LOW FLOW ANALYSIS IN KHARUN RIVER BASIN OF CHHATTISGARH STATE

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ABSTRACT

Drought duration, frequency and severity of low flow of the past events occurred in the Kharun river basin in Chhattisgarh state are analyzed using daily stream flow data. Stream flow drought severity is the total deficit or cumulative deficient runoff volume below the truncation level during the period of the event of low flow condition. The flow volumes at 75% probability are considered as truncation level to obtain deficiency volume and its severity for each event of low flow condition. As the problem of zero flows have been encountered, the probability of 'zero flow' and 'non-zero' flow values were computed separately and used to estimate joint probability to derive flow duration curves. The river experienced low flow epoch for 23 times over the period of 18 (1989-2007) years period indicating 1 or 2 low flow condition every year. The low flow events in this basin usually begin during July to October and terminate during November to December. The severity of low flow varies from 0.13 to 80.26 MCM and duration of low flow epoch ranges from 13 to 177 days. The maximum severity of 80.26 MCM has been observed for 177 days during September, 2000 to February, 2001.

Key Words: Drought, flow duration curves, truncation level, low flow, stream flow drought severity.

INTRODUCTION

The occurrence of drought leads to reduction in river flow, consequent reduction in reservoir and tank levels and depletion of soil moisture and groundwater. The surface water deficits are reflected through low stream flows and reduced reservoir storages. When the stream flows are not sufficient enough to meet the required demand of water, it is considered that the drought has set in. The drought severity, frequency and duration can be studied by low flow analysis of the local streams. During the rainfall deficient condition the deviation from normal values is greater for stream flows than the rainfall. The low stream flows are indicative of drought situations (Galkate et. al., 2010).

Chhattisgarh, a newly born state is exploiting its water resources mainly for development of irrigation schemes, domestic supply and industrial supply. The state is facing the problem of water scarcity in rural as well as in urban areas. Climatic variability, changes and uneven distribution of resources create water shortages and interrupt the usual water linked activities posing serious threat to nature, quality of life and economy (Hisdal and Tallaksen, 2003). Kharun is an important tributary of Seonath river, traverses through the fertile plains of Chhatisgarh state. It originates from Petechua in the south-east of the Durg district and after flowing 129 km through Durg, Dhamtari and Raipur districts, joins the Seonath river. The index map showing location of study area in Chhattisgarh state is given in Figure 1. The map showing location of Kharun river basin in Seonath basin is given in Figure 2. The industries like steel plant, cement plant etc. in Urla and Siltara industrial area falls in the catchment of Kharun. The Kharun river caters the water to Raipur city for domestic supply, Urla and Siltara industrial area, nistari (supply to village tanks) purposes and for irrigation to limited area. The river is supplemented from Ravishankar Sagar reservoir situated at Dhamtari on Mahanadi river to meet these water demands. The knowledge of the available flows in rivers in lean period is vital in formulation of the year plan for water uses comprising domestic and industrial water supply, irrigation scheduling, reservoir operation, in-streamflow maintenance, hydropower generation, etc. besides planning for economic and ecological activities of a given region (Clausen and Pearson, 1995). The main types of land use and land cover in the study area are agriculture, forest, settlements, barren, etc. and main crops are paddy, oilseeds, wheat, gram and vegetable.

As per the Thiesen Polygon method the mean annual and seasonal rainfall in the study area is 1132 mm and 1023 mm respectively. The mean minimum temperature in study area ranges from 9.5 to 27.1^{0}C, while mean maximum temperature ranges from 25.4 to 41.6^{0}C. In the present study, hydrological aspects of droughts have been studied in Kharun river basin through stream flow analysis using 18 years flow data of Patherdihi Gauge discharge site of CWC on Kharun river located at Latitude 21^0 20^I 28^{II} N and Longitude 81^0 35^I 48^{II} E near village Kumhari. The data has been collected from State Water Data Centre, Water Resources Department, Govt. of Chhattisgarh, Raipur.

