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Estimation of Design Flood for Dibang Multipurpose Dam in Dibang River Basin

Biswadeep Bharali[1] and Pritee Rekha Saud[2]

[1]M.E, Civil Engineering (Student) Assam Engineering College, Jalukbari, Guwahati-13, Assam
[2]J.B.L.College, (Student) Chandmari, Guwahati-03 Assam
E-mail: [1]biswa.adams@gmail.com, [2]prsaud13@gmail.com

Abstract—*The objective of this study is to estimate design flood for the Dibang Multipurpose Dam site in the Dibang River Basin, Arunachal Pradesh. The entire Dam project area is located in a highly mountainous and difficult terrain. The design flood is estimated for the Dibang Multipurpose Dam site using the frequency analysis and the empirical formulas. A comparison of design flood computed by the different methods has also been made. Using the design flood values, the risk of failure of structure during various construction periods has been computed and presented in this paper.*

Keywords: *Design flood, frequency analysis, empirical formula, risk of failure of structure.*

1. INTRODUCTION

Dibang Multipurpose project is proposed across river Dibang, a major tributary of river Brahmaputra, near Munli village in Lower Dibang Valley District of Arunachal Pradesh. The entire project area is located in a highly mountainous and difficult terrain. The project envisages construction of a 288 m high concrete gravity dam across Dibang River. At Full Reservoir Level (EL 545 m) the reservoir storage is 3748.2 M.cum and reservoir surface area is 40.1sq.km. The length of reservoir at FRL is 43 km. The Dibang Multipurpose Project is located on river Dibang, a major tributary of river Brahmaputra.

In the design of hydraulic structures it is not practical from economic considerations to provide for the safety of the structure and the system at the maximum-possible flood in the catchments. Small structures such as culverts and storm drainage can be designed for less severe floods as the consequences of a higher-than design flood may not be very serious for such structures. On the other hand, storage structures such as dams demand greater attention to the magnitude of floods used in the design. The failure of these structures causes large loss of life and great property damage on the downstream of the structure. Therefore, it is clear that the type, importance of the structure and economic development of the surrounding area dictates the design criteria for choosing the flood magnitude. Design flood is defined as the instantaneous peak discharge adopted for the design of a river headwork or control structure after accounting for the economic and hydrological factors. It is a flood that the project can sustain without any substantial damage, either to the objects which it protects or its own structures.

2. METHODOLOGY

Floods cause much loss of life and property disruption of communication etc. and the subsequent famine. The process of preventing floods from inundating the marginal and is called flood control. Exact flood calculation is difficult but probable flood can be found out and flood control measures can be taken to minimize the losses to human life and property. Different rivers have different flood characteristics and hence require different methods to control floods in them.

Methods of estimation of flood used in this paper are:

I. Empirical formula based on catchment area.
II. Flood frequency analysis.
   a) Gumbel extreme value distributions.
   b) Log- Pearson type III distribution.

I. Empirical formula

Empirical formulae are about the earliest to be used for estimating flood peaks. The empirical formulae are generally used in those regions where they are developed. Even then should be used with caution. The empirical formulae, mainly catchment area ‘A’ are involved with constant C. This constant C varies from catchment to catchment in different countries; the major limitation of using empirical formulae is the subjective decision about the value of C to be adopted. So, the empirical formula as the hydro meteorological approach could not be applied due to non-availability of physiographic data at the Dam site.

II. Flood frequency analysis

It is very difficult to model flood analytically as it is the outcome of many component parameters. Therefore, estimation of peak flood is a complex problem with earlier methods. Flood frequency analysis is based on the theory of statistics and probability. It is supposed to be the best method provided the flood data are available for a long period of time.

Flood frequency studies

Since the exact sequence of stream flow for future years cannot be predicted, probability concepts must be used to study the probable variations in flow so that the design can be completed on the basis of a calculated risk.

a) Gumbel extreme value distributions.

Gumbel Extreme Value Distribution Method: Gumbel in 1941 was the first to consider that the annual flood peaks are extreme value of flood in each of the annual series of recorded flood. Hence, floods should follow the extreme value distribution.

