Trans. Inst. Indian Geographers
Vol. 9, No. 2, July 1987

ESTIMATION OF PMP FOR THE KALLADA BASIN LOCATED IN THE WESTERN GHATS OF SOUTH KERALA

O. N. Dhar, Miss S. S. Nandargi & A. K. Kulkarni, Pune

ABSTRACT : In this study an attempt has been made to estimate PMP for the Kallada basin in South Kerala state. As this basin lies in the Western Ghats, it was considered most appropriate to use only depth-duration (DD) technique for estimation of PMP. Accordingly, rainfall data of stations in South Kerala for the period 1891 to 1986 were examined and several severe rainspells over the basin were selected for this purpose. Examination of all these severe rainspells has shown that the July 1924 rainstorm was the most severe rainspell over the Kallada basin, like of which was not experienced during the last 96 years. The July 1924 rainspell was, therefore, analysed using basin as a unit of study and raindepths for different durations were worked out. These raindepths were then maximized for moisture charge using the dew point data of Trivandrum observatory of last 35 years.

The heavy rainfall experienced in October 1964 by Ponmudi station, which is located near the southern boundary of the basin, was not considered for PMP estimation as there are no studies available in this country for hilly regions which can reduce point rainfall to areal rainfall. Considering this lacuna in our present day knowledge of rainfall distribution in hilly areas, Ponmudi record rainfall of October 1964 was not considered for PMP estimation.

INTRODUCTION

The Kallada river is a west flowing river which originates from the Kulathupuzha ranges of the Western Ghats in South Kerala. Throughout its course of about 130 kms from its source to Ashtamudi lake, this river flows entirely through the Quilon district of Kerala state. A multipurpose dam is under construction across this river at Parappar (Lat. 8°57′ N, Long. 77°4′ E). The three major tributaries of this river, viz.

(i) Kulathupuzha,
(ii) Shenthurni and
(iii) Kazhuthurutty,

join together to form the main river just before the dam site. The total area of the Kallada basin upto Parappar dam site is about 550 sq.km. This basin is mostly forested with a good sprinkling of rubber and tea garden estates. The basin lies on the western slopes of the Western Ghats and its elevation varies from about 100 m near the dam site to about 1800 to 2000 m on its eastern boundary.

At present there are following seven rainguage stations within this basin which are maintained either by Forest Department or by Tea Garden Estates or the Kallada Project authorities :

(i) Aryankavu,
(ii) Nagamala,
(iii) Kulathupuzha,
(iv) Thenmala,
(v) Shenthurni,
(vi) Linwood and
(vii) Ponmudi.

Excepting Aryankavu daily rainfall data of these stations are not available for long periods of time. However, around the basin a good network of rainguage stations have been functioning whose daily data are available for long periods of time which have proved quite useful in conducting the present study.

In this paper an attempt has been made to study the probable maximum rainfall (PMP) of the Kallada basin upto Parappar dam site on the basis of all available information within and around this basin. PMP data thus estimated, can be utilised to work out probable maximum flood (PMF) so that the spillway capacity of the proposed dam at Parappar can be designed adequately to pass off the severe flood without risking the safety of the dam as well as the lives of more than a million people who live in towns and villages, downstream of the dam.

MEAN MONSOON AND ANNUAL RAINFALL

Mean monthly and annual rainfall for the Kallada basin upto Parappar dam site has been worked out by isohyetal method on the basis of available rainfall normals (I.M.D., 1962). The mean annual rainfall upto the dam site has been estimated to be of the order 254 cm and southwest monsoon (June to September) rainfall has been found to be 57% of the mean annual rainfall. Fig. 1 shows the mean annual rainfall distribution over the basin and its immediate neighbourhood. It has also been seen that southwest monsoon (June to September) and northeast monsoon (October to December) are the two principal rainy seasons of South Kerala in which the problem basin lies. In fact this region i.e. South Kerala has a seven month rainy season from June to December and to some extent the region also receives well distributed rainfall in the month of May by way of premonsoon thundershowers. Southwest monsoon normally sets in over South Kerala region by the beginning of June but there have been years when onset of southwest monsoon has taken place as early as 11th May (in the years 1918 and 1955) and as late as 18th June (in the year 1972). It has also been noticed in some years that initial onset of southwest monsoon is followed by a temporary recession.