Flow Duration Curve

It is well known that the stream flow varies over a water year. One of the popular methods of studying this stream flow variability is through flow-duration curves. A flow-duration curve of a stream is a plot of discharge against the percent of time the flow was equaled or exceeded. This curve is also known as discharge frequency curve. The stream flow data is arranged in descending order of discharges, using class intervals if the number of individual values is very large. The data used can be daily, weekly, and 10 daily or monthly values. If *N* numbers of data points are used in this listing, the plotting position of any discharge *Q* is given by following equation.

$$p_P = {}^{m}\!\big/_{(N+1)} * 100$$

Where, P_p = percentage probability of the flow magnitude being equaled or exceeded
m = the order number of the discharge
N = number of data points

The plot of the discharge Q against P_p is the flow duration curve. Arithmetic scale paper or semi-log or log-log paper is used depending upon the range of data and use of the plot. The flow duration curve represents the cumulative frequency distribution and can be considered to present the stream flow variation of an average year. The ordinate Q_p at any percentage probability Pp represents the flow magnitude in an average year that can be expected to be equaled or exceeded Pp percent of time and is termed as P_p %

dependable flow. In a perennial river Q_{100}=100% dependable flow is a finite value. On the other hand in an intermitted and ephemeral river the stream flow is zero for a finite part of a year and as such Q_{100} is equal to zero. Flow-duration curves find considerable use in water-resources planning and development activities such as evaluating various dependable flows in the planning of water-resources engineering projects, evaluating the characteristics of the hydropower potential of a river, design of drainage system, flood-control studies, computing the sediment load and dissolved solids load of a stream and comparing the adjacent catchments with a view to extend the stream flow data.

Analysis of Flow Duration Curves

In analyzing the stream flow drought, one of the simplest techniques is to construct a flow duration curve for the given river. The daily flow data of Patherdihi site has been used to prepare monthly flow duration curves for all 12 months of the year and flow duration curves for the August month is shown in Figure 3. The flow volumes at 75% probability levels at site are obtained for flow duration curves and results of which are presented in Table 1. The flow volumes at 75 % probability are considered as truncation level to obtain deficiency volume and its severity for each event of low flow condition. Severity is the total deficit or cumulative deficient runoff volume below the truncation level during the period of the event of low flow condition. Thus the departure analysis has been carried out and the events of low flow condition persisting for more than ten days period are identified and are presented in Table 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). For determination of the truncation level, it is necessary to derive first the flow duration curve using monthly data. For stream flow data, where the problem of zero flows is encountered, can be resolved as follows:

The number of ‘zero flow’ and ‘non-zero’ flow values for each month can be separated from the available flow records to determine the percentage probability of occurrence of zero flow in each months as:

$$P_i = X_i / N$$

Where Pi = probability of zero flow in the i^{th} month;
i = an integer varying from 1 – 12;
Xi = number of zero flow values in the i^{th} month,
N = total number of flow records for the i^{th} month (i.e. number of years of records).

Then the non-zero flow values for each month are arranged in the descending order to rank the highest as 1 and the lowest as (*N*-*Xi*) for computation of the joint probability of exceedence as:

$$P_{nz_{j,i}} = (1 - P_i)\frac{R_{j,i}}{N - X_i}$$

Where $R_{j,i}$ = rank of the j^{th} flow value of the i^{th} month

$Pnz_{j,i}$ = join probability of the exceedence of the jth value of the non-zero flow in the i^{th} month

i = an integer varying from 1 – 12;

j = an integer varying from 1 – (N-Xi);

thus the flow duration curve for each month can be derived by plotting the joint probability of exceedence of non-zero flow values ($Pnz_{j,i}$) against the corresponding discharge value, and a truncation level corresponding to a fixed, for example 75 percentile (Kjeldsen et. al. 2000) can be determined.

Table 1: Derived truncation level at 75% dependability levels at site Patherdihi

S NO.	Month	Volume in cumec At 75% dependability
1	June	0.00
2	July	3.17
3	August	28.6
4	September	20.98
5	October	12.17
6	November	2.10
7	December	0.754
8	January	0.55
9	February	0.255
10	March	0.00
11	April	0.00
12	May	0.00

Table 2: Severity of low flow and its duration at site Patherdihi
(Flow data of period from July 1989 to Oct 2008)

S.No.	Event	Onset of Event	Termination of Event	Severity MCM	Duration (days)
1	I	06/10/1989	31/10/1989	14.64	26
2	II	08/11/1989	03/12/1989	1.57	26
3	III	11/12/1989	26/12/1989	0.17	16
4	IV	21/01/1990	02/02/1990	0.13	13
5	V	05/09/1991	23/09/1991	20.04	19
6	VI	27/09/1991	09/10/1991	6.59	13
7	VII	01/07/1992	20/07/1992	3.33	20
8	VIII	19/09/1992	12/10/1992	16.33	24
9	IX	01/07/1996	16/07/1996	3.33	16

