

Short duration analysis of Calcutta (Dum Dum) rainfall

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ABSTRACT: An analysis of autographic rainfall records for the period 1948 to 1965 of the Dum Dum Observatory, Calcutta, has been made with a view to determine frequency-intensity-duration relationships. The pattern of diurnal variation of rainfall has also been studied for the rainy months of May to October.

1. Introduction

The characteristics of short duration rainfall intensities of various return periods are required by the hydrological engineers particularly for local drainage and culvert designs. In this paper a study of autographic rainfall records of Dum Dum Observatory (Calcutta) over a period of 18 years from 1948 to 1965 has been made. May to October is the principal rainy period for Calcutta when more than 90 per cent of the annual precipitation is recorded (Table 1).

2. Frequency analysis of hourly rainfall data

The clock-hour has been taken as the unit of duration for this study. The observed extreme annual rainfall amounts recorded during each of the durations of 1, 2, 3, 6, 12, 18, 24, 36, and 48 hours were first picked up from the scrutiny of hourly tabulations of daily data for the period 1948 to 1965 using the extended duration principle (Chow 1953). Using Gumbel (1954) technique, the return periods of the extreme annual values for different durations were calculated using the formula $T = (N + 1)/m$ where N represents the total number of years of record and m is the rank number. The plotting of the observed points and computed straight line for 6-hour duration is shown in Fig. 1. Table 2 gives the maximum rainfall intensity for different durations and return periods. Such rainfall studies are helpful in estimating peak discharge from small basins using the "rational" formula.

3. Analysis of heavy and long rain spells

Rain spells whose total duration was 24 hours or more and which yielded 3 inches or more of rain during the entire duration of the rain spell have been considered for this study. A rain spell was considered to have ended, if the next spell did not start within 6 hours. Table 3 gives a list of 25

such spells of rain experienced at Dum Dum during the 18-year period. The maximum rainfall recorded during different durations (*viz.*, 1, 2, 3, 6, 12, 18, 24, 36 and 48 hours) in each of these 25 rain spells were first picked up. Out of the 25 rain spells considered, only 15 had durations of about 48 hours or more. Percentage ratios of maximum rainfall recorded in each of these durations to that recorded in 24 and 48 hours were then worked out for each rain spell.

Mean and median values of the percentage ratios were calculated for each duration and the same are shown in Table 4 (a and b). Since the samples are small and skewed, it is felt that mean value of the percentage ratios for each duration may not represent a realistic measure of location. In such cases adoption of the median value instead of the mean is recommended (Hoel 1954). This procedure has been followed in the present study. In a similar study of maximum 1 hour rainfall for Begumpet, Rao (1959) considered that percentage ratio as the representative of a sample which is exceeded on 55 per cent of occasions. Median values are exceeded on about 50 per cent of occasions and, therefore, there appears to be little difference between Rao's and our approach.

Parthasarathy (1961), while studying the short duration rain intensities of this country observed that on days of heavy rainfall, generally, 80 to 90 per cent of 24-hour rainfall occurs within a duration of 6 hours. It has been observed from this study that only on 20 per cent of occasions 6-hour rainfall was 80 per cent and above of 24-hour rainfall.

In the absence of recording raingauge network hydrologists find it difficult to break up 24 and 48-hour maximum rain amounts into shorter durations of 3, 6 or 12 hours for estimating peak discharge by unit hydrograph method. The above study will be helpful in breaking up 24 and 48.