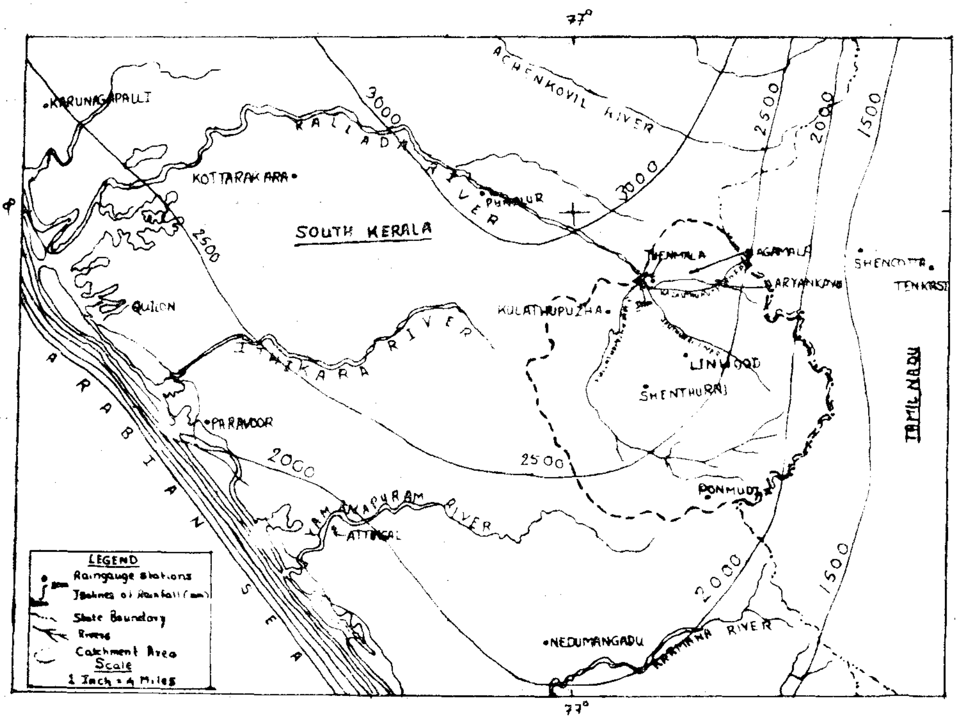


Figure 1: Mean Annual Rainfall Over the Kallada basin and Its Neighbourhood

HIGHEST ONE-DAY POINT RAINFALL

The highest one-day rainfall at some of the long-period stations in and around the basin has been picked out from their respective daily data and are given in Table I in order to have an idea of the magnitude of the highest one-day rainfall that has occurred at stations in south Kerala.

TABLE I

Magnitudes of the highest one-day rainfall at long period stations in and around Kallada basin

Station	Highest Rain fall in One-Day (mm)	Date & Year	Remarks
(a) Aryankavu	245	9-11-1925	Aranyakavu and Ponmudi are the only two stations inside the basin. Aranyakavu is located in the north of the Kallada basin while Ponmudi is located in the south.
(b) Paravur	293	10-11-1925	
(c) Adur	223	27- 5-1932	
(d) Karunagapalli	254	30- 8-1932	
(e) Kottarakara	233	22- 5-1933	
(f) Cochin	253	28- 5-1933	
(g) Trivandrum	401	18-10-1964	
(h) Quilon	280	4- 4-1966	
(i) Nilamel	397	12- 4-1966	
(j) Koni	244	17- 7-1968	
(k) Punaler	300	14- 5-1972	
(l) Ponmudi*	406	18-10-1964	

*Ponmudi is not a long-period station but has been included in the above Table as it falls within the Kallada basin and has experienced exceptionally heavy rainfall in recent years.

It is seen from Table I that one-day highest rainfall at different stations have occurred in all months from April to November excepting the months of June and September. It is also that heaviest falls have occurred in monsoon months of April and May in some years.

ANALYSIS OF SEVERE RAINSTORMS FOR PMP ESTIMATION OF THE KALLADA BASIN

Precipitation associated with the uppermost limits for a given station, area or a basin in a given duration is known as probable maximum precipitation or PMP. It is also defined as theoretically the greatest depth of precipitation for a given duration that is physically possible over a given size area at a particular geographical location at a certain time of the year (WMO, 1986). PMP estimates are normally used in the design of such hydraulic structures in whose case no risks of their failure can be undertaken.

In order to obtain quantitative estimates of probable maximum rainfall (PMP) for a plain-area basin, comprehensive analysis of most severe rainstorms that have occurred in the past, over the basin and the homogeneous area around it is generally undertaken. In the IMD's Manual of Hydrometeorology (Dhar, 1972) and Estimation of Design Flood (CW & PC, 1972), the following three methods have been recommended for undertaking rainfall studies with a view to obtain design storm depths for a given basin :

(*a*) Depth-Duration (DD) analysis,
(*b*) Depth-Area-Duration (DAD) analysis and
(*c*) Storm Transposition (ST) technique.

