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Assessment of Peak Flood Entering Hirakud Reservoir on River Mahanadi of Odisha, India

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Abstract -Estimating the Peak Flood Discharge for a desired return time is necessary for the planning, design, and management of hydraulic infrastructure like barrages, dams, spillways, and bridges. This paper presents the results of a study that examined the frequency of floods entering Hirakud reservoir on river Mahanadi of Odisha state, India using the Gumbel's distribution and Log Pearson type III techniques, two frequently used models in hydrological studies for the probability distribution to mimic stream flows. The method has been used to forecast yearly maximum discharge data of Mahanadi river for a time interval of thirty years (1988-2017). The research also demonstrates a positive connection between the observed and expected peak discharges for the Log normal, Log Pearson type III (LP3) and Gumbel's (EV1) models (R^2 = 0.989), (R^2 = 0.989), and R^2 = 0.998 respectively. Peak flood values for periods 2, 10, 25, 50, 100, 200 and 400year return periods were also determined using the same approach, which will help for flood management through the reservoir.

***Key Words*:**flood frequency, Gumbel's distribution, Log Pearson type III, Log normal, flood management, R^2

1. INTRODUCTION

One of the worst types of natural disasters is flooding, which was anticipated to be the most frequent from 1998 to 2017 and account for over 43% of all weather-related disasters, affecting almost 2 billion people died (CRED 2018). According to Doocy et al. (2013), floods have really been responsible for more than 6 million deaths worldwide from natural disasters. The frequency of heavy rainstorm events and floods has increased around the world (Lal et al. 2001; Kundzewicz et al. 2010), particularly in the central, western, and eastern Himalayas (Valdiya 2011; Mishra and Srinivasan 2013). Floods have also been a common occurrence in the Kashmir Himalayas, changing the environment and resulting in a significant loss of lives and property (Ahad 2017). In order to assess flood risk and hazards and to reduce their disastrous effects, extreme flood modelling and frequency analysis are essential (Renard et al. 2013; Benameur et al. 2017). Using structural solutions is the most well-known way to lessen flood losses, however river flow has a significant impact on how hydraulic structures are designed (Chow et al., 1988; Yue et al., 1999). Additionally, hydrological investigations frequently use probability distribution models (Helsel and Hirsch 2010).

The Narmada River's discharge could be predicted most accurately using the GEVI and LP3 models for a range of return times. Farooq et al. (2018) compared a number of probability distributions on the river Swat at several gauging stations and came to the conclusion that LP3 and GEV were the best-fit models.

Flooding is common along the Pohru river, which drains the Kashmir valley's northernmost section. Up to 30 big floods are thought to have occurred in the Kashmir valley's history (Romshoo et al. 2017). Ahed et al. (2022) presented the Pohru river floods using the Gumbel's distribution and Log Pearson type-III approaches.

Flood is a natural disaster that is caused due to overflow of water from water bodies like, rivers, oceans, lakes etc., in which water breaks levees, or overtakes channels of rivers or gets over filled at the banks of rivers, lakes etc. or crosses the boundaries of water bodies & enters into flora and fauna. Floods can occur in flowing rivers if the flow rate of water is more than the capacity of the water in channel, particularly at the bends or meanders of the rivers. Flood can also be interpreted as the additional amount of water overflow from the bank of river and inundates the side by areas outside the water bodies in an uncontrolled manner. It always results in hazardous situation like loss of lives and damage to properties and infrastructures, affecting the surrounding socially, economically and environmentally with in affected areas.

The primary losses due to floods is loss of property & lives of humans & animals. The secondary losses due to floods are long term displacement of dwellings & generation of various water borne diseases. Major reasons for flood are rapid population growth, land degradation and climate changes. Hence, it necessitates the invention of various methods to pay attention to the various reasons that causes flood, thus minimizing the occurrence of the natural disaster. One of the successful methods is flood inundation mapping in hazard prone areas.

Flood inundation mapping is used to determine the flood prone areas on both side of river bank when the stream surpasses the bank full stage, Flood inundation mapping can be employed using different tools and techniques by integrating estimating flood peak data. Estimating Flood peak data can be computed using different methods such as flood frequency analysis, rainfall-runoff model, empirical formulae or rational method.

