Flood Frequency Studies of Upper Krishna River

[1]J.P.Singh, [2]S.K.Ukarande

[1]SAKEC, Chembur, Mumbai, [2]TCEM, Karjat

Abstract— The estimation of design flood forms an important component of hydrological planning of water resources project, since the magnitude of the peak flood discharge is necessary input in the design of structures like spillways, bridges, culverts and in planning flood control. A variety of different methods are available for estimating design flood. The present study is for developing a flood frequency and flood estimating model for individual catchments. The data has been collected from central water commission of the seven gauge sites of upper Krishna basin. Four probability distributions have been taken for analysis. To find out the best fitting distribution tests of goodness of fit has been done and it has been found that the Gumbel distribution is the best choice for the basin.

Index Terms—Discharge, Distribution, Flood, Frequency

I. INTRODUCTION

A flood is an unusual high stage of a river due to runoff from rainfall and / or melting of snow in quantities too great to be confined in the normal water surface duration of the river or stream as a result of unusual meteorological combination. The damages caused by floods in terms of loss of life, property and economic activity are well known. The estimation of design flood forms an important component of hydrological planning of water resources projects, since the magnitude of the peak discharge is necessary input in design of structures like spillways, bridges and culverts.

Two main approaches are available for flood estimation viz. Deterministic approach and statistical approach. Deterministic approach assumes that input, like the precipitation is related to output in a predefined manner and there is no uncertainty involved in arriving at the output like the discharge. In statistical approach the interrelationships between processes is established through the measure of correlation. The process considered may be multivariate or univariate. For example, the rainfall-runoff process may be considered multivariate while consideration of maximum annual peak series falls under univariate process.

Flood frequency analysis deals with univariate process comprising of maximum peak flow values. A variety of different methods are available for estimating design flood. The method of frequency analysis is now days the most recommended approach. Flood frequency analysis is concerned with the estimation of flood quantity magnitudes for different return periods at station or at a number of stations in a river system by using a relationship established between the annual peak flood magnitude and their frequencies. The most important step in frequency analysis is a selection of the mathematical expression (usually called theoretical probability distribution) which best fits the probability magnitude relationship for the site. The procedure for selection consists of comparing mutually the performance of various available distributions in fitting the recorded annual flood series and choosing the best.

Economic constraints do not justify detailed hydrological and meteorological investigation at every new site on a long term basis of estimation of design flood with desired return period. For this purpose country has been divided in 7 zones and 26 hydro meteorologically homogeneous subzones (Fig.1). For preparing the flood estimation reports for these subzones systemic and sustained collection of hydro-meteorological data at the representative catchments, numbering 10 to 30 for a period of 5 to 10 years in different subzones has been carried out under the supervision and guidance of research, design and standard organization of ministry of railways. Similarly ministry of railways has undertaken the collection of data for 45 catchments through central water commission since 1979.

Present study is undertaken with the following objectives

1. To analyse the data of various sites of subzone (3h) using statistical method by using probability distribution

To check the goodness of fit in this analysis flood quantile at different return periods has been found out by frequency factor method.

II. STUDY AREA AND DATA USED

The present study concerns catchments medium to large size in the upper parts of Krishna basins spread over in Maharashtra and Karnataka covering a major portion of the state. The total of eight catchments considered can be broadly ground under their classes (1) those draining the slopes of heavy rainfall zones of the western ghats. (2) those drainig the sub humid and semi dry plains of south Indian plateau.and (3) the large catchments which cover a variety of topography and climatic characteristics. All the catchments considered have sufficiently long records. These data has been collected from central water commission Regional office Pune, Krishna division. Details of the site are given in table (1).

Krishna basin extends over an area 258948 Sq. kilometers which is nearly 8% of total geographical area of the country. The basin lies in the state of Maharashtra 69425 kilometers, Andhra Pradesh 76252 Kilometers and Karnataka 113271 kilometers. Krishna river rises in western ghats at the elevation of about 1337 meters just north of Mahabaleshwar about 64 kilometers and out falls into the bay of Bengal. The principal tributaries joining Krishna are the Ghatprabha and Mahaprabha.

Most part of the basin comparises rolling and undulating country aspect the western borders which are formed by unbroken line of ranges of the Western Ghats. An average of annual surface water potential of 78.1 cu.km. has been access in this basin out of this 58 Cu. Km. is utilizable water. Cultivable area in the basin is about 20.3 million hectares which is 10.4% of the total cultivable of the country. The hydro power potential of the basin has been access as 2997 M.W at 60% load factor. Krishna river basin is shown in figure 2.

