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Some Hydrometeorological Aspects of an Unprecedented Rainstorm in the Indian Desert

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Abstract Probable maximum precipitation (PMP) and rainfall return periods for different duration of spells have been analysed for five districts in western Rajasthan viz. Sirohi, Jalore, Pali, Jodhpur and Barmer using daily rainfall data from 1961 to 1990. Depth-Area-Duration (DAD) analysis of two severe rain storms that occurred during 1990 have been discussed in comparison with past events of the region. Analysis revealed that Barmer region is more prone to flood hazards in comparison to Jodhpur region. This study also brought out that each of these two storms have generated large volume of water which is sufficient to meet the drinking water demand of human and livestock population of the area over 100 years. Development of system for efficient harvesting of such rainfall events is a need of the region.

Key words Rainstorm, Indian desert, Return period, PMP, DAD.

Cloud burst or heavy rainfall associated with monsoonal depression/low pressure systems over Indian arid zone are not unusual (Rakhecha et al 1979). A study of literature for the period 1901-1980 revealed that there were 23 instances of heavy rainfall in this region (Dhir *et al*. 1982). However occurrence of more than 700 mm rainfall in a period of 5-6 days is a rare event in the Indian desert. Such an event occurred during 3rd to 8th July 1990. The analysis of the spatial coverage, depth and frequency of this rainfall event have been attempted in this paper as such an analysis will be of help in designing efficient economic structures for efficient manegment of the water resources and effective design of road and traffic systems. Also the probable maximum precipitation and return period for different duration of storms has been worked out in this region to compare with the present storm so as to establish its severity and develop flood control measures.

Materials and Methods

In this study the frequency analysis of 30 years (1961-1990) of daily rainfall data of five stations of western Rajasthan mainly Sirohi, Jalore, Pali, Jodhpur and Barmer have been attempted on annual time series (annual maximum values)through Log Pearson type III distribution. Jones (1981) found that this distribution fitted the best to the rainfall probability analysis in the arid regions of the world. The return period values were obtained by Weibulls' formula (Chow 1964). The same procedure was also applied to determine the magnitude of rainfall of different return periods for two, three, four and five days spells. The rainfall time series corresponding to these spells (annual maximum values) of all the stations were used for the determination of probable maximum precipitation (PMP). The following equations were used to estimate PMP (Sarma *et al.* 1975)

$$X_m = \bar{X} + \sigma K_m \qquad \text{.....(1)}$$

Where Xm = Estimate of PMP

$\bar{X}$ = Mean of the events (rainfall)

σ = Standard deviation of the events

K_m = Frequency factor

Where $K_m = (X_L - \bar{X}_{N-1})/\sigma_{N-1}$

X_L = Largest value of the rainfall series

X_{N-1} = Mean of the events excluding X_L values

Table 1 *Rainfall (mm) of different return beriod (1961-90)*

Station	Retrun period (Years)								
	1.01	2.50	5	10	25	50	100	200	Max. Rainfall recorded (1961-90)
One day									
Sirohi	37	161	225	288	372	440	520	600	272
Jalore	19	90	128	165	216	260	310	360	268
Pali	20	75	102	128	160	190	220	248	305
Jodhpur	20	70	93	117	145	170	195	220	157
Barmer	15	54	75	93	120	140	160	185	312
Two days									
Sirohi	43	205	290	380	500	605	720	840	531
Jalore	20	112	167	222	305	375	450	530	429
Pali	20	99	140	182	245	300	350	410	491
Jodhpur	19	90	128	168	225	270	318	370	253
Barmer	13	66	96	126	166	205	240	280	472
Three days									
Sirohi	28	200	320	445	630	820	1020	1000	582
Jalore	9	116	305	320	490	680	900	1000	499
Pali	21	120	178	240	325	400	480	570	591
Jodhpur	36	108	140	170	215	235	265	295	301
Barmer	13	90	140	195	275	350	430	520	479
Four days									
Sirohi	31	220	340	470	670	850	1000	1000	628
Jalore	15	137	230	340	530	700	900	1000	540
Pali	19	130	200	270	380	480	600	735	630
Jodhpur	17	115	175	240	345	430	500	640	424
Barmer	16	120	190	265	380	480	600	740	495
Five days									
Sirohi	26	217	345	480	720	940	1000	1000	674
Jalore	23	185	295	410	620	800	1000	1000	541
Pali	10	138	290	510	960	1000	1000	1000	631
Jodhpur	18	148	228	320	470	610	760	940	495
Barmer	10	128	320	340	540	730	960	1000	497