Flood frequency analysis enables us to determine magnitude and frequency of flood using annual max instantaneous peak discharge records obtained at stream gauges. The probability of flooding at river is estimated using flood-frequency analysis. Man has been creating hydraulic structures for various purposes since the dawn of time. In today's world, the design of any water project must include the following steps: Hydrologic, hydraulic, and structural design are all types of design. Hydrologic processes is stochastic process as it is space and time independent i.e., partly predictable, deterministic and partly random. Random variability of observation is so large compared with deterministic variability that observation is treated as purely random. There is no any relation between any adjacent observation, observations are stochastic, time and space independent therefore, can be used in estimating extreme events such as flood and drought. Hydrologic design is critical because any mistake made at any moment will result in design failure, regardless of how well the other steps are completed.

The purpose of frequency analysis is to generate a usable esti mate of the quantile XT for the return period T, where X is the frequency of the event that occurs at a specific time and locati on. An estimate should not only be close to the true quantile, b ut it should also provide a prediction of its accuracy estimated by three static methods i.e.: Gumbel distribution, Log Pearson type III and Log Normal methods. It is proposed to go for the estimation of peak flood using Flood Frequency Analysis for different recurrence interval.

2. STUDY AREA

Mahanadi river basin is a significant basin in eastern part of India because it affects people of 2 states in the country. Water flows through Odisha whereas the origination is at Chhattisgarh. 141,589 Km^2 of area is covered by this river basin, contributing almost 4.3% in the total area of India. Through its path, it covers 75,136 Km^2 of land in Chhattisgarh and 65,580 Km^2 of land in Odisha. At the end it merged with Bay of Bengal with a total length of 851 km from which Chhattisgarh has 357km and the rest is in Odisha. maximum length of the basin is about 587 km and width is about 400 km. from the total area of the basin 54.27% of area is used as agriculture (major stake) and 4.45% of area is occupied by water bodies. Jira, Tel, Ong and Ib are the main tributary to Mahanadi River. The altitude difference of the basin is from 1500meter to 5meter.

Mahanadi river basin has 66880 million cubic meter potential capacity of water, by India-WRIS from which 50000 million cubic meters of water is utilized by various purpose. CWC (central water commission) has installed 39 hydrological observation station with 4 flood forecasting station. The largest dam is Hirakud Dam which was constructed in Mahanadi River with a total capacity of 7189 million cubic meter. According to Hydrological point of view, this dam has a significant impact in the river basin with catchment area of about 83,400 square km and command area of almost 83,400 square km.

By location, this basin is experiencing dry sub humid tropical climatic condition. Total humidity of this basin varies from 83% to 31.6%. the climatic variation through different season (like- south west monsoon, post monsoon, cold and hot weather) is faced by this basin every year. The average rainfall recorded in this basin is range between 1200 to 1600 mm from which 85% is contributed by monsoon. Average temperature of this basin is from 12°C to 40°C.

The part of river considered for the analysis of this work passes through five gauging stations namely, Basantpur, Rampur, Jondhra, Bamnidhi and Seorinarayan. The coordinates of these gauging station are 21.7385, 82.7859/21.7185, 82.5975/ 21.7125, 82.3331/21.9085, 82.7136/21.7185, 82.5975 respectively. This part was considered because data from these gauging stations were available for flood frequency analysis using thirty years of hydrological data. All of these stations were located in the middle and upper Mahanadi Subbasins. The study area comes under the upstream side of Hirakud Dam. The main reason for construction of Hirakud Dam was to control flood in the downstream side.