Table 1: Site details

Name	River	Catchment area	State	Record Duration
Karad	Krishna	5462	Maharashtra	15 yrs
Arjunwad	Krishna	12660	Maharashtra	15 yrs
Kurunwad	Krishna	15190	Maharashtra	15 yrs
Galgali	Krishna	22560	Maharashtra	15 yrs
Warunji	Krishna	920	Maharashtra	15 yrs
Sadalga	Krishna	2322	Maharashtra	15 yrs
Terwad	Krishna	2425	Maharashtra	15 yrs

Fig. 2: Map of Krishna basin in India

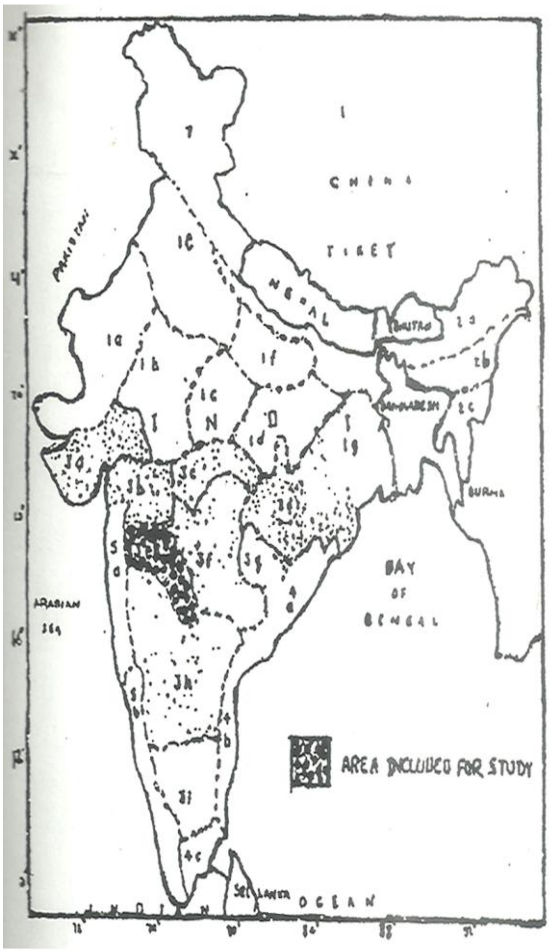

Fig. 1: Location map of zone 3

3 (a) mani and Sabarmati

3 (b) Lower Narmada

3 (c) Upper Narmada

3 (d) Mahanandi

3 (e) Upper Godavari

3 (f) Lower Godavari

3 (g) Indravati

3 (h) Krishna

3 (i) Kaveri

III. DATA ANALYSIS

A. Statistical Parameter

First step in the analysis of data is calculation of statistical parameters. By using the formula, statistical parameters of all the gauged sites have been calculated and the values are presented in table (2) for original series of data and in table (3) for log transformed series. The values of statistical parameters are used in the analysis of data for individual gauge site and test of goodness of fit in the next section

Table 2: Statistical parameters of original series for various sites

Site No.	$\bar{X}$	σ	C_V	C_S
S_1	2241.8	1550	0.699	1.30
S_2	1385.29	938	0.677	0.13
S_3	925.09	750.55	0.811	0.226
S_4	1025.25	676.8	0.66	0.62
S_5	3155.45	1918.5	0.60	0.43
S_6	4005.3	2360.6	0.58	0.31
S_7	753.84	737.4	0.978	0.1

Note :-

$\bar{X}$ = Mean
σ = Standard Deviation
C_V = Coefficient of variation
C_S = Coefficient of Skewness

Table 3: Statistical parameters of of log-transformed series for various sites

Site No.	$\bar{X}$	σ	C_V	C_S
S_1	3.26	0.317	0.097	0.001
S_2	3.02	0.342	0.113	0.014
S_3	2.95	0.311	0.105	2.858
S_4	2.99	0.248	0.083	0
S_5	3.41	0.296	0.086	0
S_6	3.28	0.645	0.10	0.001
S_7	2.74	0.497	0.18	0

B. Analytical method (frequency factor method)

Chow (1951) has shown that most frequency distribution function applicable in hydrologic studies can be expressed by the following equation known as the general equation of hydrologic frequency analysis.

$$X_T = \bar{X} + K\sigma$$

Where X_T = value of variate x of random hydrologic series with a return period of T

K = frequency factor which depends upon the return period T and assumed distribution.

