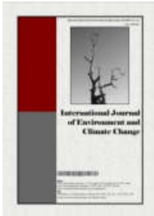

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Flood Frequency Analysis for Burhi Gandak River Basin

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SH, KP and VKT designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KCP and GS managed the analyses of the study. Author SM managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study is aimed at finding the best distribution to match the steam flow and calculation of magnitude and frequency of flow. In the current study, we have used several statistical distributions to find the best fit distribution for stream flow and used flood frequency analysis techniques to find the magnitude and frequency of stream flow and non-exceedance probability of peak discharge. The study has been performed at Sikandarpur and Rosera gauging sites of BurhiGandak River. Historical (50 years) maximum annual peak discharge data of each station are used for statistical analysis for estimating maximum peak discharge in 5, 10, 25, 50, 100 year return period. In this study, Lognormal distribution, Galton distribution, Gamma distribution, Log Pearson Type III distribution, Gumbell distribution, Generalised extreme values distribution have been considered to describe the annual maximum stream flow. Flood frequency analysis methods were used for estimating the magnitude of the extreme flow events and their associated return periods. For both Sikandarpur and Rosera stations, Log Pearson type III distributions showed the lowest value of K–

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S and Chi-square test statistic. The annual probable peak discharge for 5, 10, 25, 50, and 100 years return period is calculated for each distribution. The most suitable distribution for both the stations is found to be the log-Pearson type III distribution.

Keywords: Frequency analysis; flood; return period; distribution; gumbell distribution; and log pearsontype III distribution.

1. INTRODUCTION

Flood frequency analysis is generally used for water resource management in the possibility of extreme events occurs in flood-prone areas. The application of the frequency analysis methods has been widely recognized by numerous researchers in various fields. In the design and planning of several water resources projects, engineers are frequently focused on estimating flood peak magnitudes to obtain a set of non-exceedance. Apart from the unit hydrograph methodology, rainfall-runoff models method and rational method, the frequency analysis method is one of the best techniques applied to establish a relationship among the flood frequency and magnitude of an event with which it exceeded [1]. Different frequency distribution techniques have been developed for the determination of hydraulic frequency analysis. But, no single distribution methods can be accepted as the universal distribution for describing the flood frequency for any gauging site. The selection of suitable distribution methods typically relies on the properties of data of a particular site [2].

Natural calamities like floods cause huge damage like the destruction of infrastructure, damages in environmental and agricultural lands, mortality, and economic losses, throughout the globe [3]. The primary causes of the occurrence of floods are extreme rainfall, glacier melting, failure of dams, and the inability of the river channels to pass the excess water. The primary objective of the study is to perform flood frequency analysis for the Burhi Gandak river basin using the maximum annual peak discharge data obtained from Sikandarpur and Rosera station. To describe the flood frequency in the study area, the choice of an appropriate probability distribution and parameter estimation methods are of immense importance. The probability distributions used in this study include the log-normal distribution, Galton distribution, Gamma distribution, log-Pearson type III, Gumbel distribution, Generalised extreme values distribution. Many countries use these distributions for analysis of flood frequency [4].

2. DESCRIPTION OF STUDY AREA

The Burhi Gandak basin arises from the upper portion of the West Champaran district from the springs of Someshwar hills located at an altitude of 300 meters. It drains into River Ganga about 7 km east from Khagaria district of Bihar. The total length of the river is 320 km, which covers the catchment area to 12180 km^2. The basin lies between 27°27′21″N and 25°26′02″N latitudes and 86°36′25″E and 84°03′48″E longitudes. The basin is covered by the Kosi river basin in the east, Gandak catchment in the west, the Himalayas on the north, and the Ganga River on the south. The basin receives most of the water from its minor tributaries but during high flood conditions, some overbank connection gets established with the main Gandak channel. The main tributaries of Burhi Gandak River are Masan, Harbora, Tilawe, SiriswaKoria, Pasaha, TiarHahwa, with their catchment in Someshwar hills. The Burhi Gandak River passes through Samstipur, West Champaran, Muzaffarpur, and Khagaria districts of Bihar.

