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Flood Frequency Analysis of Jiadhal River Basin, India using Log Pearson Type III Distribution Method

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Abstract - **Flood is considered as the most widespread and disastrous natural calamity in the world which adversely affects the socio-economic condition and lives of the people living within the floodplain areas of the world. The Jiadhal River basin of Dhemaji district, Assam experiences a high magnitude of flood almost every year, leaving the people of that area in jeopardy. In this regard, flood frequency analysis is considered an important step for proper planning and managing the region in terms of floods. Flood frequency analysis (FFA) is one of the utmost important and necessary measures taken to develop any floodplain region. In this present study, a FFA of the Jiadhal River Basin is carried out using the Log Pearson Type III (LP3) probability distribution method which is used to predict future flood events based on historical records. The data used in the study was for a period of 46 years. The method was used to predict the flood discharge estimations at 2, 10, 25, 50 and 100 years recurrence period. The result says that after 10 years the return period will surpass the water-carrying capacity of the Jiadhal River.**
Keywords: **LP3, Frequency Analysis, Jiadhal River**

I. INTRODUCTION

Floods are among the most common natural hazard or destructive act of nature worldwide (Sathe *et al.,* 2012) which destroys many lives and properties and leave people at great risk. Flood occurs when there is a sudden rise in the water level of a river due to heavy rainfall or due to high volume of water discharged from the up catchment areas which exceed the water carrying capacity of the river (Chakravartty, 2018) and lead to the overbank flow of water and inundate the adjoining areas by breaching of the embankment or road. Over the years, floods have created a tremendous impact worldwide by destroying infrastructures, drowning agricultural fields and even many people are left homeless (Mujere, 2011). To protect the people of the flood-affected areas and the properties it is necessary to protect the region with structural and non-structural measures (Ward, 1978) by understanding the flood frequency and magnitude within the region. So, to know and understand the nature, frequency, and magnitude of the high-water discharge of a particular river, flood frequency analysis (FFA) is considered one of the most important statistical techniques used in the field of fluvial geomorphology. FFA has great significance in calculating the recurrence of floods in a particular river. Many engineers, hydrologists, watershed managers and regional planners worldwide use this method while designing any water resource projects to predict the magnitude and frequency of the flood (Bhagat, 2017; Odunuga & Raji, 2014) and to avoid any kind of damage that can be caused by the temporal variability of water discharge (Sathe *et al.,* 2012).

FFA predicts the re-occurrence of a probable flood from a given series of data on a river at a particular site. It is a dimensionless mechanism that is used to analyse and interpret the magnitude of severer flood events to the frequency of their recurrence interval (Bhat *et al.,* 2019; Chow *et al.,* 1988). It is generally used to predict the future flood events along with their recurrence interval. This technique is analyzed using the annual maximum peak flow water discharge data and with the help of these data the mean or the average, standard deviation and skewness are calculated in order to predict the recurrence interval along with the peak water discharge of a river at a particular hydrological station.

One of the advantages of this technique is that the prediction of extreme flood events of larger intervals which are longer than the recorder period can be determined with the help of FFA (Ganamala & Kumar, 2017). There exists a good relationship between the magnitude and the frequency of the flood with which it occurs. Floods of different magnitudes do not occur with the same intensity, as small floods are seen more frequently or can be expected to occur more often than larger floods.

In fluvial geomorphology and hydrology, the magnitude and the frequency of flood are defined by FFA using time series discharge data (Kumar, 2019). There are different methods used to analyze the flood frequency, some of them are- Normal Distribution (Yue, 1999), Log-Normal Distribution (Reis & Stedinger, 2005), Gumbel Distribution (Gumbel, 1941) and LP3 Distribution. Each method can be used to predict the recurrence interval of peak flood for any catchment but in the year 1967, the United States Water Council suggested that the LP3 Distribution for FFA fits well to the peak flood in many cases (Subramanya, 2008). Thus, FFA is one of the methods that is used to show the relationship between the magnitude and frequency of any flood event.

FFA is vital for flood-affected rivers like the Jiadhal of Dhemaji district. Many past records reveal that the Jiadhal River in the district of Dhemaji, Assam, India witnessed a series of flood after the famous earthquake of 1950, which left the entire river system of Assam severely disturbed. Previous studies on the Jiadhal River also pointed out that the magnitude, frequency and damages caused by floods increased after the 1950 earthquake. According to Hazarika, 2010 and Das, 2013 some of the major flood events were recorded in the years 1969, 1973, 1984, 1988, 1989, 1992, 1994, 1997, 1998, 2002, 2007, 2009, 2011, 2014 and 2017. One of the major causes of flood in the catchment is the continuous rainfall in the monsoon season, however, deforestation, landslide and heavy downpour in the upper catchment also increase the risk of flood in the floodplain areas. The present study aims to compute the FFA of the Jiadhal River catchment using the annual maximum peak water discharge data from 1973 to 2018. The specific objective of the study is to predict the return period for 2, 10, 25, 50 and 100 years using the LP3 method.