$\bar{X}$ = Means of the variation

σ = Standard Deviation

In this method first statistical parameter from the observed data will be calculated. The value of K to be used in the above equation for different distribution can be obtained from statistical tables (E:4 7.6, 7.7) from C.T. Haan. By using this method flood quantile at different recurrence intervals have been calculated for all the gauged sites. Results are given in tables 4,5,6,7,8, and 9..

Table 4: Flood quantile for Arjunwad gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	2841.0	3516.8	2215.12	3329.30
10	10	2841.15	4090.3	2215.27	4237.60
20	5	2841.2	4772.3	2215.39	5107.60
25	4	2841.3	5004.8	2215.41	5376.90
30	3.33	2841.3	5175.3	2215.45	5593.80
40	2.5	2847.3	5500.8	2215.60	5965.90
50	2	2841.5	5702.3	2215.65	6229.30
75	1.33	2841.6	5795.3	2215.72	6105.36
100	1	2841.7	5688.3	2215.82	7066.40

Table 5: Flood quantile for Karad gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	1433.1	2173.2	1385.6	2059.7
10	10	1436.8	2604.7	1385.7	2609.38
20	5	1438.7	2961.1	1385.8	3135.6
25	4	1439.7	3026.8	1385.9	3299.0
30	3.33	1440.0	3176.8	1389.9	3430.1
40	2.5	1440.0	3401.9	1386.0	3655.3
50	2	1440.8	3525.9	1386.2	3814.7
75	1.33	1443.5	3589.6	1386.3	3739.6
100	1	1446.3	3655.3	1386.4	4321.3

Table 6: Flood quantile for Sadalga gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	973.875	1544.29	925.22	1467.70
10	10	974.25	1863.27	925.465	1904.55
20	5	974.626	2186.01	925.790	2325.60
25	4	975.37	2276.00	925.805	2456.20
30	3.33	97582	2366.14	926.00	2561.20
40	2.5	976.577	2433.69	926.115	2741042
50	2	976.877	2598.81	926.208	2869.01
75	1.33	977.0	2666.36	926.312	2808.9
100	1	977.63	2748.93	926.335	3409.80

Table 7: Flood quantile for Karunwad gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	3466.247	4671.065	3155.69	3155.67
10	10	3473.20	5630.31	3155.83	3155.84
20	5	3476.00	6589.56	3155.92	3156.00
25	4	3477.00	6704.67	3155.97	3156.05
30	3.33	3477.50	6858.155	3156.00	3156.09

40	2.5	3477.70	7318.60	3156.20	3156.20
50	2	3480	7663.925	3156.20	3156.20
75	1.33	3510.00	8047.625	3156.30	3156.30
100	1	3518.00	8469.695	3156.40	3156.40

Table 8: Flood quantile for Terwad gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	1025.45	1511.9	1141.67	1429.36
10	10	1025.27	1908.56	1243.70	2011.44
20	5	1025.71	2288.28	1144.00	2309.27
25	4	1025.75	2406.06	1144.24	3469.42
30	3.33	1025.76	2500.82	1144.27	3763.65
40	2.5	1025.72	2663.27	1144.38	3076.75
50	2	1025.76	2778.3	1144.55	2884.61
75	1.33	1025.78	2724.19	1144.70	2695.80
100	1	1026.00	3143.85	1144.80	3469.42

Table 9: Flood quantile for Galgali gauge site

Return Period (T) years	Prob (1/T) %	Probability Distributions			
		Normal	Log -Normal	Log - Person	Gumbel
5	20	4288.64	5940.50	2215.12	3329.30
10	10	4291.37	6990.70	2215.266	4237.60
20	5	4261.60	8064.70	2215.39	5107.16
25	4	4291.60	8276.90	2215.41	5376.86
30	3.33	4291.80	8760.10	2215.45	5593.80
40	2.5	4291.92	9079.30	2215.60	5965.86
50	2	4292.00	9551.30	2215.65	6229.36
75	1.33	4292.00	9669.10	2215.72	6105.36
100	1	4293.00	10023.30	2215.82	7066.36

IV. TEST OF GOODNESS OF FIT

The validity of probability distribution function proposed to fit the empirical frequency distribution of a given sample may be tested graphically or by analytical methods. Graphical methods are usually based on comparing visually the probability density function with the corresponding empirical density function of the sample under consideration. In other words model CDF is compared with empirical CDF. Often these CDF graphs are made on especially designed paper such that the model CDF plots as a straight line. An example of this is a Gumbel probability paper. If the empirical CDF plots on the straight line on the Gumbel probability paper it is an indication that the Gumbel distribution may be a valid model. For the data at hand often, graphically approaches for the judging how good a model is quite subjective. A number of analytical tests have been proposed for testing the goodness of fit of proposed model. Three of these tests are presented subsequently.