In the case of Kallada basin, PMP estimates have been recommended since no risks regarding dam failure can be taken in this case. The proposed dam will be located upstream of a densely populated region of South Kerala which under no circumstances can be exposed to the danger of a dam failure.

In this study PMP estimates for the Kallada basin have been worked out by DD method as transposition of rainstorms from outside the basin, may not be appropriate because of the rugged terrain and orography of the Western Ghats in which the Kallada basin is located. The average height of mountain ranges in and around the basin varies from about 150 m along the plains to the west to about 1,800 to 2,000 m along the eastern northeastern and southeastern boundaries of the problem basin. Accordingly, to obtain an estimate of PMP for this basin, all the severe most rainstomrs experienced by this region in the past 96 years from 1891 to 1986 were examined and analysed by the technique of depth-duration (DD) method and then maximised for moisture charge to obtain PMP.

DEPTH-DURATION (DD) ANALYSIS OF MAJOR RAINSTORMS OF THE KALLADA BASIN

Daily rainfall data of all the stations in and around Kallada basin upto Parappar dam site were examined for all the heavy rainspells which occurred during the last 96 year period. It was found that there were in all 13 rainspells which were responsible for causing heavy rainfall over and near the basin. These rainspells were, therefore, selected for detailed depth-duration (DD) analysis. The list of these heavy rainspells is given in Table II.

TABLE II

List of heavy rainspells that occurred over the Kallada basin during the period 1891 to 1986

(a) 6–8 May, 1909	(h) 7–8 Jun, 1957
(b) 18–19 Oct., 1912	(i) 6–7 Aug., 1958
(c) 23–25 June, 1915	(j) 7–9 June, 1961
(d) 16-17 Dec., 1923	(k) 17–19 July, 1968
(e) 16-18 July, 1924	(l) 12–14 May, 1972
(f) 9 10 Nov., 1925	(m) 3–5 Nov., 1978
(g) 27 May, 1941	

Table II shows that excepting the month of September heavy rainspells over the Kallada basin have occurred in all the months from May to December. It was quite evident from an examination of the daily rainfall data during the month of September that rainfall activity over southern Kerala is considerably less in this month compared to other southwest monsoon months.

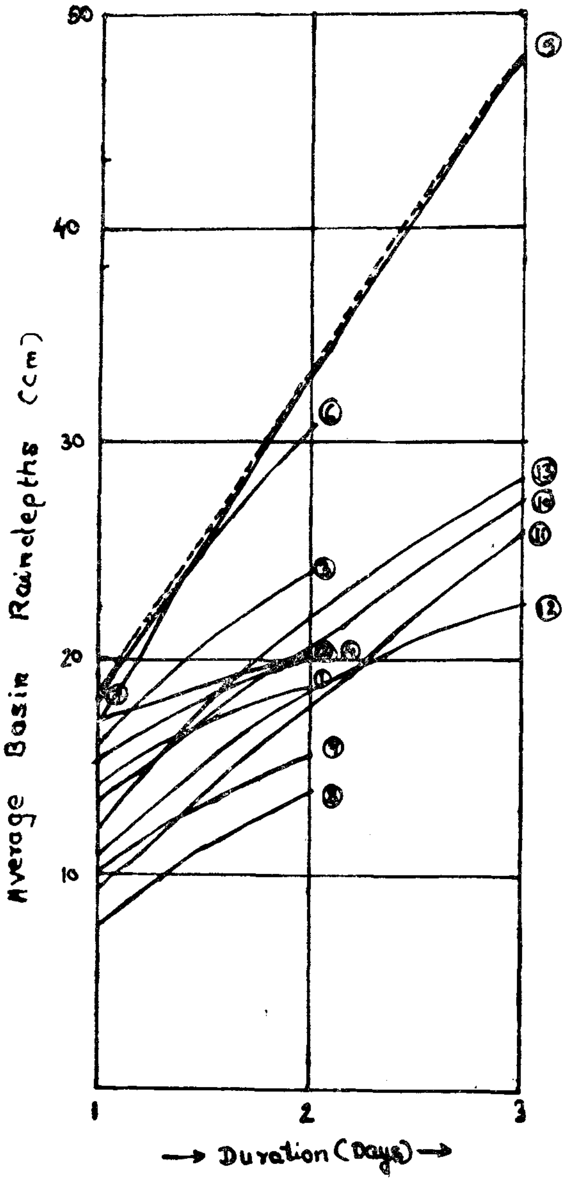
In the Depth-Duration (DD) method of analysis, the problem basin is taken as the unit of study and all heavy rainspells experienced by the basin are analysed for different durations. For each day of rainspell, a separate isohyetal map of the basin and its surrounding region was prepared. Each isohyetal map was then planimetered and average depth of rainfall over the basin was obtained for each day of the rainspell upto the proposed dam site. Table III gives average depths of rainfall received by the basin on individual days of the rainspell.