2.1 Flood Frequency Analysis

To describe the flood frequency at a specific area, the selection of an appropriate probability distribution is always essential. We have considered a log-normal distribution, Galton distribution, Gamma distribution, log-Pearson type III, Gumbel distribution, Generalised extreme values distribution for the analysis of flood frequency at two gauging sites of the Burhi Gandak River. In literature, these statistical models have been recommended for flood frequency analysis. Generally, the steps followed in flood frequency analysis are as follows:

Step 1: Selection of the data

Annual maximum daily peak discharge covering a period of 1956 to 2005 collected from the two stations were selected for this study. The research focused on determining the magnitude and frequency of stream flow and non-exceedance probability of peak discharge using annual maximum peak flood discharge records.

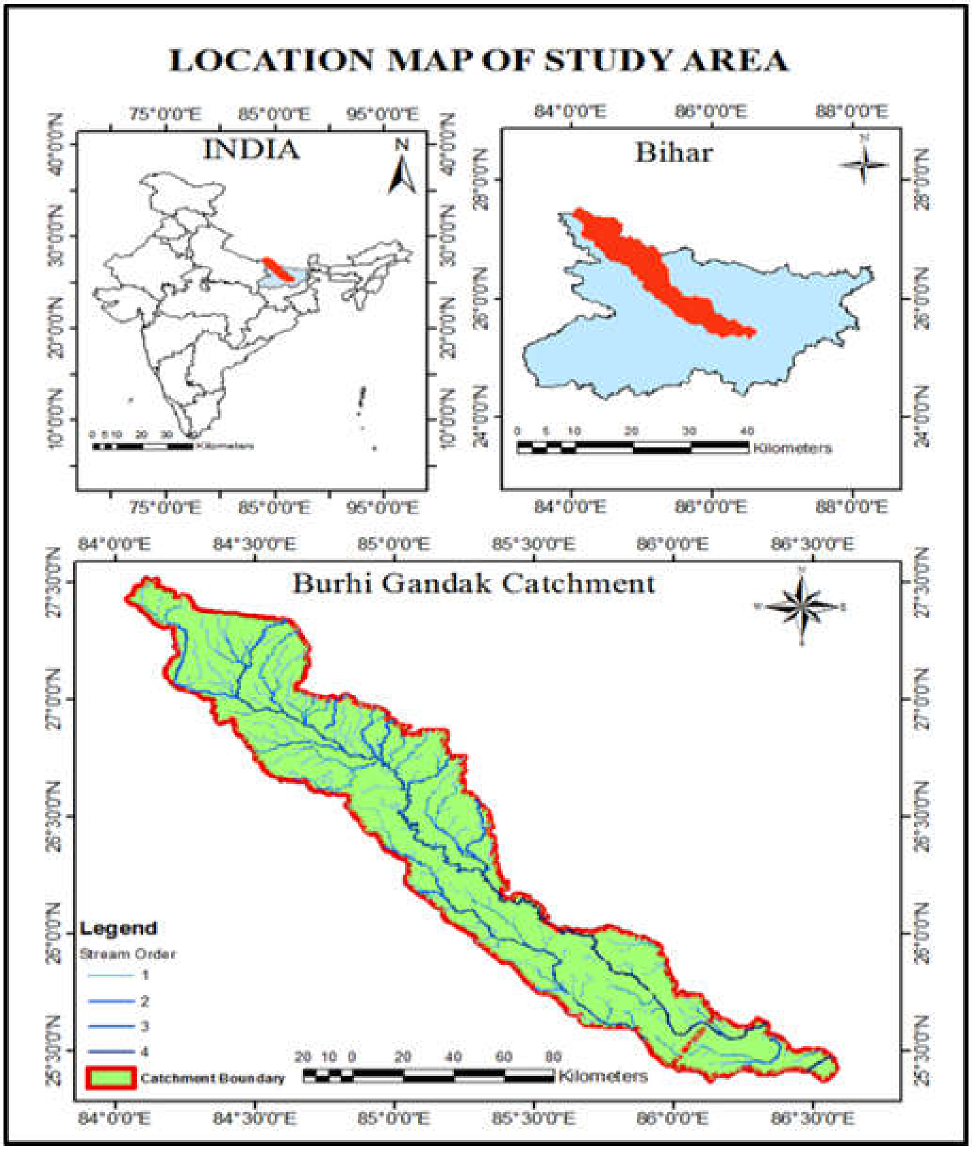

Image 1. Location map

Step 2: Fitting the probability distribution

Many programs are available to analyse statistical extreme values precisely. Most frequently used packages include: PeakFQ to perform statistical flood-frequency analysis of annual-maximum peak discharge [5], CumFreq for inspection of hydrological parameters in space and time, RAINBOW program [6], 'Hydrognomon' [7], and Hyfran for analysis of extreme events [8]. Applying frequently used probability functions e.g. Gumbel, gamma, normal, log-normal, Weibull, exponential, or Pareto distribution, we can perform analysis of extreme events like flood. In the current study, Hydrognomon software is utilized for flood frequency analysis. Hydrognomon is data processing software and is not typically used for flood frequency analysis [7]. It has been utilised by scientists to model the hydrological parameters of the Kaduna River in Niger and for simulating future climatic alterations [9]. However, no study has been done on flood frequency analysis using the Hydrognomon software. One of the merits of this program is that it can process several time steps, from the minute scales up to decadal-scale and also fill the missing entities. The software is chosen because it can perform over thirteen statistical distributions and statistical tests.

