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ASSESSMENT OF DROUGHTS IN BINA RIVER BASIN OF MP

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ABSTRACT

Present paper deals with the drought assessment analysis conducted in the sub catchment of Bina River, a tributary of Betwa River in water scare Bundelkhand region of Madhya Pradesh. The rainfall data and stream flow data was analyzed for assessment of meteorological and hydrological drought situation. The Bina river basin area experiences on an average one drought year in every 3 years which are mostly of moderate nature and whole Bina basin area can be categorized as drought prone area. Low flow analysis was carried out using flow duration curve technique. The dependable flow at 75% probability of exceedance was considered as truncation level to obtain deficiency volume and its severity for each event of low flow condition. The river experienced 6 low flow events over the period of 9 years (1990-1998) indicating 1 to 2 low flow events every year. The low flow events in this basin usually begin during July to October and terminate during November to December.

Key Words: Meteorological drought, hydrological drought, departure analysis, flow duration curves, truncation level, low flow analysis.

1.0 INTRODUCTION

Drought is generally viewed as a sustained and regionally extensive occurrence of appreciably below average natural water availability, either in the form of precipitation, surface water runoff or ground water (Gbeckor-Kove, 1995 [1]). Recurrent droughts not only reduce the agricultural production but also threat the country with famine. Meteorological drought is usually defined by the measure of the departure of precipitation from the normal and the duration of the dry period. According to Indian Meteorological Department (IMD), a meteorological subdivision (part of India) is considered to be affected by drought if it receives total seasonal rainfall less than 75% of the normal value. According to the National Commission on Agriculture (1976) [2], agricultural drought refers to the inadequate soil moisture during crop growing period and the hydrological drought refers to marked depletion of surface water storage in lakes, reservoirs, rivers and streams etc. In fact the meteorological drought precedes the agricultural and hydrological drought. The agricultural and hydrological drought needs not to occur simultaneously but occur subsequent to a meteorological drought. Banerjee et al., (1976) [3] studies the hundred years of southwest monsoon rainfall over India and suggested a simple approach to delineate good or bad monsoon years. They considered a year to be a bed monsoon year if in more than two-third number of meteorological stations, the seasonal rainfall is deficient. In the present study efforts were made to analyze meteorological and hydrological aspects of drought in Bina river basin which is tributary of Betwa basins in Madhya Pradesh. The area under Bina river basin is characterized by water scarcity, increasing water demand and over exploitation of the available water resources and comes under the drought prone Bundelkhand region. The assessment of water scarcity situation due to droughts may be helpful in planning and development of water resources to meet the various water demands in the river basin. In

present study, rainfall data was thoroughly examined using departure analysis, frequency analysis, probability distribution technique and runoff data using low flow analysis for assessment of the meteorological and hydrological drought situation.

2.0 STUDY AREA

Bina river is an important tributary of Betwa River in Bundelkhand region of Madhya Pradesh. It originates in Raisen district, enters in Rahatgarh block and traverse through Khurai and Bina blocks of Sagar district. Bina river basin is situated at 24° 09' 36" to 24° 42' 00" N latitude and 78° 09' 06" to 78° 23' 05" E longitude partly covering Sagar, Vidisha and Raisen districts of Madhya Pradesh. The Water Resources Department, Govt. of Madhya Pradesh has planned a "Bina Complex-Irrigation and Multipurpose Project (BC-IMP)" on Bina river to meet the irrigation water demand and domestic water demand of towns like Rahatgarh, Khurai and Bina and industrial water demand of Bina Refinery and proposed JP power project. The Bina basin up to Rahatgarh G/D site was considered for the study which is covered by Rahatgarh and Jiasinagar raingauge stations. The index map of the study area showing location of gauging sites are shown in Fig. 1. As per the Revenue records the average annual rainfall of the study area is about 1196 mm and the mean minimum and maximum temperature of the region is 11.50°C and 40.9°C respectively. Agriculture is the main occupation in this region and main crops grown in the area are paddy, oilseeds, wheat, gram and vegetable.

