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DESIGN FLOOD ESTIMATION OF UPPER TUNGA BASIN FOR VARIOUS RETURN PERIODS

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Abstract— It is very much necessary to have a complete knowledge about the design discharge of the dam site so that preventive measures can be taken to protect the downstream part of it. This paper clearly demonstrates one such kind of work where in estimation of flood discharge of the Gajanur dam has been made using daily discharges for nearly about 20 years. Daily discharges are estimated using the semi distributed hydrological model, SWAT (Soil and Water Assessment Tool) with the help of Arc-GIS Interface. Flood frequency analysis is carried out using Gumbel's Extreme value type-I distribution and Log Pearson type-III distribution. Graphical test is been performed to check the reliability of the method for the selected study area and based on the results obtained design flood is estimated for various return periods. The study is also aimed at rendering its help with the obtained data to take necessary precautions to protect the downstream end of the dam by the engineers.

KEYWORDS— SWAT, Frequency Analysis, Gumbel's Extreme Value Type-I, Log Pearson Type-III, Return period

I. INTRODUCTION

Runoff is an important component of the very old existing cycle, Hydrological Cycle or Water Cycle. Excess runoff which is also termed as floods is very frequent in certain areas of India due to its topography or inefficiency in managing the surface water, also the heavy rainfall causes floods to occur at some parts of the country hence they are termed as one of the Natural Disaster.

In general, India is a country which is subjected to flooding very often which is having the total geographical area of 329 million hectare 'Mha' faces 13% of annual floods. i.e., 40 Mha comes under the flood prone areas out of 329 Mha. Floods are produced when the capacity of the river channel is inadequate to carry the quantity of water produced from heavy rainfall causing the river to overflow its banks and inundate the surrounding low-lying areas causing damages to mankind, assets, substructure and community, etc.

Estimation of design flood pays way for managing the excess water effectively and also to prevent any harm for the downstream end of the selected area which also aids in keeping the balanced ecosystem. It's true that floods cannot be stopped or controlled completely but it can be mitigated to certain extent by taking suitable measures if the design flood data is available at the area under consideration.

In the present study an attempt has been made to estimate the design flood at the upper Tunga basin selecting Gajanur dam as the outlet point for various return periods with the help of flood frequency analysis. For the analysis purpose, Gumbel's Extreme value type-I and Log Pearson type-III methods has been employed to calculate the design flood for various return periods. The main objectives of the study are listed as below:

1. Obtaining Daily Discharge data using SWAT Model.
2. Flood Frequency analysis by Gumbel's Extreme value type-I and Log Pearson type-III Method
3. Check for best fit using Graphical test
4. Design Flood Estimation for various Return Periods.

II. STUDY AREA

The upper Tunga Basin is one of the main tributary of Tungabhadra River which is the chief tributary of Krishna River. The Tunga basin lies in between latitudes north 13°51’16.145” and 13°44’19.085” and longitudes between east 75°25’24.386” to 75°36’49.296” and is as shown in fig 1. The river Tunga takes its birth on Western Ghats of Karnataka on a hill known as Varaha Parvatha at a place called Gangamoola. The selected basin is surrounded by the cities Chikmagalur and Shivamogga districts and it joins the Bhadra River at a place called kudli, a small town which is situated in Shivamogga to form Tungabhadra. The river has an overall length of 147 km from its origin. Later on it joins the Krishna River and flows through Andhra Pradesh before reaching the Bay of Bengal. The Tunga River is famous for its sweetness and a dam is built across this river which is situated at Shivamogga known as Gajanur dam.

In the present study, the upper Tunga is delineated from the starting point of Tunga river i.e., Gangamoola till the Gajanur dam to estimate the design flood. The reason behind selecting this study area is that the adjacent area experiences frequent high floods resulting in loss of lives and property.

