of 45 km^2. Since the total area of the 1st Division is 3,437 km^2, density of rain gauge in this division is approximately 40 km^2/gauge. Judging from this value, density of rain gauge in the 1st Division is not so small compared with that of other countries.

The weekly rain gauges used in this Division are the ones which can record rainfall data for a week at the chart speed of 1.8 mm/hr. Thus, it is not so easy to determine the value of hourly rainfall from the record, especially in case of heavy rainfall. Table–1 summarizes the initiation years after which observation was initiated at each rainfall station. As it can be seen from this table, rainfall data has been recorded for more than 10 years at most stations. However, some data are missing at each station due to the troubles of their clocks contained in the recorders. Thus, it is rather difficult to determine how long the rainfall data has been recorded.

The values of the maximum 1-hour rainfall used for this study were determined through the following sources:

(i) Sarawak Hydrological Year Book 1976 P. 15–57

The Year Book above summarizes current values of the maximum moving 1-hour rainfall determined from the records obtained at 21 self-recording rain gauge stations in Sarawak. These values are listed in Table–2.

(ii) Previous recordings of rainfall

Sarawak Hydrological Year Book does not contain the values of hourly rainfall at each station, except the data of the maximum moving 1-hour rainfall mentioned above. Thus, previous records of rainfall preserved were checked again to determine the maximum values of clock hourly rainfalls for the months of December, January and February which are in rainy season, and for the months of June, July and August in dry season. Here, it should be noted that only the records in which daily rainfalls have exceeded 40 mm were used to determine the values of hourly rainfalls for the months in dry season. These values of the maximum clock hourly rainfall were listed in Table–2.

2. ANALYSIS

(1) The maximum values of moving 1-hour rainfall

The maximum values of moving 1-hour rainfall in Table–2 were plotted on the map as shown in Fig.–1. Unfortunately, this map does not show clearly which area had a large amount of rainfall and which area had less of rainfall during heavy rain. Further analysis was made on the maximum values of moving 1-hour rainfall.

(a) Seasonal distribution of the maximum moving 1-hour rainfall

To investigate in which season the maximum moving 1-hour rainfall occurrs most frequently, frequency of occurrence of the maximum moving 1-hour rainfall were studied in each month. The following table summarizes the frequency of occurrence for each season.

Season	Frequency
December, January and February	6
March, April and May	7
June, July and August	4
September, October and November	5

This table indicates clearly that such a heavy rain causing the maximum moving 1-hour rainfall may fall possibly in any season of the year.

(b) Chronological distribution of the maximum moving 1-hour rainfall

The frequency that the maximum moving 1-hour rainfall occurred in the past were studied. The result is shown below.

Year	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Frequency	1	3		1		1	1	2	1	3	2	2	2	2

This table indicates that the frequency of occurrence is not concentrated in any special year, although a little higher frequency is observed in the year of both 1964 and 1972.

(2) **Areal distribution of the maximum (clock) 1-hour rainfall in rainy season**

Fig.–2 shows the areal distribution of the maximum 1-hour rainfall in rainy season. The values in this season are smaller than those in Fig.–1. This is because the values of the moving maximum were selected so as to be the largest among the neighbouring values by moving time scale.

(3) **Areal distribution of the maximum (clock) 1-hour rainfall in dry season**

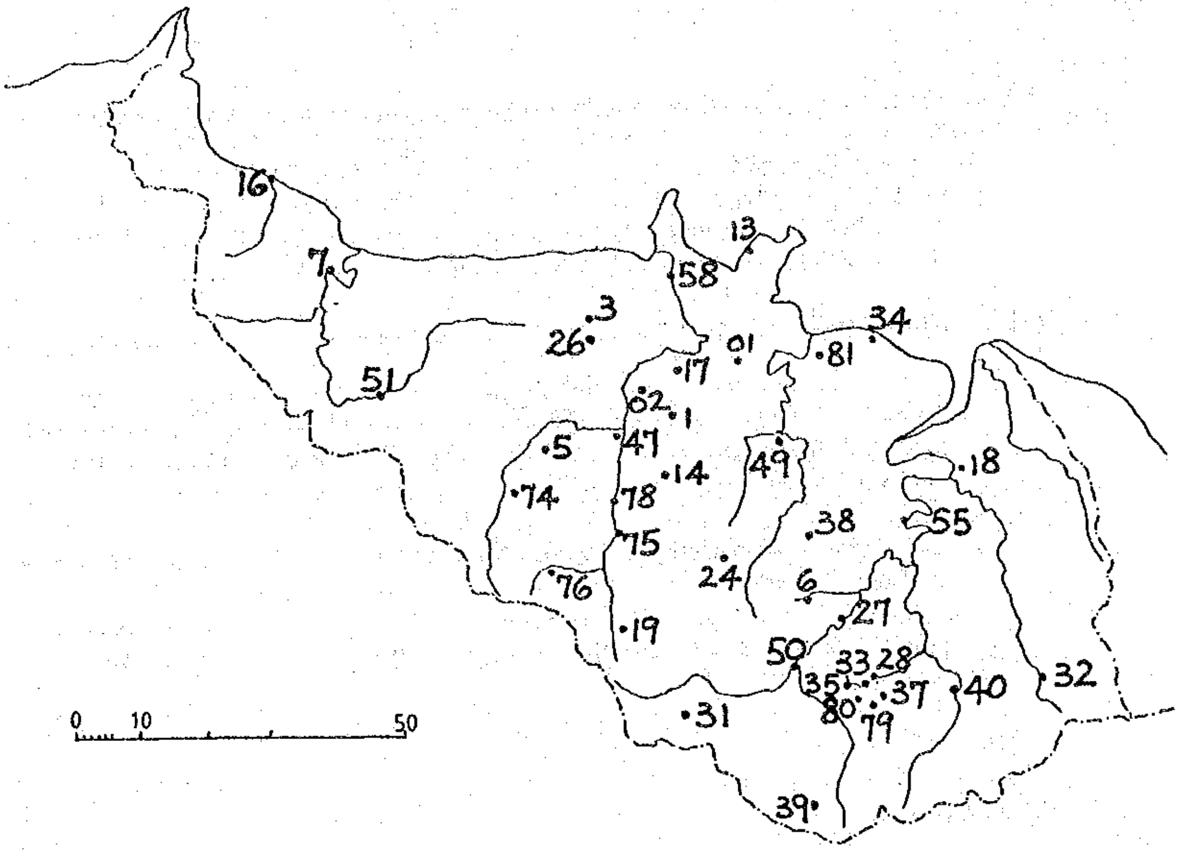
Fig.–3 shows the areal distribution of the maximum 1-hour rainfall in dry dry season. These values are also smaller than those shown in Fig.–1 because of the similar reason mentioned in (2) above. The difference between the values shown in Fig.–2 and Fig.–3 is not so large.

It can be anticipated that duration of heavy rainfall in dry season may be short. In order to ascertain this, ratios between the maximum 1-hour rainfall and the daily rainfall on that day were calculated. These values are shown in Table–2. These ratios ranged from 0.93 to 0.44, although the average was 0.70.

3. CONCLUSIONS

(1) Rainfall with the intensity around 100 mm/hr may fall at any place in the 1st Division at any time of the year.

(2) When the maximum 1-hour rainfall occurrs during heavy rainfall in dry season, duration of the heavy rain is short in general.



STATION NO.