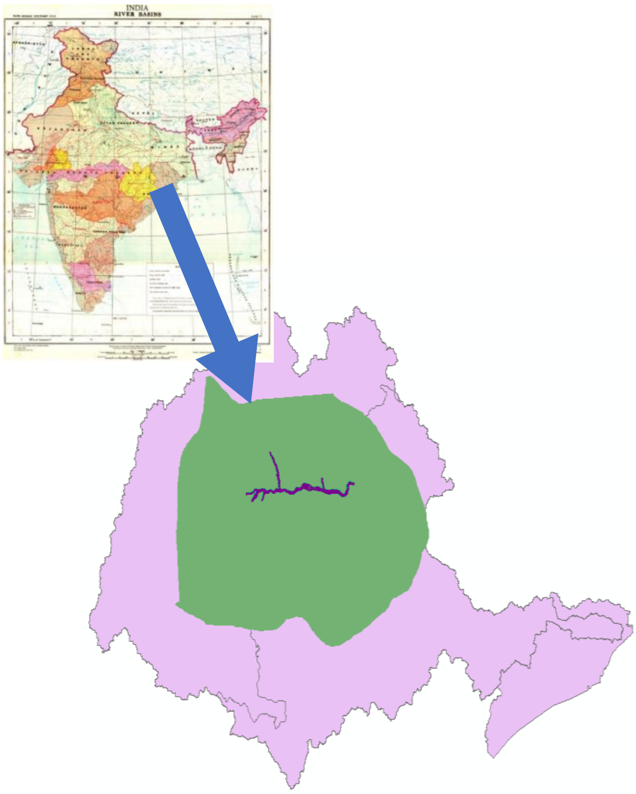

Fig -1:Location of the study area

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3. DATA COLLECTION

The flood frequency analysis requires to estimate annual peak discharge for different recurrence interval. DEM was employed to extract Bathymetric data using HEC GeoRAS and HECRAS. Therefore, Downloaded DEM used for identification of river geometry for the current analysis. Landsat multispectral imagery is used for identification of NDWI for the study area. Daily discharge data was taken for a time interval of thirty years (1988-2017) from which annual peak discharge were taken out.

Daily discharge data are taken from WRIS and DEM and LANDSAT 8 are downloaded from satellite mention below:

Table -1: Description of data

TYPE OF DATA				
SATELLITE NAME	SENSORS DATA	DECRIPTION	SPECTRAL RESOLUTION ON GROUND	MONTH/YEAR OF ACQUISITION
Nasa's terrain (ASTER)	SRTM/DEM	Surface radar terrain mapper/ digital elevation model 1m pixel precision±7 vertical accuracy	30 meters	2020
LANDSAT8	Multispectral reflectance sensor	Different colour reflectance of Earth surface's features.	30 meters	2020

Table -2: Source of data

DATA TYPE	DATA SOURCE
DEM, Landsat8	USGS earth explorer https://earthexplorer.usgs.gov/
Recorded daily discharge data (1988-2017)	India-WRIS https://indiawris.gov.in/wris/

4. METHODOLOGY

The daily flow data of the river Mahanadi was taken from the WRIS website for 30 years (from 1988 to 2017) at five separate stations: Jondhra, Seorinarayan, Basantpur, Rampur, and Bamnidhi. For assessing flood peak data, there are two methods: yearly partial duration series and annual peak series. The yearly floods series is studied on the assumption that peak flows are independent of other events, hence the highest peak discharge seen each year was considered. In partial duration series, all flood flows surpassing a threshold in any year are included.

4.1. Flood Frequency Analysis

Flood frequency analysis calculates the chance of exceeding, relative frequency, and average recurrence interval. Flood Frequency Analysis is used to compute peak flood by utilizing historical data which is used to provide information about future flooding behaviour. The risk that a flow will be greater than or equal to a specific amount is known as the probability of exceedance. relative frequency is the probability that the flow will be less than a specified value.

The average recurrence interval is referred to as the return peri od using the formula below:

T(X) = 1/P(X) = 1/(1-F(X)) ------**(1)**

Where,

Exceedance Probability = P (X)

F represents the relative frequency (X)

T represents the average recurrence interval (X)

statistical methods used in this paper are gumbel's method, logPearson type 3,log normal.

4.1.1.Gumbel's Approach

Gumbel's distribution provides an analytical method for predicting severe hydrological affairs, such as floods. Because

(a) The river is less altered or less affected due to destruction or urbanisation
(b) Flow data are independent and homogeneous, and thus lack long- term trends;
(c) For good result long periods of data(more than 30) used to determine peak flood
(d) There is no major tributary of the stream whose inflo w can influences the flood peak.

The equation for Gumbel's distribution for return period T is

$X_T = \bar{X} + K.\sigma_X$ -----(2)

where x is the standard deviation of the distribution.

X = Sample Size Standard Deviation

K = Frequency Factor, which is written as,

$K = \frac{y_t - \overline{y_n}}{s_n}$-------------**(3)**

In which, y_t= Reduced Variate,

y_t = - [Ln. Ln. $(\frac{T}{T-1})$)]------**(4)**

(3) The values of $\overline{y_n}$ and s_n are selected from Gumbel's Extreme Value Distribution considered depending on the sample size.

4.1.2. Logs Pearson Type III

Log Pearson type III distribution is a statistical approach for using frequency distribution datato forecast the design flood for a river at a particular location. Once the statistical data for the river site has been recorded, a frequency distribution can be generated. Floods of varying sizes may be calculated using the curve. This distribution, also known as the Gamma distribution, is considered by many academics to be a standard flood frequency analysis tool, and it isrising popularity in India. Because of its adaptability, the US Water Resource Council has been recommending it for a long time. Using this method, the annual peak is determined, first logarithms of flood are gives rise to corresponding discharge series mean, standard deviation, and variance are estimated, The coefficient of skewness is used to calculate the peak discharge for a givenrecurrence period or event, as well as its probability. The predicted discharge for a certain period may be determined by taking the Antilogarithm of the planned flood.