10	X	01/07/1999	20/07/1999	4.21	20
11	XI	01/08/2000	16/08/2000	24.59	16
12	XII	05/09/2000	28/02/2001	80.26	177
13	XIII	20/10/2001	31/10/2001	4.42	12
14	XIV	01/07/2002	15/08/2002	37.11	46
15	XV	08/09/2002	17/10/2002	42.89	40
16	XVI	15/11/2002	28/02/2003	5.35	106
17	XVII	17/02/2004	29/02/2004	0.26	13
18	XVIII	08/11/2004	12/12/2004	2.11	35
19	XIV	14/12/2004	05/01/2005	0.64	23
20	XX	10/01/2005	28/01/2005	0.46	19
21	XXI	19/02/2005	28/02/2005	0.14	10
22	XXII	18/11/2006	30/11/2006	0.83	13
23	XXIII	18/12/2007	31/12/2007	0.87	14

RESULTS AND DISCUSSION

Low flow analysis has been carried out in Kharun river basin using daily stream flow data. With the help of Flow Duration Curves, the probability of occurrence of particular flow at the site can be established, which is helpful for planning of water resources projects. From Table 1, it can be seen that the maximum 75% dependable flow is 28.6 cumec in August whereas the minimum 75% dependable flow is 0.00 cumec in March April May and June.

Analysis has also been carried out to obtain deficit volume and severity of low flow at the Patherdihi site as shown in Table 2. From the departure analysis of stream flow from its truncation level, it is observed that the Kharun river has experienced low flow epoch for 23 times over the period of 18 years period (1989-2007) indicating 1 or 2 low flow condition every year. From the analysis it is observed that low flow events in this basin usually begin during July to October and terminate during November to December. The severity of low flow in the river varies from 0.13 to 80.26 MCM and duration of low flow epoch ranges from 13 to 177 days. The maximum severity of 80.26 MCM has been observed for 177 days during September, 2000 to February, 2001. The years 1989, 2002 and 2004 experienced three low flow events each, which are highest in any one year. In year 1989 three low flow events of total 68 days has experienced total severity of 16.38 MCM. In year 2002 three low flow events of total 172 days has experienced total severity of 85.34 MCM. In year 2004 three low flow events of total 71 days has experienced total severity of 3.02 MCM. Therefore it can be concluded that year 1989, 2000, 2002 are years of sever deficit runoff volume at Patherdihi and are considered as severe hydrological drought years. The information on frequency of occurrence of low flow and runoff volume deficit in 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.

CONCLUSIONS

Drought studies can provide an important input to water resources planners for water conservation and water management purposes. 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. Low flow analysis technique helps in assessing the hydrological drought severity, frequency and its duration in the river basin using long term stream flow data. The Kharun river in Chhattisgarh state generally experiences 1 or 2 low flow condition every year. The low flow events in this basin usually begin during July to October and terminate during November to December. The truncation approach appears to be more effective in the investigation of drought characteristics of the river system.

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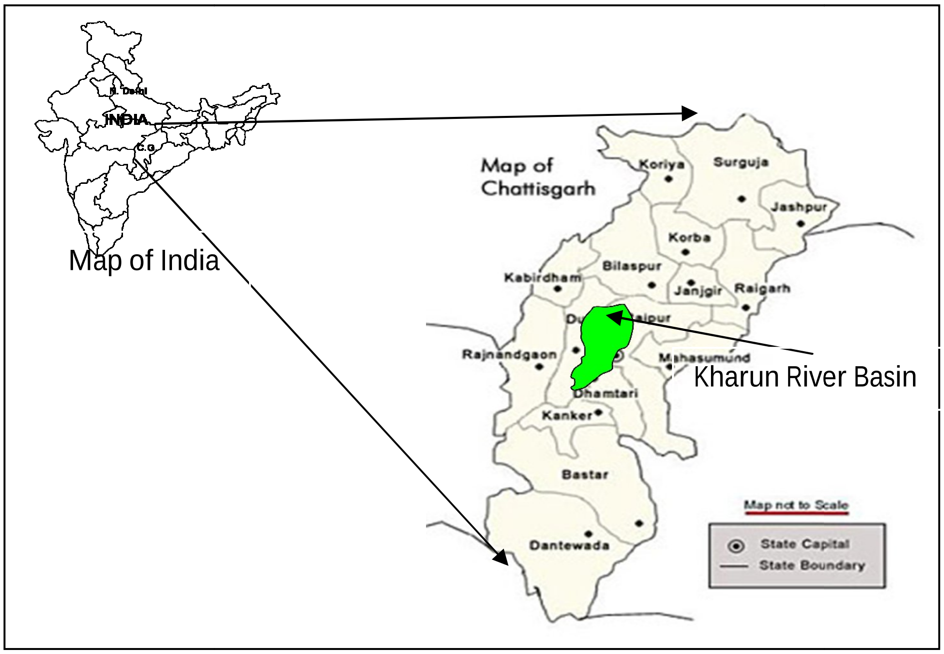