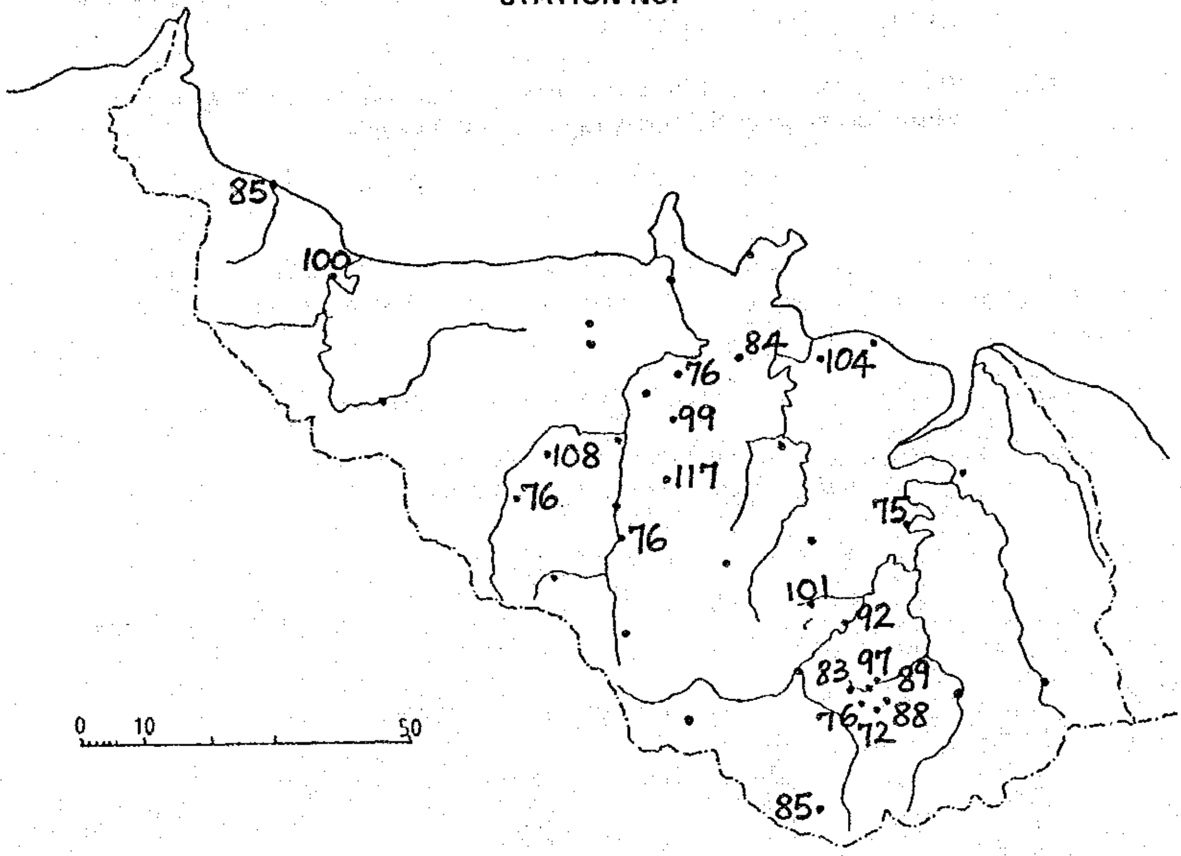


FIG.–1 AREAL DISTRIBUTION OF THE MAXIMUM MOVING 1-HOUR RAINFALL IN THE 1ST DIVISION

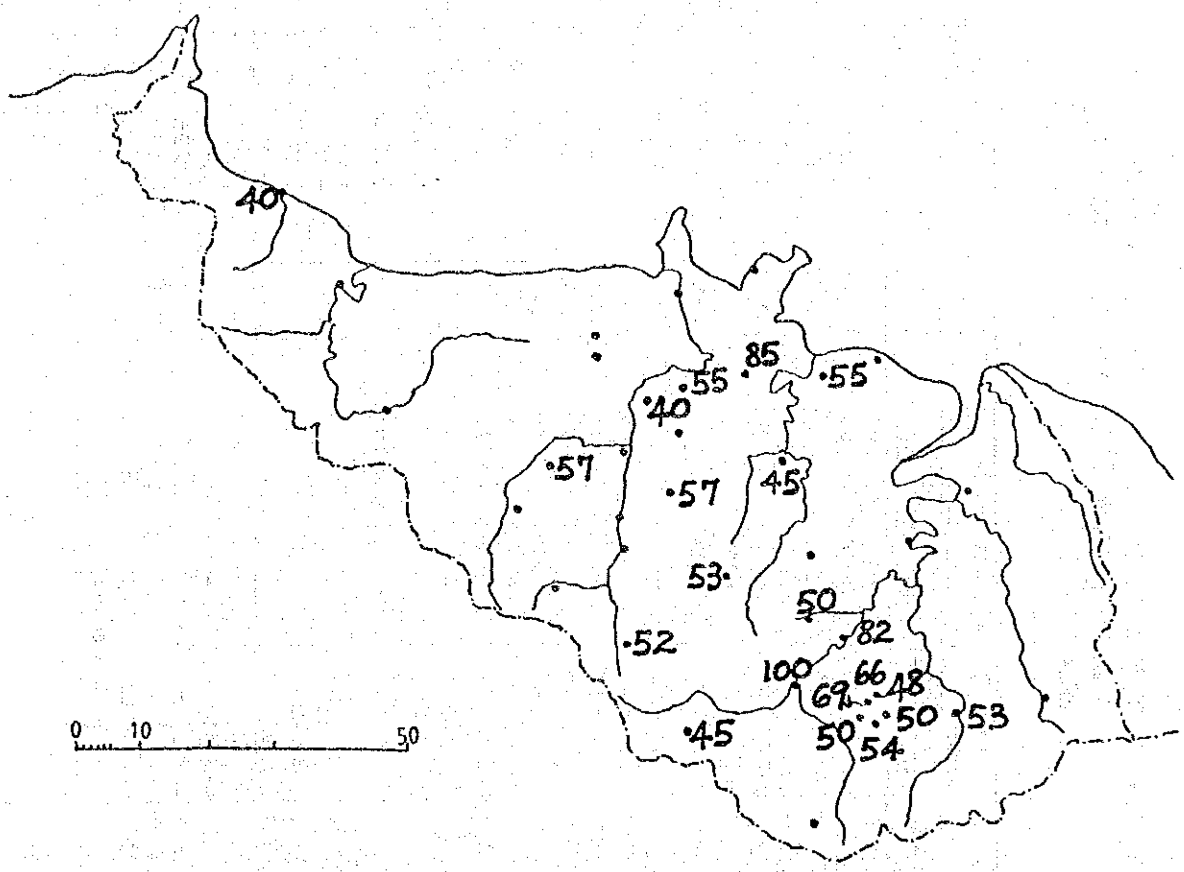


FIG.–2 AREAL DISTRIBUTION OF THE MAXIMUM (CLOCK) 1-HOUR RAINFALL DURING RAINY SEASON IN THE 1ST DIVISION

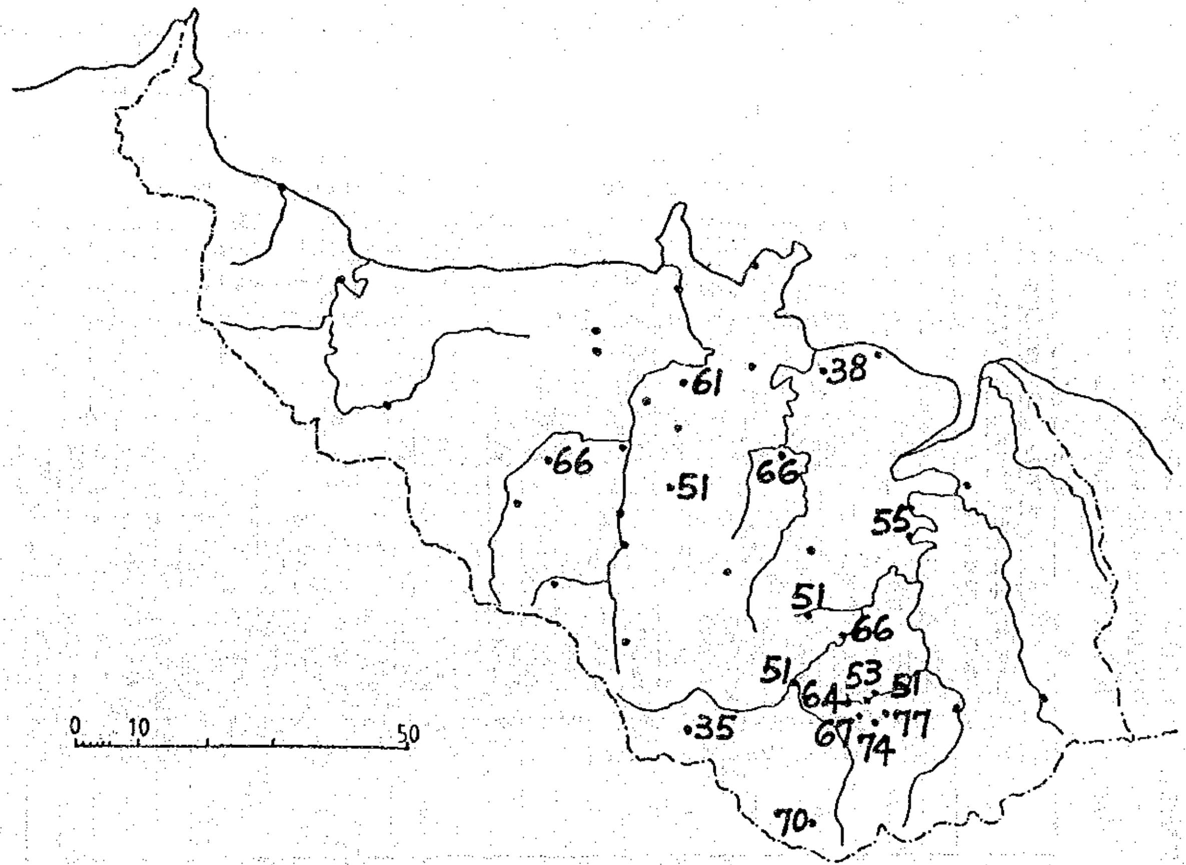


FIG.–3 AREAL DISTRIBUTION OF THE MAXIMUM (CLOCK) 1-HOUR RAINFALL DURING DRY SEASON IN THE 1ST DIVISION

TABLE–1 INITIATION OF RECORDING AND TYPE OF RECORDER FOR RAINFALL OBSERVATION IN THE 1ST DIVISION

NO	STATION NAME	STATION NUMBER	YEAR OF INITIATION TYPE OF RECORDER W	D	M
1	KUCHING	1			
2	BAU	5	'69		
3	TARAT	6	'60		
4	LUNDU	7	'80	'62	
5	SEMONGOK	14	'62		
6	SEMATAN	16	'69		
7	D.I.D. KUCHING	17	'74	'71	
8	PADAWAN	19	'70		'75
9	BATU LINTANG	25	'58		
10	SERIAN	27	'58	'64	'80
11	SG. BEDUP	28	'58		
12	TEBEDU	31	'63		'76
13	SG. MERANG	33	'71	'64	
14	SIMUJA NONOK	35	'64		
15	SG. TEB	37	'64		
16	KPG. BUNAN	39	'67		
17	BALAI RINGIN	40	'79		
18	PAYA PALOH	49	'77		
19	TEBAKANG	50	'76		
20	KPG. STUNGKOR	51	'80		
21	MID-SADONG	55		'66	
22	KROKONG	74	'70		
23	SEGU BUNUK	75	'70		
24	BUKIT MATUR	79	'71		
25	SG. BUSIT	80	'70		
26	NONOK SCHEME	81	'76		
27	3rd MILE	01	'74		
28	BINTAWA	02	'80		'80

LEGEND: W WEEKLY, D DAILY, M MONTHLY

TABLE–2 THE MAXIMUM VALUES OF CLOCK HOURLY AND MOVING HOURLY RAINFALL DURING HEAVY RAIN

STATION NO	MAXIMUM MOVING 1-HOUR RAINFALL (mm)	DATE	MAXIMUM CLOCK 1-HOUR RAINFALL RAINY SEASON r_r (mm)	DATE	DRY SEASON r_d (mm)	DATE		r_d / r_r		r_d / Ro	DAILY RAINFALL Ro (mm)
1	99										
5	108	1-9-'74	57	2-1-'80	66	27-6-'75		1.16		0.88	75
6	101	2-2-'64	50	28-1-'83	51	11-8-'73		1.02		0.62	82
7	100	28-2-'64	40	22-12-'81							
14	117	21-3-'64	57	23-2-'75	51	13-6-'78		0.95		0.78	65
16	85	11-3-'73									
17	76	30-1-70	55	23-2-'77	61	28-6-'73		1.11		0.80	76
19			52	27-1-'83							
24			53	26-1-'83							
25	107	1-3-'63									
27	92	14-3-'76	82	24-1-'83	66	22-8-'71		0.80		0.90	73
28	89	15-8-'66	48	21-1-'78	51	31-8-'71		1.06		0.62	82
31			45	20-2-'77	35	11-6-'77		0.78		0.59	59
33	97	17-4-'68	66	23-2-'75	53	26-6-'74		0.80		0.63	84
35	83	3-10-'70	69	23-2-'75	64	26-6-'74		0.93		0.57	113
37	88	25-8-'72	50	4-3-'75	77	25-8-'72		1.54		0.85	91
39	85	18-4-'69			70	7-6-'73				0.46	153
40			53	20-2-'77							
49			45	9-1-'78	66	1-8-'78		1.47		0.93	71
50			100	20-2-'77	51	6-6-'73		0.51		0.44	117
51											
55	75	24-11-'71			55	'13-7-'77 3-8-'77				0.87	63
74	76	6-4-'76									
75	76	23-9-'75									
79	72	2-8-'72	54	15-12-'74	74	3-8-'72		1.37		0.91	81
80	76	26-6-'74	50	20-2-'77	67	26-6-'74		1.34		0.53	127
81	104	13-2-'72	55	24-1-'83	38	17-8-'72		0.69		0.58	66
01	84	23-9-'75	85	2-1-'80							
02			40	24-1-'83							

REPORT 11 MONTHLY MAXIMUM OF ACCUMULATED RAINFALL RECORDED IN KUCHING IN THE PERIOD FROM 1951 TO 1980

1. BASIC DATA USED FOR THE ANALYSIS

One of the reports shown in the reference section contains tables which summarize the monthly maximum of accumulated rainfall fallen in Kuching in the period from 1951 to 1980. These values are classified into 14 groups due to the length of their durations as shown below.

Duration of falling (unit in hour)

1/4, 1/2, 3/4, 1, 2, 3, 4, 5, 6, 12, 24, 48, 72, 96

The monthly maximum of accumulated rainfall was determined by selecting the maximum values among the ones obtained in the period from 1951 to 1980. The values are listed in Table–1. In this table, the figures in the parenthesis show the year when the monthly maximum of accumulated rainfall appeared.

2. ANALYSIS

Fig.–1, 2 and 3 show the plottings of the data shown in Table–1, although different time scales, namely, day, hour and minute are adopted on abscissa respectively. Fig.–1 indicates clearly that the rainfall duration curves for January and February locates higher portion compared with the ones for other months. In these two months, accumulated values of rainfall keep increasing continuously as the duration increases up to 12 hours, although the increasing rate becomes smaller when duration becomes greater than 12 hours.

In Fig.–2, it is observed that accumulated values of rainfall for January and February keep increasing as the duration becomes greater. Rainfall-duration curve for July follows the curves for January and February within the duration less than 2 hours, although it becomes almost flat after duration becomes longer than 2 hours. The curve for June locates at the lowest portion, and those for August and September locate at the next lower portion.

Fig.–3 has an abscissa with more detailed time scale. Thus, it is possible to read the maximum values of the accumulated rainfall for such short duration as 1/4, 2/4, 3/4 and 4/4 hr. from this figure. The monthly maximum values for the duration of 1/4 hr. range from 32 mm to 46 mm. This means that the maximum values of the accumulated rainfall may often reach to the value of about 40 mm/15 min. at any time of the year. The rainfall-duration curves for the duration of 1/2 – 1 hour locate in the following order.

Months	Location
May, June and August	Lowest
March, April and September	Middle
January, February, July and October and November	*Highest*

The maximum vaues of the accumulated rainfall are quite large and locate in higher portion in January and February which are in rainy season, and in July which is in dry season. Furthermore, the maximum values are also large in October and November if they are counted within a short duration. The phenomena might be caused due to the existence of air-stream boundaries during this season.

3. CONCLUSIONS

The rainfall-duration curves were prepared based on the rainfall data for each month recorded at Kuching rainfall station. Through these curves, the following characteristics were found on the duration of heavy rainfall:

(1) Heavy rain may keep falling for the duration longer than 12 hours in January and February which are both in rainy season.

(2) Heavy rain in July also shows similar pattern of rainfall-duration curves to those found for heavy rainfall in both January and February although the duration of heavy rain in July is usually less than 2 hours.

References

(1) Malaysia Meteorological Service: "Climatological Summaries Rainfall Analysis 1951 – 1980"

(2) Meteorological Service Singapore: "Rainfall in East Malaysia and Brunei" Memori No. 8