σ_{N-1} = Standardisation of the events excluding X_L values

The depth-area-duration (DAD) analysis of two consecutive storms of different nature that occurred during 3rd to 8th July 1990 and 3rd to 8th August 1990 are also studied. These two storms covered the same region comprising Sirohi, Jalore, Pali, Jodhpur and Barmer districts of W Rajasthan. Daily rainfall data of about 40 raingauge stations covering above districts are used for DAD analysis.

Results and Discussion

Synoptic conditions : The monsoon arrived over this region in the last week of June 1990. By 3rd July an intense low pressure system prevailed over Jodhpur (Fig.1). This is clear from the surface synoptic chart that strong south westerly winds were concentrating towards Jodhpur and surrounding area from the west coast of India where as to the north of this region the winds were very low which caused a strong convergence in the region and deep moisture inflow into the monsoon circulation from the Arabian sea and Indian Ocean. It was this strong inflow of moisture laden winds coupled with the convergence conditions that resulted in the torren-

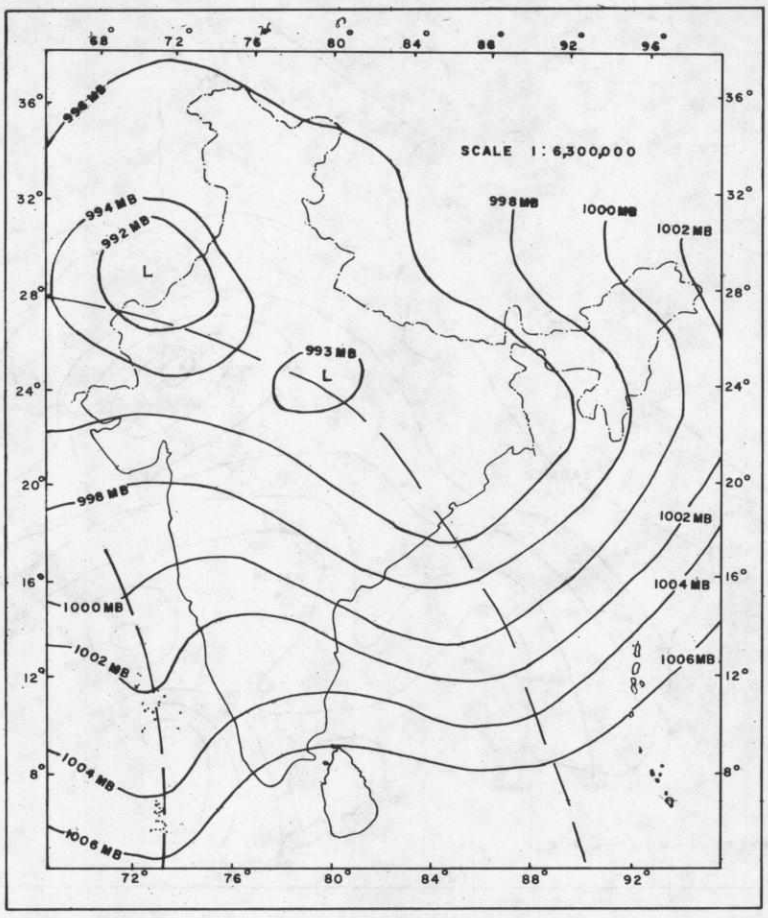


Fig 1 Surface synoptic conditions associated with the monsoon depression (3rd to 8th July 1990)

tial rainfall for a period of 5-6 days over south west Rajasthan.