Let Q_1, Q_2, Q_3,…, Q_n are the annual extreme values of flood in a particular river of catchment area. In Gumbel method, the exceedance probability P of a given flow Q_t having a return period of T years being equaled or exceeded is given by:

$$P = 1 - e^{-e^{-y}}$$

Where, y is called '**reduced variate**', e is the base of Naperian logarithm.

Since, $P = \frac{1}{T_r}$

Therefore, $\frac{1}{T_r} = 1 - e^{-e^{-y}}$

When size of the sample is infinite,

$$y = a\,(Q_t - Q_f)$$

Where, $a = \frac{1}{0.78\sigma}$

Here, σ is standard deviation which is given by:

$$\sigma = \sqrt{\frac{\sum(Q-\bar{Q})^2}{N-1}}$$

Where, $\bar{Q} = \frac{Q_1+Q_2+\cdots+Q_n}{N}$

$$Q_f = \bar{Q} - 0.45\sigma$$

Therefore, using the above equations,

$$Q_t = \bar{Q} + (0.78y - 0.45)\sigma$$

However, if the flood records available are for limited period with limited samples as suggested by Chow,

$$Q_t = \bar{Q} + k\sigma$$

Here, k is the frequency factor.

b) Log- Pearson type III distribution.

Log-Pearson Type-III Distribution Method: K. Pearson in 1930 developed this method. In this method, it is recommended to convert the data series to logarithms and then compute the following:

- Compute Logarithms of flow

  (log Q).
- Estimate Standard

  $$log\,\bar{Q} = \frac{\sum log\,Q}{n}$$
- Compute Standard deviation

  $$\sigma_{\log\,Q} = \sqrt{\frac{\sum(\log Q - \log \bar{Q})^2}{n-1}}$$
- Compute skew coefficient

  $$C_s = \frac{n\sum(\log Q - \log \bar{Q})^3}{(n-1)(n-3)(\sigma \log Q)^3}$$

Then,

$$\log Q_t = (log\bar{Q}) + K(\sigma logQ)$$

Where, K is the log Pearson frequency factor

3. ANALYSIS

The water availability series available in "Feasibility Report of Dibang Multipurpose Project CWC (2003)" has been modified and updated by CWC and Brahmaputra Board and extended up to April 2003. It is given in report of "Power Potential studies of Dibang Multipurpose Project and Cost Benefit Analysis for Optimization of Project Parameters, Brahmaputra Board (Jan-2005)". This series has been finally adopted in the DPR of Dibang Multipurpose Project. The peak discharge of different years are presented in the below graph.

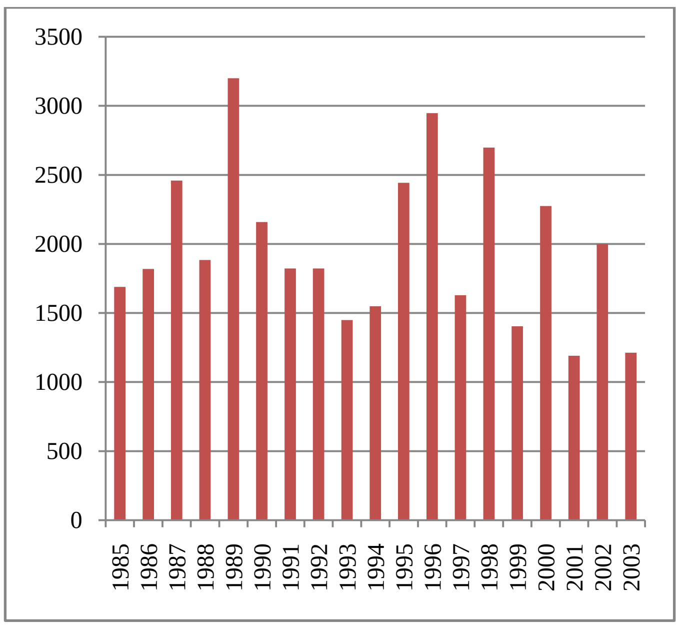

Fig. 1: Peak annual discharge at dam site. (1985- 2003)

Different Frequency analysis method are carried out for the maximum annual discharge data and graphs are plotted, discharge against different return period for each method.

