Original Research Article

Flood frequency analysis of Araniar Medium Irrigation Project in Chittoor District by using Gumbel's Distribution

ABSTRACT

Aims: The main objective of the study was to do a Flood Frequency Analysis for the project's data on inflows into the Araniar project. Based on the collected data, the results of the analysis obtained by the study gives accurate details regarding the potential flood to be expected in the reservoir during various return periods.

Place and Duration of study: The Araniar reservoir was constructed across the Araniar river near Pichatur village in Chittoor District of A. P. The flood frequency analysis was conducted on the Araniar reservoir using Gumbel's extreme value distribution method in the year 2019-2020.

Methodology: Daily maximum inflows data were collected from 1990-2019 obtained from the measurement carried out by the Department of Water Resources, Chittoor, A. P. and were subjected to flood frequency analysis applying the Gumbel's extreme value distribution.

Results: From the R^2 value acquire from the trend line equation is 0.9803, indicating that Gumbel's extreme value distribution is suitable for estimating predicted reservoir flood flow. The estimated flood flow for coming years of 2years, 10years, 50 years, 100 years,150 years, 200 years, 300 years, and 400years the estimated flood obtained are 38.29 Mm^3/year, 66.96 Mm^3/year, 92.08 Mm^3/year, 102.71 Mm^3/year, 108.90 Mm^3/year, 113.29 Mm^3/year, 119.47 Mm^3/year and 123.85 Mm^3/year respectively. the mean instantaneous flow in the reservoir is 40.88149 Mm^3/year which is nearly equal to a return period of about 2 years. This means that floods in the reservoir may be predicted rather accurately.
Conclusion: finally, these analysis shows the estimated flood flows of the Araniar reservoir was useful for constructing important dam hydraulic strictures, advising agricultural patterns in the command area, and protecting lives and property downstream of the catchment region.

Keywords: Araniar reservoir measured inflow, cropping patterns, Flood frequency, Gumbel's extreme value distribution, Hydraulic strictures, Return period,

1. INTRODUCTION

While planning and designing water resources projects, engineers and planners are usually focused in determining the magnitude and frequency of floods that will occur in project regions. In addition to the unit hydrograph method, rational technique, and rainfall-runoff models' method, frequency analysis is one of the major tactics used to describe the relationship between the magnitude of an event and the frequency with which that event is exceeded [3].

The analysis of how often a specific event will occur is known as flood frequency analysis. Before carrying out the estimation, it is critical to analyse the inflow data in order to obtain a probability distribution of floods. Hydrologists and engineers all across the world adopt Flood Frequency Analysis (FFA), which entails estimating flood peak volumes for a set of non-exceedance probability.

The fitting of a probability model to a sample of yearly flood peak observed over a period of the fitting of a probability model to a sample of annual flood peaks observed over a period of examination for a watershed in a certain region is known as flood frequency analysis flood frequency analysis. The obtained model parameters can then be utilised to predict extreme events with a large recurrence interval. Floodplain management requires accurate flood frequency estimates in order to protect the public, reduce flood-related expenses to government and private organisations, build and locate hydraulic structures, and analyse risks associated with the development of flood plains.

Varies statistical distributions have been employed in research to estmate the likelihood and severity of floods, but none has received international approval and is specific to any country [6]. The Gumbel's extreme value distribution, a stochastic generating structure that generates random results, was used to predict the yearly peak inflows data of Araniar reservoir from 1990-2019 In order to provide security and cost-effective hydrologic design in the catchment area.

The main aim of the study was to carry out the Flood Frequency Analysis for the Araniar reservoir inflows data of project. Based on the collected data, the results of the analysis obtained by the study provide precise information about the potential flood to be expected in the reservoir during various return periods. This data will be extremely useful for engineering applications, such as when developing structures in or near the reservoir that may be flooded, as well as when constructing the flood structure to prevent against the expected events [4]. This could include the design of dams, bridges, and flood control structures that will help the region's storm water management or reduce flood disasters in the catchment.