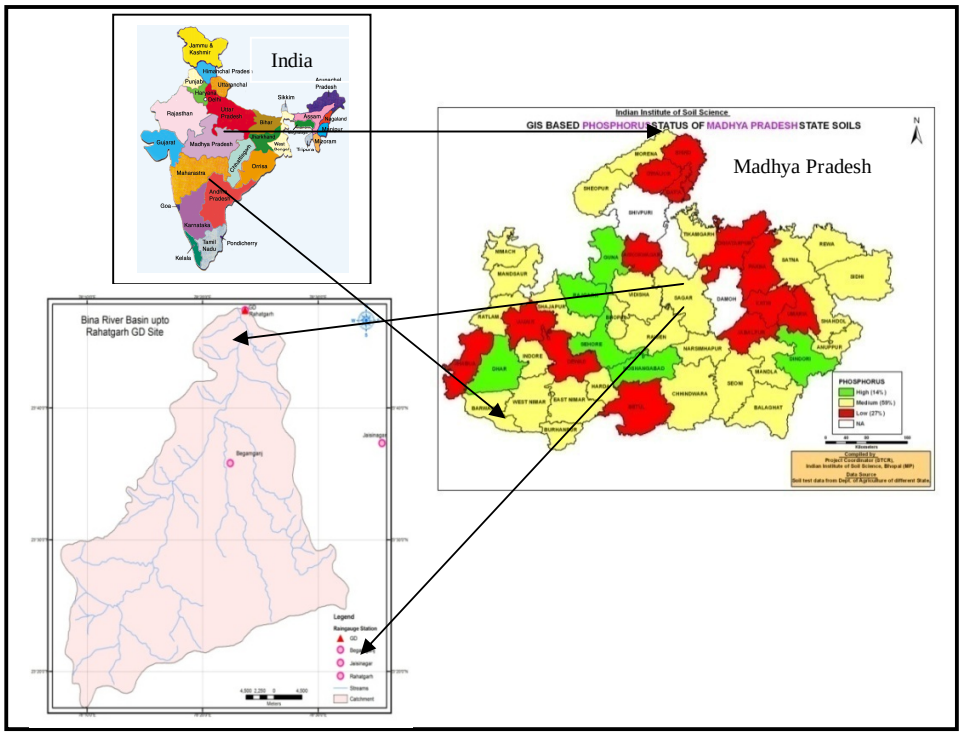

Fig. 1: Index Map of Bina River Basin up to Rahatgarh Gauge Discharge (G/D) Site

3.0 METHODOLOGY

In this paper, the rainfall data of 15 years period from 1993 to 2007 of Rahatgarh and Jiasinagar raingauge stations was analyzed to study the magnitude and frequency of meteorological drought in terms of rainfall deficiency. Rainfall data was subjected to various kinds of analysis including

seasonal and annual rainfall departure, probability distribution etc. The hydrological drought was studied by low flow analysis to estimates low flow volume and severity. The statistical analysis of rainfall data of the study was carried out to estimate its mean, mode, median, standard deviation, variance and coefficient of variance to study the rainfall characteristics in the basin.

3.1 Meteorological Drought

According to the Indian Meteorological department (IMD) an area is considered to be drought affected if it receives seasonal total rainfall less than 75% of its normal value. According World Meteorological Organization (WMO) [4] an area is considered to be drought affected if it receives seasonal or annual rainfall less than 75 % of its normal value.

3.1.1 Seasonal rainfall departure

In Bina river basin the entire agricultural operations are governed by quantity, distribution and time of onset and withdrawal of monsoon. Moreover the Bina river falls under water scared region with the water resource development much below of its potential therefore in this study a year was considered as a drought year if the total amount of seasonal rainfall over an area was deficient by more than 20% of its normal value. In order to compute the deficiency of rainfall, the seasonal rainfall departure analysis was carried out considering 20% of the seasonal rainfall deficit as a truncation level. Drought severity was assessed on the basis of percentage departure of rainfall from mean value. The droughts were classified as a mild drought when the percentage annual rainfall departure lies between 20% to 25%, a moderate drought when the percentage annual rainfall departures lies between 25% to 50%, and if the departure percentage was greater than 50%, the year was considered to be a severe drought year.

3.1.2 Probability distribution analysis

The probability analysis of annual rainfall is important to predict the relative frequency of occurrence in different group interval of annual rainfall with reasonable accuracy. The estimated probability of an event is taken as the relative frequency of occurrence of the event when the number of observation is very large. The percentage probability of occurrence of 75% of mean annual rainfall was worked out to assess the drought proneness status of raingauge stations. An area can be considered as drought prone if the probability of occurrence of 75% of normal rainfall is less than 80% (CWC, 1982) [5]. The drought prone blocks of the study area, having less than 80% probability of occurrence of 75% of mean annual rainfall were identified.