Rainfall situation : The normal annual rainfall (mm) recorded at Sirohi (583), Pali (427), Jalore (381), Jodhpur (368) and Barmer (266). The region is well known for receiving erratic and short duration intense rainfall. Also most of the annual rainfall in this region received during SW monsoon period (June to September) is mainly associated with few intense showers associated with passing low pressure system over the vicinity of this region. Some times a single rainstorm precipitates more than annual rainfall over the region. Study of such storms is extremely important as such events occurred two times during 1990.

With the arrival of rainstorm on 3rd July associated with monsoon depression; it caused heavy down pour on first day itself and was mainly confined over Jodhpur and surrounding area. The rainfall recorded on first day was maximum (152 mm) at Jodhpur. Later on during 4th, 5th and 6th July it further intensified and had covered entire SW part of Rajasthan. Finally the storm remained deeply concentrated upto 8th July with a southward shift over the region resulting in heavy showers in Sirohi, Pali, Jalore, and part of Jodhpur and Barmer districts. Many stations in the region recorded more than 500 mm rainfall during 3rd to 8th July with maximum rainfall (mm) at Bali (714) followed by Revdar (648), Sanchore (550), Jalore (541), Jodhpur (516), Sirohi (494) and Pali (344). The

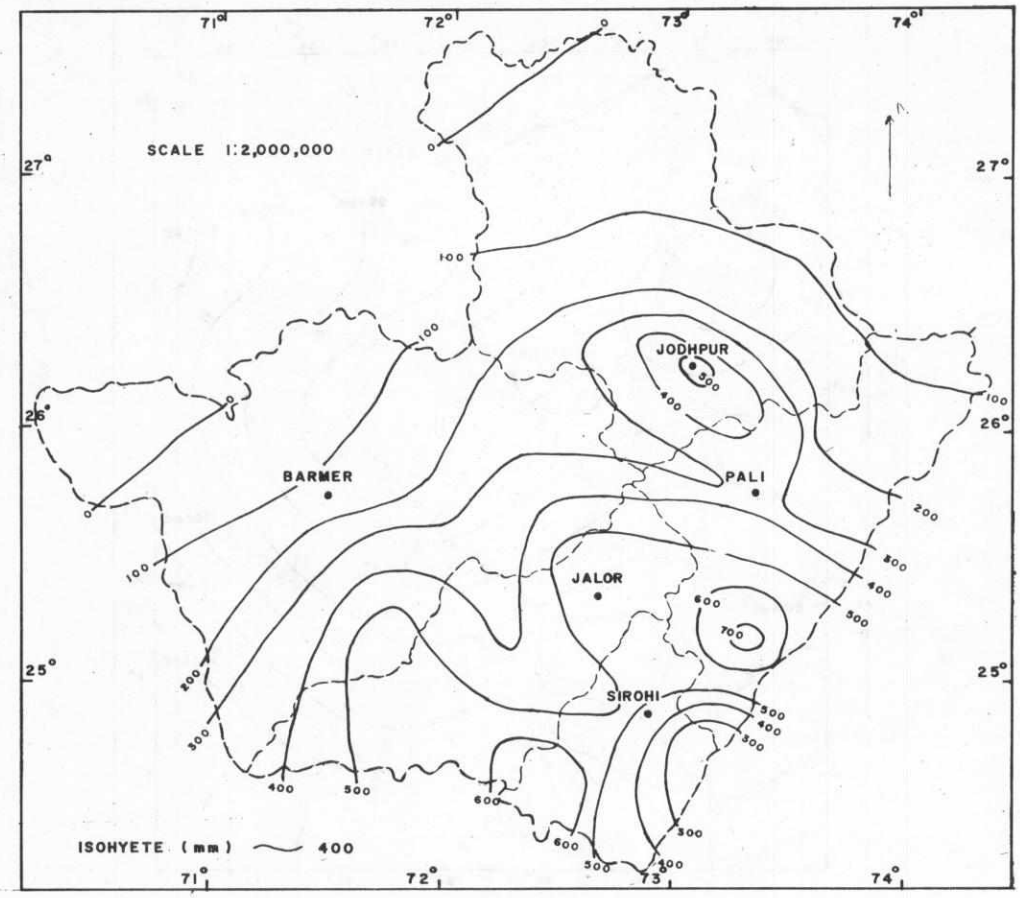


Fig 2 Spatial distribution of rainfall (mm) during storm period (3rd to 8th July 1990)

Western region comprising areas like Shergarh (203), Barmer (120), Osian (104), Jaitaran (105) and Bhopalgarh (101) received comparatively lesser amount of rain (Fig 2). Interestingly the region west of Phalodi recorded very little rainfall during 1st-8th July, 1990 indicating that this is an intense and concentrated event associated with the specific synoptic condition that prevailed during this period over a limited region. Afterwards this depression weakened and merged with the seasonal thermal low over Pakistan and adjoining area.