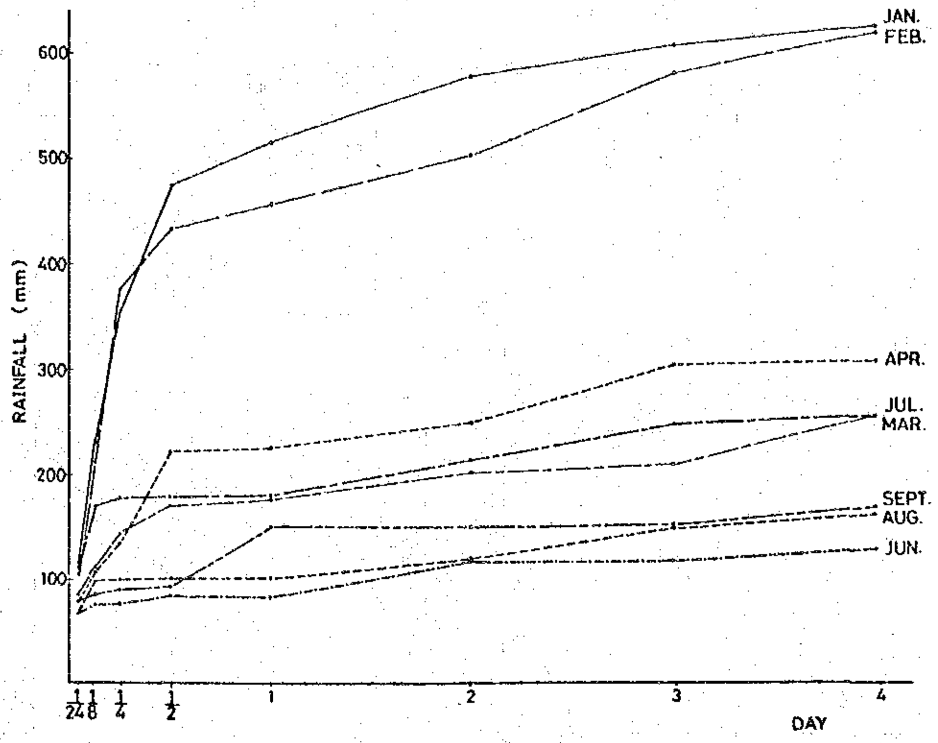


FIG.—1 RAINFALL-DURATION CURVE IN KUCHING (1) TIME SCALE: DAY

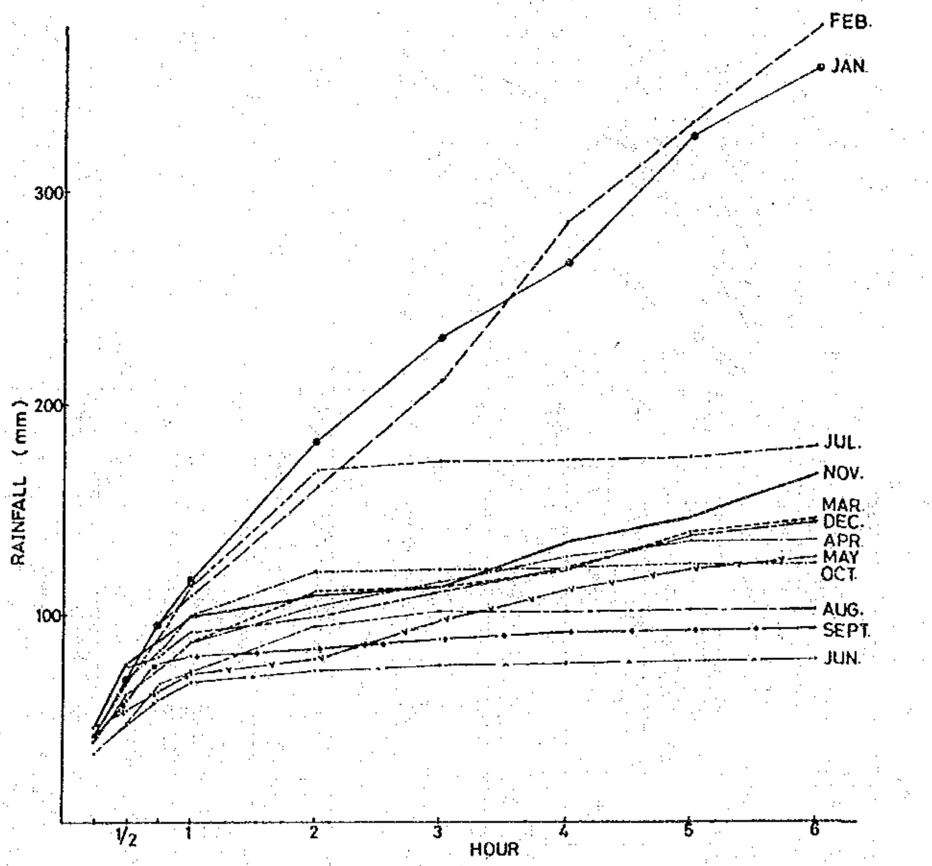


FIG.—2 RAINFALL-DURATION CURVE IN KUCHING (2) TIME SCALE: HOUR

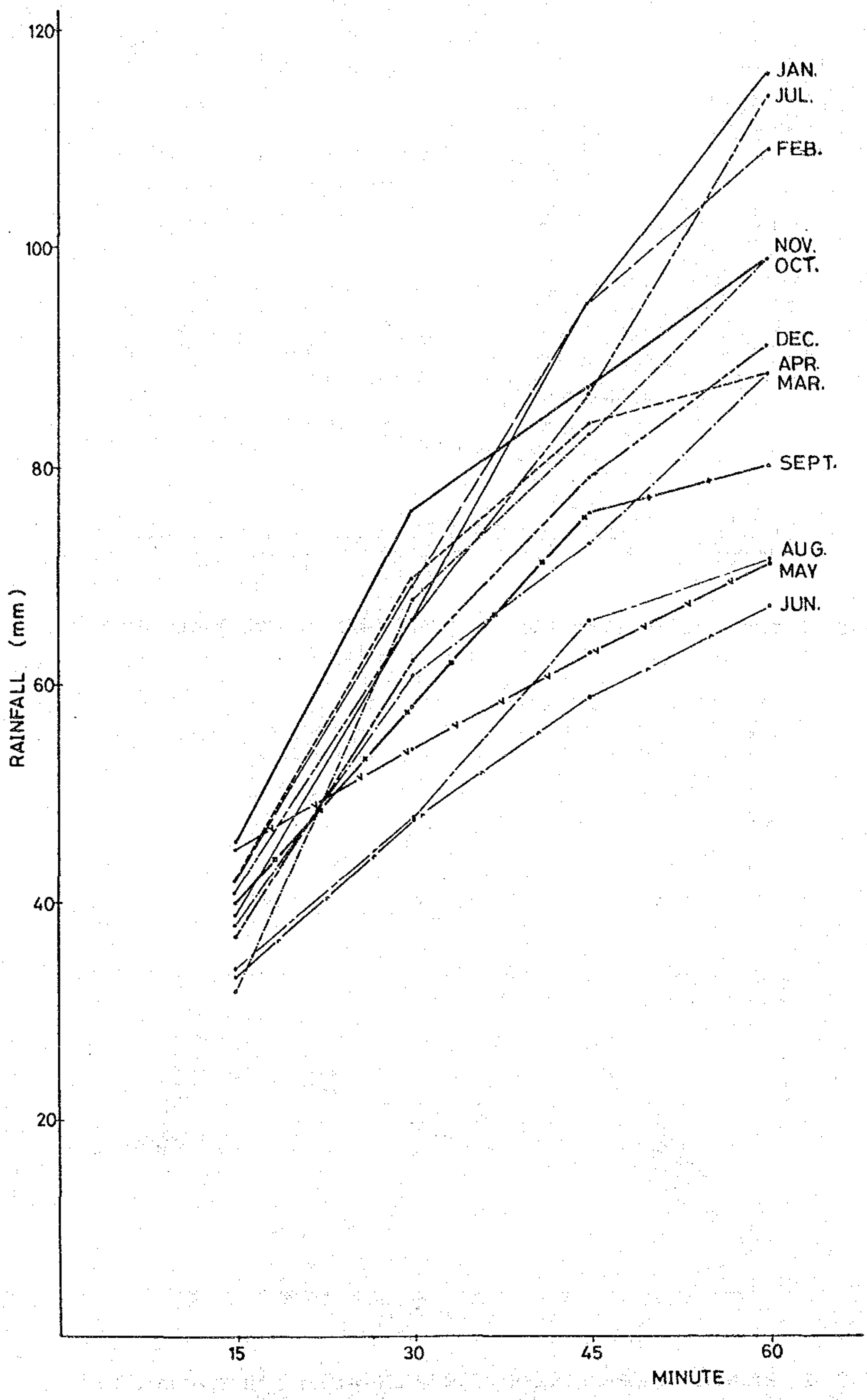


FIG.—3 RAINFALL-DURATION CURVE IN KUCHING (3) TIME SCALE: MINUTE

TABLE–1 MONTHLY MAXIMUM VALUES OF THE ACCUMULATED RAINFALL IN KUCHING

MONTH \ DURATION (HOUR)	1/4	1/2	3/4	1	2	3	4	5	6	12	24	48	72	96
JAN.	39 (78)	66 (78)	95 (80)	116 (80)	182 (80)	231 (80)	266 (80)	326 (80)	358 (80)	477 (80)	516 (71)	580 (71)	608 (71)	628 (71)
FEB.	42 (63)	69 (63)	95 (63)	109 (64)	160 (64)	210 (64)	284 (64)	332 (64)	377 (64)	434 (64)	457 (64)	505 (64)	582 (64)	621 (64)
MAR.	38 (66)	61 (66)	73 (73)	86 (62)	111 (62)	113 (62)	121 (59)	138 (59)	145 (59)	171 (59)	177 (77)	202 (77)	210 (77)	258 (63)
APR.	43 (79)	70 (79)	84 (79)	86 (79)	104 (77)	115 (77)	127 (77)	134 (77)	135 (77)	225 (77)	226 (77)	251 (77)	304 (77)	311 (77)
MAY	45 (54)	54 (54)	63 (63)	71 (63)	78 (69)	97 (69)	111 (69)	121 (69)	126 (69)	134 (69)	134 (69)	166 (51)	176 (69)	198 (69)
JUN.	33 (68)	48 (80)	59 (66)	67 (70)	73 (60)	75 (60)	76 (60)	77 (60)	77 (60)	85 (66)	85 (66)	116 (66)	118 (66)	130 (70)
JUL.	41 (77)	66 (77)	87 (60)	114 (60)	169 (60)	173 (60)	173 (60)	174 (60)	179 (60)	181 (60)	181 (60)	214 (60)	248 (60)	257 (60)
AUG.	34 (74)	48 (69)	66 (66)	71 (75)	94 (75)	101 (75)	101 (75)	101 (75)	101 (75)	101 (75)	101 (75)	119 (74)	150 (74)	161 (69)
SEPT.	40 (75)	58 (63)	76 (63)	80 (75)	83 (75)	88 (75)	91 (75)	92 (75)	92 (75)	92 (75)	150 (68)	153 (68)	154 (68)	169 (57)
OCT.	42 (78)	68 (78)	83 (78)	99 (67)	120 (67)	121 (67)	122 (67)	123 (67)	123 (67)	123 (67)	127 (69)	206 (67)	213 (67)	223 (67)
NOV.	45 (79)	76 (79)	87 (79)	99 (79)	109 (79)	110 (79)	134 (71)	144 (71)	166 (71)	210 (71)	215 (71)	278 (71)	297 (71)	299 (71)
DEC.	37 (66)	62 (66)	79 (66)	91 (66)	98 (66)	108 (75)	122 (75)	136 (75)	142 (75)	189 (75)	335 (75)	348 (75)	357 (75)	412 (73)
HIGHEST	45 (79)	76 (79)	95 (63) (80)	116 (80)	182 (80)	231 (80)	284 (64)	332 (64)	377 (64)	477 (80)	516 (71)	580 (71)	608 (71)	628 (71)

REPORT 12 MONTHLY MAXIMUM VALUES OF 1-HOUR RAINFALL IN KUCHING

1. BASIC DATA USED FOR THE ANALYSIS

One of the reports shown in the reference section contains the monthly maximum values of (moving) 1-hour rainfall recorded in Kuching in the period from 1951 to 1980. These values are tabulated in Table–1.

2. ANALYSIS

(1) Seasonal variation of the monthly maximum values of 1-hour rainfall

Data of the maximum values of 1-hour rainfall mentioned above were classified into the following four groups due to their seasons in which the data were measured:

The 1st season which consists of December, January and February, the 2nd season including March, April and May, the 3rd season including June, July and August, and the 4th season including September, October and November. In each season, the monthly maximum values of 1-hour rainfall were rearranged in the order of their magnitude. Fig.–1 shows the plots of these values in each season although the abscissa expresses the relative percentage that the monthly maximum value of the 1-hour rainfall exceeds the value shown on the ordinate. From these distributions curve, the following facts can be observed:

(i) In the range where 18% of total data in each season has large values of 1-hour rainfall than the respective ones on the ordinate which corresponds to 18% on abscissa.

Four curves are located in the order of curves obtained in the 1st, 4th, 2nd and 3rd seasons respectively, although the distribution curve obtained in the 3rd season locates at the second high position in the range where 2% of total data has larger rainfall than the one on the ordinate which corresponds to 2% on abscissa.

(ii) In the range where the rest of 82% of total data in each season has smaller values of 1-hour rainfall than the respective ones on the ordinate which corresponds to 18% on abscissa.

The distribution curves obtained in both the 1st and 4th seasons locate very close each other, although the rest of the curves locate in the same order as the one observed in the range (i).

(2) **Monthly variation of the monthly maximum values of the 1-hour rainfall recorded for the past 30 years**

Fig.—2 shows monthly variation of the monthly maximum values of the 1-hour rainfall which have been recorded for the past 30 years in Kuching. For more information, the secondary maximum values in each month are also plotted together in this figure.

This figure indicates that there exist three peaks in the variation of the monthly maximum values of 1-hour rainfall. These peaks are the ones appeared in the months of October and November, in dry month of July and in rainy months of December, January and February. Among these peaks, the reason why the peak appears in October and November might be somehow related to the existence of the air-stream boundaries generated around these months of the year. Another remarkable findings is that the secondary maximum values in July and December are quite smaller than the maximum values in each of the corresponding month.

3. CONCLUSIONS

(1) Distinctly different curves are obtained for each of four seasons in Kuching which were prepared to check the distribution of the monthly maximum values of 1-hour rainfall.

(2) Three peaks are observed in the variation of the monthly maximum values of 1-hour rainfall appeared in the past 30 years in Kuching. These peaks appear in July, in October and November, and in January and February respectively.

References

(1) Malaysia Meteorological Service: "Climatological Summaries Rainfall Analysis 1951 – 1980"

(2) Meteorological Service Singapore: "Rainfall in East Malaysia and Brunei" Memori No. 8