TABLE III

Average raindepths experienced during severemost rainspells over Kallada basin during 1891–1986

Rainspell Duration	Daily Average Depth of Rainfall 1st Day (cm)	2nd Day (cm)	3rd Day (cm)	Total Average Depth of Rainfall (cm)
(a) 6– 8 May, 1909	14.2	4.5	—	18.7
(b) 18-19 Oct., 1912	16.9	3.0	—	19.9
(c) 23-25 June, 1915	7.9	16.0	—	23.9
(d) 16-17 Dec., 1923	15.2	5.9	—	21.1
(e) 16-18 July, 1924	16.0	17.1	15.1	48.2
(f) 9-10 Nov., 1925	18.2	12.9	—	31.1
(g) 27 May, 1941	17.9	—	—	17.9
(h) 7- 8 June, 1957	7.6	6.0	—	13.6
(i) 6- 7 Aug., 1958	10.1	5.6	—	15.7
(j) 7- 9 June, 1961	13.4	6.9	7.1	27.4
(k) 17-19 July, 1968	8.8	8.1	9.4	26.3
(l) 12-14 May, 1972	4.0	10.8	7.6	22.4
(m) 3- 5 Nov., 1978	12.2	10.0	6.1	28.3

Maximum 1, 2 and 3–day raindepths were calculated from the average raindepth data given in Table III. Depth-duration (DD) curves for each rainspell were then prepared and in this way 13 DD curves were drawn and these are shown in Fig. 2. A curve which envelopes all these 13 curves was then drawn (see Fig. 2) in order to give an idea of the highest raindepths which the basin can experience in durations of 1 to 3 days. The highest raindepths from the envelope curve for different durations are as follows :



Curve No.	Rainspells
1	6-8 May, 1909
2	18-19 Oct, 1912
3	23-25 Jun, 1915
4	16-17 Dec, 1923
5	16-18 Jul, 1924
6	9-10 Nov, 1925
7	27 May, 1941
8	7-8 Jun, 1957
9	6-7 Aug, 1958
10	7-9 Jun, 1961
11	17-19 Jul, 1968
12	12-14 May, 1972
13	3-5 Nov, 1978

--- Envelope curve

Figure 2 : Depth-duration curves for severe most Rainstorms over the Kallada basin upto Parappar dam site.

Rainstorm duration (days)	*Raindepths obtained by DD method* (cm)
1–day	18.2
2–day	33.1
3–day	48.2

Dhar et al (1981) have found, during their earlier studies of DD raindepths of Indian catchments, that in this country for majority of basins one-day raindepths are nearly 50% and two-day raindepths are about 80% of the three-day raindepths. The DD raindepth data of Kallada basin shows that one-day raindepths are of low magnitude. This may, probably, be due to the fact that as this basin is located in a comparatively low rainfall region, it does not therefore experience intense or heavy rain-spells. It has been seen that southern Kerala as a whole, does not experience very heavy rainfall. This is evident from the following comparison of the mean annual rainfall of the two southernmost districts of Kerala with the two northern districts.

equivalent to the Kallada basin upto the Parappar dam site has experienced in the past in the major rainstorms of this region. This could be achieved by the depth-area-duration (DAD) analysis of the most severe rainstorms of the region. During the last 96–years period it was found that the southern Kerala region was affected by the following severemost rainstorms :

(*a*) 16–18 July, 1924,
(*b*) 9–10 November, 1925.
(*c*) 27 May, 1941 and
(*d*) 7 August, 1958.

It was also noticed that most of the above rainstorms had their heavy rain centres outside and to the north of Kallada basin in the high ranges of Cardamom hills in the Idukki district.

Rainstorm of August, 1958 was subjected to DAD analysis by George et al (1966), hence its DAD analysis was not carried out. The other three rainstorms were subjected to DAD analysis, in which case a rainstorm is considered as a unit of study and not the basin area, as in the case of DD analysis. With the help of data obtained by DAD

Southern districts of Kerala	*Mean annual rainfall* (mm)	*Northern districts of Kerala*	*Mean annual rainfall* (mm)
(*a*) Trivandrum	2002	(*a*) Cannanore	3438
(*b*) Quilozn*	2760	(*b*) Kozhikode	3796

* As mentioned earlier, entire Kallada basin is located in the Quilon district of South Kerala.