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TABLE 1

Mean monthly and annual rainfall for Dum Dum Observatory, Calcutta
(Based upon the rainfall data of the period 1931-1960)

Month	Rainfall (inches)	Per cent of annual rainfall	Month	Rainfall (inches)	Per cent of annual rainfall
January	0.52	0.8	August	12.52	20.3
February	0.86	1.4	September	9.94	16.1
March	1.17	1.9	October	5.28	8.5
April	1.96	3.2	November	1.15	1.9
May	5.30	8.6	December	0.14	0.2
June	10.36	16.8	Annual	61.80	100
July	12.60	20.4	May to October	56.00	90.6

TABLE 2

Maximum rain intensity (inches/hour) for different durations and return periods

Duration (hrs)	2-year	3-year	5-year	7-year	10-year	15-year	20-year	25-year
1	1.84	2.05	2.27	2.40	2.55	2.73	2.85	2.93
2	1.50	1.37	1.57	1.70	1.85	2.00	2.10	2.19
3	0.90	1.03	1.18	1.27	1.35	1.46	1.52	1.57
6	0.53	0.60	0.67	0.73	0.78	0.83	0.88	0.92
12	0.31	0.36	0.42	0.45	0.49	0.53	0.55	0.57
18	0.23	0.27	0.31	0.34	0.37	0.40	0.42	0.44
24	0.18	0.21	0.25	0.27	0.29	0.33	0.34	0.36
36	0.14	0.17	0.19	0.21	0.23	0.25	0.27	0.28
48	0.11	0.13	0.16	0.17	0.19	0.21	0.22	0.23

hour maximum rain amounts into shorter durations for small areas in and around Calcutta.

4. Comparison between continuous and discontinuous rain spells

In the foregoing study all the heavy and long rain spells were considered including those that were broken up by dry spells of duration less than 6 hours. A study of continuous rain spells in which every clock-hour has recorded some measurable amount of rainfall, including trace rainfall, has also been made. This has been done with a view to find out whether there is any large difference in the percentage ratios obtained from continuous and discontinuous rain spells. From the available recorded rainfall data only 6 continuous rain spells could be obtained whose duration was 24 hours or more. Table 5 gives the mean and median values of percentage ratios obtained from these spells with respect to 24-hour maximum rainfall.

Comparing the percentage ratios (median values) obtained from the continuous and discontinuous rain spells given in Tables 4 and 5, it is seen that for duration upto 12 hours, discontinuous rain spells give higher percentage ratios when compared to continuous rain spells and beyond that the ratios are practically of the same order. As there were no 48-hour continuous rain spells during the period under consideration, this type of comparison could not be carried out for durations of 24 and 36 hours.

5. Time distribution of rain spells

Daily rainfall as usually reported does not represent the true 24-hour rainfall unless the entire rain spell has occurred within the two observations, *i.e.*, 0830 IST of previous date to 0830 IST of date. A 2-day observational rainfall might have occurred

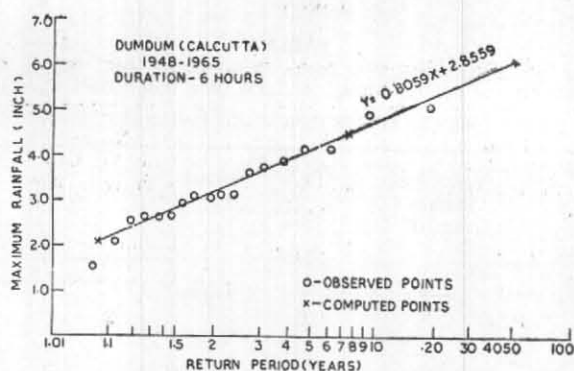


Fig. 1. Frequency curve for 6-hr extreme annual rainfall

in a couple of hours only, that is, a short period before the hour of observation and another short period after the hour of observation. In the absence of recording rainfall data, hydrologist has to use the observational one-day maximum rainfall, or observational 2-day maximum rainfall for getting an indication of the maximum rainfall that could have occurred in 24 or 48 hours. This aspect of rainfall distribution is studied below.

In Table 3 each spell of rain has been indicated in terms of 3 units of time, viz., (i) observational-day, (ii) calendar-day and (iii) clock-hours. From this table, the following average time distribution has been worked out —

- (i) Observational two-day rainfall occurred in a duration of about 32 clock-hours,
- (ii) Observational three-day rainfall occurred in a duration of about 48 clock-hours and
- (iii) Observational four-day rainfall occurred in a duration of about 68 clock-hours.