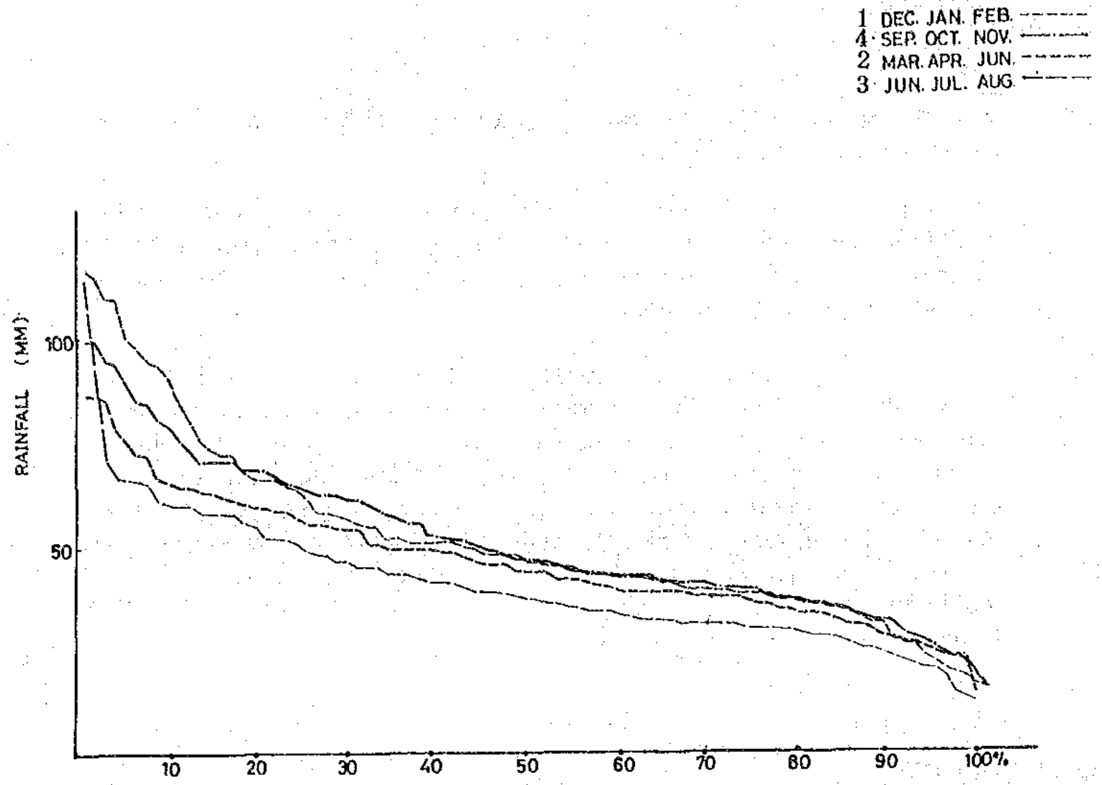


FIG.–1 SEASONAL VARIATION OF THE MONTHLY MAXIMUM VALUES OF 1-HOUR RAINFALL RECORDED IN KUCHING FOR THE PAST 30 YEARS

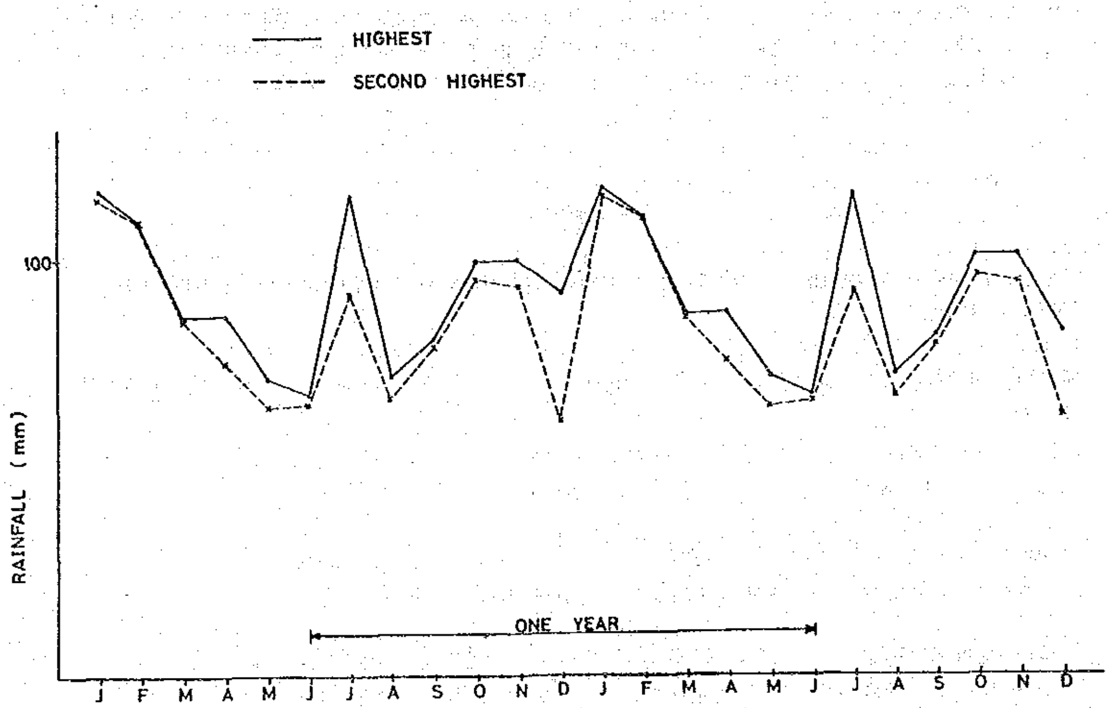


FIG.–2 MONTHLY VARIATION OF THE MONTHLY MAXIMUM VALUES OF 1-HOUR RAINFALL RECORDED IN KUCHING FOR THE PAST 30 YEARS

TABLE—1 MONTHLY MAXIMUM VALUES OF 1-HOUR RAINFALL RECORDED IN KUCHING IN THE PERIOD FROM 1951 TO 1980

YEAR \ MONTH	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
1951			45		65	56	48	37	40	31	65	46
1952	114	41	37							31		
1953	94	50	48	63	39	41	58	25	70	67	52	45
1954	38	38	45	57	64	26	34	43	40	60	39	54
1955	49	89	66	55	34	47	36	35	50	40	18	58
1956	37	15	54	49	46	31	55	31	62	23	62	30
1957	43	48	33	37	45	31	32	34	73	63	43	39
1958	39	80	41	58	50	30	12	21	51	48	34	33
1959	41	16	63	38	61	31	60	24	40	28	26	34
1960	27	45	38	37	43	65	114	33	35	42	43	29
1961	46	72	30	27	55	38	39	41	42	46	45	44
1962	45	51	86	30	59	37	38	41	51	22	64	55
1963	57	109	48	23	71	47	29	30	78	88	36	38
1964	26	109	59	38	22	31	28	20	36	42	38	36
1965	37	44	37	50	26	32	14	34	15	18	38	48
1966	48	72	78	37	26	61	20	66	45	55	75	91
1967	31	55	43	38	35	58	22	20	62	99	46	25
1968	51	19	39	22	54	52	45	58	68	84	48	45
1969	43	51	49	72	43	39	32	66	27	85	35	
1970	51	39	40	58	31	67	18	43	56	41	39	39
1971	58	43	32	34	37	33	31	42	33	52	57	46
1972	66	52	47	25	38	39	28	30	68	70	36	57
1973	31	48	85	55	62	52	28	32	43	70	22	48
1974	23	40	49	13	33	48	25	60	61	42	32	33
1975	66	83	54	41	49	27	43	71	80	61	68	45
1976	43	36	21	38	41	43	58	29	25	47	43	52
1977	51	58	64	75	27	45	91	51	31	46	93	53
1978	97	66	35	36	43	35	30	40	37	94	34	38
1979	73	56	49	86	29	45	36	60	39	70	99	54
1980	116	20	46	38	60	49	23	52	41	58	55	61
MAXIMUM	116	109	86	86	71	67	114	71	80	99	99	91
MINIMUM	23	15	21	13	22	26	12	20	15	18	18	25
MEAN	53	53	49	44	44	43	39	40	48	54	48	46

REPORT 13 DAILY DISTRIBUTION OF 1-HOUR RAINFALL IN EACH MONTH IN KUCHING

1. BASIC DATA USED FOR THE ANALYSIS

The Kuching Office, Malaysia Meteorological Service, has prepared a table titled,

> "Values of the hourly rainfall in each month in Kuching for the period from 1953 to 1980"

This is shown in Table–1.

The values in Table–1 were calculated out by the following way: Hourly rainfall in each hour of a day was added up for the total days of each month. This procedure was performed for the data obtained in each of 28 years. Finally, the summed up values of each hourly rainfall was divided by the total number of the data for the past 28 years.

2. ANALYSIS

Fig.–1 shows the daily distribution of 1-hour rainfall in each month which were drawn by plotting the data shown in Table–1.

On the other hand, Fig.–2 was prepared to investigate the distribution of hourly rainfall during a day more precisely. This figure shows two kinds of rainfall during a day more precisely. This figure shows two kinds of rainfall, namely, the rainfall summed up the averaged 1-hour rainfall in the morning from 0 to 12 o'clock, and the one summed up the averaged 1-hour rainfall in the afternoon from 12 to 24 o'clock. In this figure, daily rainfall in each month was also shown together.

(1) Morning rainfall

Daily distribution of hourly rainfall in each month is shown in Table–1. The peak of hourly rainfall does not appear in the morning, although considerably large values of hourly rainfall are observed in the morning especially in January and February. This can be seen in Fig.–2 too, which also shows the peak in the morning. However, the ratios of the morning rainfall to the corresponding values of the daily rainfall are 56% – 65% at most. This is probably because there are a lot of rainfall in the afternoon as well in these months.

(2) Afternoon rainfall

Fig.–1 indicates clearly that distinct peaks always appear in the afternoon portion of the daily distribution of hourly rainfall in the months ranging from April to December. The ratios of afternoon rainfall to the corresponding value of the daily rainfall range from 68% to 83%, in which the maximum ratio of 83% occurrs in May. However, monthly variation of the afternoon rainfall is not so large as that of the morning rainfall. morning rainfall.

3. CONCLUSIONS

(1) The values of the average morning rainfall are large in January and February.

(2) Monthly variation in the values of the average afternoon rainfall is not so remarkable as that of the morning rainfall, although the ratio of the minimum to the maximum is about 2 at most.