Again after a gap of 25 days monsoon became active suddenly on 3rd August and continued upto 8th August, when another storm of similar nature passed over the region. This storm also caused wide spread rainfall and once again large areas experienced more than 300 mm rain, almost over the same region. However, this time the very heavy rainfall zone was confined over Barmer and surrounding areas. During the August storm maximum rainfall (mm) recorded was at Barmer (498) followed by Chohtan (433), Sirohi (424), Siwana (375), Pali (344), Jalore (321), Revadar (260), Bilara (233), Sanchor (162), Bali (148), Jodhpur (123), Shergarh (85), Shiv (70), Bhopalgarh (46), and Osian (33).

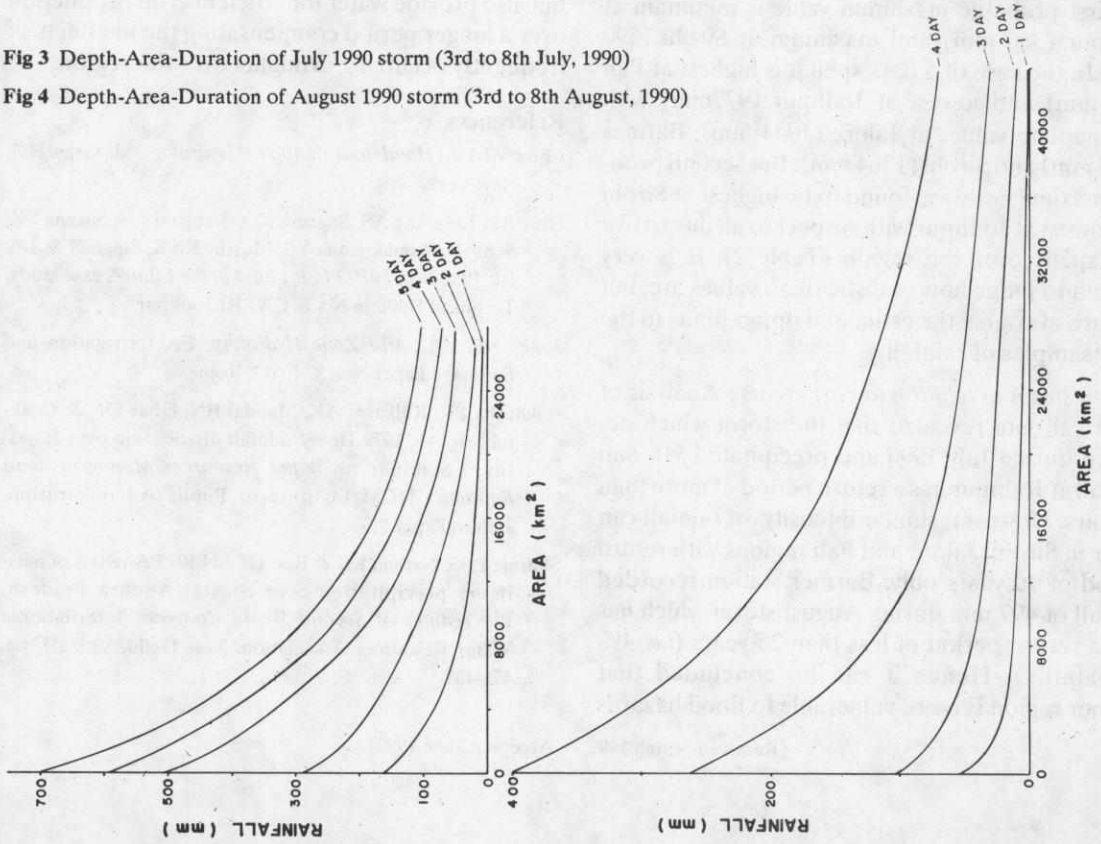
Probability analysis : The amount of rainfall (mm) with different return periods were computed based on extreme values of rainfall for 1 day, 2 days, 3days, 4days and 5days spell. The study revealed that one to two days rainfall amount is highest at Sirohi followed by Jalore, Pali and Jodhpur whereas in Barmer it is lowest (Table 1). However, in the case of three to five days spells, the amount of rainfall with more than 5 years return period is higher at