II. STUDY AREA

The Jiadhal River is an important north bank sub-tributary of the mighty River Brahmaputra situated in the district of Dhemaji, Assam, India. The latitudinal extent of the basin is between 27°12ˈ44ˈˈN and 27°45ˈ2ˈˈN and the longitudinal extent is between 94°15ˈ19ˈˈE to 94°37ˈ23ˈˈE. The total area of the catchment is 1053.20 km^2 of which 696.80 km^2 and 356.4 km^2 come under Assam and Arunachal Pradesh respectively. The river originates in the West Siang district of Arunachal Pradesh where three important rivers Sika, Siri and Sido meet at a place called Tinimukh, and from there it flows down as the river Jiadhal (Fig.1). After passing through the narrow gorge at Jiadhalmukh, the river debouches on to the Brahmaputra plain where many braided channels are formed. The catchment according to the Geological Survey of India is divided into two distinct geological divisions - i. the Siwalik formation which belongs to the Tertiary period of the Miocene epoch and ii. The alluvium sediment of the Quaternary period. Due to this, two distinct physiographic divisions in the area - i. the mountains and ii. the plains are visible clearly.

The entire basin comes under climatic zone - I, where rainfall occurs mostly during the monsoon season and winters remain dry. There can be seen a variation in the temperature, humidity and rainfall within the study area due to its location in the foothills of the Arunachal Himalayan region. The annual rainfall of the basin ranges from 2600 mm to 3300 mm with an average of 2590 mm every year. With the increase in rainfall in the upper catchment areas, the water discharge of the river also increases and led to flash floods with an abundant supply of siltation within the riverbed.

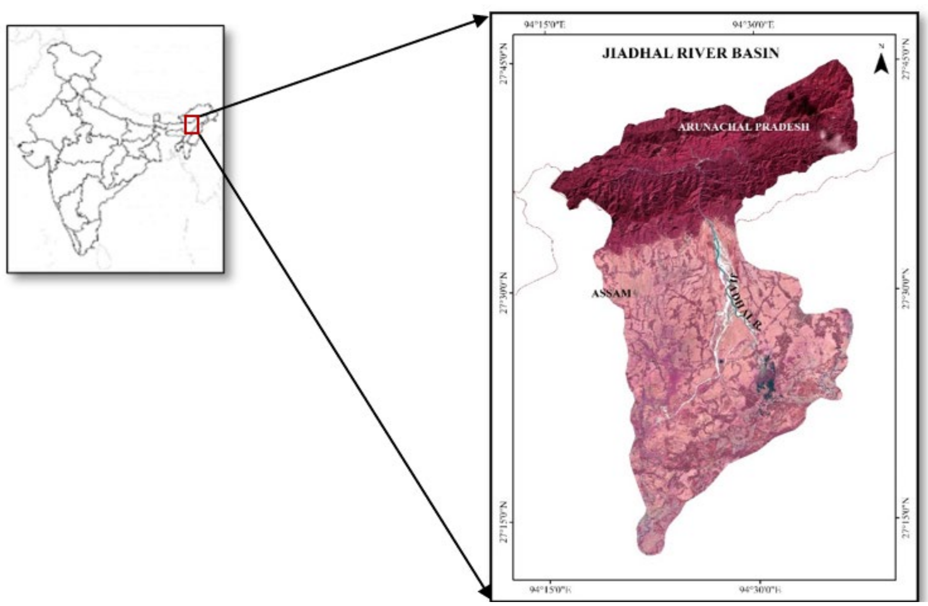

Fig. 1 Study area (Jiadhal River Basin)

III. DATABASE AND METHODOLOGY

In the present study, the data used for the FFA were recorded in the Jiadhalmukh hydrological site and were collected from the Brahmaputra Board, North Lakhimpur Branch, Govt. of Assam from 1973 to 2018. It includes the annual maximum peak discharge data. For the FFA, many statistical parameters like mean, standard deviation and skewness are used (Kumar, 2019), but if there is any gap between the data set or the data series is for a short duration then this may lead to errors in the result. Hence, a continuous data series of minimum 15 years should be taken to avoid errors in the result. For the study, a data series of 46 years has been taken to avoid any possible errors that might affect the result. In order to perform the FFA of the Jiadhal River, LP3 Distribution Method has been used as it is considered to be one of the methods for frequency analysis by the U.S Water Council.

A. LP3 Distribution Method

LP3 Distribution is considered the most widely used frequency distribution technique. It is considered a standard technique used by the Federal Agencies of the United States (Sathe *et al.,* 2012). It is a member of the Pearson Type III distribution family and is also referred to as the three-parameter Gamma distribution (Bhat *et al.,* 2019; Millington *et al.,* 2011). Since the recommendation by the U.S Water Council in 1967 this method has been used extensively for frequency distribution. In this method, the variate is first transformed into logarithmic form (base 10), and then the transformed data is analysed (Subramanya, 2008). The mean logarithm ($\overline{Y}$), the standard deviation of the logarithm ($\sigma \log x$) and the skewness co-efficient (C_S) are computed to estimate peak discharge for a given return period for a specific event. Using this frequency distribution method, to estimate the return period for the river Jiadhal, the following equation has been used.

$$\log x = \overline{Y} + K\sigma_{\log x} \quad (1)$$

where,
x = flood discharge value of some specified probability
$\overline{Y}$ = average of the log x discharge values
K = frequency factor which is a function of recurrence interval and
σ = standard deviation of the log x values.