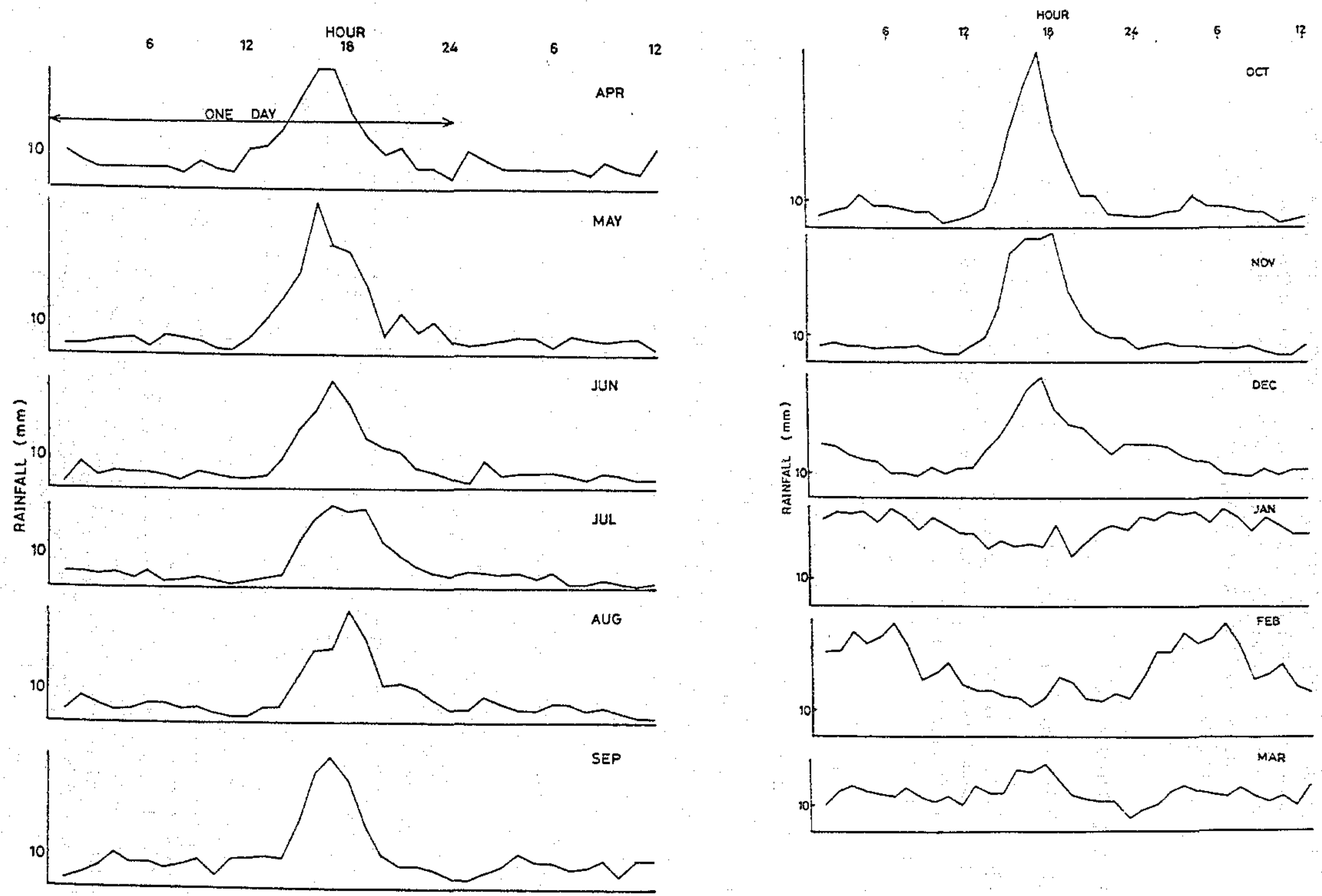


FIG.–1 DAILY DISTRIBUTION OF HOURLY RAINFALL IN EACH MONTH OF THE YEAR IN KUCHING

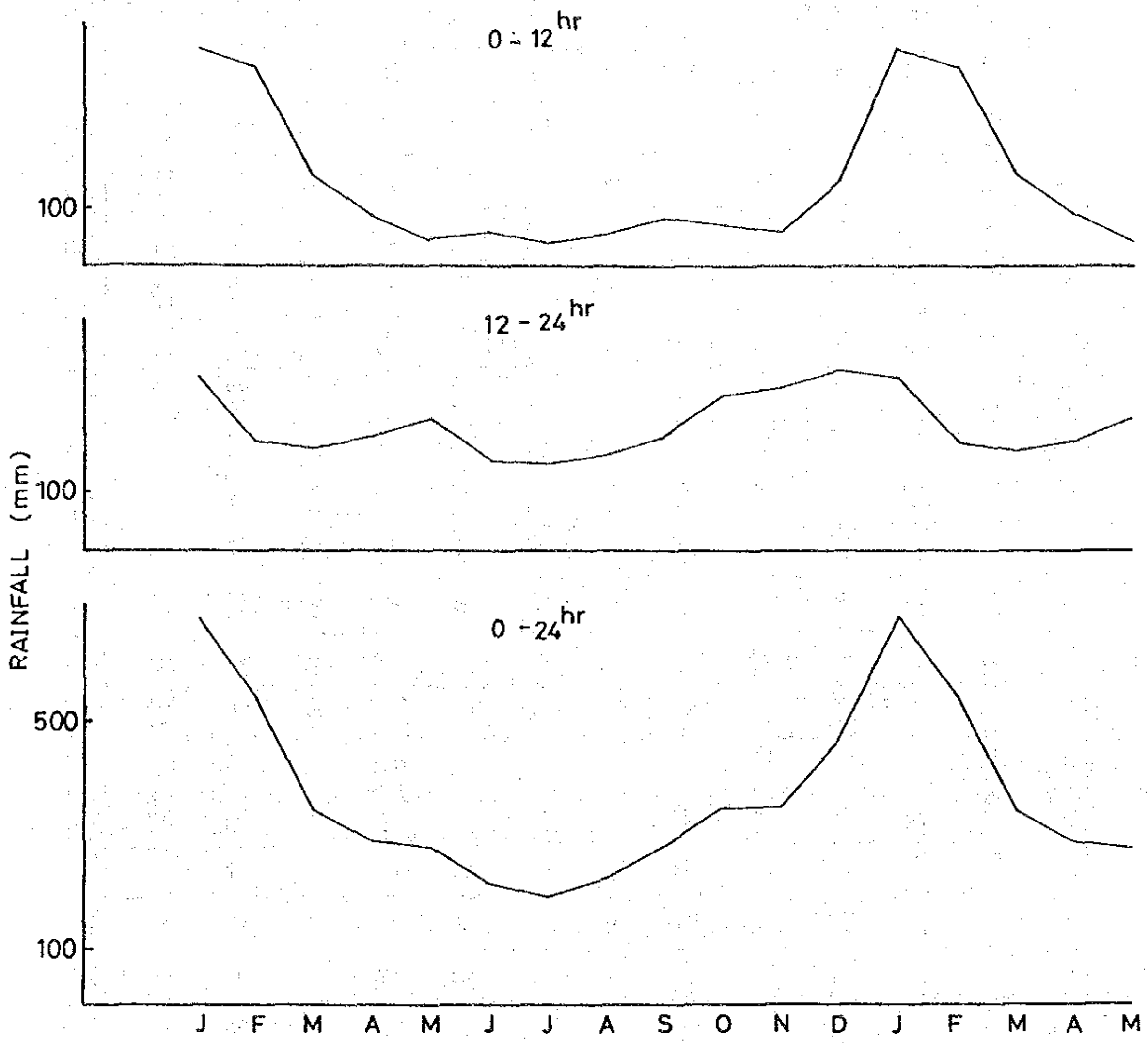


FIG.–2 MONTHLY DISTRIBUTION OF HOURLY RAINFALL AVERAGED IN THE MORNING AND IN THE AFTERNOON IN KUCHING

TABLE–1 VALUES OF HOURLY RAINFALL IN EACH MONTH IN KUCHING

MONTH \ HOUR	0-1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	23-24	
JAN.	32	35	34	35	31	36	33	28	33	30	27	27	21	24	22	23	22	30	18	23	28	30	28	33	(637) 683
FEB.	31	31	38	34	36	41	33	21	23	27	19	17	17	15	14	11	14	22	20	14	13	16	14	22	(570) 543
MAR.	10	15	17	15	14	13	16	13	11	13	10	17	14	14	23	22	25	19	13	12	11	11	5	8	(342) 341
APR.	11	8	6	6	6	6	6	4	8	6	5	12	13	18	27	36	36	23	15	10	12	6	6	3	(288) 289
MAY	3	3	4	5	5	2	6	5	4	2	2	5	12	17	25	46	33	31	21	11	13	7	10	4	(269) 276
JUN.	2	8	4	5	5	5	4	3	5	4	3	3	4	9	18	23	32	25	15	12	11	6	5	3	(204) 214
JUL.	5	5	4	5	3	5	2	2	3	2	1	2	3	4	14	21	25	23	24	14	10	7	5	4	(186) 193
AUG.	4	8	6	4	4	6	6	4	5	3	2	2	5	5	14	22	22	33	25	11	12	10	7	4	(224) 224
SEPT.	3	5	7	11	8	8	6	7	9	4	9	9	10	9	20	35	40	32	19	10	7	7	6	3	(260) 284
OCT.	4	6	7	12	8	8	7	6	6	2	3	4	7	18	36	52	65	36	23	12	12	5	5	4	(332) 348
NOV.	6	7	6	6	5	5	5	6	4	3	3	6	9	20	41	46	46	48	26	16	11	9	9	5	(332) 348
DEC.	20	19	16	14	13	9	9	8	11	9	11	11	18	23	31	40	44	32	27	26	21	16	20	20	(457) 468
TOTAL	131	150	149	152	138	144	133	107	122	105	95	115	133	176	285	377	404	354	246	171	161	130	120	113	(4101) 4211

REPORT 14 DATA INTERPRETATION ON STORM RAINFALL PATTERN (10-MINUTE) AT KUCHING NURSES' HOME EXPERIMENTAL BASIN

Abstract

Distribution of rainfall during storm period with heavy rainfall is analysed in this paper. Based on the rainfall data recorded at Kuching Nurses' Home Experimental Basin (KNHEB) during 33 rain storms, distribution patterns of 10-minute rainfall are investigated carefully. As a result, it is found that they are classified into several categories which have unique distribution patterns, respectively.

1. DATA USED

A monthly recording rain gauge has been installed at KNHEB. This rain gauge has been recording rainfall data with the chart speed of 18 mm/hr. and with a tipping bucket having the measuring capacity of 0.5 mm. To analyse the distribution of heavy rainfall, rainfall data during 33 rain storms were abstracted among the continuous records of rainfall recorded by the rain gauge stated above for the period of 18 months covering February 1982 to July 1983. These data were selected due to the following criteria.

(a) Rainfall are more or less continuous and do not have any break which exceed more than one hour during the storm period.

(b) Rainfall exceed 20 mm in any successive period of longer than 40 minutes during the storm period.

The details of the storm selected were listed in Table–1. Distribution patterns of 10-minute rainfall for each storm are also shown in Fig.–1, –2 and –3.

2. ANALYSIS

By checking the distribution of rainfall data recorded during heavy rainy storms selected above, one may notice that there exists a pulsative pattern in each distribution. Roughly speaking, durations of each pulsation seem to be one to two hours. However, further detailed discussion on each duration cannot be made on the basis of 10-minute rainfall data.

Some of the rainfall data recorded during these heavy storms have the durations lasting about 8 hours in total. Within these durations, there exist several pulsations whose durations are one to two hours.

Among the patterns of heavy rainfall recorded during various storms selected, the simplest pattern is the one having an isolated pulsation in it with the duration of approximately one hour. A slightly complicated pattern is the one having a peak isolated pulsation accompanied by several small pulsations with shorter duration of approximately 10-minute.

Thus, distribution pattern of 10-minute rainfall fallen during storm period seems to be classified into the following three categories.

	Type of distribution pattern	Duration	Number of cases
(a)	Isolated pulsation	40 min. – 1 hr. 30 min.	14
(b)	Isolated pulsation accompanied by small pulsations (Accompanied isolated pulsation)	1 hr. 30 min. – 2 hr. 20 min.	7
(c)	Combined pulsations by several peaks (Combined pulsation)	3 hr. 40 min. – 10 hr. 50 min.	12

(a) Distribution pattern of rainfall with an isolated pulsation

Distribution pattern of this type has a prominent characteristic with short duration but heavy intensity of rainfall. Rainfall data recorded in 14 rainy storms may have the distribution pattern of this type.

Fig.–1 shows the distribution patterns of these rainfall data, which have the durations of the isolated pulsation ranging from 40 minutes to 1 hour and 30 minutes, and do the average value of 1 hour and 15 minutes. Further, the total amount of rainfall in each storm ranges from 19 mm to 64.5 mm, with the average of 35 mm.

Correlation analysis was made between the total amount of rainfall and the duration of pulsation. As a result, it was found that the correlation between the intensity and duration of rainfall recorded in rainy storm was much less than that found in dry season.

Fig.–2 shows the relation between the accumulated values of 10-minute rainfall and the length of time used for the accumulation. Data in 4 rainy storms have been plotted in this figure. It can be seen from this figure that the maximum accumulated values of 10-minute would reach 19 mm for 10 minutes and 38.5 mm for 30 minutes, respectively at KNHEB during storm period.

These values were compared with the corresponding values obtained by analysing the similar rainfall data recorded at Kuching Airport for the past 30 years. As a result, it was found that former values were only the half of the latter values.

(b) Duration pattern of rainfall with accompanied isolated pulsation

This type has a peak isolated pulsation accompanied by small additional pulsations in the distribution of rainfall. Rainfall data recorded in 7 rainy storms may have the distribution pattern which belongs to this type. Distribution patterns of these rainfall are shown in Fig.–3.

The total durations of these rainfall range from 1 hr. 30 min. to 2 hr. 30 min., and the average of them is 1 hr. 50 min. The total amounts of rainfall for each storm range from 25 mm to 58.5 mm, and the average of them is 41 mm. The ratio of rainfall fallen within the duration of peak isolated pulsation to the sum of the rainfall fallen within the total duration was calculated for each storm. These ratios ranged from 63% to 85% and the average values of them was 78%.

(c) Distribution pattern of rainfall with combined pulsations

Distribution pattern of this type is characterized by the appearance of several peak isolated pulsations within the total duration. This type has rather a long duration in general, and the intensity of rainfall in each pulsation is comparatively high in some cases.

Rainfall data recorded in 12 rainy storms had the distribution patterns which might belong to this type. The data are shown in Fig.–4.

The duration of rainfall for each storm ranges from 3 hr. 40 min. to 10 hr. 50 min. and the average of them is 7 hr. 40 min. The amount of total rainfall range from 37.5 mm to 205.5 mm, and the average of them is 90 mm. The ratio of rainfall fallen within the duration of peak pulsations to the sum of rainfall fallen within the total duration ranges from 22% to 87%.

Rainfall data recorded from 23rd to 26th January 1983 show the typical distribution pattern which belong to this type. (See No. 18 in Fig.–4 (ii)) The values of rainfall data are tabulated in Table–2, –3, –4 and –5, respectively. Total duration of rainfall was about 10 hours during which 4 peak isolated pulsations were observed. The total amount of rainfall of 205.5 mm have fallen for the duration of 9 hr. 50 min. The intensity of rainfall recorded during the duration of 4 peak pulsations was 30 mm/hr. or 5 mm/10 min.

Reference

1) REPORT 11: Monthly maximum of accompanied rainfall recorded in Kuching in the period from 1951 to 1980