Table 2 *Probable maximum precipitation (mm) during different duration, Km = 7.0*

Station	Probable Maxima	Duration (days) 1	2	3	4	5
Sirohi	First	590	980	1173	1241	1364
	Second	544	769	962	967	1017
Jalore	First	464	668	829	922	1044
	Second	381	480	598	654	759
Pali	First	511	799	971	1124	1415
	Second	394	580	666	782	953
Jodhpur	First	300	441	550	742	977
	Second	268	367	463	547	592
Barmer	First	504	727	836	1025	1115
	Second	363	474	556	654	745

Fig 3 Depth-Area-Duration of July 1990 storm (3rd to 8th July, 1990)

Fig 4 Depth-Area-Duration of August 1990 storm (3rd to 8th August, 1990)



Barmer than at Jodhpur thereby indicating that in the case of longer duration spells (≥ 3 days) the probabilities of getting higher rainfall is more at Barmer than at Jodhpur and vice versa. Rainfall with different return periods for three to four days spells are also highest at Sirohi followed by Jalore and Pali, but 5 days spell rainfall is highest at Pali for return periods above 5 years. Analysis also indicates that maximum rainfall (mm) during a period of 5 days spell may occur at Pali (510) followed by Sirohi (480), Jalore (410), Barmer (340) and minimum at Jodhpur (320), in case of ten years return periods.

Probable Maximum Precipitation : A knowledge on PMP values is very useful for planning in constructional works like roads, bridge, building railway tracks and dams. These PMP values were computed after substituting the highest values of Km (*i.e.* $K_m = 7$) calculated for the study area as the envelope curve (Table 2). Study revealed that one day first probable maximum value is minimum at Jodhpur (300 mm) and maximum at Sirohi (590 mm). In the case of 5 days spell it is highest at Pali (1415mm) and lowest at Jodhpur (977mm) with intermediate values at Jalore (1044 mm), Barmer (1115 mm) and Sirohi (1364 mm). But second probable maxima is always found to be highest at Sirohi and lowest at Jodhpur with respect to all one to five days spells over the region (Table 2). It is very difficult to judge how realistic these values are, but they are of course the estimated upper limits to the likely samples of rainfall.

Present storm in relation to past events : Analysis of historical data revealed that the storm which occurred during July 1990 and precipitated 516 mm rainfall at Jodhpur has a return period of more than 25 years. However, similar intensity of rainfall can occur in Sirohi, Jalore and Pali regions with return period of 10 years only. Barmer station recorded rainfall of 497 mm during August storm which has also a return period of less than 25 years (*i.e.* 4% probability). Hence it can be concluded that Barmer region is more vulnerable to flood hazards in comparison to Jodhpur region in spite of the former receiving less normal annual rainfall than the later.

Depth area duration (DAD) analysis : For design of flood control measures and drought mitigation programme, DAD analysis of the July and August storms of 1990 was carried out (Fig. 3 and 4). The July storm was more intensified at Bali, Revdar Sanchore and Jodhpur whereas August storm was more intensified at Sirohi, Barmer, Chohtan in Barmer district and at Marwar Junction in Pali district. These storms generated rainfall volume of about 26×10^9 and 18×10^9 m^3, respectively over the five districts under study. Thus, it can be seen that each of these storms generated a large amount of water which is sufficient to meet the drinking water demand of human and livestock population over 100 years and if such storm events are properly managed and harvested they can help not only to improve the ground water resources in the region but also provide water for efficient crop production over a longer period compensating the ill effects of frequently occurring droughts over the region.

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