1. D – INDEX METHOD

2. CHI – SQUARE TEST

3. KOLMOGOROV – SMIRNOV TEST

Two tests of goodness of fit naming the Chi-square and Smirnov-Kolmogorov have been applied on records of seven gauge sites of upper Krishna basins and results are given in table no. 10 & 11. Final analysis of the results have been done by taking into considerations that for how many sites both the tests are best corresponding to a particular distribution.

Table 10: Chi-Square test results

Gauge site	Probabilty Distribution			
	Normal	Log - Normal	Log -Pearson	Gumbel
Arjunwad	1.71 A	3.11A	3.23A	3.82A
Karad	2.0A	3.32A	4.0A	2.0A
Sadalga	2.14A	1.32A	3.8A	4.64A
Karunwad	5.32A	2.66A	4.33R	4.66A
Terwad	1.0A	0.0A	1.0A	1.0A
Galgali	1.71A	14.0R	14.0R	3.82A
Warunji	5.2A	3.07A	3.07A	6.71R

A –ACCEPTED, R- REJECTED

Table 11: Kolmogorov-Smirnov test results

Gauge site	Probability Distribution			
	Normal	Log - Normal	Log -Pearson	Gumbel
Arjunwad	0.314 A	0.13A	0.14A	0.16A
Karad	0.147A	0.91R	0.122A	0.14A
Sadalga	0.132A	0.8R	0.312A	0.107A
Karunwad	0.13A	0.15A	0.27A	0.16A
Terwad	0.089A	0.046A	0.19A	0.215A
Galgali	0.135A	0.13A	0.343R	0.156A
Warunji	0.37A	0.27A	0.22A	0.354R

V. CONCLUSION

The methodology of flood frequency analysis for individual gauge site, test of goodness of fit of different distributions has been applied to the field data of upper Krishna basin. The conclusions from the study are as follows;

1.The analysis of data of upper Krishna basin by four different frequency distributions, estimate of the flood quantiles for different return periods like 5,10,20,40,50,75and 100 years by frequency factor method reveal that the calculated discharges at different recurrence intervals by Normal, Log-normal, Log-Pearson and Gumbel fluctuate about amean value. This indicates that these distributions are almost equally fitting the records of upper Krishna basin.

2.By studying flood quantile results at different periods, it is concluded that there are more chances of high flood in longer return periods.

3. While evaluating the goodness of fit it is found that Chi-Square test has shown that Normal distribution fits at 95% confidence level. Log-normal and Gumbel distribution seem to agree quite well.

4. The results of S-K test has shown that Normal, Log-Pearson and Gumbel distributions are fitting at 95% confidence level.

5. By studying the results of goodness of fit, it is concluded that Normal and Gumbel distribution are the best estimator for upper Krishna basin.

REFERENCES

[1] Chow. V.T., Maidment D.R And Mays L.W (1988), Applied hydrology Mc Graw-Hill international edition 350-405, 507-530.

[2] Flood frequency analysis 1987-88 workshop course materials, N.I.H.Roorkee.

[3] Haan, C.T 1995, Statistical methods in hydrology East-Weast Press Pvt Ltd.

[4] Kuczera George 1982 b, Robust flood frequency models, Water Resources Research !8(2): p 315-324.

[5] Mysooru R. Yadupathi Putti,1996, Flood frequency studies for Kaveri and Krishna basins in Karnataka, National conference Hydro-96, Indian Institute of Technology Kanpur,P 29-33.

[6] Singh V.P. (1994), Elementary hydrology, Prentice Hall of India Pvt Ltd. P 800-852.

[7] Singh J.P, P.V. Parameswaran 1999, Flood frequency studies of upper Godavari basins, National workshop on challenges in the management of water resources and environment, Delhi College of Engineering P 30-38.