3.2 Hydrological Droughts

Hydrological droughts are indicative of surface water deficit which are reflected through low stream flow and reduced reservoir storage. When the stream flow is not sufficient enough to meet the required demand of water, it is considered that the hydrological drought has been set in. The daily flow data of Rahatgarh G/D site on Bina river for the period of 9 years from 1990 to 1998 was analyzed to carry out low flow analysis using flow duration curves technique. The geographical area of the Bina basin up to Rahatgarh G/D site is 1180 km^2.

3.2.1 Flow duration curves

A Flow Duration Curve (FDC) is a simple and very useful method of displaying the complete range of river discharges from low flows to flood events. It is a relationship between any given discharge value and the percentage of time that this discharge is equaled or exceeded, or a

relationship between magnitude and frequency of stream-flow discharges **(**Smakhtin, 2001[6]). FDC technique is useful in water resources planning to evaluate dependable flows, river characteristics and its potential. In present study monthly FDC were prepared using daily flow data for the nine years period of Rahatgarh G/D site. The monthly FDC were drawn by plotting the values of probability of exceedance against the corresponding discharge data. The flow duration curves can also be plotted using different time resolutions of stream flow data like daily, 10-daily, weekly, monthly and annually.

3.2.2 Estimation of truncation level

The variable truncation approach is efficacious in depicting both the drought and wet events and therefore, in describing drought duration and severity (Pandey et. al., 2008[7], Galkate et. al., 2010[8]). In the present study truncation level has been considered as the value of dependable flow at 75% probability of exceedance. The truncation levels for all 12 months were derived by drawing the monthly FDC using daily flow data of each month.

3.2.3 Low-flow analysis

Low flow is a seasonal phenomenon and an integral component of a flow regime of any river. In present study, the dependable flows at 75% probability of all 12 months were considered as a truncation level of respective months. If the river flow on a particular day is lower than the truncation level, then it was considered as deficit flow or low flow condition whereas if the river flow is higher than the truncation level, then it was considered as surplus condition or high flow. The prolonged deficit flow condition below its truncation level can be considered as the low flow event. Considering the size of the catchment, type of river and on stream demands the events of continuous deficit flow conditions for more than ten days were considered as the low flow event. The analysis was carried out for the 9 years of daily flow data to identify the low flow events and their durations. Severity of each low flow event was taken as the total deficit or cumulative deficient runoff volume below the truncation level during the period of low flow event.

4.0 RESULTS AND DISCUSSION

The outputs of the statistical analysis of annual and seasonal rainfall are shown in Table 1. It was observed that the mean annual and seasonal rainfall in Bina basin computed using Thiessen Polygon method was 1191 and 1146 mm respectively. The standard deviation for annual rainfall was observed ranging from 338 to 402 mm and seasonal rainfall ranges from 328 to 388 mm showing significant temporal variation.

Table 1: Statistical Analysis of Annual and Seasonal Rainfall

S. No	R.G. Station	Mean		Median		Mode		Standard Deviation	
		Annual	Seasonal	Annual	Seasonal	Annual	Seasonal	Annual	Seasonal
1	Rahatgarh	1155	1115	1244	1173	1421	1289	338	328
2	Jaisinagar	1226	1177	1196	1113	1135	985	402	388
	Average	1191	1146					370	358

4.1 Meteorological Drought

The departure analysis of seasonal rainfall based on its deficit from normal rainfall values was carried out to identify drought years in Bina basin. The positive departure is the sign of wet

condition where as the negative departure is the indicator of the drought condition. The graphical presentations of seasonal rainfall departure at Rahatgarh and Jaisinagar are shown in fig. 2 and 3 and summarized in Table 2. From the analysis it was observed that the Bina basin area had been experiencing one drought year in every 3 years. The analysis revealed that the severe drought conditions were seldom experienced in study area but study area experienced moderate drought situation during most of the years.

