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Flood Frequency Analysis by Gumble Distribution for Krishnai River of Assam

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Abstract: This paper presents the study of annual maximum flood frequency analysis, by Gumble distribution at the Velterghat Gauging station for Krishnai river of Goalpara district of Assam. The chi-square test, Anderson Darling test is done to check the goodness of fit, which shows that the Gumble distribution fits the data. In addition Q-Q plot and P-P plot are performed as a goodness of fit criteria.

Keywords: Frequency, Flood, Gumble, Distribution, Parameter

I. INTRODUCTION

Flood is part of nature which always to be existed. The natural disaster occurs not only in Assam, but in all part of world. It is the most costly natural hazard since its ability to destroy human lives and properties. So a preventive measure has to be taken to save unnecessary cost and economic loss as well as preventing danger due to over flow of water in Assam. This can be done by construction of barrages, dams, water reservoirs and widening or Deeping the river. These require high financial cost as well as high potential in destroying the ecosystems of the river itself. Thus these flood protection projects without proper planning and designing will only create drawbacks. So, to reduce the drawbacks, information related to these aspects need be carefully considered. A clear knowledge related to magnitudes and their frequencies of the flood occurrences are basically needed to overcome all that types of difficulties. Information regarding accurate estimation of flood magnitudes and their frequencies occurrence are of great importance in planning, designing and management of each structure at the location or station of interest. The design should be done by considering the maximum flows that exceeds certain level in a given return period. On the other hand, the flows below the critical value are less important since they do not negatively affect the design.

II. METHODOLOGY

The research methodology is as follows

A. Study Area: The river Brahmaputra basin is nearly an area of 580,000km^2 and lies in Tibet, Bhutan, India and Bangladesh. The drainage area of the basin lying in India is 194,413 km^2; which form nearly 5.9% of the total geographical area of the country.

The main study area of the Krishnai river catchment is belongs to the states of Meghalaya and Assam. The physiographic of the entire region is mainly divided into two divisions, namely the Meghalaya plateau and the plains of river of river Brahmaputra valley which falls into the state of Assam accounting for about 70% and 30% of the total area respectively. The Assam state comprises of two main river valleys. The northern valley is called the Brahmaputra valley and the southern valley is known as Surama and Barak valley. The plain valley Brahmaputra lies between the foot hills of Bhutan range on the north and two other hill tracts of Naga,Mikir,Ksasiya , Jayantia,Garo hills etc on the south. The Brahmaputra valley is nearly is nearly 720 km. long and 80 km. wide covering about 56339 square km. of riverine area between both banks of the brahmuptra starting from Sodiya in the east and Dhubri in the west. The river Brahmuptra receives number of tributaries and sub-tributaries throughout its course.The river Dudhnoi is one of such major south bank tributary. The river Krishnai is again a tributary of the river Dudhnoi. The river Krishnai originates in Meghalaya from Garo hills at an elevation of about 280 m above mean sea level and meets with river Dudhnoi near Tomuni at about 12km north from Dudhnoi at an elevation of about 150 m above mean sea level and finally flows towards river Brahmuptra. A good number of streams originating from Garo hills having elevation between 500m to 300m above mean sea level fall to the Krishnai river in the Meghalaya area which produces good discharges for Krishnai river. The Krishnai river catchment lying between $25^0 35^/$ to $26^0 2^/$ north latitude and $90^0 20^/$ to $90^0 45^/$ east longitude is in Garo hills district of Meghalaya, in the northern slope of the state adjoining Assam.

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B. Data: Annual peak discharge flow data (in m^3/s) covering 46 years of records i.e. from 1972 to 2018 for the Veltherghat Gausing station on Krishnai river were obtained from Goalpara Investigation Division (Irrigation),Goalpara.

C. Gumble Distribution: In hydrology the type I extreme value distribution is known as Gumble distribution. Gumble in 1941 was the first to consider the use of distribution of largest values as suggested by Fisher and Tippet. The Type-I extreme value distribution is also known as Double Exponential distribution. Gumble was the first to consider that the annual flood peaks are extreme value of flood in each of the annual series of recorded flood or rainfall. There are two methods of analyzing the flood peaks. They are the annual maximum series and the partial duration series. The annual numbers of observations are sufficiently large and are independent of each other and hence the highest peak discharge recorded every year is used for analysis. In partial duration series, all flood discharges above a threshold in any year are taken for analysis. In this study, the annual peak discharge series of 46 years of Krishnai river has been analyzed. To analyze the data Graphical plotting formula which optimize Gumble distribution is as given below

$qi = \frac{i-a}{N+1-2a}$ *and* $pi = 1 - qi$;Where qi =exceedance probability associated with each observation.

N= Number of annual maximum observation.

i =Rank of specific observation with i=1 being the largest to i=N being the smallest observation.

a =constant for estimation=0.44 using Gringoten's method.