Frequency analysis by Gumbel's method

The design discharge is calculated at different return period by using Gumbel's method and the values are presented in **Table 1**. A graph is plotted, computed design flood against various return period.

Table 1: Computations of Flood Discharge

Return Period (Years) (1)	X bar (2)	S (3)	Yt (4)
5	1981.463158	552.6857	1.500392995
10	1981.463158	552.6857	2.250955556
15	1981.463158	552.6857	2.674416611
20	1981.463158	552.6857	2.970913185
25	1981.463158	552.6857	3.199293342
50	1981.463158	552.6857	3.902824486
75	1981.463158	552.6857	4.31174361
100	1981.463158	552.6857	4.601160867
1000	1981.463158	552.6857	6.908682432

(Yn)¯ (5)	standard deviation (6)	K (7)	design discharge (cumecs) (8)
0.522	1.0566	0.925982391	2493.24038
0.522	1.0566	1.636338781	2885.8442
0.522	1.0566	2.037115854	3107.34796
0.522	1.0566	2.317729685	3262.43921
0.522	1.0566	2.533875963	3381.90017
0.522	1.0566	3.199720317	3749.90282
0.522	1.0566	3.586734441	3963.79999
0.522	1.0566	3.86064818	4115.1882
0.522	1.0566	6.044560318	5322.20521

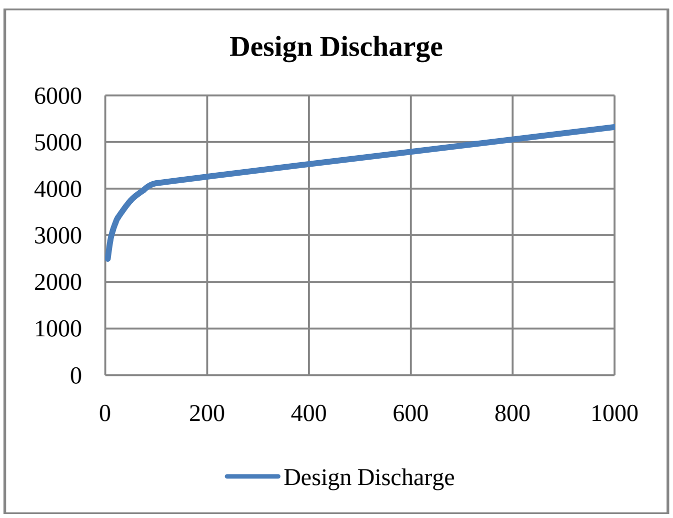

Fig. 2: Discharge Vs Return period using Gumbel's method.

Frequency analysis by Log Pearson type III distribution:

The design discharge is calculated at different return period by using Log Pearson method and the values are presented in **Table 2**. A graph is plotted, computed design flood against various return period

Table 2: Computations of Flood Discharge

Return Period (Years) (1)	Cs (2)	K (3)	σ_(logQ) (4)
5	0.1	0.836	0.122733
10	0.1	1.292	0.122733
15	0.1	1.456	0.122733
20	0.1	1.621	0.122733
25	0.1	1.785	0.122733
50	0.1	2.107	0.122733
75	0.1	2.254	0.122733
100	0.1	2.4	0.122733
1000	0.1	3.235	0.122733

logQ¯ (5)	σ_(logQ) x k (6)	Log Q (7)	Design Discharge (cumecs) (8)
3.280495	0.1026044	3.383099	2416.013599
3.280495	0.15857044	3.439065	2748.308067
3.280495	0.17869858	3.459194	2878.681052
3.280495	0.19894945	3.479444	3016.090845
3.280495	0.21907758	3.499573	3159.166787
3.280495	0.25859746	3.539092	3460.130134
3.280495	0.27663915	3.557134	3606.900119
3.280495	0.2945581	3.575053	3758.833311
3.280495	0.39703977	3.677535	4759.208569