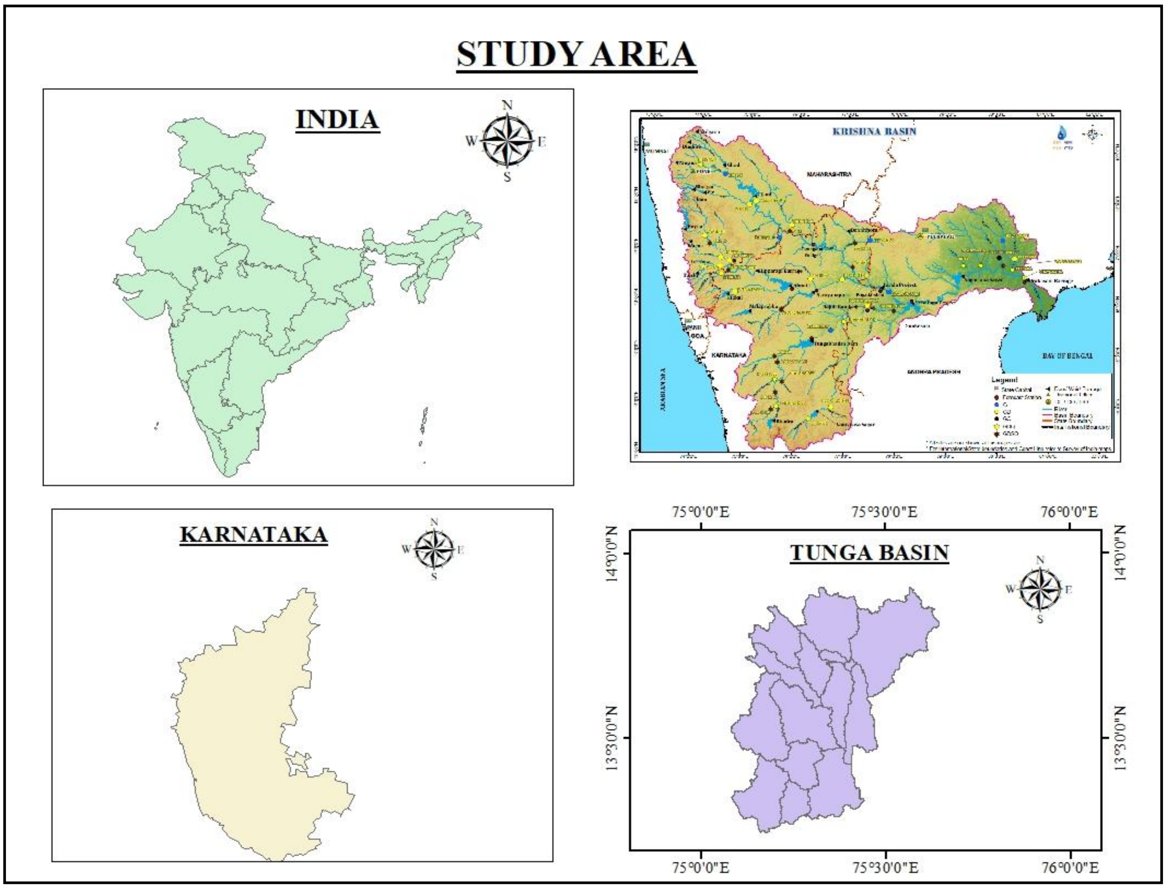

Fig. 1 Location of the Selected Study Area

III. METHODOLOGY

This paper aims in estimating the design flood discharges for various returns with the help of various techniques. The daily discharge at the basin outlet is estimated using semi-distributed SWAT (Soil and Water Assessment Tool) model in the Arc-GIS interface. The Surface Runoff generation using SWAT model and calibration and validation of the model was explained in my previous paper, RAINFALL RUNOFF MODELLING OF UPPER TUNGA BASIN WITH THE INTEGRATION OF ARC-GIS AND SWAT (Vol. 4, Issue 5, May-2018, IJTIMES). The various steps involved in estimating the Design Flood is illustrated in the below flow chart.