Now to calculate the Return period of flood, let X is a random variable, which has a cumulative distribution function $F_X(X)$. The probability that X is less than equal to a given event Xp is given by

$$F_X(x)=P\ (X \le Xp)=p$$

The probability that this event will be exceeded is then equal to 1-p and the percent exceedance is denoted as 100(1-p). For such an event Xp, the return period corresponding to this exceedance probability is denoted by T where, $T=\frac{1}{1-P}$; Using this definition, the 100- year return period can be understood as an event with a probability of exceedance =1-p=0.01 or a non-exeedance probability p=0.99; ie there is a 99% chance that this event will not be exceeded within a given year. The Tp estimated represents the estimated distribution using $T=\frac{1}{1-P}$

Now we assume that the data follows Gumble distribution and so the parameter of this distribution is to be estimated. The CDF of the extreme value Type-I or Gumble distribution is given by

$F_X(x)= \text{Exp}\ [-\exp(-\frac{x-u}{\alpha})]=p$; where x is the observed discharge data u and α are the calculated parameters of the distribution. In order to calculate the theoretical estimate of 'P' the following formulas is used $\bar{x} = \frac{\sum_{i=1}^{n} xi}{n}$ and

$$Sx^2= \frac{1}{n-1}\sum_{i=1}^{n}(x-\bar{x})^2$$

$$u = \bar{x} - 0.5772\alpha$$

$$\alpha = \frac{\sqrt{6}s_x}{\pi}$$

D. Quantile - Quantile (Q-Q) Plot And P-P Plot: If the data follow the assumed distribution, then the points on the Q-Q plot will fall approximately on a straight line. A Q-Q plot is a plot of the quantiles of the first data set against the quantiles of the second data set.

P-P plot A P-P plot compares the empirical cumulative distribution function of a data set with a specified theoretical cumulative distribution F(.)

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Table I.The Summary of calculation for exceedance probability is given as follows.

Year	Data (m^3/s)	Tp Estimated	p theoretical	Tp theoretical
2016	113.48	1.012291484	0.567921818	2.314395965
2001	129.14	1.035008977	0.568062245	2.315148393
2011	150.2	1.058769513	0.568251052	2.316160824
2002	150.61	1.083646617	0.568254727	2.31618054
1997	158.22	1.109720885	0.56832294	2.316546539
2008	166.72	1.137080868	0.568399123	2.316955439
2003	186.91	1.165824065	0.568580048	2.317927106
1994	191.17	1.196058091	0.568618217	2.318132197
2006	197.91	1.227902023	0.568678602	2.318456737
2013	198.98	1.261487965	0.568688188	2.318508264
1998	201.88	1.29696288	0.568714168	2.318647927
1999	204.15	1.334490741	0.568734503	2.318757258
2005	208.57	1.374255066	0.568774098	2.31897016
1990	222.02	1.416461916	0.568894569	2.319618189
2010	222.06	1.461343473	0.568894927	2.319620117
2000	229.1	1.509162304	0.568957976	2.319959411
2007	247.25	1.560216509	0.5691205	2.320834477
2015	264.39	1.614845938	0.569273946	2.321661276
1975	284.93	1.673439768	0.569457789	2.322652634
2012	285.26	1.736445783	0.569460742	2.322668566
1981	296.77	1.804381847	0.569563742	2.32322436
1996	302.93	1.877850163	0.56961886	2.323521891
1985	334.6	1.957555178	0.569902169	2.325052416
1978	339.21	2.044326241	0.5699434	2.325275324
1991	345.36	2.139146568	0.5699984	2.325572742
1980	345.54	2.243190661	0.57000001	2.325581448
1987	376.28	2.357873211	0.570274858	2.327068869
1976	376.63	2.484913793	0.570277987	2.327085812
2004	393.42	2.62642369	0.570428063	2.327898808
1983	419.53	2.785024155	0.570661384	2.329163888
2009	458.07	2.964010283	0.571005644	2.331033
2017	464.33	3.167582418	0.571061547	2.331336797
1972	519.1	3.401179941	0.571550464	2.333997161
1982	553.8	3.671974522	0.571860052	2.335684873
1988	559.82	3.989619377	0.571913748	2.335977844
1979	567.98	4.367424242	0.571986526	2.336375044
1984	596.43	4.824267782	0.572240209	2.337760632
1977	610.6	5.387850467	0.572366527	2.33845118
1986	622.54	6.100529101	0.572472948	2.339033276
1992	641.81	7.030487805	0.572644669	2.339973152
1974	646.19	8.294964029	0.572683695	2.340186857
1993	697.51	10.11403509	0.5731408	2.342692858
1989	724.2	12.95505618	0.573378411	2.343997648
1995	833.6	18.015625	0.57435154	2.349356556
1973	833.99	29.56410256	0.574355007	2.349375691
2014	930.37	82.35714286	0.575211221	2.354111145