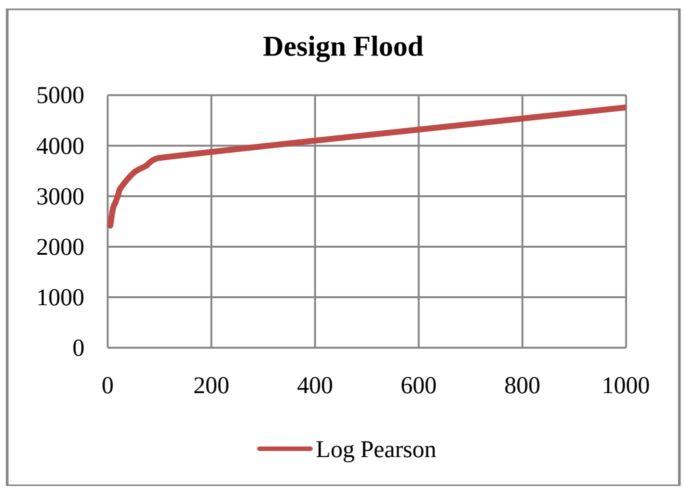

Fig. 3: Discharge Vs Return period using Log Pearson method.

4. RESULT

The values of the design flood at the Dibang multipurpose dam using Gumbel's method and Log Pearson method are shown in Table 1 and Table 2 respectively. Gumbel's distribution method produces higher values of design flood when compared to Log Pearson method.

Fig. 4 shows the comparison of design flood at the dam using different methods. It can be seen from Fig. 4 that the Gumbel's method produces higher values of design flood as we increase return period when compared to Log Pearson method. The estimated design flood computed by Gumbel's method is considered as it gives higher values than the Log Pearson method.

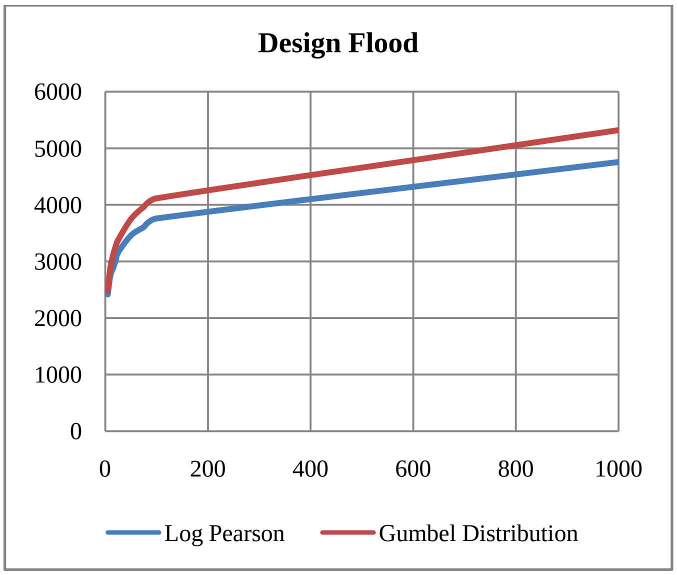

Fig. 4: Comparison of Design Flood at Dibang dam.

Using the design flood values, the risk of failure of a structure during various construction periods has been computed. In order to facilitate decision making the value of the flood for different return periods and the risk corresponding to the various assumed construction periods are presented in Table 3

Table 3: Percentage risk during various construction periods at Dibang dam.

Return Period (years)	Design Flood (cumecs)	Construction Period (years)			
		5	10	15	20
5	2493.24	67.2	89.2	96.4	98.8
15	3107.35	29.1	49.83	64.47	74.83
25	3381.9	18.4	33.51	45.79	55.79
75	3963.8	6.49	12.56	18.23	23.54
100	4115.19	4.9	9.5	14	18.2
1000	5322.21	0.49	0.996	1.589	1.48

5. CONCLUSION

Flood estimation is of crucial importance and the major aspect of hydrologic design. It is extremely crucial for reservoir design and management. In the present paper, design floods for different return periods have been computed using Gumbel's and Log-Pearson method Dibang multipurpose dam. A comparison of design flood values obtained using the two methods and it indicates that the Gumbel's method produces higher values of design flood when compared to Log Pearson method. The estimated design flood computed by Gumbel's method is considered for the design of hydraulic structure as it gives higher value than Log Pearson method. For the Dibang dam site the 1000-year return period flood based on Gumbel's and Log-Pearson methods were found to be 5322.2 and 4759.2 cumec respectively. Using the design flood values, the risk of failure of structure during various construction periods has been computed and presented in the paper.

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