2. MATERIALS AND METHODS

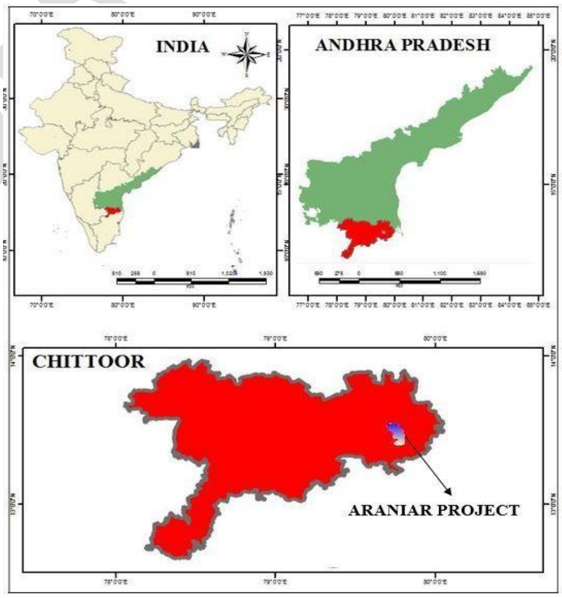

Fig. 1 Location of Araniar medium irrigation project command area

The Araniar River also known as Arani. It flows through the states of Tamil Nadu and Andhra Pradesh. The Araniar medium irrigation project was constructed across the Araniar River near Pichatur village (latitude 13.35 to longitude 79.25), Pichatur Mandal, and Chittoor District in Andhra Pradesh in the year 1958. It has got 150 sq. miles and 2 sq. miles of free catchment and intercepted respectively gross capacity of the reservoir is 1.851 TMC. It irrigates a total ayacut of 3682.6 ha in Pichatur and Nagalapuram mandals of Chittoor district of Andhra Pradesh, in India.

The Gumbel extreme value distribution approach, which was employed in the current study for flood frequency analysis, is a statistical method for analysing extreme hydro-logical occurrences like floods [5]. Gumbel was the first to recognise that yearly flood peaks represent the extreme value of flood in each annual sequence of recorded flood or rainfall, which he did in 1941. As a result, floods should follow the distribution of extreme values [2]. The equation for Gumbel's extreme value distribution. as well as to the procedure with a return period T is given as, The equation for Gumbel's extreme value distribution. as well as to the procedure with a return period T is specified as,

$$X_T = \text{X} + K.S_x \; . \; . \; .. \; . \quad (1)$$

X_T= Probable discharge with a return period of T years

$\overline{x}$ = Mean flood

S_x= Standard deviation of the Sample Size.

K is known as frequency K can be modified as: $K_T = \frac{Y_{T-}Y_n}{\boldsymbol{\sigma}\mathbf{n}}$ . . . . . (2)

In which, Y_T = Reduced Variate, Y_T = - [ln. ln $\frac{T}{T-1}$] . . . . . (3)

The values of Yn and Sn are chosen from Gumbel's Extreme value Distribution considered depending on the sample size.

Daily highest inflows data were collected from 1990 to 2019 (30 years flood data) acquire from calculation carried out by the Department of Water Resources, Chittoor, A. P. and were subjected to flood frequency analysis applying the Gumbel's extreme value distribution.

The steps to estimate the design flood for any return period using Gumbel's extreme value distribution. as given by Chow, V. T. 1988 is presented below:

Step 1: Annual peak flood data was collected from 1990 - 2019.

Step 2: From the maximum flood data for n years, the mean x and standard deviation σx are computing using:

$$\sum_{i=1}^{n} X_i \text{ And } \sigma_x = \sqrt{\frac{\mathbf{1}}{(\boldsymbol{n}-\mathbf{1})} + \sum_{i=1}^{n}(x-\bar{x})^2} \; ..... \; (4)$$

Step3: From the Gumbel's Extreme value distribution the table value Yn and Sn are taken as 0.5362 and 1.1124.

Step4: From the given return period T_r , the reduced variant Y_T is computed using equation (3).

Step 5: From Y_n, S_n and Y_T The flood frequency factor K is computed using equation (2).

Step 6: With use of Equation (1), the magnitude of flood is computed.