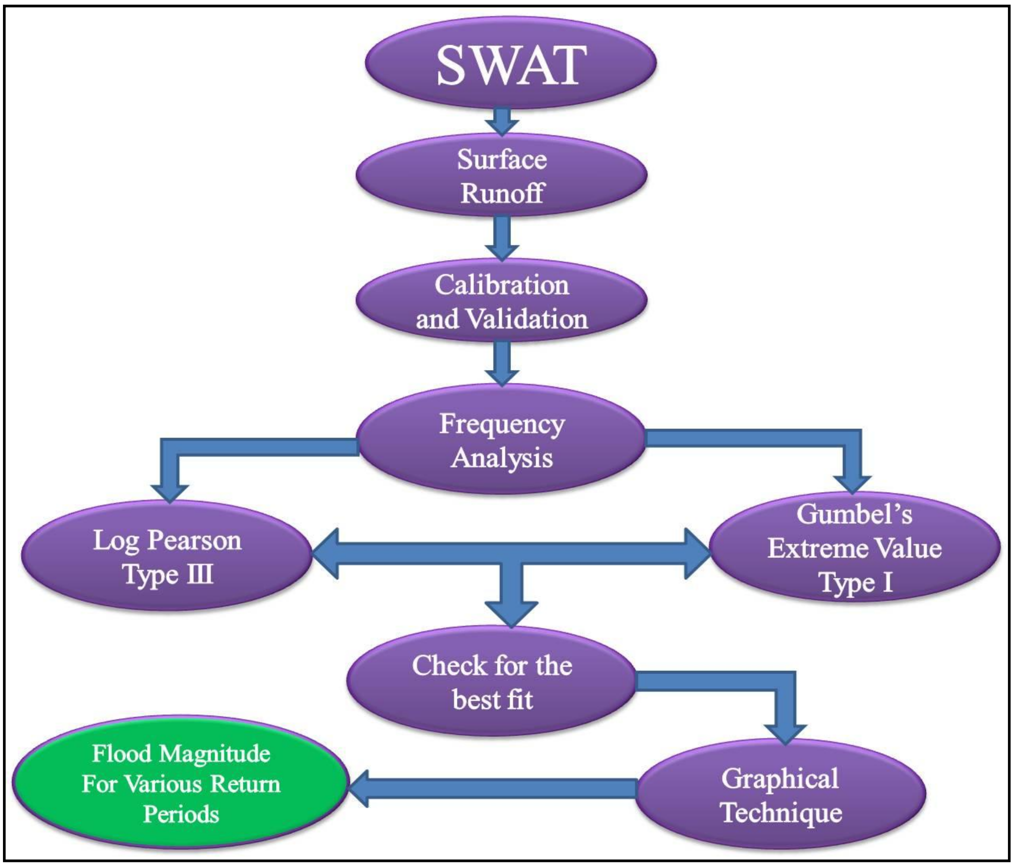

Fig. 2: Work flow process for obtaining Design Flood

At first, using SWAT model the daily surface runoff was generated at the outlet of the basin, i.e., at the Gajanur Dam. The results obtained from the model were compared with the observed discharge data. In order to predict the flood flows corresponding to various return periods a statistical method of frequency analysis is carried out. Of the various methods, the more commonly used methods are Gumbel's Extreme Value Type-I distribution and Log Pearson Type-III distribution. In the present case, frequency analysis is carried out using both the distributions.

After obtaining the results from both the distributions, check for best fit is done with the help of Graphical technique where in both the distribution is compared and based on the results obtained the design flood discharges are derived for various return periods.

A. Flood Frequency Analysis by Gumbel's Extreme value type-I Distribution

Step 1 – For the available 18 years data on flood peaks, the mean and standard deviation are computed first.

Step 2 – For the known sample size of 26 years, the values of Mean $\overline{y_n}$ and Standard Deviation σ_n are obtained from the standard tables. (Ref: Table 14.3, Jaya Rami Reddy P. "A textbook of Hydrology", Third Edition-2011, Lakshmi publications, pp. 469-470).

Step 3 – For the given return period T_r the reduced variate y_t is found.

Step 4 – with the obtained values of y_n, σ_n and y_t, the frequency factor K_T is calculated using the equation,

$$K_T = \left(\frac{y_T - \overline{y_n}}{\sigma_n} \right)$$

Step 5 – with all the above data, the magnitude of the flood X_T is computed using the equation,

$$x_T = \overline{x} + K_T \times s_x$$

B. Flood Frequency Analysis by Log Pearson type-III Distribution

Step 1 – The flood discharge data series is converted into their logarithms.
Step 2 - The mean, standard deviation and the skewness co-efficient of the series are determined.
Step 3 - For the given return period, T_r and the estimated skewness co-efficient, the value of frequency factor K_T is selected from the standard tables. (Ref Table 14.4, Jaya Rami Reddy P. "A textbook of Hydrology", Third Edition-2011, Lakshmi publications, pp 473-474)

Step 4 - The logarithm of the estimated flood is computed using the equation,

$$y_T = \overline{y} + K_T \times s_y$$

Step 5 - The estimated flood is calculated as,

$$x_T = anti\log(y_T) = 10^{y_T}$$

Then, flood peak values are evaluated for the known data for various return periods. The return period is calculated for each event using the Weibul's formula. The results of frequency analysis shall be considered as the estimated values for further analysis on knowing the best fit distribution.

$$T_r = \frac{n+1}{m}$$

Where,

T_r = return period in years,

m = order,

n = number of years of record.