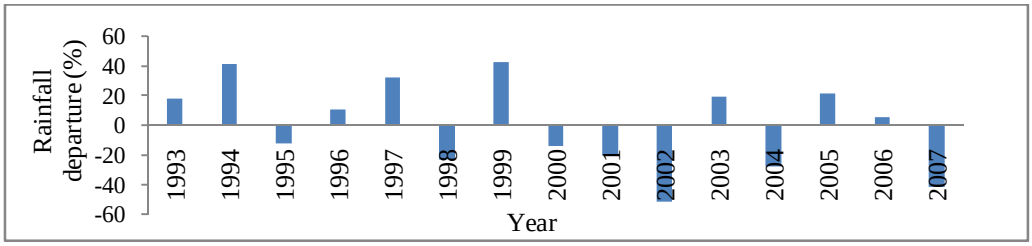

Fig. 2: Seasonal Rainfall Departure (%) at Rahatgarh

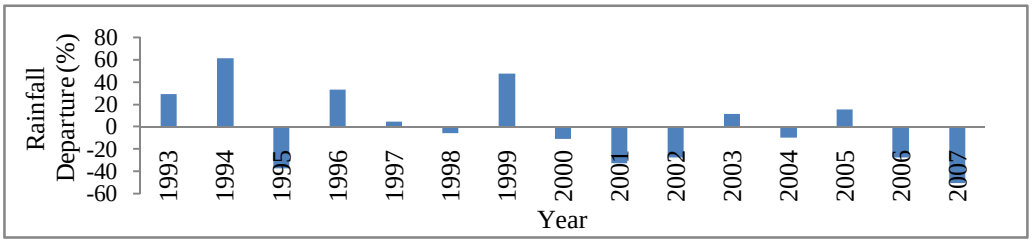

Fig. 3: Seasonal Rainfall Departure (%) at Jaisinagar

Table 2: Frequency and Severity of Droughts

Sl. No.	R.G. Station	Normal Rainfall (mm)	80% of Normal Rainfall (mm)	Drought Year	Percentage Departure From Normal	Severity of Drought	Frequency of Drought
1	Rahatgarh	1115	892	1998	22.82	Mild	One in 3 year
				2001	20.29	Mild	
				2002	34.99	Moderate	
				2004	27.93	Moderate	
				2007	41.00	Moderate	
2	Jaisinagar	1115	941	1995	37.65	Moderate	One in 3 year
				2001	32.89	Moderate	
				2002	27.57	Moderate	
				2006	27.65	Moderate	
				2007	50.40	sever	

From Table 3 it was observed that the probability of occurrence of rainfall equivalent to the 75% of the normal seasonal rainfall for all the stations of study area was less than 80% indicating that all the stations are drought prone and study area a whole could be categorized as drought prone area

Table 3: Probability Distribution Analysis of Annual Rainfall.

S.No.	Name of Station	Mean Annual RF (mm)	75% of mean RF (mm)	Prob. of occurrence of rainfall equivalent to75% of mean Rainfall (%)	Status
1	Rahatgarh	1115	866	78.87	Drought prone
2	Jaisinagar	1177	919	70.04	Drought prone
3	Begamganj	1195	906	79.50	Drought prone

4.2 Hydrological drought

Low flow analysis was carried out in Bina river basin using daily stream flow data of Rahatgarh G/D site. Flow Duration Curves technique was used to obtain dependable flow at 75% probability of exceedance which was considered as truncation level. The typical Flow Duration Curve for the August month is shown in Fig. 4. The derived truncation levels for 12 months are given in Table 4. From Table 4, it could be seen that the river had maximum dependable flow 28.1 m^3/s at 75% probability during August whereas the minimum dependable flow 0.77 during July. The dependable at 75% probability was zero during nine months from October to June. From the analysis it could be concluded that Bina river is an intermittent river having stream flow during monsoon season and 2-3 months thereafter.

Figure 4: Flow Duration Curves for August at Rahatgarh

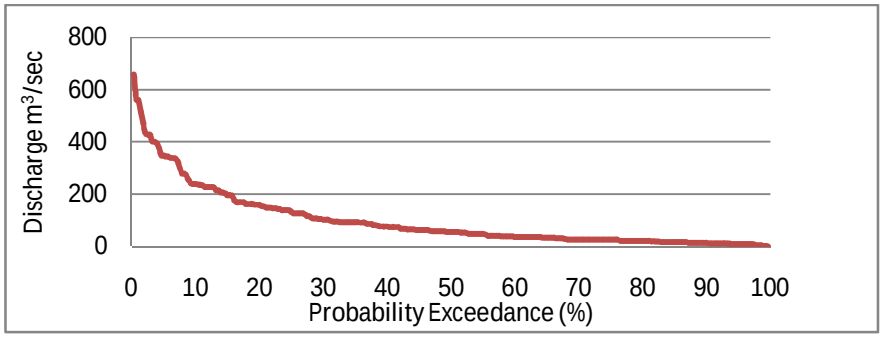

Table 4: Derived Truncation Level at 75% Dependability Levels at Rahatgarh (m^3/s)

Sl. No.	Month	Dependable flow at 75% probabilty of exceedance	Sl. No.	Month	Dependable flow at 75% probabilty of exceedance
1	January	0	7	July	0.77
2	February	0	8	August	28.1
3	March	0	9	September	7.52
4	April	0	10	October	0
5	May	0	11	November	0
6	June	0	12	December	0

The departure of daily stream flow from its truncation level demonstrating low flow conditions persisting for more than ten days period is shown in Fig. 5. From the analysis it could be seen that the Bina river had experienced 6 low flow events over the period of 9 years from 1990 to 1998 indicating 1 or 2 low flow events every year.