In a similar study, Huff and Neill (1959) have found in respect of Illinois (U.S.A.) that (i) Observational 2-day rainfall occurred in a period of 30 hours and (ii) observational 3 day rain occurred in a period of 45 hours.

It is seen from the above that the durations of 2 and 3 observational days in Illinois (U.S.A.) are of the same order of magnitude as for Dum Dum (Calcutta).

If we only consider the actual hours of rain in a rain spell, the following results were obtained —

- (i) On an average, observational 2-day rain was recorded in 25 hrs,
- (ii) 3-day rain in 32 hrs and
- (iii) 4-day rain in 54 hrs.

Huff and Neill's (1959) findings in respect of Illinois (U.S.A.) were 17 and 22 hrsf or 2-day and 3-day rain spells respectively.

6. Relation between observational day and 24-hr maximum rainfall

An attempt has been made to evolve relationships between (i) 24-hr to observational one-day maximum rainfall, (ii) 48-hr to observational 2-day maximum rainfall, and (iii) 72-hr to observational 3-day maximum rainfall. Maximum rainfall amounts recorded in observational 1, 2, 3 etc, days and corresponding 24, 48, 72 hrs etc in respect of 25 rain spells indicated in Table 3 were first picked up. On the basis of this data, for each duration of 24, 48 and 72 hrs scatter diagrams were prepared which are shown in Fig. 2 (a, b, and c). Straight lines of the form $Y=mx$ have been fitted to this data. The slopes of the computed straight lines are 1.11 for 24-hour duration, 1.02 for 48-hour and 72-hr. durations. Thus to get 24-hr maximum rainfall from the observational one day maximum rainfall the latter has to be increased by 11 per cent. Similarly to obtain 48-hour maximum rainfall, from the observational 2-day maximum rainfall, we have to increase the latter by 2 per cent. In other words, within 2 per cent error, observational 2 and 3-day maximum rainfall amounts are fairly representative of the 48 and 72-hr maximum rainfall.

The average factors obtained in U.S.A. for conversion of 1, 2 and 3 observational day maximum rainfall into 24, 48 and 72 hours maximum rainfall are 1.13, 1.02 and 1.01 respectively (Huff and Neill, 1959; U. S. Weath. Bur. 1961, 1964). These factors nearly agree with those obtained in the present study. Another method usually followed (Wisler and Brater 1959) is to add half and larger rainfall that falls on either the preceding or succeeding day to the observational-day maximum rainfall. To examine the validity of this method, a comparison of rainfall amounts obtained by this method with the actual maximum

TABLE 3

List of heavy and long rain spells experienced during the period of 1948-1965 at Dum Dum (Calcutta)

Rain spells		Total rainfall in the rain spell (inches)	No. of observational days in rain spell (days)	No. of calendar days in the rain spell (days)	Duration of rain spell (hrs)	Actual No. of rain hours in the rain spell (hrs)
Begin. (hrs IST date)	End (hrs IST date)					
0600 (2-9-48)	0500 (3-9-48)	3.57	2	2	24	16
0900 (7-5-49)	1500 (8-5-49)	9.17	2	2	31	29
0200 (16-9-49)	0200 (17-9-49)	3.06	2	2	25	19
1000 (23-6-50)	1600 (25-6-50)	3.55	3	3	55	32
1200 (21-6-53)	1100 (23-6-53)	4.45	3	3	48	26
1400 (29-9-55)	1100 (1-10-55)	3.08	3	3	46	25
0100 (31-5-56)	0200 (3-6-56)	11.08	4	4	74	68
0500 (24-9-56)	1200 (26-9-56)	10.73	4	3	56	44
0300 (18-7-57)	1200 (19-7-57)	4.83	3	2	34	22
1700 (11-6-59)	0800 (13-6-59)	4.15	2	3	40	30
2100 (8-9-59)	2000 (12-9-59)	13.19	5	5	96	75
1000 (30-9-59)	1200 (2-10-59)	7.78	3	3	51	41
0200 (13-8-59)	1000 (14-8-59)	3.23	3	2	33	18
0900 (2-7-60)	1900 (4-7-60)	6.73	3	3	59	49
1600 (10-7-60)	1300 (12-7-60)	5.34	3	3	46	38
1000 (10-6-61)	0800 (12-6-61)	3.99	3	3	57	33
0500 (4-8-61)	1300 (5-8-61)	4.19	2	2	33	23
0900 (20-9-62)	1000 (22-9-62)	4.83	3	3	50	38
1100 (29-10-62)	1700 (30-10-62)	3.26	2	2	31	29
1100 (17-6-63)	0700 (19-6-63)	6.54	2	3	45	38
0700 (26-9-63)	1500 (27-9-63)	3.46	3	2	33	30
1600 (22-10-63)	0200 (25-10-63)	3.30	3	4	59	36
0900 (29-6-65)	0900 (2-7-65)	6.10	4	4	73	49
1200 (23-8-65)	1900 (25-8-65)	7.29	3	3	56	39
2000 (4-9-65)	1900 (5-9-65)	3.76	2	2	24	19