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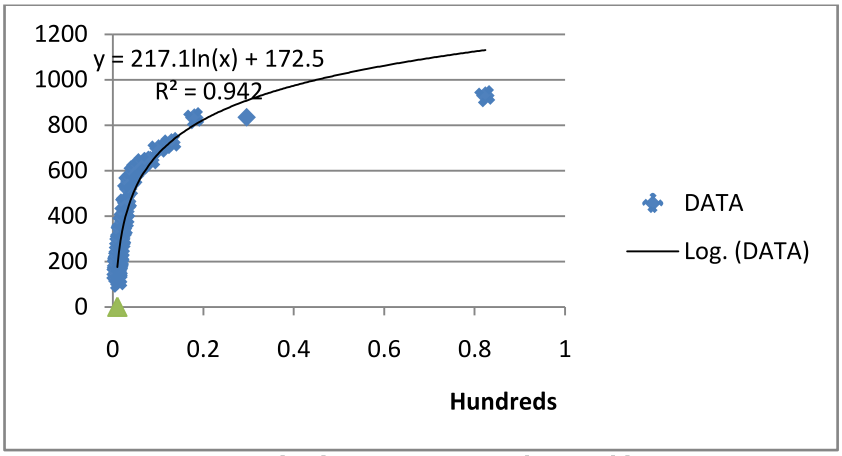

Fig.1 .Flood Frequency Curve by Gumble

III. FITTING OF THE GUMBLE DISTRIBUTION BY MAXIMUM LIKELIHOOD(ML) METHOD

In this section, parameters and test statistic as calculated as follows.

A. Parameters

	Estimate	Std. Error
a	290.0530	24.40236
b	157.6314	19.30578

B. Loglikelihood: -307.0503 AIC: 618.1005 BIC: 621.7578

C. Correlation matrix:

	a	b
a	1.0000000	0.3040407
b	0.3040407	1.0000000

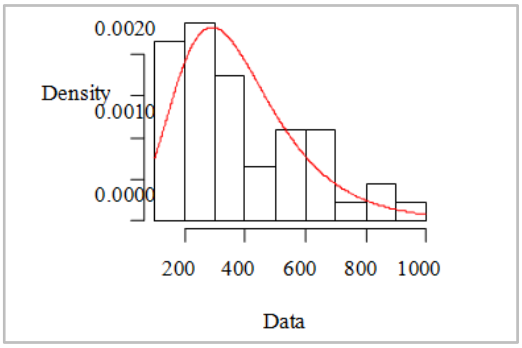

Figure 2. Empirical and Theoretical Density

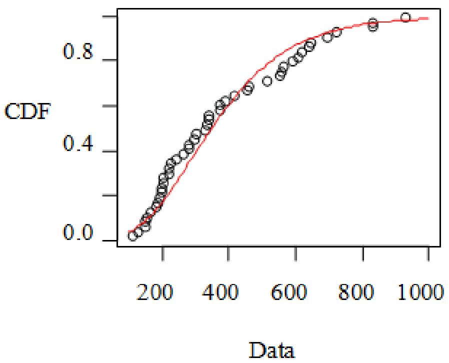

Figure 3. Empirical and Theoretical CDFs

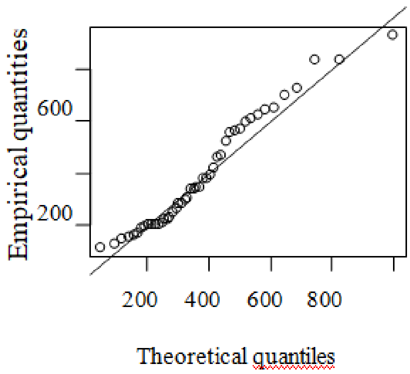

Figure 4. Q-Q plot

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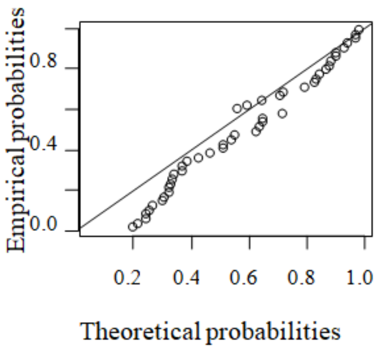

Figure 5. P-P plot

IV. RESULTS AND DISCUSSION

From the Q-Q plot, P-P plot and Empirical and theoretical CDFs plots of the fitted distribution it is seen that all the plots are around the lines respectively indicating that the data is fitted for the assumed distribution. The Kolmogorov-Smirnov, Andrson-Darling and Chi-square test was applied to check the goodness of fit. The entire tests revealed a good fit as summarized in the following table.

Table 2.Shows the results of test statistic with sample size=46.

Test name	Statistic	p-value
Kolmogorov-Smirnov test	0.11194	0.57305
Anderson- Darling test	0.72352	-
Chi-square test	04.2743	0.37016

CONCLUSION

This study provides the flood frequency analysis of annual maximum flows for 46 years of Krishnai river by Gumble distribution model. The result shows no significant differences between the predicted and observed flow magnitudes. Hence the model can be used to predict the maximum flood flows for the river.

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