Comparative Study of Flood Frequency Analysis of Different Rivers in Bangladesh

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Abstract

Bangladesh is a country of rivers. A large portion of the country has been flooded almost every year because of heavy rainfall and spilling of water from the major rivers of the country. It is observed that each year's highest flood record is being broken by the subsequent years flood and so do damages and sufferings of human being and their properties. Therefore for Bangladesh, study of changes in flood frequency, Magnitude and depth of flooding are very important. In most of the practical cases, Flood frequency analysis is carried out due to the safe design of hydraulic structures. This paper represents a statistical study on flood frequency analysis of Meghna, Gomti, Balu river using three different statistical methods. The Flood frequencies of 30, 50, 100 years return period were analyzed using the methods of Gumbel's type I, log-normal type II and log pearson type III. Comparing these three methods of flood frequency analysis, our objective is to find the optimum method in terms of safe design of hydraulic structures. From the comparison between three methods the Gumbel's method may be recommended for designing and locating hydraulic structures.

Keywords: Frequency analysis, Magnitude, Statistical, Optimum.

Introduction

The unusual swelling of water that overflows the banks of the rivers and submerging a vast area of land is called flood. It is a natural calamity. It is sometimes called deluge. It is devastating and horrible when causes a colossal loss to lives and properties. Bangladesh, being a land of rivers, often falls victims to floods almost every year.

Excessive and continuous heavy rainfall is the main cause of flood in our country. When there is heavy rain for a number of days the rivers cannot hold and carry down so much water to the sea. As a result, the water overflows the bank of rivers and submerges a vast area of land. Sometimes heavy discharge of water running down from the mountains makes the situation severe. Again, melting of snow in the mountains and tidal bore of the sea create flood. Recently the sudden release of water from the Farakka barrage at the upstream during rainy season overflows the rivers and subsequently flood occurs in the country.

The heavy monsoon downpour and synchronization of flood-peaks of the major rivers are generally considered to be the main causes of the floods. Some underlying factors also deserve serious consideration as possible contributors to the recent floods: change in the base level of the rivers due to local sea level rise and subsidence, inadequate sediment accumulation on flood plains, a possible increase in the watershed area due to seismic and neotectonic activities in the region, river bed aggradation due to siltation and damming of rivers, soil erosion due to unwise tilling practices, deforestation in the upstream region, and excessive development and population growth. [1]
Thus the objectives of the present study are as follows:

- To apply various distribution method for flood frequency analysis of various rivers.
- To assess the design flood for various frequencies like T=30, 50 and 100 years.
- To find out the changing trends of water level on climate change.

**Hydrological Aspects of Meghna River**

Bangladesh is situated in the active delta of the major rivers Meghna. Due to its unique geographical location, the occurrence of water-induced disasters is a regular phenomenon. In addition, the anticipated change in climate is likely to lead to an intensification of the hydrological cycle and to have a major impact on the overall hydrology of these basins and ultimately lead to the increase in the frequency of water-induced disasters in Bangladesh. The Meghna River is a comparatively smaller, rain-fed, and relatively flashier river that runs through a mountainous region in India before entering Bangladesh. The intensity, duration, and geographic extent of floods in Bangladesh mostly depend on the combined influences of river systems, the Meghna.

In addition, climate change is likely to have significant effects on the hydrology and water resources of the Meghna basin and may ultimately lead to more serious floods in Bangladesh. However, the assessment of climate change impacts on the basin-scale hydrology by using well calibrated hydrologic modeling has seldom been conducted in the Meghna basin due to the lack of observed data for calibration and validation [2].

![Fig 1: Meghna–Ganges–Brahmaputra–Padma–river basin](image)

**Methodology**

**Data Collection and Interpretation**

Water level and discharge data has been collected from Bangladesh Water Development Board (BWDB). Several station visits were conducted in proposed rivers around Dhaka, Comilla and Kishoreganj city during November, 2015. The main objective of this station-visit was to analyze the flood situation and the performance of the flood control works around the cities.

During field visits, the study team interviewed local people and officials of the responsible authorities. Data analysis was conducted based on the performance of flood control works. Discharge and Water level data for 33 years of SW 273 gauging station on Surma-Meghna River, 32 years of SW 110 gauging station on Gumti River and 18 water years of SW 7.5 gauging station on Balu River was collected from BWDB. The flow recording station SW 273, SW 110 and SW 7.5 was equipped with an automatic recorder. This study has been carried out based on secondary data and field visits.