Step 3: Goodness of fit test to identify the best fitting distribution

The reliability of a specified or assumed probability distribution function can be analyzed with the Goodness of fit test [10]. The test shows, how much precisely the observed data fit the selected probability distribution model. Root means square error (RMSE) test, Kolmogorov–Smirnov (K-S) test, Anderson–Darling (A-D) test, and Chi-square test is most frequently used goodness-of-fit tests. In the test, the K-S test statistic distribution is independent of the cumulative distribution function for which it is being tested. The Chi-square test helps to extract more comprehensive information from the test statistic than any other test [11]. The test can also be applied to any other univariate distribution. Because of the above reasons, the K–S test and Chi-square test are picked for analyzing the best-fit distribution. The fact that the Chi-square test requires a significant sample size is not a problem in the current study since we have a large sample size.

3. RESULTS AND DISCUSSION

In the study, different frequency distribution functions were tested to compute the return period of major flood events in Burhi Gandak River. The tests were performed for two hydrological stations using the maximum daily discharge data from the year 1956 to 2005. It was noticed that the maximum yearly discharge varies significantly among the stations (Fig. 1). The discharge of the two stations is found to follow a similar trend. The recorded maximum discharge for Sikandarpur station was 4861 m^3/s occurred in 1975 and for Rosera station is 3486 m^3/s occurred in 1987. The Sikandarpur station recorded the high flood discharge in many years as it is located downstream of the Burhi Gandak River.