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TABLE 4

Percentage ratios of 1, 2, 3, 18-hour to 24-hour and 48-hour maximum rainfall

	Duration (hrs)						Duration (hrs)							
	1	2	3	6	12	18	1	2	3	6	12	18	24	36
	(a) % ratios of 1, 2, 3, . . . 18-hr to 24-hr max. rainfall						(b) % ratios of 1, 2, 3, . . . 36-hr to 48-hr max. rainfall							
Mean (%)	27	39	46	58	75	87	17	25	30	39	50	59	71	91
Standard error of mean (%)	2.3	3.3	3.4	3.8	3.4	3.1	1.4	1.9	2.5	3.3	3.6	3.7	3.7	1.2
Median (%)	24	34	40	54	81	90	15	21	25	41	50	55	74	93
Highest (%)	56	76	84	96	99	100	28	41	46	66	78	82	51	99
Lowest (%)	11	19	19	29	38	53	9	15	15	21	29	41	97	70

In part (a) of the table mean etc are based upon the data of 25 rain spells while in part (b) these are based upon the data of 15 rain spells only

TABLE 5

Percentage ratios of maximum rainfall of 1, 2, 3, 18-hour duration to that of maximum 24-hr rainfall for continuous rain spells

Duration	1-hr	2-hr	3-hr	6-hr	12-hr	18-hr
Mean (%)	15	25	32	49	74	90
Standard error of mean (%)	1.3	2.0	2.8	3.3	4.6	2.1
Median (%)	14	24.5	31.5	52	73.5	91.5
Highest (%)	19	34	44	57	89	95
Lowest (%)	12	22	22	29	56	80

values for different durations was also made. It has been observed that 24-hr maximum rainfall thus calculated is an over-estimate by about 5 per cent while the 48 and 72-hr rainfall amounts are correct within one per cent.

7. Frequency distribution of continuous rain spells of different durations

The frequency of occurrence of rain spells of different durations and the total amount of rainfall received in each duration for different months were calculated. Percentage frequency of rainfall of different durations as well as percentage distribution of rainfall amounts in different durations for each of the rainy months are given in Table 6. This table reveals the following—

- (i) During the period under study Dum Dum (Calcutta) experienced only once (*i.e.*, in June 1956) a continuous rain spell of 36 hours which yielded a rainfall of 8.02 inches. Also, there were only six spells of

continuous rain whose duration was 2 hours or more during this period,

- (ii) The highest average intensity of rain per hour was found to be of the order of 0.35 inches in only 2 rain spells of duration 26 and 24 hours in the months of May 1949 and September 1956 respectively, and
- (iii) The percentage frequency of 1-hour rain spells was found to be the highest in the month of August thereby indicating that August rainfall is mostly made up of short spells whose duration generally is 1 hour or less.