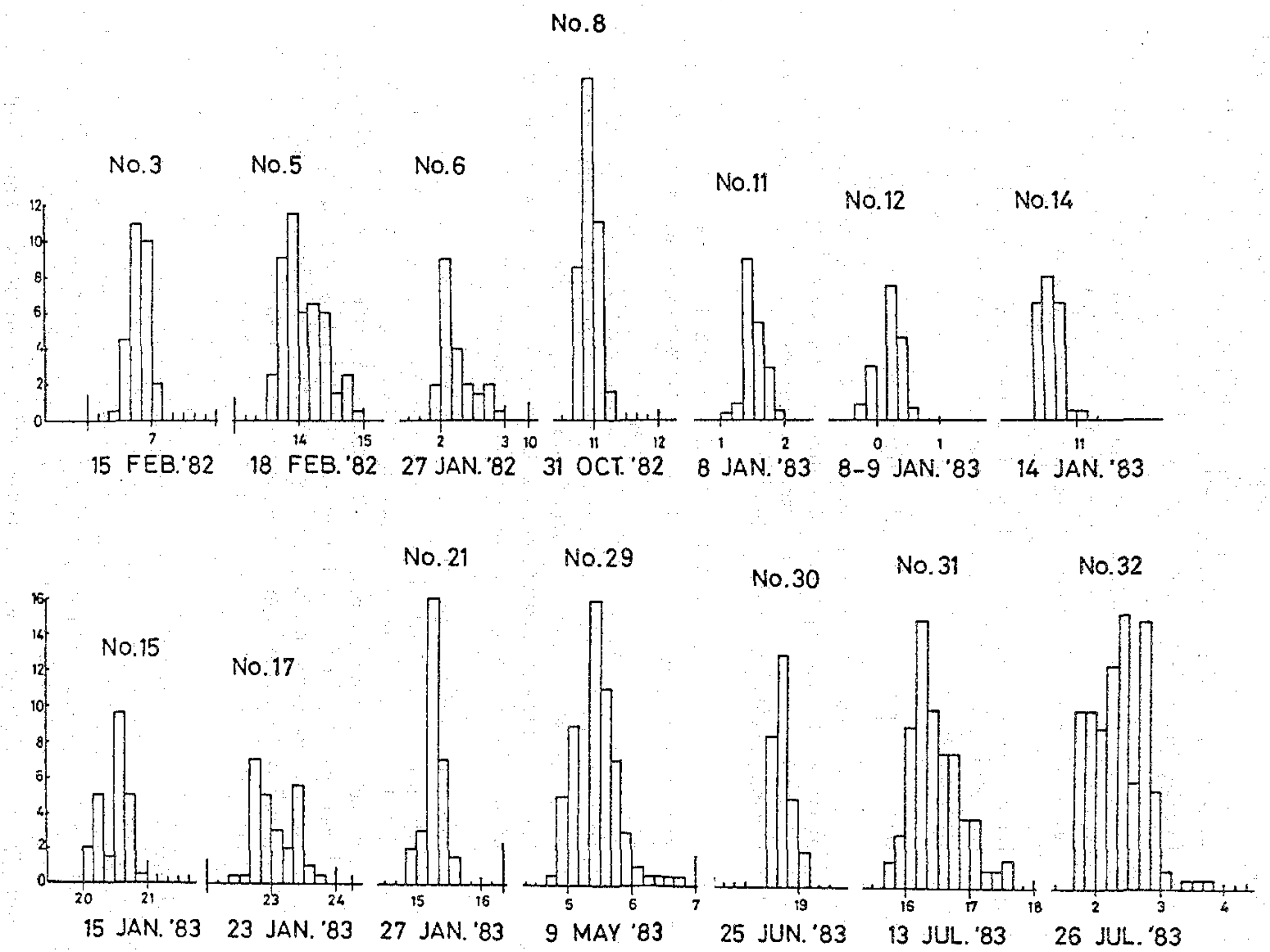


FIG.—1 (a) DISTRIBUTION PATTERN OF RAINFALL WITH AN ISOLATED PULSATION

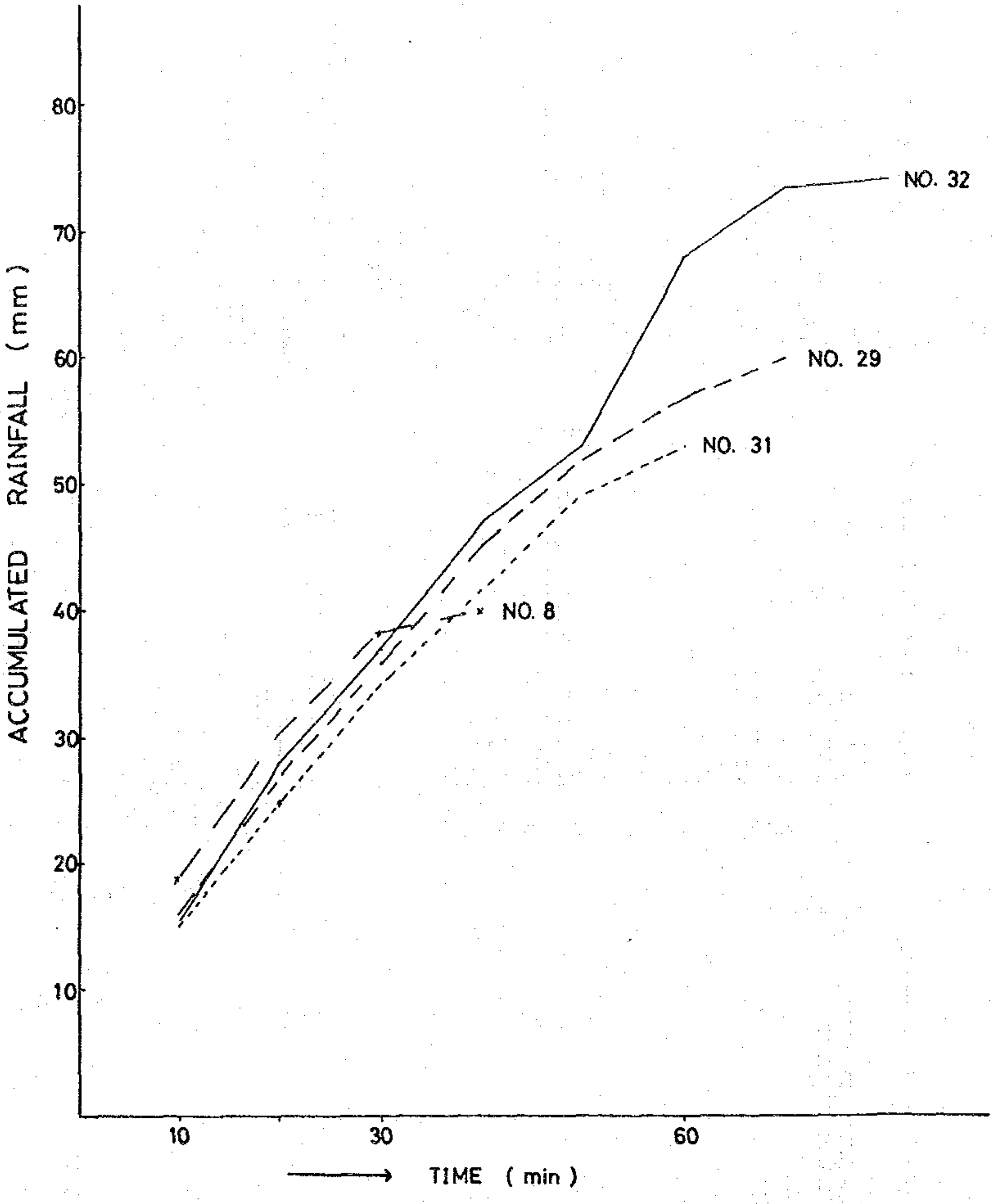


FIG.–2 RELATION BETWEEN ACCUMULATED VALUES OF 10-MINUTE RAINFALL AND THE LENGTH OF TIME USED FOR THE ACCUMULATION

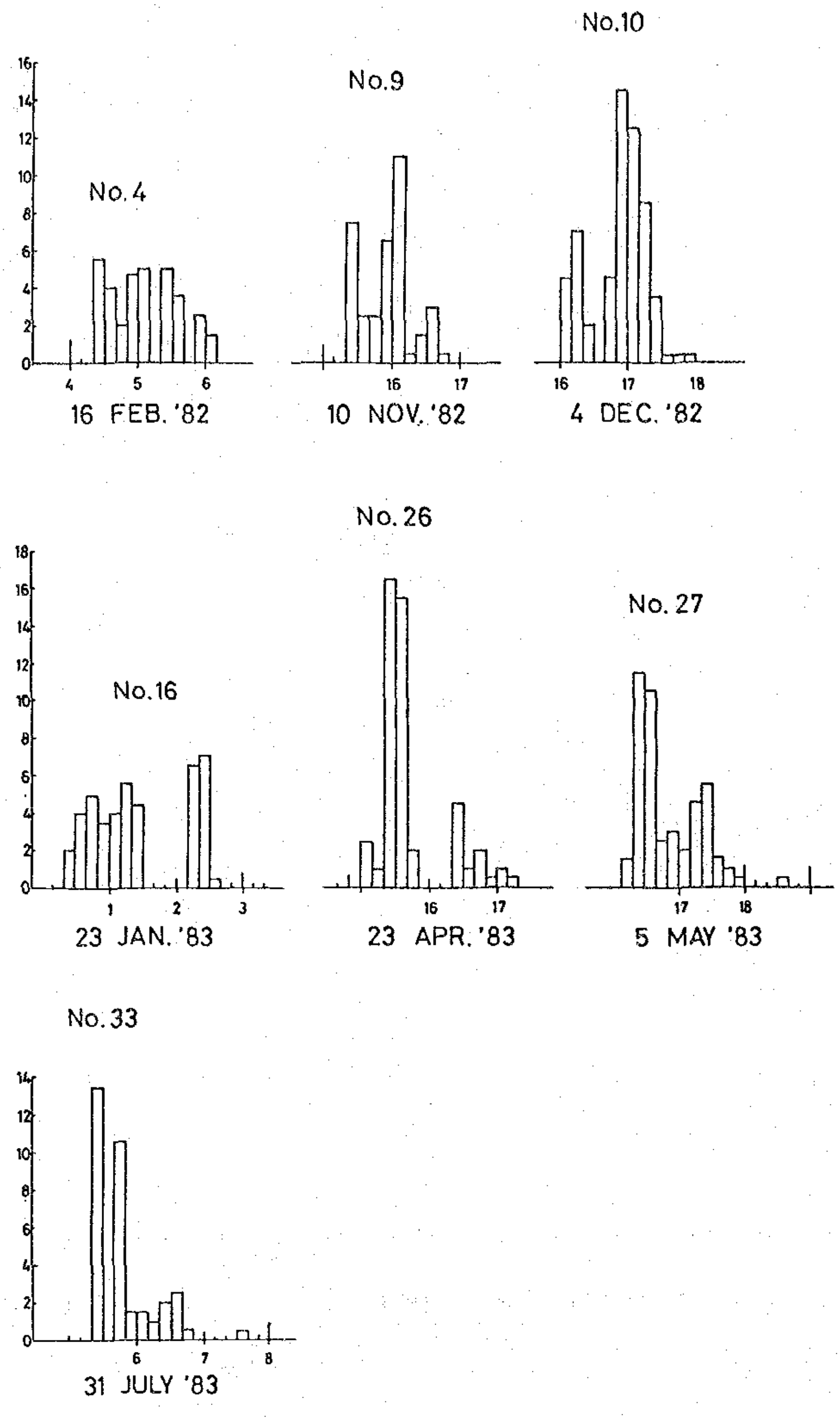


FIG.–3 (b) DISTRIBUTION PATTERN OF RAINFALL WITH ACCOMPANIED ISOLATED PULSATION

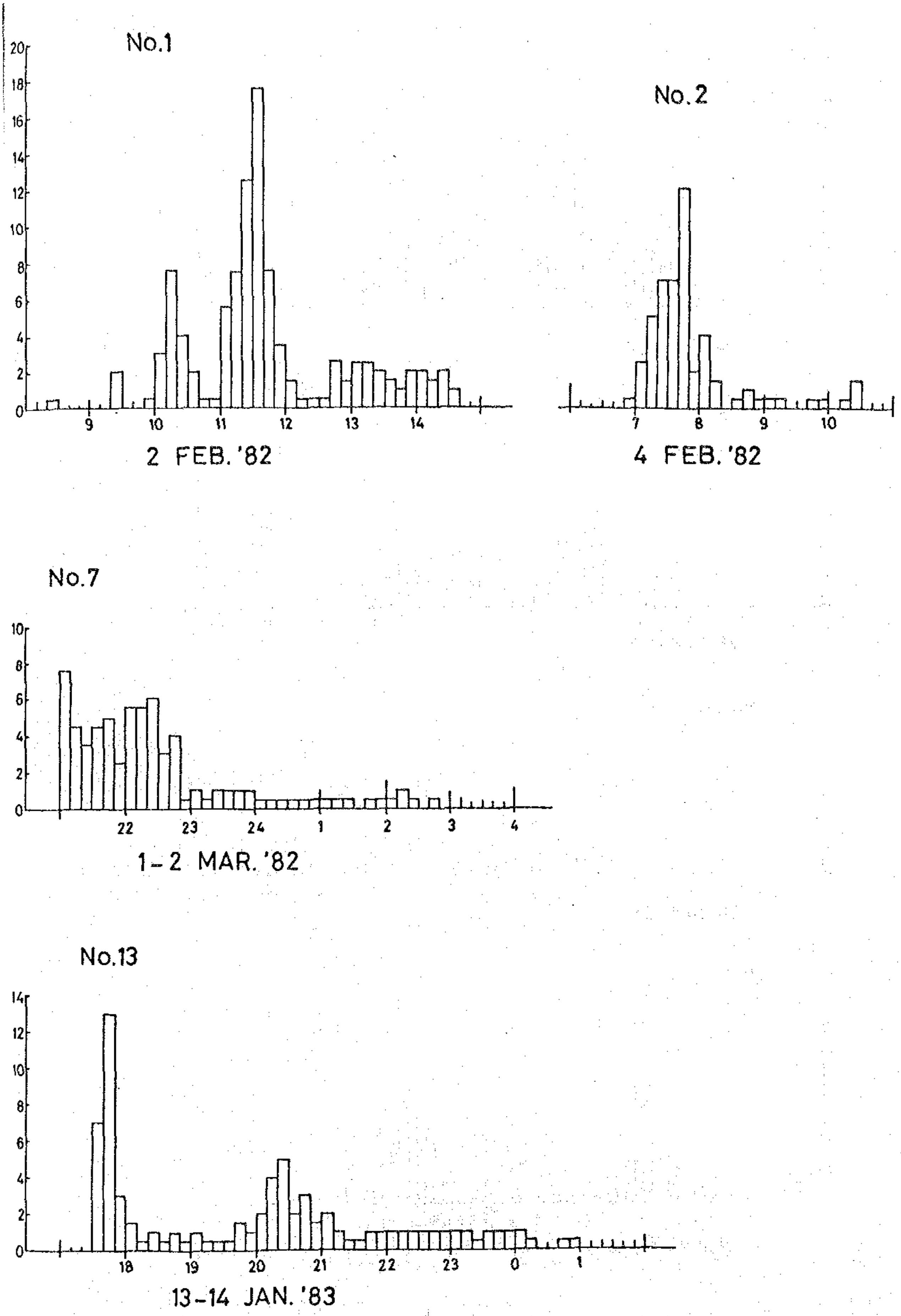
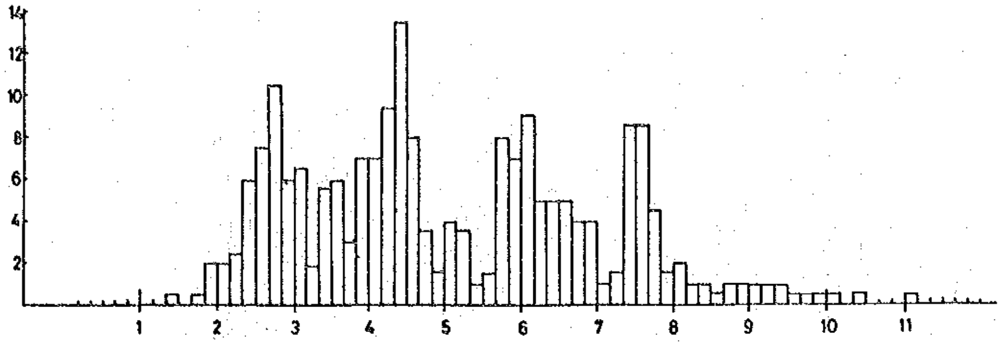