The mean, variance and standard deviation of the data series are calculated using the following formulas.

$$\overline{Y} = \frac{\Sigma(\log Q)}{n} \quad (2)$$

$$\text{Variance} = \frac{\sum_i^n (\log Q - Y)^\wedge 2}{n-1} \quad (3)$$

$$\sigma \log x = \sqrt{variance} \quad (4)$$

$$\text{Skewness coefficient } (C_S) = \frac{n\Sigma(\log x - Y)^3}{(n-1)(n-2)(\sigma \log x)^3}$$

IV. RESULTS OF THE STUDY

The data series shows that the maximum peak water discharge of 1020.47 cumec was recorded in the year 2004 and the minimum peak discharge of 232.76 cumec was recorded in the year 2010. By applying the LP3 probability distribution method, the recurrence interval for 2, 10, 25, 50 and 100 years is being estimated for the river Jiadhal. From the annual maximum data series, the mean ($\overline{Y}$), standard deviation ($\sigma \log x$) and skewness coefficient (C_S) of the log-transformed data obtained were 2.76, 0.1405 and -0.6533 respectively. The K factor values for different return periods were obtained using the frequency factor table values.

The calculation for the derivation of expected water discharge for all the flood with return periods of 2, 10, 25, 50 and 100 are shown in Table I and the graphical representation is shown in Fig. 2 for the river Jiadhal.

TABLE I ESTIMATION OF FLOOD AT DIFFERENT RETURN PERIOD USING LP3 FOR THE RIVER JIADHAL

Return Period (T)	**Skew coefficient K (-0.6533)**	**Discharge(Q)**
2	0.0899	595.1375
10	1.2091	854.8337
25	1.5493	954.3238
50	1.7504	1018.4723
100	1.9194	1075.7363

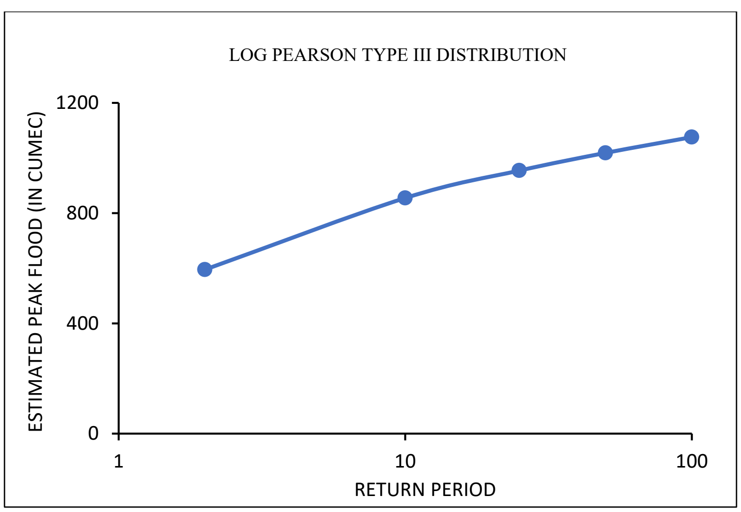

Fig. 2 Return Period v/s Peak discharge

The frequency of flood discharge increases in the downstream areas as many tributaries contributes to the water discharge in the upper stream of the river Jiadhal. The result shows that the Jiadhal River Basin experience flood every year and the FFA computed using LP3 shows an increasing trend in the peak flood for the return period 2, 5, 10, 25, 50 and 100 years.

V. CONCLUSION

FFA is a technique used to forecast the long-term behavior of a river. Proper information and understanding about the frequency and magnitude for the recurrence of the flood are necessary to design the structures like dams, bridges, culverts etc. and it is also useful in zoning different flood hazard zones for various flood-related studies. FFA is considered an important method in the studies of floods and is considered an important hydrological tool as it can forecast the long-term flow pattern of a river. Using the probability distribution methods, it is easy to predict the return period of various flood events which later helps in planning and designing flood-prone areas for development. FFA computed using the LP3 distribution method at different recurrence interval is vital for constructing a proper embankment and strengthening the prevailing embankments along the river Jiadhal which may prevent major flood events in the future. In the study, using the peak discharge data from the year 1973 to 2018 at Jiadhalmukh hydrological station of the river Jiadhal, estimation for the return periods 2, 10, 25, 50 and 100 are done. The study says that the discharge rate after 10 years of recurrence interval will exceed the water carrying capacity of the river. This might happen due to the high sediment brought down by the river which will increase the height of the river bed. Thus, to minimize the impact of flood, it is important to dredge the river bed and the construction of embankment must be high enough to prevent flood.

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