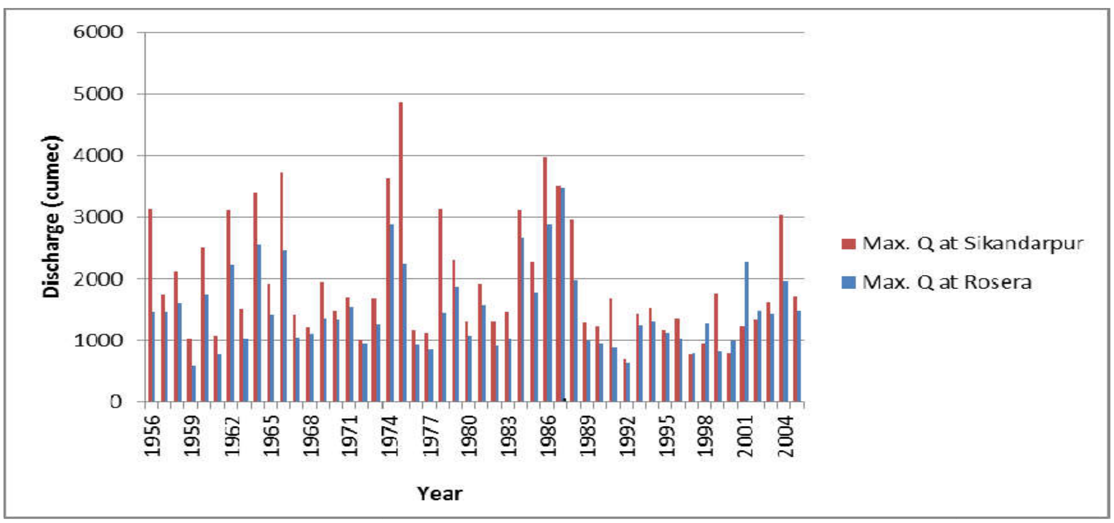

Fig. 1. Maximum annual peak discharge for Sikandarpur station (in red) and Rosera station (in blue)

Table 1. Summary of best-fitted distribution for Sikandarpur and Rosera station

Distribution	Sikandarpur station		Rosera station	
	K-S test	Chi square test	K-S test	Chi square test
Log Normal	0.10647	8.52	0.07112	4.32
Galton	0.12733	16.64	0.07914	9.92
Gamma	0.12411	16.64	0.09055	11.04
Log Pearson type 3	**0.10579**	**8.52**	**0.069**	**4.88**
Gumbel Max.	0.12501	16.64	0.07874	9.92
GEV Max.	0.12757	16.64	0.07757	9.92

3.1 Selection of the Best-fitted Distribution

The maximum discharge data of each station for 50 years was used for the flood frequency analysis. The results of the goodness-of-fit test for each station are summarized in Table 1. The value of Kolmogorov–Smirnov (K–S) test and chi-square test for log-normal distribution, Galton distribution, Gamma distribution, Log-Pearson