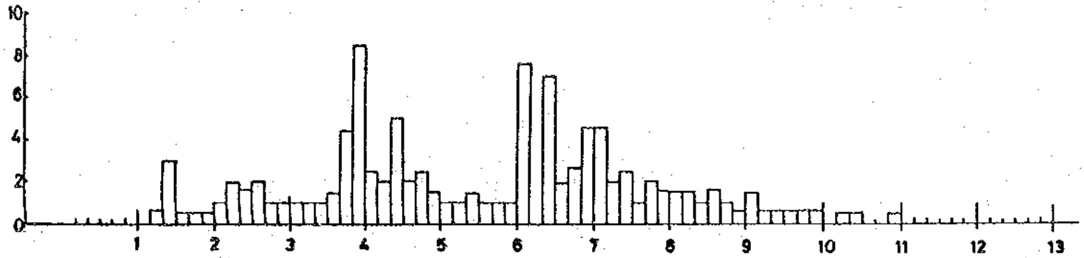
FIG.-4 (i) (c) DISTRIBUTION PATTERN OF RAINFALL WITH COMBINED PULSATIONS

No.18



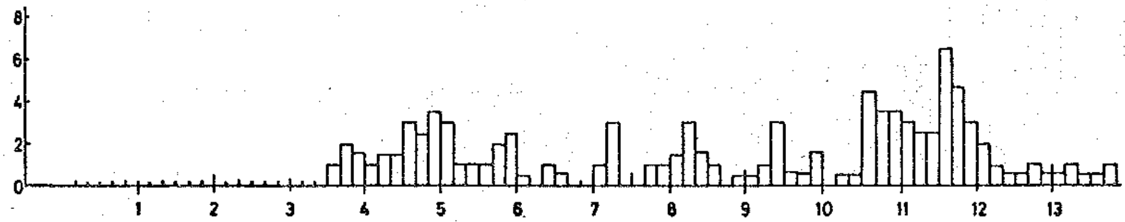
24 JAN. '83

No.19



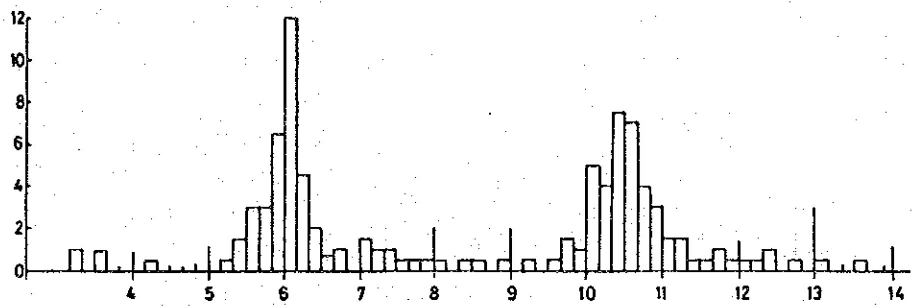
25 JAN. '83

No. 20



26 JAN. '83

No. 21



29 JAN. '83

FIG.–4 (ii) (c) DISTRIBUTION PATTERN OF RAINFALL WITH COMBINED PULSATIONS (CONTINUED)

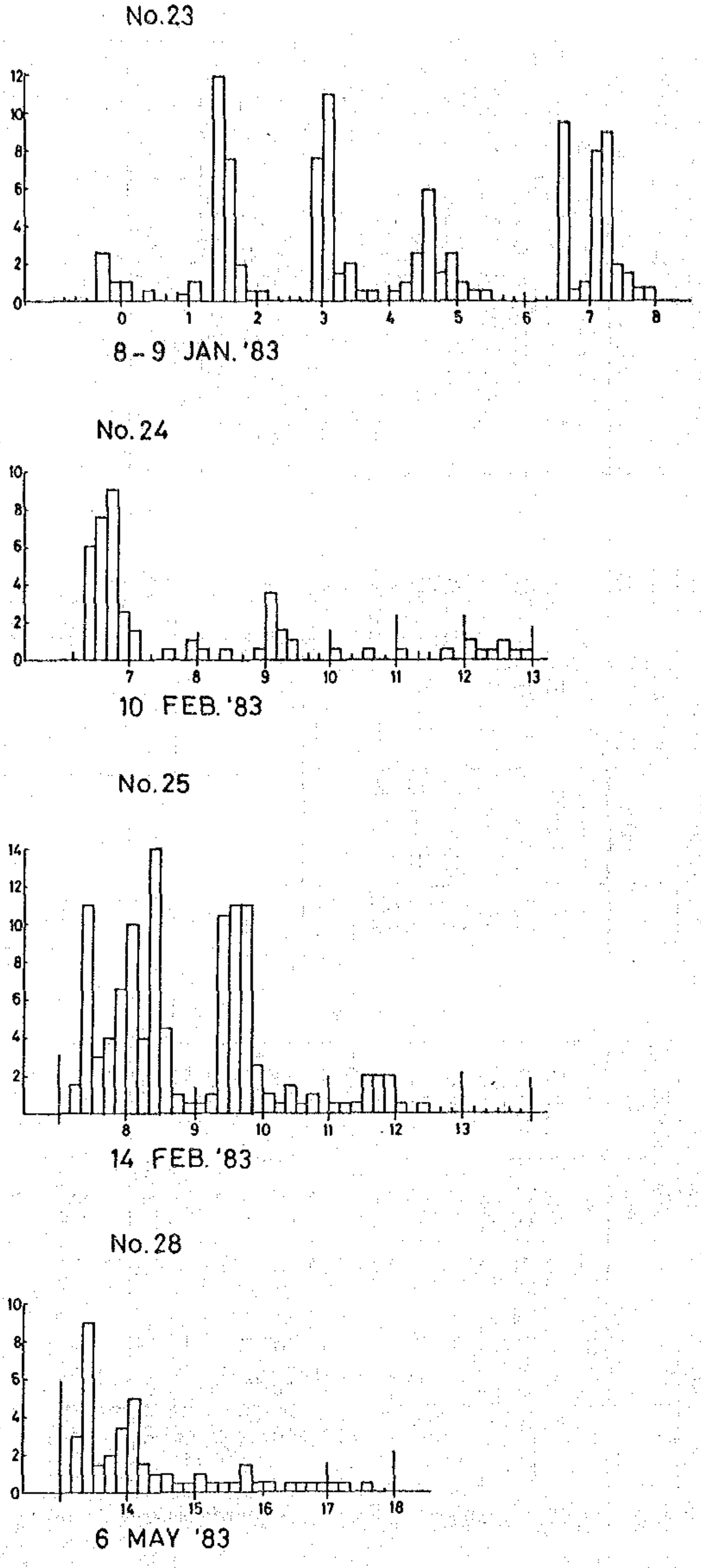


FIG.—4 (iii) (c) DISTRIBUTION PATTERN OF RAINFALL WITH COMBINED PULSATIONS (CONTINUED)

TABLE–1 CLASSIFICATION OF RAINFALL PATTERN

(a) ISOLATED PULSATION			
NO.	DATE	RAINFALL (mm.)	DURATION hr. min.
3	15 FEB. '82	28	:50
5	18 FEB. '82	46.5	1:30
6	27 FEB. '82	21.	1:10
8	31 OCT. '82	40.	:40
11	8 JAN. '83	20.5	1:00
12	9 JAN. '83	19.	1:00
14	14 JAN. '83	22.	:50
15	15 JAN. '83	23.5	1:00
17	23 JAN. '83	25.	1:30
21	27 JAN. '83	26.5	:50
29	9 MAY. '83	61.5	1:30
30	25 JUN. '83	28.5	:40
31	13 JUL. '83	61.5	1:30
32	26 JUL. '83	74.5	1:30
MEAN		36.	1:15

(b) ACCOMPANIED PULSATION			
NO.	DATE	RAINFALL (mm.)	DURATION hr. min.
4	16 FEB. '82	33.5	1:50
9	10 NOV. '82	35.5	1:30
10	4 DEC. '82	58.5	2:00
16	23 JAN. '83	42.5	2:20
26	26 APR. '83	45.	2:20
27	5 MAY. '83	44.5	1:50
33	31 JUL. '83	25.	1:30
MEAN		41.	1:50

(c) COMBINED PULSATION			
NO.	DATE	RAINFALL (mm.)	DURATION hr. min.
1	2 FEB. '82	99.5	6:10
2	4 FEB. '82	47.5	3:40
7	1-2 MAR. '82	65.5	5:50
13	13-14 JAN. '83	70.5	7:30
18	24 JAN. '83	205.5	10:50
19	25 JAN. '83	109.	9:50
20	26 JAN. '83	103.5	12:30
22	29 JAN. '83	87.	10:30
23	8-9 FEB. '83	100.5	8:20
24	10 FEB. '83	41.5	6:40
25	14 FEB. '83	109.5	5:20
28	6 MAY. '83	37.5	4:30
MEAN		90.	7:40

TABLE–2 10-MINUTE RAINFALL ON 23RD JANUARY 1983

MINUTE / HOUR	0-10	10-20	20-30	30-40	40-50	50-60	0-60
0-1			3.0	3.0	4.5	4.0	14.5
2	5.0	6.5	3.5	0	0	0	15.0
3	1.5	5.0	7.5				14.0
4		0					
5		0.5					0.5
6			0.5	0.5		0.5	1.5
7	0.5	0	0.5	1.0	3.5	3.5	9.0
8	3.0	0	0	0	0.5	0.5	4.0
9	0.5	0.5					1.0
10							
11							
12		0.5				0.5	1.0
13	0.5	0.5	1.0	1.0	0.5	0.5	4.0
14	0.5	0.5	0.5				1.5
15							
16							
17							
18							
19							
20							
21							
22			0.5	0.5	7.0	5.0	13.0
23	3.0	2.0	5.5	1.0	0.5		12.0
23-24							
						TOTAL	91.0

TABLE–3 10-MINUTE RAINFALL ON 24TH JANUARY 1983

MINUTE / HOUR	0-10	10-20	20-30	30-40	40-50	50-60	0-60
0-1							
2			0.5		0.5	2.0	3.0
3	2.0	2.5	6.0	7.5	10.5	6.0	34.5
4	6.5	2.0	5.5	6.0	3.0	7.0	30.0
5	7.0	9.5	13.5	8.0	3.5	1.5	43.0
6	4.0	3.5	1.0	1.5	8.0	7.0	25.0
7	9.0	5.0	5.0	5.0	4.0	4.0	32.0
8	1.0	1.5	8.5	8.5	4.5	1.5	25.5
9	2.0	1.0	1.0	0.5	1.0	1.0	6.5
10	1.0	1.0	1.0	0.5	0.5	0.5	4.5
11	0.5	0	0.5	0	0	0	1.0
12	0.5	0	0	0			0.5
13							
14				0.5	0	1.0	1.5
15	2.5	2.5	1.0	1.0	0	0	7.0
16	0.5						0.5
17							
18			0.5	0	1.0	0	1.5
19	0.5						0.5
20							
21	0.5	0	1.0	0			1.5
22	0.5						0.5
23							
23-24			3.5	5.0	0.5		9.0
						TOTAL	227.5

TABLE–4 10-MINUTE RAINFALL ON 25TH JANUARY 1983

HOUR \ MINUTE	0-10	10-20	20-30	30-40	40-50	50-60	0-60
0-1							
2		0.5	3.0	0.5	0.5	0.5	5.0
3	1.0	2.0	1.5	2.0	1.0	1.0	8.5
4	1.0	1.0	1.0	1.5	4.5	8.5	17.5
5	2.5	2.0	5.0	2.0	2.5	1.5	15.5
6	1.0	1.0	1.5	1.0	1.0	1.0	6.5
7	7.5	6.5	7.0	2.0	2.5	4.5	30.0
8	4.5	2.0	2.5	1.0	2.0	1.5	13.5
9	1.5	1.5	1.0	1.5	1.0	0.5	7.0
10	1.5	0.5	0.5	0.5	0.5	0.5	4.0
11	0	0.5	0.5	0	0	0.5	1.5
12							
13	0.5	0	0.5				1.0
14							
15						0.5	0.5
16	2.5	3.0	7.0	2.5	1.5	1.0	17.5
17	2.0	0.5				0.5	3.0
18							
19							
20			0.5	0.5	0.5	1.0	2.5
21	0.5			0.5			1.0
22			1.0	0	2.0	0	3.0
23						0.5	0.5
23-24							
						TOTAL	138.0

TABLE–5 10-MINUTE RAINFALL ON 26TH JANUARY 1983

HOUR \ MINUTE	0-10	10-20	20-30	30-40	40-50	50-60	0-60
0-1	0.5		0.5		0.5		1.5
2			0.5				0.5
3							
4				1.0	2.0	1.5	4.5
5	1.0	1.5	1.5	3.0	2.5	3.5	13.0
6	3.0	1.0	1.0	1.0	2.0	2.5	10.5
7	0.5	0	1.0	0.5	0	0	2.0
8	1.0	3.0	0.5	0	1.0	1.0	6.5
9	1.5	3.0	1.5	1.0	0	0.5	7.5
10	0.5	1.0	3.0	0.5	0.5	1.5	7.0
11	0	0.5	0.5	4.5	3.5	3.5	12.5
12	3.0	2.5	2.5	6.5	4.5	3.0	22.0
13	2.0	1.0	1.5	0.5	1.0	1.0	7.0
14	0.5	1.0	0.5	0.5	1.0	0.5	4.0
15	1.0	0.5	1.5	0	0.5	0.5	4.0
16	0	0.5	0.5	0.5	1.0	0.5	3.0
17							
18			0.5	0.5			1.0
19							
20							
21						0.5	0.5
22							
23							
23-24							
						TOTAL	107.0

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TABLE–1 HOURLY RAINFALL DURING HEAVY RAIN IN KUCHING, SARAWAK
(i) (1971 – 1977)

No.	1		2		3		4		5		6
Time \ Gaging Station	JAN 8, 1971	JAN 9, 1971	JAN 21, 1971	JAN 22, 1971	JUN 22, 1972	JUN 23, 1972	DEC 24, 1973	DEC 25, 1973	FEB 23, 195	FEB 24, 1975	DEC 28, 1975
0 ~ 1		11				4		42	7	44	
2		18		1		1		16	7	8	
3		42	2			2		25		8	
4		24				12		16		3	
5		32				23		24		1	
6		18		1		17		6		1	
7		22		3		29		8			
8		14		12		57		4			
9		7	2	20		51		3			
10		17		32		13		3			
11		13	22	38		4		4			
12		23		30		3		8			2
13		20		8		3		2			1
14		27				2					10
15		18	6	1		2					30
16		21	1			1					37
17		25		6							38
18	7			12							11
19	7			3							13
20	55		1	13							5
21	31		1	3			9				3
22	18		6	1	1		3				
23	18		1	2	2		9				
23 ~ 24	31		12		20		16		50	19	13
Total											
(9 ~ 9)											