Figure 1: Index map showing location of Kharun river basin in Chhattisgarh state

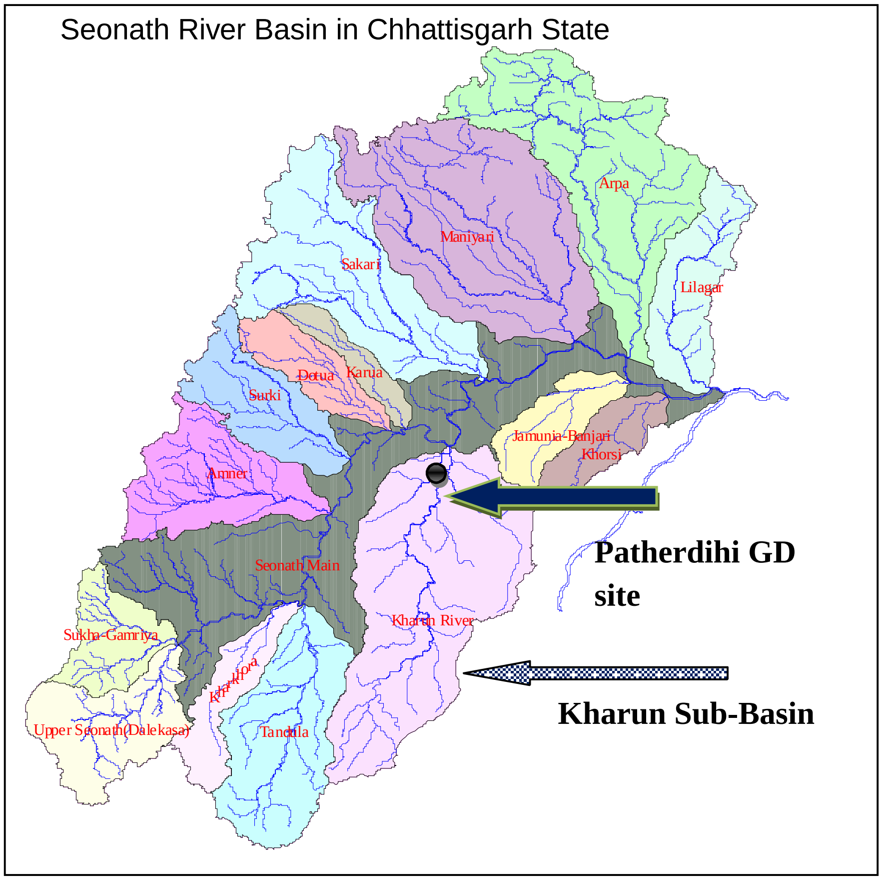

Figure 2: Location of Kharun river basin in Seonath basin

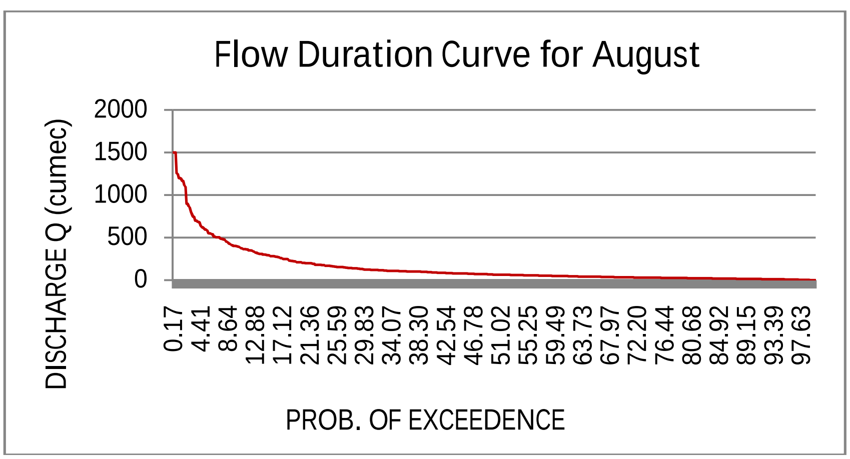

Figure 3: Flow duration curves for August month flow at Patherdihi