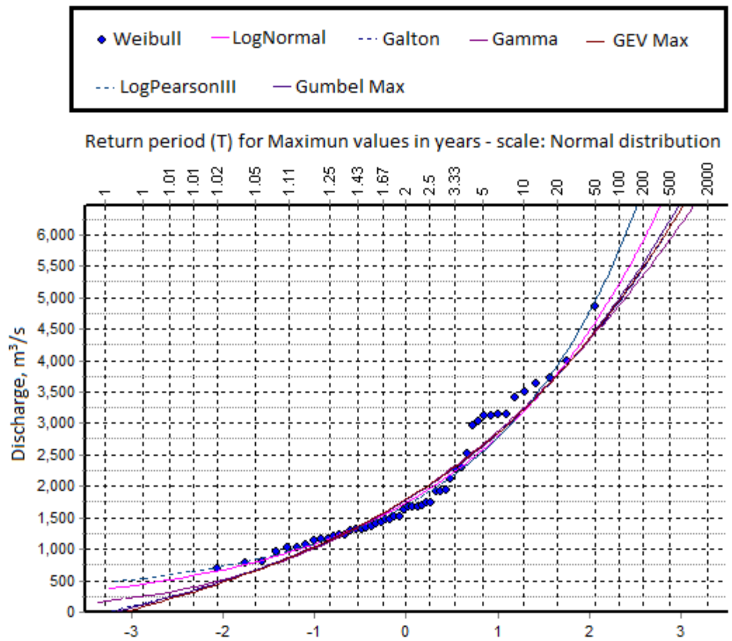

Fig. 2a. Probability distribution plot for Sikandarpur station

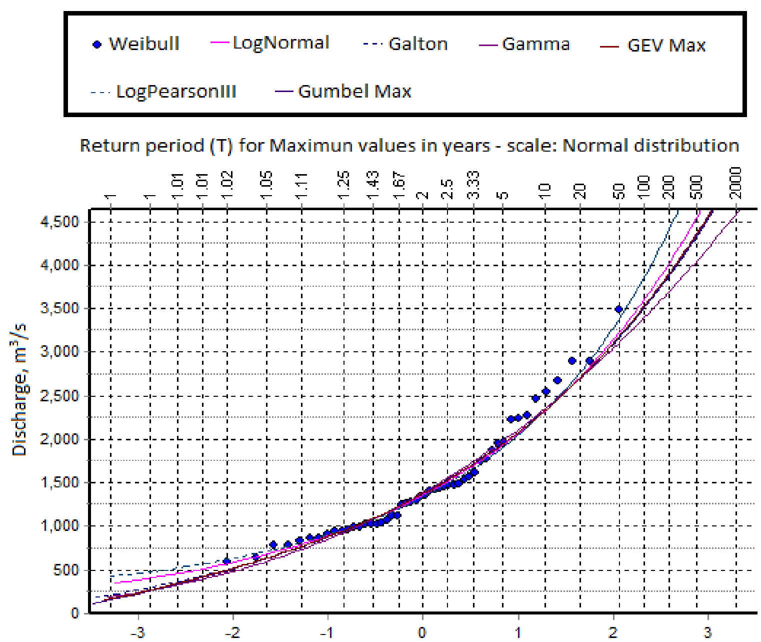

Fig. 2b. Probability distribution plot for Rosera station

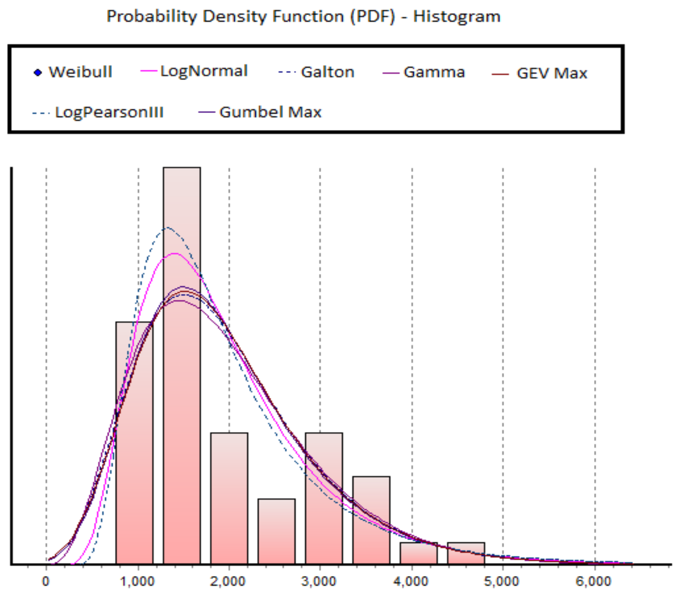

Fig. 2c. Probability density function for Sikandarpur station

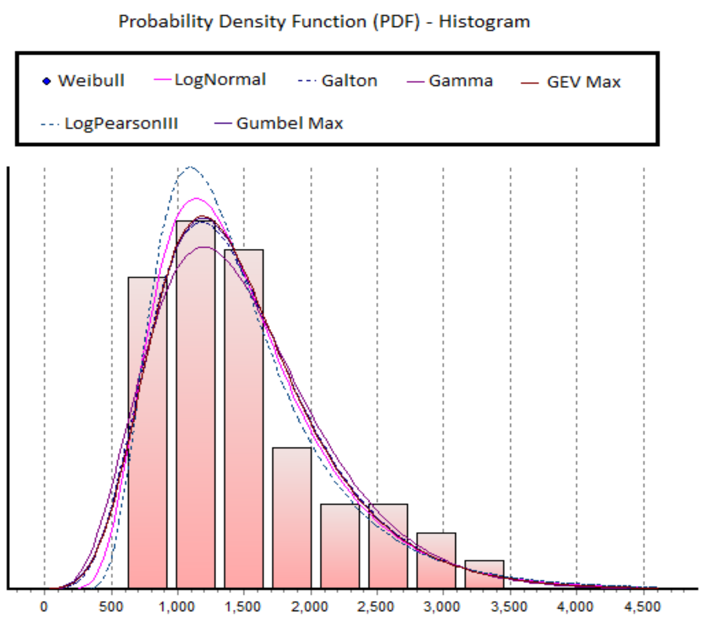

Fig. 2d. Probability density function for Rosera station

type III distribution, Gumbel distribution, and Generalised extreme values distributions are given in Table 1.

The value of K–S, and Chi-square for all the statistical distributions is presented in Table 1. The comparison of goodness-of-fit by K–S and Chi-square test showed that the best-fitted distribution for both Sikandarpur station and Rosera station is the Log-Pearson type III distribution, as it has the lowest K-S and Chi-square value for both of the stations (highlighted in Table 1). However, other distributions also showed test results close to the Log-Pearson type III distribution.

Table 2. Summary table of return period and corresponding peak discharge

Return period (year)	Log Pearson Type 3		Return period(year)	Gumbel Max.	
	Sikandarpur Station	Rosera Station		Sikandarpur Station	Rosera Station
	Max. Discharge (cumec)	Max. Discharge (cumec)		Max. Discharge (cumec)	Max. Discharge (cumec)
5	2563.88	1912.58	5	2648.11	**1952.33**
10	3222.40	2333.64	10	3218.64	**2333.82**
25	4156.20	2910.38	25	3939.50	**2815.82**
50	4928.03	3332.88	50	4474.28	**3173.41**
100	5767.18	3863.94	100	5005.11	**3528.35**

Return period (year)	Galton Extreme Value		Return period(year)	Generalized Extreme Value	
	Sikandarpur Station	Rosera Station		Sikandarpur Station	Rosera Station
	Max. Discharge (cumec)	Max. Discharge (cumec)		Max. Discharge (cumec)	Max. Discharge (cumec)
5	2663.39	1956.88	5	2657.40	**1949.68**
10	3226.14	2336.89	10	3223.69	**2331.94**
25	3924.90	2812.60	25	3931.96	**2816.73**
50	4438.23	3164.47	50	4452.22	**3177.69**