No.	6	7			8				9		
Time \ Gaging Station	DEC 29, 1975	JAN 11, 1976	JAN 12, 1976	JAN 13, 1976	FEB 4, 1977	FEB 5, 1977	FEB 6, 1977	FEB 7, 1977	FEB 22, 1977	FEB 23, 1977	FEB 24, 1977
0 ~ 1	10	3	8			19	3			46	34
2	19	1	8			25	18	2	2	23	4
3	18	2	10			16	3	21		10	
4	7		5	1		21	3	51		8	2
5	9		4			14	2	33		4	
6	20		11		5			14	2	3	
7	23		11		13		2	7		2	
8	14		4	1	2		2	1			
9	12	1	10		7						
10	13	1	9	23			2	1	3		
11	16	1	8		2						
12	5		2						3		
13	7		13	1					12		
14	2		11		4						
15	1	2	13		2				7		
16	1	5	11						2		
17	2	7	5				1		7		
18	1			1		3			9		
19		1	5			4	1		3		
20		13	6	1							
21		17		16	2		1		2		
22		14		31	5				10		
23		9		9	22	2			6		
23 ~ 24		11		5	20			1	13	9	
Total											
(9 ~ 9)											

TABLE–2 HOURLY RAINFALL DURING HEAVY RAIN IN KUCHING, SARAWAK
(ii) (1978 – 1983)

No.	10				11	12					
Time \ Gaging Station	FEB 21, 1978	FEB 22, 1978	FEB 23, 1978	FEB 24, 1978	JAN 2, 1980	JAN 23, 1983	JAN 24, 1983	JAN 25, 1983	JAN 26, 1983		
0 ~ 1	8.	5.		18.			1.	3.	2.		
2	3.	3.		29.			5.	6.			
3	12.	3.	9.	6.			14.	13.			
4		55.	21.	4.	40.		4.	10.	3.		
5		57.		10.	28.		12.	36.	11.		
6		14.		6.	27.		25.	17.	9.		
7		6.		3.	94		10.	9.	10.		
8	2.	5.		3.	76.		5.	22.	4.		
9		17.		4.	53.		7.	10.	8.		
10	5.	3.		2.	35.		5.	3.	16.		
11		1.			61.		2.	1.	10.		
12					34		1.	2.	37.		
13		3.	3.		22.			1.	6.		
14	2.	4.	13.		3.				6.		
15			10.		1.				5.		
16					4.			20.	2.		
17					3.			18.			
18		2.			2.						
19	1.	4.									
20	2.	2.						1.			
21	16.	5.						5.			
22	3.	2.									
23	27.	4.	3.			10.					
23 ~ 24	5.	4.				29.					
Total											
19 ~ 9											

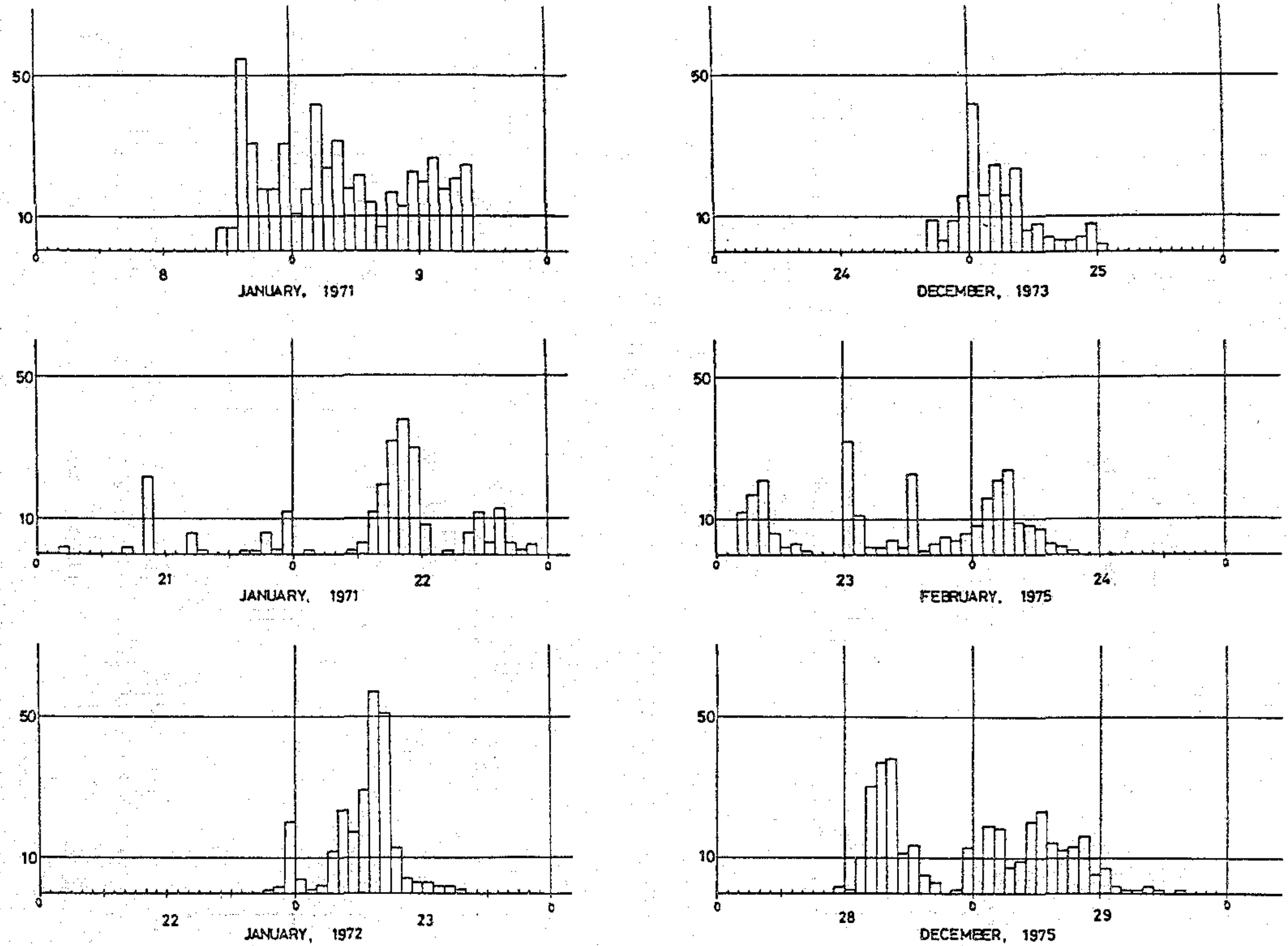
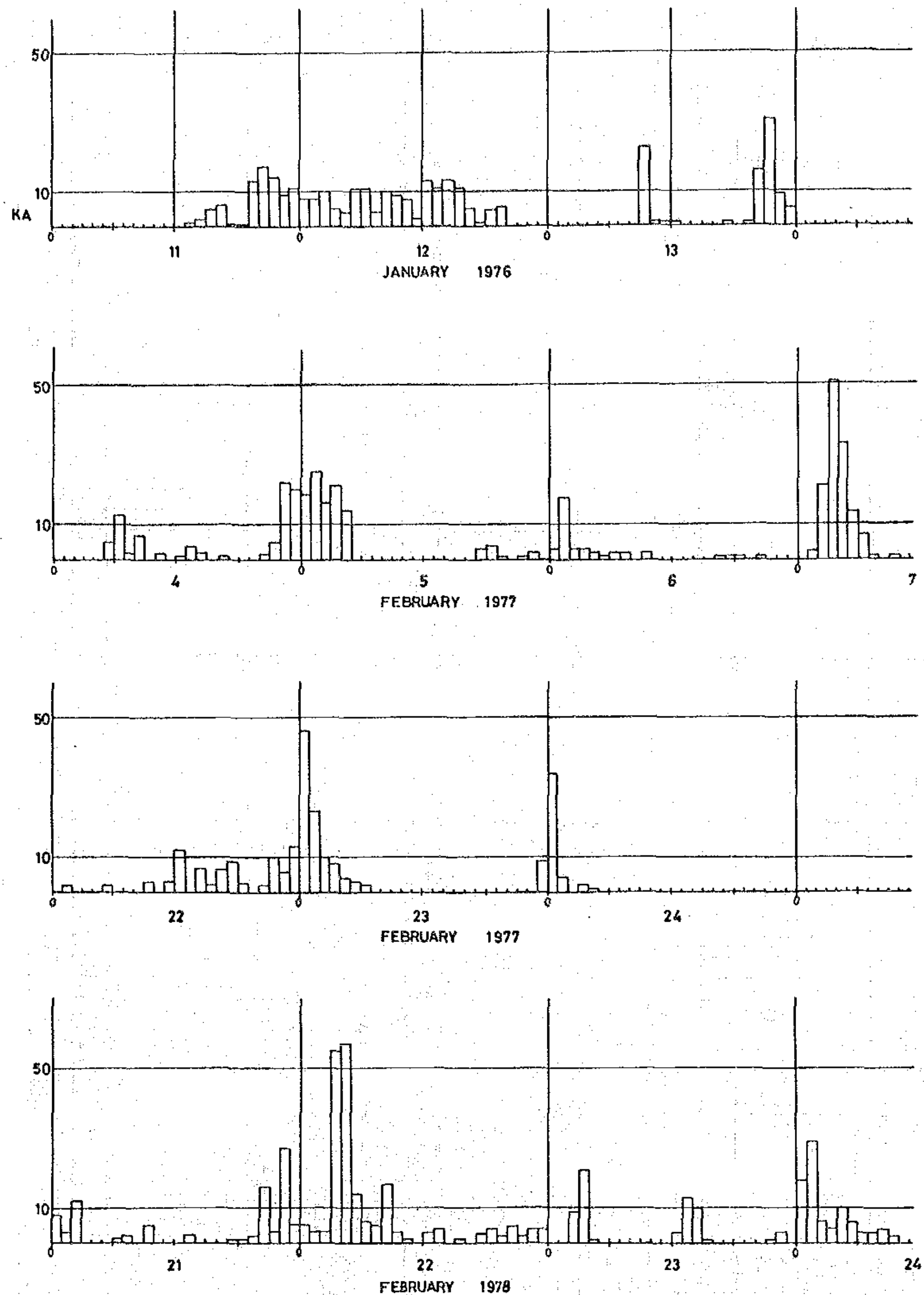


FIG.–1 HOURLY RAINFALL DISTRIBUTION DURING HEAVY RAIN IN KUCHING, SARAWAK
(i) (1971 – 1975)



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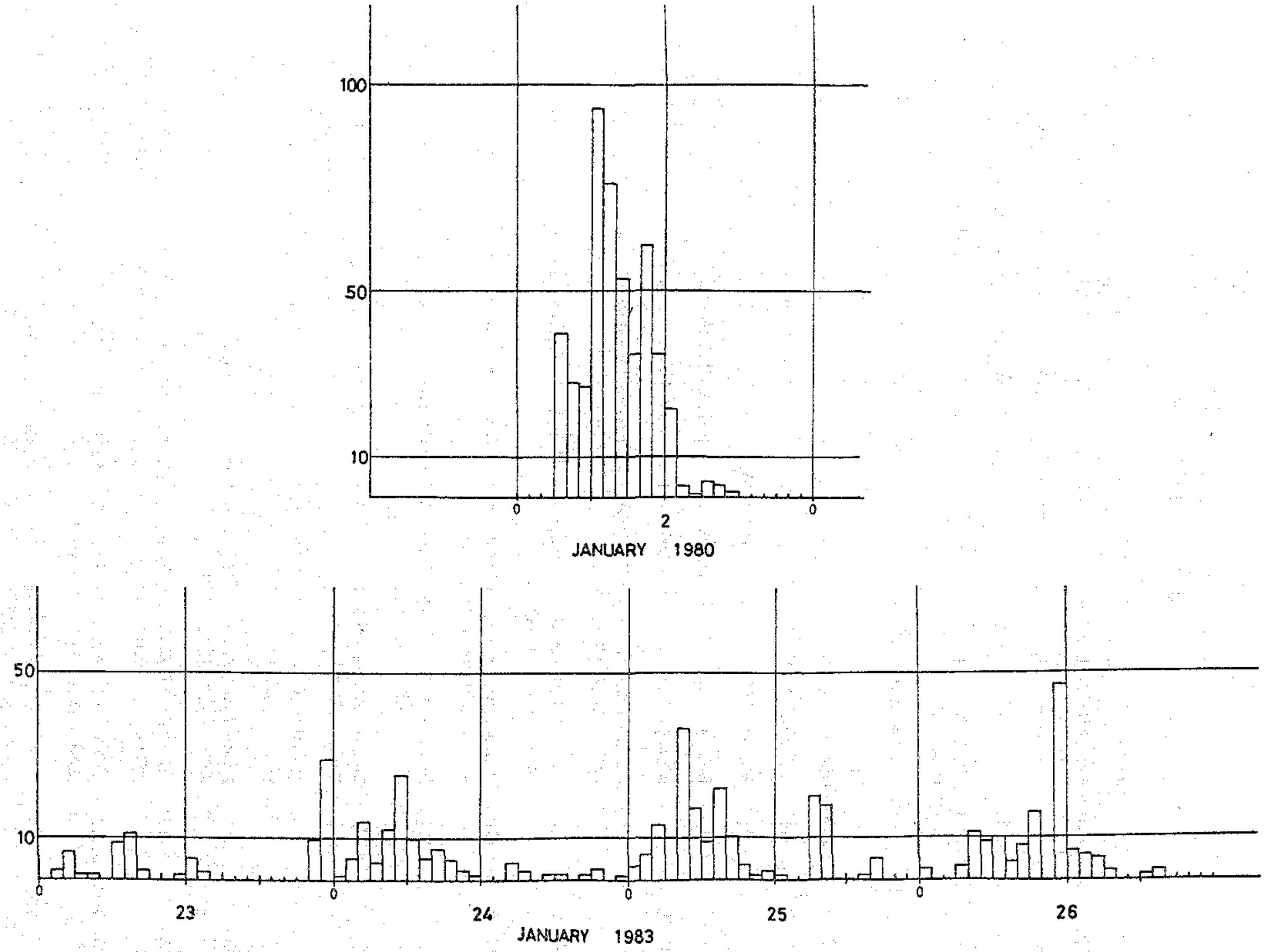

FIG.–3 HOURLY RAINFALL DISTRIBUTION DURING HEAVY RAIN IN KUCHING, SARAWAK
(iii) (1980 – 1983)