**Analysis and Consistency Check**

**The Log Pearson Type III Method**

In this method the variate is first transformed into logarithmic form (base 10) and the transformed data is then analyzed. If X is the variate of a random hydrologic or meteorologic series, then the series of Z variate where

\[ Z = \log X \]  

... (viii)

are first obtained for this z series, for any recurrence interval T.
\[ Z_T = Z_{avg} + Kzsz \] 

Where \( Z_{ave} \) = arithmetic mean of \( Z \) values \( K_z \) is a frequency factor which is a function of recurrence interval \( T \) and the coefficient of skew \( C_s \). For \( N \) = number of sample = \( n \) number of years of record.

\[ \sigma_Z = \text{Standard deviation of } Z \text{ variate sample} = \sqrt{\frac{\sum (Z-\overline{Z})^2}{N-1}} \]

\[ C_s = \text{coefficient of skew of variate } Z = \sqrt{\frac{\sum (Z-Z)^2}{N-1}(6Z)^2} \]

Corresponding value of \( X = \text{antilog} (ZT) \).

The Log Normal Method

The method is basically same as the Log Pearson Type III method except the skewness coefficient \( C_s \) is taken as zero. The log normal distribution plots as a straight line on logarithmic probability paper.

**Results**

The highest measured discharge of 19400 m³/s was recorded in year 1988 and lowest discharge of 7374.54 m³/s was recorded in year 2011 for Mehna River at station Bhairab Bazar. The highest measured discharge of 1010 m³/s was recorded in year 1993 and lowest discharge of 30.8 m³/s was recorded in year 1983 for Gumti River at station Comilla. And the highest measured discharge of 744.1 m³/s was recorded in year 1998 and lowest discharge of 87.65 m³/s was recorded in year 1996 for Blu River at station Demra Bridge.

**For Gumbel's Method**

<table>
<thead>
<tr>
<th>River Name</th>
<th>N</th>
<th>( \sigma )</th>
<th>( Y_T )</th>
<th>( K_z )</th>
<th>( X_{Tm³/s} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surma Meghna</td>
<td>33</td>
<td>3183.146</td>
<td>3.385</td>
<td>3.903</td>
<td>18900, 20154, 21672</td>
</tr>
<tr>
<td>Gumti-Burinadi</td>
<td>32</td>
<td>226.303</td>
<td>3.385</td>
<td>3.903</td>
<td>948, 1023, 1127</td>
</tr>
<tr>
<td>Balu</td>
<td>18</td>
<td>159.55</td>
<td>3.385</td>
<td>3.903</td>
<td>745, 797, 871</td>
</tr>
</tbody>
</table>

**Log-Pearson Equation**

<table>
<thead>
<tr>
<th>River Name</th>
<th>N</th>
<th>( \sigma )</th>
<th>( C_s )</th>
<th>( K_z )</th>
<th>( Z_T )</th>
<th>( X_{Tm³/s} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surma Meghna</td>
<td>33</td>
<td>0.113</td>
<td>0.029</td>
<td>1.823</td>
<td>2.069</td>
<td>2.347, 4.276, 4.304, 4.336</td>
</tr>
<tr>
<td>Gumti-Burinadi</td>
<td>32</td>
<td>0.300</td>
<td>-1.07</td>
<td>1.556</td>
<td>1.709</td>
<td>1.865, 2.95, 2.996, 3.043</td>
</tr>
<tr>
<td>Balu</td>
<td>18</td>
<td>0.227</td>
<td>-0.62</td>
<td>1.559</td>
<td>1.711</td>
<td>1.663, 2.829, 2.864, 2.853</td>
</tr>
</tbody>
</table>

**Log-Normal-Distribution**

<table>
<thead>
<tr>
<th>River Name</th>
<th>N</th>
<th>( \sigma )</th>
<th>( C_s )</th>
<th>( K_z )</th>
<th>( Z_T )</th>
<th>( X_{Tm³/s} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surma Meghna</td>
<td>33</td>
<td>0.113</td>
<td>0.0</td>
<td>1.810</td>
<td>2.054</td>
<td>2.326, 4.275, 4.303, 4.334</td>
</tr>
<tr>
<td>Gumti-Burinadi</td>
<td>32</td>
<td>0.300</td>
<td>0.0</td>
<td>1.810</td>
<td>2.054</td>
<td>2.326, 3.026, 3.099, 3.181</td>
</tr>
<tr>
<td>Balu</td>
<td>18</td>
<td>0.227</td>
<td>0.0</td>
<td>1.810</td>
<td>2.054</td>
<td>2.326, 2.886, 2.942, 3.004</td>
</tr>
</tbody>
</table>