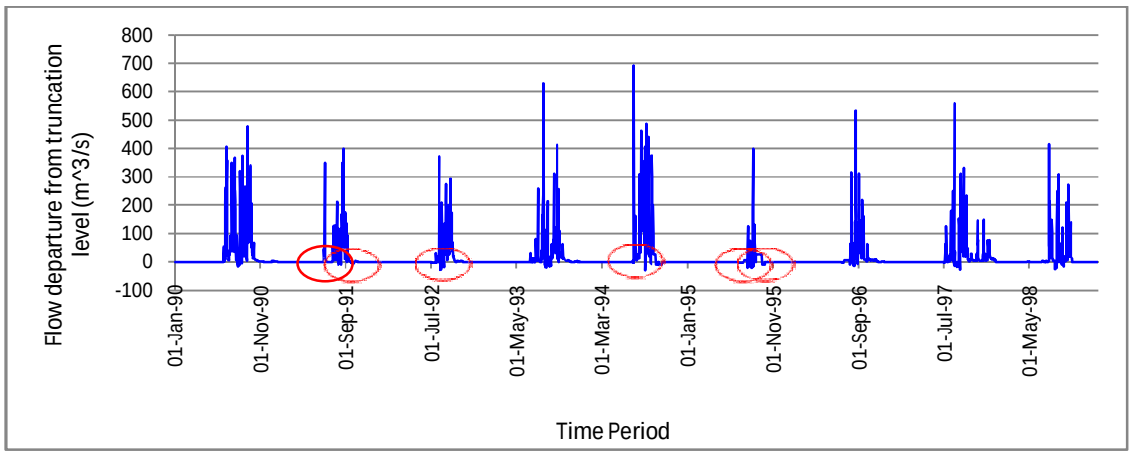

Fig. 5: Low Flow Events at Rahatgarh

Analysis was also carried out to obtain deficit flow volume and severity of low flow events as shown in Table 5. The low flow events in the basin usually began during July to September and terminated during November to December. The severity volume of low flow in the river varied from 2.88 to 287.37 MCM and duration of low flow was ranging from 10 to 22 days. The maximum severity volume of 287.37 MCM was observed for 22 days during September, 1994.

Table 5: Duration and Severity of Low Flow

Events	Periods	Duration	Severity Volume (MCM)
1	1-10 July, 1991	10	2.88
2	9-30 September, 1991	13	36.39
3	1-16 July, 1992	16	17.03
4	9-30 September, 1994	22	287.37
5	1-18 July, 1995	18	21.56
6	20-30 September 1995	11	74.13

The years 1991 and 1995 had experienced two low flow events each total duration of 23 and 29 days and severity 39.27 and 95.69 MCM respectively. Therefore, on the basis of above analysis, it could be concluded that years 1991 and 1995 were the drought years of severe deficit runoff volume in Bina river at Rahatgarh. The information on frequency of occurrence of low flow and runoff volume deficit in the river is useful in improvement of existing backup practices and to undertake water resources management and development of river basin in systematic manner to meet the various water demands.

5.0 CONCLUSIONS

Drought studies can provide an important input to water resources planners in formulating water conservation and water management strategies. In present study, the seasonal rainfall analysis and probability distribution of rainfall was found useful for identifying the frequency of drought years and to identify whether the area is drought prone or not. The Bina river basin area experiences on an average one drought year in every 3 years which are mostly of moderate nature and whole study area can be categorized as drought prone area. Flow Duration Curves technique helps to determine the probability of occurrence of particular flow at the site and dependable flow at various probability levels, which is helpful for planning of water resources projects and deriving truncation levels for specific purposes. The study indicated that the Bina river is of an intermittent nature, generally experiences 1 or 2 low flow condition every year. The low flow events in this basin usually begin during July to September and terminate during October to December. The truncation approach appears to be more effective in the investigation of drought characteristics of the river system.

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