Before applying this method for flood frequency analysis, it is of a great importance to recognize whether the input flood data series representing the catchment area, satisfies the Gumbel's extreme value distribution. or not (WMO 233, 1969 and WMO-NO. 168, 1994)

To do this, the acquire data is organized in decreasing order (from highest to lowest) and each flood is given a return period. Equation (3) is used to calculate the reduced variate for each flood. A graph is illustrated with a plot of reduced variate and flood size; if the plot indicates a straight line, it is acceptable to conclude that the observed flood data follows the Gumbel's extreme value distribution. and is a good fit. The expected flood for the return periods of 2 years, 10 years, 50 years, 100 years, 150 years, 200 years, 300 years and 400 years are estimated and presented in the results.

3. RESULTS AND DISCUSSION

The Gumbel's extreme value distribution. analysis was performed using the approach described above, and the results are shown in Table 1. The highest annual inflow was 86.08 Mm^3/year in 2015, and the lowest annual inflow was 13.96 Mm^3/year in 2014. The return period ranges from 31 to 1.03. The average instantaneous peak flood over the last 30 years is 40.88149 Mm^3/year. The standard deviation (S.D.) for this sample is 16.92.

Table 1. Gumbel's reduced mean variable and standard deviation based on data

Year	Flood peak (Mm^3)/year	Flood peak (Mm^3)/year In descending order	Order (m)	$sx^2 = (n-\bar{x})^2$	Return period $T_r = \frac{(n+1)}{m}$	Reduced Variate $Y_T = -\ln \ln \frac{(T_r)}{(T_{r-1})}$
1990	41.48	86.08	01	2043.19	31.00	3.41
1991	58.36	75.91	02	1227.51	15.50	2.70
1992	37.15	74.67	03	1141.76	10.33	2.28
1993	74.67	59.29	04	339.07	07.75	1.97
1994	42.75	58.36	05	305.53	06.20	1.73
1995	29.02	55.78	06	222.08	05.16	1.53
1996	51.90	51.90	07	121.51	04.42	1.36
1997	55.78	50.99	08	102.35	03.87	1.20
1998	23.24	45.53	09	21.64	03.44	1.07
1999	29.02	42.75	10	3.52	03.10	0.94
2000	40.60	41.48	11	0.36	02.81	0.82
2001	45.53	40.60	12	0.07	02.58	0.71
2002	27.63	40.37	13	0.25	02.38	0.60
2003	28.79	39.81	14	01.14	02.21	0.50
2004	36.64	37.15	15	13.91	02.06	0.41
2005	50.99	36.81	16	16.56	01.93	0.32
2006	31.09	36.72	17	17.26	01.82	0.22
2007	59.29	36.64	18	17.97	01.72	0.14
2008	75.91	35.60	19	27.88	01.63	0.05
2009	16.42	32.22	20	74.94	01.55	-0.03
2010	40.37	31.09	21	95.83	01.47	-0.12
2011	32.22	29.02	22	140.58	01.40	-0.21
2012	36.81	29.02	23	140.58	01.34	-0.30
2013	36.72	28.79	24	146.00	01.29	-0.39
2014	13.96	27.63	25	175.41	01.24	-0.49
2015	86.08	26.30	26	212.41	01.19	-0.60
2016	35.60	23.24	27	310.93	01.14	-0.71
2017	22.18	22.18	28	349.70	01.10	-0.84
2018	39.81	16.42	29	598.18	01.06	-1.00
2019	26.30	13.96	30	724.75	01.03	-1.23
	Sum	1226.44				
	Average	40.88				
			S. D	16.92		

Fig. 2 indicate a plot of reduced variate v/s peak flood. From the trend line equation, R^2 gives a value of 0. 9803 shows that the pattern of the scattered is narrow and that Gumbel's extreme value distribution. is suitable for predicting expected inflow in the reservoir. The plot Fig. 2 also gives the relationship between the anticipated flow and return period as: 15.064x+32. 804.By using this equation the flood values may be extrapolated. These values obtained will be useful in the Engineering design of hydraulic structures. Using the Gumbel's extreme value distribution analysis, our results agree with the study of Bhaga [2] and Mukherjee MK [8].