DEPTH–AREA-DURATION (DAD) ANALYSIS OF MOST SEVERE RAINSTORMS AROUND KALLADA BASIN

It has been stated earlier that transposition of rainstorms over this basin has been ruled out due to rugged topography of the Western Ghats in which the Kallada basin is located. Nevertheless it was found worth having an idea of the highest rainfall which an area

analysis of rainstorms, rainfall curves for different durations and areas for each rainstorm were prepared. Examination of these curves showed that July 1924 rainstorm (see Fig. 3) yielded maximum depths of rain over different areas and for 2 and 3–day durations while the DAD curve of November, 1925 rainstorm for 1–day duration slightly exceeded that of July 1924 rainstorm. Picking up the maximum rain-

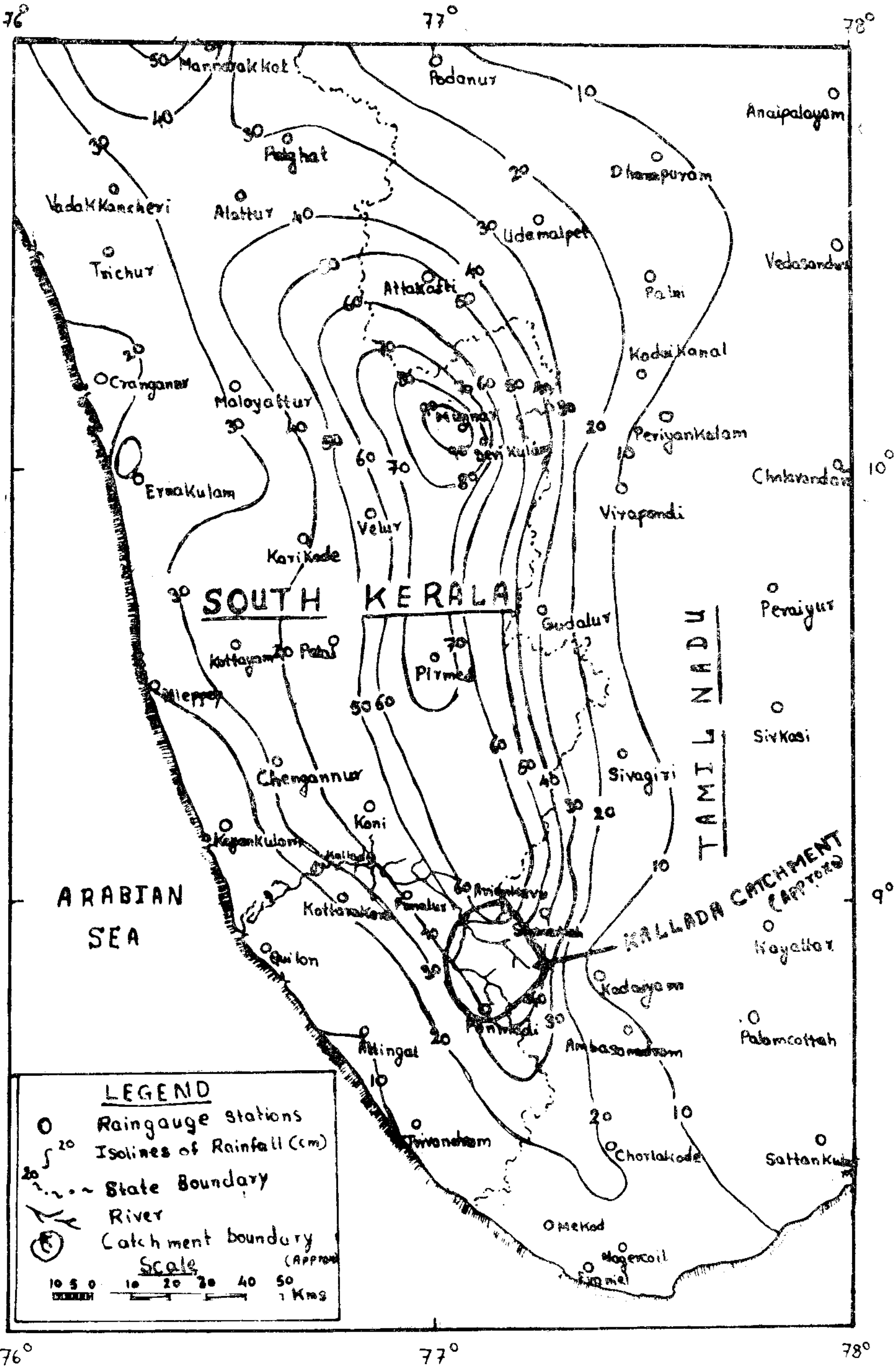


Figure 3: Isohyetal Pattern of July -1924 Rainstorm Over South

depths from envelope DAD curves shown at Fig. 4 for an area equivalent to the Kallada basin (upto Parappar dam site), the maximum DAD raindepths obtained for 1, 2 and 3-day durations are given in Table IV and DD raindepths obtained under Sec. 3.1 are also shown in this table by way of comparison.

It is seen from Table IV that DAD raindepths are 1.8 to 2.4 times the DD raindepths for duration of 1 to 3 days. It is evident from the above that there have been areas in the Western Ghats, mostly to the north of Kallada basin, which have received heavier raindepths than were actually received by the Kallada basin which is located towards