Z = Zavg+ K_z σ_X.-----**(5)**

Where Zavg is the logarithm series' mean.

4.1.3. Log Normal Distribution

When CS (skewness) = 0, the log Pearson type III distribution converted to a log normal distribution. The log normal distribution appears as a straight line on a loga rithm probability paper

The predicted peak discharge is

Z = Zavr+$k_0\sigma z$---------**(6)**

The mean of the logarithm series is Zavr, the standard deviatio n is σz, and k_0 is the frequency factor for a certain return time with zero coefficient of skewness.

4.2.D-Index Test

To compare the relative fit of a distribution to another, for goo dness of fit.

The D-INDEX method is used to analyse hydrological data.

The D-INDEX test is calculated using formulae

D-Index=$1/\overline{X}\sum_{i=1}^{4}|x-x^*|$---(7)

Where,

$\overline{X}$= Average of the Annual peak Discharge Series

X= i^{th} highest six annual peak flood.

X^*=i^{th} the corresponding estimated flood.

4.3 Procedure For Flood Frquency Analysis

Annual Peak data (flood data) was derived from daily discharge data taken from WRIS for duration of 1988-2017(30 years discharge data) for station basantpur, bamnidhi,jondhra, seorinarayan and Rampur were considered for flood frequency analysis.

Steps for estimating design at different recurrence interval for gauging station basantpur, bamnidhi, jondhra, Rampur and seorinarayan are as follow:

1. Annual peak data was compiled for period of 30 years from(1988-2017) for all station.

2. The observed data was arranged in descending order(highest to lowest).

3. Return period was assigned for each flood.

T=$\frac{n+1}{m}$,----------------(8))

n is number of years for which flood data was taken

(a) for Gumbel's distribution

4. The mean and standard deviation was calculated from the maximum flood data for n years using

$\sigma_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x-\bar{x})^2}$---------(9)

5. From the Gumbel's Extreme Value distribution table,$\overline{y_n}$value is 0.5362 and Sn value is 1.1124

6. From the given return period T , the reduced variate Y_t was calculated using Equation 4

7. Frequency factor K and estimated magnitude of flood was calculated for different return period using the equation 3,

(b) Log Pearson's type III

8. For z variant logarithmatic flood data was calculated for each flood data.

9. For n years, Standard deviation and coefficient of skew of was calculated from the maximum flood data for z variant using

$\sigma_z=\sqrt{\sum\frac{(z-\bar{z})^2}{n-1}}$------------(10)

$C_s=\frac{n\sum(z-\bar{z})^3}{(n-1)(n-2)(\sigma_z)^3}$ ------(11)

10. Frequency factor K_z was found for $C_s$usingtable mention in book

11. Magnitude of z variant flood was calculated.

12. Antilog log of z variant flood was calculated i.e. the required estimated flood.

(c)Log Normal

13. For z variant logarithmatic flood data was calculated for each flood data.

14. Assume C_s and Standard deviation was calculated from the maximum flood data for z variant using

$\sigma_z=\sqrt{\sum\frac{(z-\bar{z})^2}{n-1}}$-----------(12)

15. For C_s=0, Frequency factor K_z was taken from the book.

16. Magnitude of z variant flood was calculated.

17. Antilog log of z variant flood was calculated i.e., the required estimated flood.

18. Graph was plotted between reduced variate and magnitude of flood estimated

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By (a) Gumbel's method

(b)Log Pearson's type III

(c) Log Normal

For quaging station basantpur,bamnidhi,jondhra,Rampur and seorinarayan.

19.Goodness of fit was analysis using D-index test.

20. The first highest six annual peak flood and corresponding estimated flood was computed,

21. D-index was calculated using the formulae mention above.

(The distribution which have minimum D-index is considered as the suitable method for estimation)

First, polygon was created using goggle earth Pro,byanalysiing the study areas in goggle map and the file was saved in kml format.