8. Diurnal variation of rainfall

The mean rainfall for each clock-hour of the day was calculated for each of the rainy months (May to October) and the mean rainfall of the calendar days thus obtained was utilised to indicate the

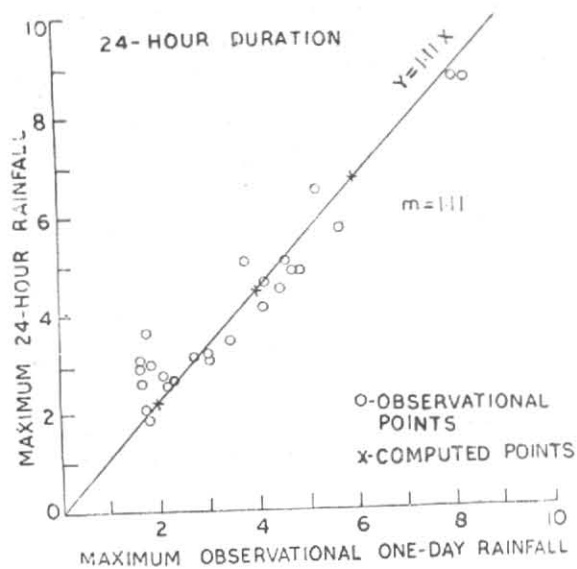


Fig. 2(a). One-day rainfall

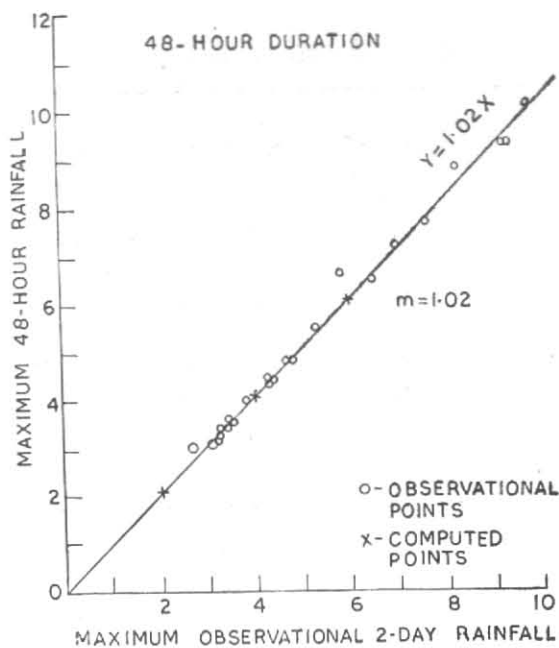


Fig. 2(b). 2-day rainfall

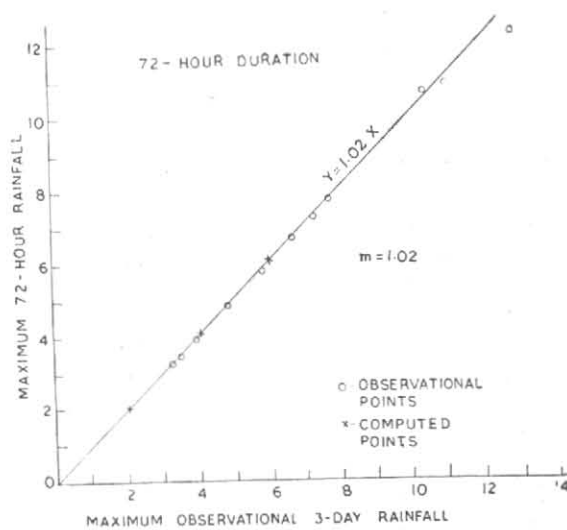


Fig. 2(c). 3-day rainfall

Fig. 2. Maximum observational rainfall

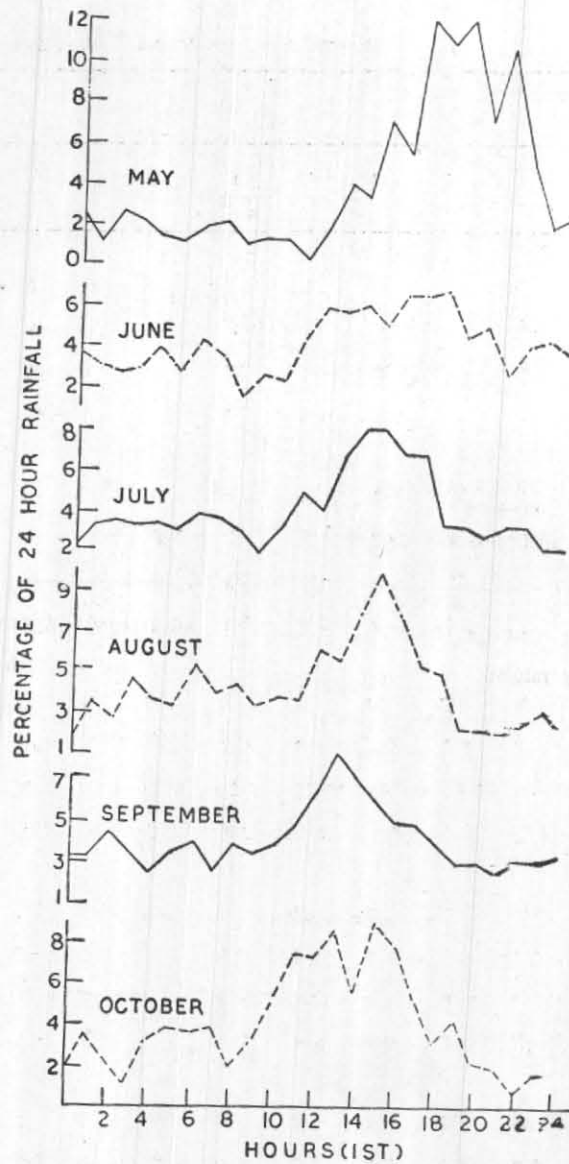


Fig. 3. Diurnal curves of rainfall for different months at Dum Dum (Calcutta)

percentage of the day's rainfall for each of the clock-hours. Fig. 3 shows diurnal variation of this percentage for each of the six months from May to October. The important features brought out by the diurnal curves in Fig. 3 are —

(i) The maximum which occurs at about 17 to 19 IST in the month of May moves backwards as the season advances to about 13 IST in the month of September and slightly gets delayed to about 13 to 15 IST in the month of October,

(ii) At 13 and 15 IST peaks occur in most of monthly diurnal curves,

(iii) The afternoon maxima is about 8 to 12 per cent of the day's total, and

(iv) There is a secondary maxima in the early morning hours when about 4 to 5 per cent of the day's rainfall is received. Only in the month of May the early morning maximum is about 3 per cent of the day's rainfall,

TABLE 6
Frequency of cooccurrence of continuous rain spells of different durations