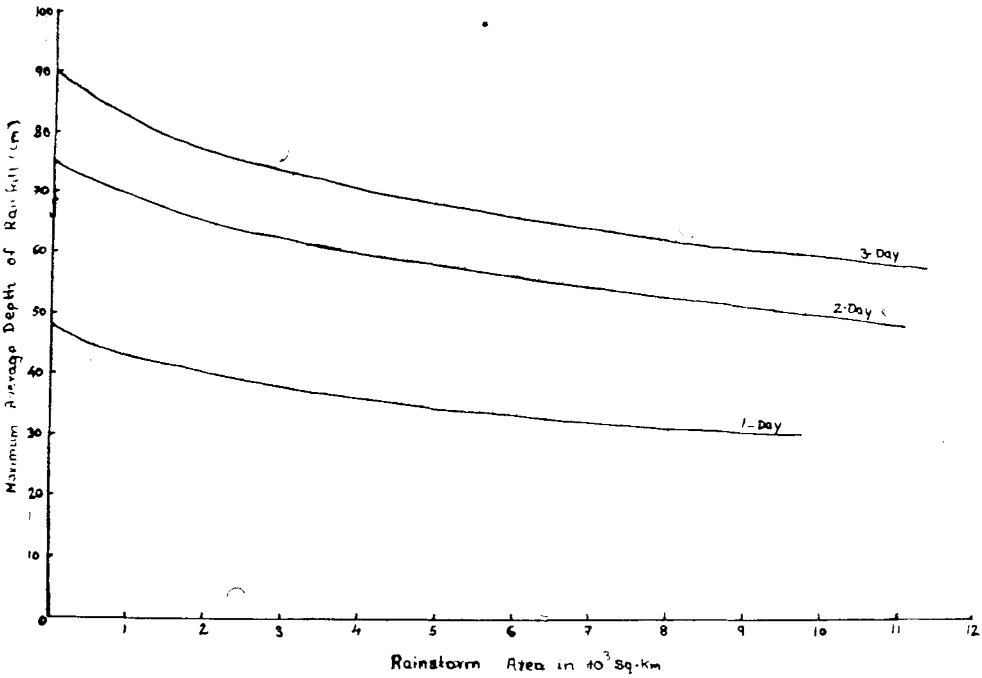


Figure 4 : Envelope Depth-area-duration curves of rainstorms to the North of Kallada basin for 1 to 3-days

TABLE IV

Storm raindepths obtained by DD and DAD methods for area equivalent to that of Kallada basin upto Parappar dam site

Rainstorm Duration (Days)	Maximum Raindepths obtained by		Ratio of DAD/DD
	DD Method (cm)	DAD Method (cm)	
1-Day	18.2	44.5	2.4
2-Day	33.1	71.0	2.1
3-Day	48.2	85.5	1.8

the south of the rainstorm centres. It is, however, seen that those hilly areas in the north, normally, do receive heavier falls of rain because of their pronounced orography and as such transposition of rainstorms from those areas cannot be recommended to the basin under consideration. It was further noticed that centres of heavy rainfall invariably occurred either at Peermade or Devikulam to the north of Kallada basin because of the orography and geographical location of these two stations. Considering the above, the question of transpositton of

DAD raindepths from the northerly areas to Kallada basin does not appear to be correct.

In view of the above, it was felt that realistic PMP estimates for the Kallada basin could best be obtained by maximizing the DD raindepths obtained earlier (vide Sec. 3.1) by moisture maximization method using the technique given in the WMO Mannual for PMP (WMO, 1986) and IMD, Hydromet Mannual (Dhar, 1972).