**Comparison of the Methods**

For flood frequency analysis, 33 years of annual peak flood readings of Meghna River at Bhaireb bazar station, 32 years of annual peak flood readings of Gumti River at Comilla Tikkar chor bridge station, 18 years of annual peak flood readings of Balu River at Demra bridge station was used. For analysis Gumbel method, Log-Pearson method, as well as Log-normal-distribution method were used. A tabular comparison of the three methods are given below:
<table>
<thead>
<tr>
<th>Rivers Name</th>
<th>Methods</th>
<th>$X_{10}$</th>
<th>$X_{50}$</th>
<th>$X_{100}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meghna</td>
<td>Gumbel's</td>
<td>20287.488</td>
<td>21340.683</td>
<td>22805.561</td>
</tr>
<tr>
<td></td>
<td>Log-Pearson</td>
<td>18900.000</td>
<td>20154.000</td>
<td>21572.000</td>
</tr>
<tr>
<td></td>
<td>Log-normal</td>
<td>18836.000</td>
<td>20076.000</td>
<td>21553.000</td>
</tr>
<tr>
<td>Gumti</td>
<td>Gumbel's</td>
<td>948.379</td>
<td>1023.255</td>
<td>1127.368</td>
</tr>
<tr>
<td></td>
<td>Log-Pearson</td>
<td>891.000</td>
<td>990.000</td>
<td>1103.000</td>
</tr>
<tr>
<td></td>
<td>Log-normal</td>
<td>1062.000</td>
<td>1257.000</td>
<td>1518.000</td>
</tr>
<tr>
<td>Balu</td>
<td>Gumbel's</td>
<td>744.688</td>
<td>797.478</td>
<td>871.000</td>
</tr>
<tr>
<td></td>
<td>Log-Pearson</td>
<td>675.000</td>
<td>731.000</td>
<td>713.000</td>
</tr>
<tr>
<td></td>
<td>Log-normal</td>
<td>770.000</td>
<td>875.000</td>
<td>1008.000</td>
</tr>
</tbody>
</table>

Hence Log-Pearson method, as well as Log-normal-distribution method cannot be used for the safe design of a hydraulic structure. Gumbel method gives the most probable maximum flood in the life period of structure. However in this study, the Gumbel method using annual flood data give safe design values.

**Graphs and details of Graphs**

![Comparison of the three methods of Meghna River](image1)

**Fig. 2: Comparison of the three methods of Meghna River**

![Comparison of the three methods of Gumti River](image2)

**Fig. 3: Comparison of the three methods of Gumti River**
From the above graphs for all three rivers it is found that Gumble distribution gives a satisfactory value than the other two methods. Gumble distribution is more accurate. In the discharge vs return period graph for Meghna river Gumble distribution gives an higher value of discharge than the other two methods, for Gumti and Balu river log-normal distribution gives higher value. It is because Meghna river has a higher discharge value all the year round than Gumti and Balu river.

**Recommendation for Future Study**

An increased amount of precipitation can cause flooding. An above normal monsoon downpour in the Ganges- Brahmaputra- Meghna drainage system is thought to be the primary cause of the 1988 flood in Bangladesh. Factors responsible for the recent low frequency floods in Bangladesh can be analyzed in terms of short-term (immediate causes) and long-term processes. Evident phenomena that take place prior to and during floods, which can easily be related as plausible causes for floods, are termed short-term processes. On the other hand, the slowly occurring phenomena which cannot be tied to the flood problem directly are termed long-term processes [5]. For further study some recommendations can be given below:

- In this research three main rivers of our country has been considered. But for further research other rivers may be considered.
- Scour analysis can be done by using cross-sectional data for future study of the selected river.
- Wide range of data can be used.
- More number of stations can be included.
- Flood frequency analysis for other rivers can be considered in others different methods rather than the three methods Gumbel's, Log Pearson, Log-normal.
- Effect of climate change on water level can be studied.

**Conclusion**

Flood frequency analyses for the rivers Meghna, Gomti and Balu have been carried out using three well known methods. Parameter characterization and statistical tests shows that Gumble's distribution method complies relatively better than other two methods. The design discharge obtained from present study will be utilized in the design of river management works of the rivers under study.

It is found that the obtained discharge value for Meghna, Gomti and Balu are 22805, 1127 and 871 m$^3$/s for return period 100 years using Gumble distribution method. Comparison shows that the values of the other two method are lower than Gumble distribution method. Therefore for the flood frequency analyses of various rivers, this method can be recommended.
References

1 Khalequzzaman D.M. "Recent floods in Bangladesh: possible causes and solutions."


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5 Tarequl Islam Munna “Floods in Bangladesh: Possible Causes and Solutions.”