Month	Duration															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
May																
<i>F</i>	101	58	29	10	0	2	4	1	0	0	2	0	0	0	0	1
<i>PF</i>	48.1	27.6	13.8	4.8		1.0	1.9	0.5			1.0					0.5
<i>A</i>	7.83	23.85	19.00	4.67		3.36	4.96	0.37			1.85					0.39
<i>PR</i>	10.1	30.7	24.5	6.0		4.3	6.4	0			2.4					0
Jun																
<i>F</i>	277	132	61	27	24	13	6	6	4	1	4		0	0	0	1
<i>PF</i>	49.5	23.6	10.9	4.8	4.3	2.3	1.1	1.1	0.7	0.2	0.7					0.2
<i>A</i>	18.04	32.66	25.26	19.70	14.79	10.04	9.56	8.93	7.03	1.55	5.55					0.98
<i>PR</i>	10.5	19.0	14.7	11.5	8.6	5.9	5.6	5.2	4.1	1.0	3.2					0.6
Jul																
<i>F</i>	239	201	105	49	25	14	13	8	7	0	2	2	0	1	1	0
<i>PF</i>	35.7	30.0	15.7	7.3	3.7	2.1	1.9	1.2	1.0		0.3	0.3		0.2	0.2	
<i>A</i>	25.89	38.42	30.39	30.14	17.18	10.44	18.75	7.36	8.39		2.55	3.57		2.06	2.87	
<i>PR</i>	12.6	18.7	14.8	14.7	8.4	5.1	9.1	3.6	4.1		1.2	1.7		1.0	1.4	
Aug																
<i>F</i>	487	221	107	40	25	16	10	8	0	2	1	0	1	0	1	0
<i>PF</i>	53.0	24.0	11.6	4.3	2.7	1.7	1.1	0.9		0.2	0.1		0.1		0.1	
<i>A</i>	30.32	36.63	38.42	22.46	18.08	12.20	8.37	9.88		6.68	0.84		0.84		3.31	
<i>PR</i>	16.1	19.5	20.4	11.9	9.6	6.5	4.5	5.3		3.5	0.4		0.4		1.8	
Sep																
<i>F</i>	273	126	60	39	23	12	12	6	9	2	2	2	1	1	1	1
<i>PF</i>	47.66	22.0	10.5	6.8	4.0	2.1	2.1	1.0	1.6	0.3	0.3	0.3	0.2	0.2	0.2	0.2
<i>A</i>	18.56	33.58	25.59	20.99	18.72	11.25	8.70	7.77	11.74	1.62	4.55	1.59	0.81	4.05	3.33	3.78
<i>PR</i>	9.7	17.5	13.4	11.0	9.8	5.9	4.5	4.1	6.1	0.8	2.4	0.8	0.4	2.1	1.7	2.0
Oct																
<i>F</i>	132	88	32	15	10	12	6	3	3	4	1	0	1		0	0
<i>PF</i>	42.6	28.4	10.3	4.8	3.2	3.9	1.9	1.0	1.0	1.3	0.3		0.3			
<i>A</i>	10.99	18.57	10.24	6.99	6.27	8.01	3.75	1.75	3.42	2.62	0.61		0.66			
<i>PR</i>	13.8	23.4	12.9	8.8	7.9	10.1	4.7	2.2	4.3	3.3	0.8		0.8			
Average rain inten- sity/hr (inches)	0.07	0.11	0.13	0.15	0.14	0.13	0.15	0.14	0.15	0.14	0.12	0.11	0.06	0.22	0.21	0.11

F — Frequency of occurrence
A — Rainfall amount in inches

PF — Percentage frequency distribution
PR — Percentage rainfall distribution

9. Summary

What has been stated in the foregoing sections can be summarised as follows —

(1) Maximum rain intensities for different durations from 1 to 48 hrs and return periods from 2 to 25 years have been worked out and are given in Table 2.

(2) Percentage ratios of 1,2,3 etc hours to 24 and 48-hour maximum rainfall have also been worked out and are given in Table 4. From this table it is seen that 6-hour maximum rainfall is about 54 and 41 per cent (using median values) of the 24 and 48-hour maximum rainfall respectively. If only continuous rain spells are considered, percentage ratios are slightly less in magnitude (upto 12-hr duration) when compared to discontinuous rain spells.

(3) On an average, observational 2,3 and 4-day maximum rainfall occurs in durations of 32, 48 and 68 hours respectively. If actual rain hours in a spell are considered, a 2-day rain spell was found to have occurred in about 25 hours only.

(4) Observational 1-day maximum rainfall

when increased by 11 per cent will give maximum 24-hr rainfall. Similarly, 48 and 72-hr maximum rainfall amounts can be obtained by increasing observational 2 and 3-day maximum rain amounts by 2 per cent.

(5) Frequency of one-hour rain spells is the highest in the month of August. The highest rainfall intensity per hour for a continuous long spell was found to be 0.35 inches and the longest continuous rain spell was found to be of 36-hour duration.

(6) Diurnal curves of rainfall show that the rain generally occurs in the afternoon between 13 to 19 IST. The diurnal curve for the month of May is conspicuous by its most pronounced peaks at 17 and 19 IST.

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