RAINSTORM MAXIMIZATION

Long-period dew point temperature data are not available for any station in and near the basin. However, the nearest station for which this data are available for a long period of time is IMD observatory at Trivandrum which is located along the West Coast and is about 50 km to the southwest from the centre of the basin. The dew point data for this station were readily available for the 35-year period from 1951 to 1985. Persisting 24-hour highest dew point temperatures were picked out from a survey of past records of dew point data of 0830 and 1730 hrs IST observations and minimum temperature data for the month of July of the 35-year period. Similarly, the highest persisting 24-hour storm dew point temperatures were determined for the July 1924 storm period. The moisture maximization factor (MMF) was then worked out for Trivandrum and found to be 1.35 on the day of the highest rainfall. Because of the fact that dew point data of only one station was used, the maximization factor of 1.35 was not reduced for barrier effect or distance from the sea.

The envelope DD raindepths obtained earlier were then considered for moisture maximization. As 2 and 3-day raindepths represent, more or less, 48 and 72-hour rainfall, it was considered reasonable that we may maximize 2 and 3-day DD raindepths only and not one-day rainfall which has to be increased by about 15% (Harihara Ayyar et al, 1973) to represent 24 hour rainfall. The magnitude of true 24-hour rainfall can be obtained either from 48 or 72-hour rainfall by applying proper time distribution factors based upon short duration rainfall data of nearby self-recording rainguage data. Accordingly, 2 and 3-day raindepths of July, 1924 rainstorm were maximized by moisture maximization factor of 1.35 and these PMP raindepths are giveu below :

Rainstorm duration (days)	*PMP design raindepths* (cm)
2-day	45.1
3-day	65.2

The PMP design raindepths obtained above are based upon observational-day raindepths. In order to convert them into true 48 and 72-hour raindepths, the factor applicable to Indian catchments, for these two durations is 1.02 (Dhar, 1970 and Harihara Ayyar et al, 1973). The PMP estimates for true 48 and 72-hour durations for the Kallada basin (upto Parappar dam site) work out to be as follows :

Rainstorm duration	*PMP design raindepths*
48-hour	46.0 cm
72-hour	66.5 cm

ESTIMATION OF PMP BASED UPON RECORD-RAINFALL OF PONMUDI STATION IN OCTOBER, 1964

Ponmudi station which is located near the southern boundary of the basin at a height 1080 m recorded a rainfall of 406 mm on 18th October, 1964. On this very day Trivandrum city observatory which is located along the west coast at a distance of about 35 km to the southwest of Ponmudi recorded the highest rainfall of 402 mm. On this day Trivandum Air Port recorded just 168 mm of rainfall and stations located in between Ponmudi and Trivandrum did not record rain amounts greater than 50 to 100 mm. Dannial and Subramaniam (1966), who have studied this heavy rainspell, have stated that this heavy rainspell was caused by intense thunderstorm activity during the night and early morning hours of 18th October, 1964. According to them differential thermal advection was primarily responsible for causing such an unprecedented rainfall at Trivandrum and rainfall at Ponmudi was largely due to orography of the Western Ghats in which Ponmudi (1080 m) is located.

Due to lack of long-period rainfall data for stations within the Kallada basin, some meteorologists have been tempted to use point rainfall data of Ponmudi for 18 to 20 October, 1964 for working out PMP estimates of Kallada basin. They have used point to areal reduction factors to convert 1, 2 and 3-day point rainfall of Ponmudi into basin rainfall by applying the reduction factors of 85%, 90% and 95% for 1, 2 and 3-day durations respectively. The basin areal raindepths thus obtained have then been maximized by moisture maximizing factor appropriate to the month of October.

The objection to the above procedure mainly arises from the fact that October, 1964 rainspell was not a uniformly distributed rainspell covering a large area as is normally the case in a depression or a cyclonic storm. Aryankavu, a station about 28 kms from Ponmudi to the north and located within the basin did not experience any rain during this spell. As such, this spell did not have the severity of July, 1924 rainspell which caused heavy to very heavy rainfall all over south Kerala over a period of 3 days. Secondly, conversion of point rainfall to areal rainfall in a hilly terrain like Western Ghats with reduction factors which normally are applicable to plain areas may not give correct estimate of areal raindepths. Moreover, it is felt that PMP type rainstorms over south Kerala can only be obtained from disturbances associated with southwest monsoon season (July to September) and not with northeast monsoon season when rain potential of rainstorms over south Kerala is not as great as that of southwest monsoon. It has been seen that Quilon, the district in south Kerala in which Kallada basin is located, receives nearly 2.5 times the normal rainfall during southwest monsoon season than what is received in northeast monsoon and naturally the intensity and duration of rainspells during southwest monsoon are much greater. Considering the above facts, it appears that in the present case the application of point rainfall of a station for areal estimation of PMP may lead to erroneous results.