Source: Jaya Rami Reddy P. "A textbook of Hydrology", Third Edition-2011, Lakshmi publications.

IV. RESULTS AND DISCUSSIONS

A. Flood Frequency Analysis

The semi distributed hydrological Modelling SWAT was used to generate the daily discharges for the period 2000 to 2017. Once after the Calibration and Validation of the model was done, average annual flood peaks are derived for the selected outlet point. Then the flood frequency analysis is carried out using both the distribution adopting the procedure as discussed in the above section.

Frequency analysis makes use of the observed data in the past to predict the future flood events along with their probabilities or return periods. If the sample is too small the predictions about the future floods cannot be expected to be reliable. The data used in the frequency analysis should not only be accurate in measurement but also be homogeneous. In the present study, 20 years data has been used for analysis purpose.

The average annual flood peaks were used to generate the design floods for various return periods using both the distributions. The results for Gumbel's extreme value type-I distribution and SWAT results are tabulated in the table 1 and results for Log Pearson type-III distribution and SWAT results are tabulated in table 2.

TABLE I: FLOOD VALUES FOR VARIOUS RETURN PERIODS USING GUMBEL'S EXTREME VALUE TYPE-I DISTRIBUTION AND FROM SWAT FOR UPPER TUNGA BASIN

RETURN PERIOD (YEARS)	ESTIMATED FLOOD (CUMECS)	FLOOD VALUE AS PER SWAT (CUMECS)
19.00	1557.20	1467.64
9.50	1306.19	1278.78
6.33	1154.59	1093.19
4.75	1043.83	1023.54
3.80	954.71	1017.62
3.17	879.55	998.45
2.71	811.81	946.31
2.38	753.13	735.60
2.11	695.96	626.50
1.90	643.33	623.32
1.73	593.27	533.65
1.58	541.18	524.60
1.46	491.79	466.50
1.36	422.91	436.64
1.27	389.78	426.65
1.19	330.74	389.45
1.12	262.27	225.34
1.06	174.83	199.32

TABLE III: FLOOD VALUES FOR VARIOUS RETURN PERIODS USING LOG PEARSON TYPE-III DISTRIBUTION AND FROM SWAT FOR UPPER TUNGA BASIN

RETURN PERIOD (YEARS)	ESTIMATED FLOOD (CUMECS)	FLOOD VALUE AS PER SWAT (CUMECS)
19.00	1412.80	1467.64
9.50	1228.60	1278.78
6.33	1079.97	1093.19
4.75	986.53	1023.54
3.80	858.88	1017.62
3.17	783.24	998.45
2.71	732.68	946.31
2.38	698.29	735.60
2.11	671.18	626.50
1.90	659.15	623.32
1.73	656.54	533.65
1.58	654.32	524.60
1.46	652.47	466.50
1.36	650.63	436.64
1.27	649.53	426.65
1.19	648.06	389.45
1.12	646.96	225.34
1.06	646.23	199.32

B. Check For Best Fit

After obtaining the Flood discharges from both the distributions, check for best fit is carried out using Graphical method. In Graphical Method, the observed discharge and simulated discharge from the model are plotted in a graph. A 45 degree line is drawn in a graph. The values which are very close to 45 degree line will be selected as the best fit distribution and Management strategies are carried out for those flood discharges for various Return Periods.