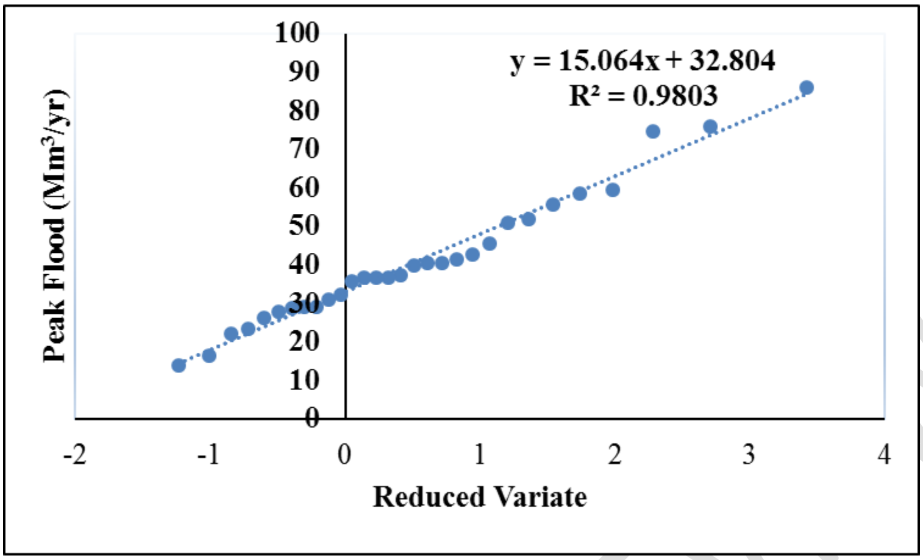

Fig. 2 Plot of Reduced Variate v/s Peak Flood for Araniar Project

Table 2 indicate the floods with various recurrence intervals that were computed. It shows the most essential flood frequency analysis parameters as well as the study's findings. It shows the many floods that are forecast, as well as their return periods. The results from the table shows the expected flood for the return periods of 2years, 10years, 50years, 100years, 150years, 200years, 300years and 400years are 38.29 Mm^3/year, 66.96 Mm^3/year, 92.08 Mm^3/year, 102.71 Mm^3/year, 108.90 Mm^3/year, 113.29 Mm^3/year, 119.47 Mm^3/year and 123.85 Mm^3/year respectively. The study's projected values are important in managing Araniar reservoir's extreme flood events. Same results are observed by Mukherjee M.K [9].

Table 2. Computing expected flood in Araniar project

Return period (T)in year	Reduced variate Y=-ln ln $\left(\frac{T_r}{T_r - 1}\right)$	Frequency factor $K_{(T)} = \frac{Y_T - \overline{Y_n}}{\sigma_n}$	Expected Flood $X_T = \overline{X} + K_T S_X$
2	0.36	-0.15	38.29
10	2.25	1.54	66.96
50	3.90	3.02	92.08
100	4.60	3.65	102.71
150	5.00	4.01	108.90
200	5.29	4.27	113.29
300	5.70	4.64	119.47
400	5.99	4.90	123.85

4. CONCLUSION

Using 30 years of annual peak inflow data, a flood frequency analysis was conducted for Araniar reservoir. Figure 2 depicts a representation of the reservoir's reduced variate and peak flood based on observed data. R^2 equals 0.9803 when the trend line equation is used. The value of R^2 = 0.9803 indicates that the scatter pattern is limited and that Gumbel's extreme value distribution. approach is appropriate for predicting projected reservoir flow. Also, the mean instantaneous flow in the reservoir is 40.88149Mm^3/year which is nearly equal to a return period of about 2years as shown in Table 2 and it is visible in the flood peak data also. This means that floods in the reservoir may be predicted rather accurately. This flood prediction can be used to construct essential hydraulic infrastructure in the project region. Emergency evacuations of people can also be carried out well in advance in the event of severe flooding. Because the method utilised for the study is based on a standard formula, a similar investigation can be carried out in any other study region.

5. REFERENCES

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