CONCLUSIONS

From the foregoing the following broad conclusions may be drawn :

(i) Mean monsoon rainfall based on the data of 1950 normals of rainfall of stations in and around the Kallada basin was calculated by the isohyetal method and the mean annual rainfall and mean monsoon rainfall of the basin upto Parappar dam site were found to be 254 cm and 146 cm respectively.

(ii) After examining 96 years' data of severe rainspells during the period 1891 to 1986, it was found by DD method that the July, 1924 rainstorm gave the highest average raindepths for 48 and 72 hour durations over the Kallada basin.

(iii) Among the three heavy rainstorms which affected the region in which the problem basin is located, it was found that the July, 1924 rainstorm gave the highest DAD raindepths for an area equivalent to the Kallada basin. The 3-day raindepth (see Fig. 3) was found to be of the order of 85 cm. Since the centre of this rainstorm was located to the north of the basin in a highly hilly terrain of the Western Ghats, transposition of this storm to Kallada basin was not considered for obtaining PMP design depths.

(iv) The PMP design raindepths were provided by the July, 1924 rainstorm which yield DD raindepths of the order of 33 cm and 48 cm in 2 and 3 days respectively. The maximization factor, using Trivandrum dew point data of last 35 years, was found to be of the order 1.35 which when applied to above raindepths yielded PMP raindepths of 46 cm and 67 cm respectively for 48 and 72 hours.

(v) Ponmudi, a station located near the southern boundary of the Kallada basin, recorded the highest 1-day rainfall of 40 cm on 18 October, 1964. To utilise this point rainfall for PMP estimation of the basin by using point to areal reduction factors, does not appear to be correct. This is because of the fact that such reduction factors have not been worked out for hilly areas and hence application of these may give erroneous estimates of PMP.

ACKNOWLEDGEMENTS

Authors are grateful to Prof. D. R. Sikka, Director, IITM, for his keen interest in Hydromet studies and for giving necessary facilities to undertake this work. Thanks are also due to S/Shri R. B. Sangam and B. D. Kulkarni of the C and H division for their assistance in collection, compilation and scrutiny of data and selection of rainspells. Authors are also thankful to the Chief Engineer, Kallada Project for supplying us the rainfall and dew point data of recent times for stations in the region. Thanks are due to Mr. A. E. Zagni, Irrigation Engineer of the Regional Office of the World Bank, New Delhi for discussions on this subject with him and the other World Bank experts.

REFERENCES

Central Water and Power Commission, New Delhi (1972) : Estimation of Design Flood–Recommended Procedure.

Daniel, C. E. J. and Subramaniam, A. H, (1964) : Exceptionally Heavy Rainfall in South Kerala on 17/18 October, 1964· IJMG, Vol. 17, No. 1.

Dhar, O. N. and Ramchandram, G. (1970) : Short Duration Analysis of Calcutta (Dum-Dum) Rainfall, IJMG, Vol. 21, No. 1.

Dhar, O. N. (1972) : Manual of Hydro-meteorology, Part I–Storm Transposition. IMD Publication.

Dhar, O. N., Rakhecha, P. R. and Mandal,B. N. (1981) : Some Facts About Indian Rainfall–A Brief Appraisal from Hydrological Considerations, Indian Journal of Power and River Valley Development, Vol. 31, No. 7 and 8.

George, P. A., Raman, P. K. and Raghavan, K. (1966) : The Catastrophic Flood of 7th August, 1958 in South Kerala. Indian Journal of Meteorology and Geophysics, Vol. 17, Special No.

Harihara Ayyar and Tripathi N. (1973) : Relationship of the Clock-hour to 60–Minute and the Observational–Day to 1440–Minute Rainfall, Indian J. of Met. and Geo., Vol. 24, No. 3.

India Met. Deptt. (1962) : Mem. Ind. Met.Dept., Vol. 31, Part–3.

W.M.O. (1986) : Manual for Estimation of Probable Maximum Precipitation, Operational Hydrology, Report No. 1, (Second edition).

Address of the Authors

Dr. O. N. Dhar, Miss S. S. Nandargi and A. K. Kulkarni
Indian Institute of Tropical Meteorology,
Pune–411005.