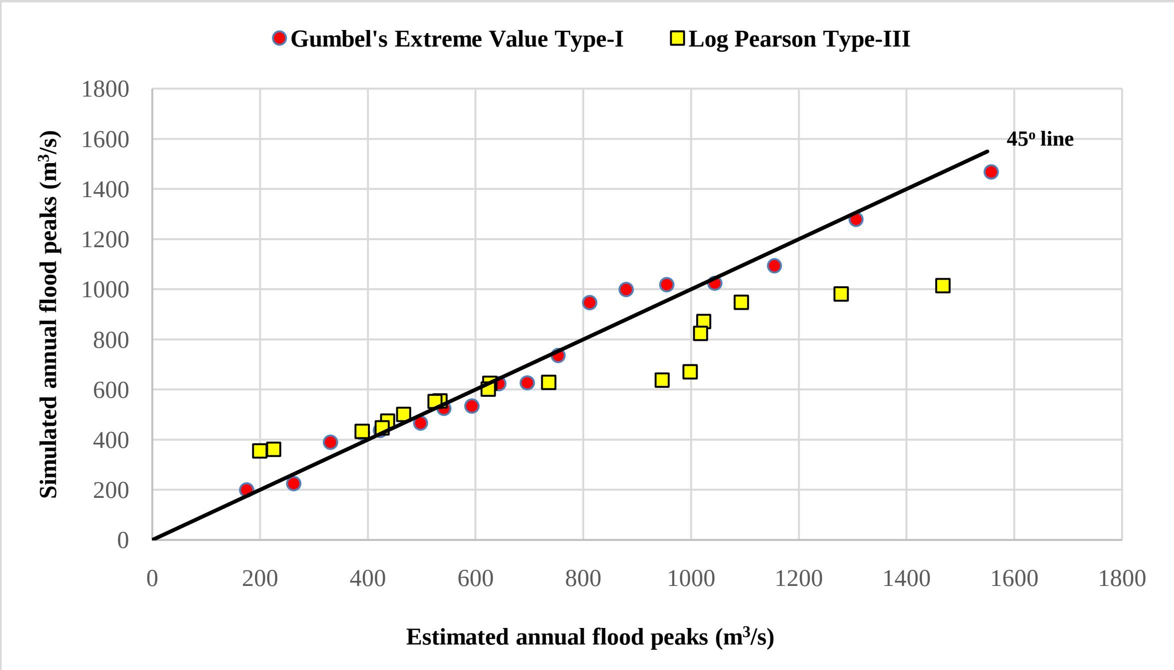

Fig. 3 Simulated v/s Estimated annual peak flood for upper Tunga basin

From the above graphs it is evident that, the deviation from the 450 line for the Gumbel's distribution is less between estimated and the simulated values when compared to L.P Type-III distribution. Also L.P. Type-III distribution underestimates the discharge values for lower magnitudes of simulated values. So, Gumbel's Extreme value Type-I Distribution is found to give good estimates compared to the other method. Hence the results obtained for flood magnitude for various return period based on Gumbel's Extreme Value Type-I distribution is assumed to give reliable results.

C. Design Flood Discharges for Various Return Periods

As per the above observations, the Gumbel's Extreme Value type-I distribution is recommended for the design flood estimation of the upper Tunga basin. The results obtained from the Gumbel's Extreme value type-I distribution for various return periods have been illustrated as shown in the below table:

TABLE IIIII: ESTIMATED PEAK FLOOD DISCHARGES FOR VARIOUS RETURN PERIODS

Sl. No	Return Period (yrs)	Flood Discharge (m^3/s)
1	5	1063.894
2	10	1325.038
3	20	1575.534
4	30	1719.638
5	50	1899.775
6	100	2142.749

V. CONCLUSIONS AND SCOPE FOR FUTURE STUDIES

The study demonstrates the use of Gumbel's Extreme Value type-I and Log Pearson type-III distributions in arriving at the design flood discharges for the upper Tunga basin with the integration of SWAT model. This method can be very well employed where the available discharge data is not in existence because of numerous reasons. This proves to be a counteractive solution to the problem with non-availability of the data especially country like India where the data maintenance is substandard. Also from the Graphical analysis it is revealed that Gumbel's Extreme Value Type-I distribution fits well for the simulated data as compared to L.P Type-III distribution.

Scope for future studies

1. Frequency Analysis results accuracy could be increased if more number of previous years records are used.
2. It is advised to try the other statistical approaches to estimate design floods.
3. It is also proposed to check the best fit distribution using various techniques other than graphical method.
4. It is proposed to do study on mitigating the flood along the downstream river course to reduce likely damage.
5. It is proposed to suggest the structural as well as the non-structural measures to mitigate the flood loss.

VI. AKNOWLEDGMENT

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