100	4946.58	3514.74	100	4964.33	**3537.10**

Return period (year)	Log Normal distribution		Return period (year)	Gamma distribution	
	Sikandarpur Station	Rosera Station		Sikandarpur Station	Rosera Station
	Max. Discharge (cumec)	Max. Discharge (cumec)		Max. Discharge (cumec)	Max. Discharge (cumec)
5	2591.65	1933.98	5	2684.77	**1985.99**
10	3191.14	2326.63	10	3253.08	**2355.57**
25	3983.97	2833.56	25	3937.94	**2795.33**
50	4598.03	3218.34	50	4424.95	**3105.20**
100	5230.81	3608.89	100	4893.60	**3401.57**

3.2 Return Period Calculation

The best-fit distribution i.e. log-Pearson type 3 is picked for the return period calculation. The return period for peak discharge is computed using a 95% confidence interval. Table 2 contains the result of the flood frequency analysis conducted using data from the two stations.

4. CONCLUSION

Determination of the best-fitted distribution for the estimation of an appropriate return period is very important in flood frequency analysis. In this study, different probability distribution function and probability density functions were applied to the time series data of two stations in Burhi Gandak catchment. Each distribution is tested by the K–S test and Chi-square test, which helped to decide the best-fitted distribution for each station. After selecting the best fit distribution, maximum peak discharge for the 5, 10, 25, 50, and 100 years return periods was calculated. This information would be beneficial for designing engineering structures, such as a dam, bridges, flood control structures, etc. Furthermore, the techniques employed in the study can also be used to develop flood hazard maps for the study area. More significantly, by knowing the recurrence interval of peak flood discharge, development planners can design flood control structures appropriately.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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