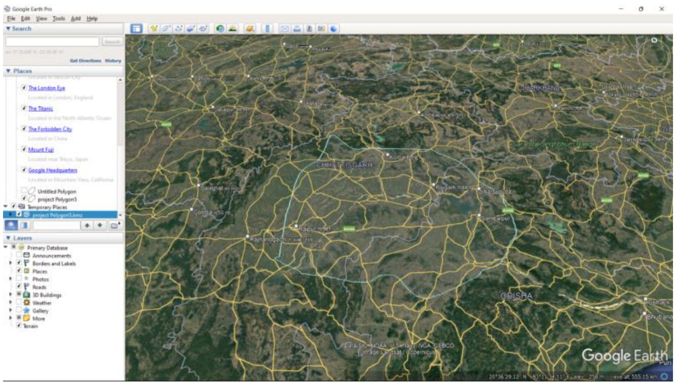

Fig -2:Polygon file in goggle Earth Pro

5. RESULTS AND DISSCUSSION

By the above methodology, The flood frequency Analysis was done using three different probability distribution methods i.e. gumbel's method, Log Pearson TypeIII and LogNormal for five different gauging station Basantpur, Bamnidhi, Jondhra, Rampur and seorinarayan.

5.1. Gumbel's methods

Table -3: Computation Table using Gumbel'smethod for basantpur

Year	PEAK FLOOD	PEAK FLOOD IN Descending order	Order	$S_x=(X-\bar{X})^2$	Return period	Reduced variate
1988	6001	33087.95	1	448427994.7	31.0000	3.41764
1989	2441	23365.9	2	131195685.2	15.5000	2.70768
1990	14915	19935	3	64371232.78	10.3333	2.28492
1991	14236	17661	4	33052938.44	7.7500	1.97941
1992	17201	17201	5	27975303.42	6.2000	1.73789
1993	11006	16826.73	6	24156227.27	5.1667	1.53660
1994	17661	16117.48	7	17687479.31	4.4286	1.36284
1995	15619	15685	8	14236800.53	3.8750	1.20901
1996	6300	15619	9	13743098.29	3.4444	1.07019
1997	12324	14919.62	10	9046791.661	3.1000	0.94298
1998	8789	14915	11	9019021.039	2.8182	0.82495
1999	7234	14236	12	5401759.216	2.5833	0.71427
2000	5134	12324	13	169882.8724	2.3846	0.60951
2001	15685	12200	14	83041.08439	2.2143	0.50954
2002	3402.191	12020.52	15	11813.19003	2.0667	0.41340
2003	33087.95	11520.71	16	152976.0278	1.9375	0.32029
2005	7890.561	11006	17	820530.7064	1.8235	0.22950
2006	11520.71	9138.497	18	7691384.249	1.7222	0.14037
2004	14919.62	8825.123	19	9527769.364	1.6316	0.05226
2007	12200	8789	20	9752076.577	1.5500	-0.03546
2008	16826.73	7890.561	21	16170616.43	1.4762	-0.12346
2009	16117.48	7234	22	21882107.54	1.4091	-0.21250
2010	9138.497	6331.108	23	31144474.78	1.3478	-0.30347
2011	23365.9	6300	24	31492652.78	1.2917	-0.39748
2012	8825.123	6001	25	34937929.02	1.2400	-0.49605
2013	12020.52	5134	26	45938999.84	1.1923	-0.60133
2014	19935	4281.509	27	58221821.45	1.1481	-0.71671
2015	4281.509	3402.191	28	72413981.44	1.1071	-0.84817
2016	6331.108	2946.046	29	80385309.63	1.0690	-1.00826
2017	2946.046	2441	30	89696649.3	1.0333	-1.23372
	Sum	357354.945		1308808348		
	Average	11911.8315				
		standard deviation		6717.984992		

Previous table consist computational result using Gumbel methods for basantpur station. Similarly, Gumbel methods for bamnidhi, Rampur, jondhra and seorinarayan was calculated using formulae mention in methodology.

The above results shows that the peak flow of 33087.95 m^3/s was recorded in 2003 and minimum flow of 2441 m^3/s was recorded in 1989. And the flood with different return periods 2,10,25,50,100,200 and400 were calculated and result shown below:

Table -4: Computation Table for estimated flood for basantpur

Return period T	Reduced Variant Yt	Frequency Factor K	Expected flood XT
2	0.366512921	-0.1525	10887.06
10	2.250367327	1.5409	22264.00
25	3.198534261	2.3933	27990.15
50	3.901938658	3.0256	32238.14
100	4.600149227	3.6533	36454.76
200	5.295812143	4.2786	40655.99
300	5.702113489	4.6439	43109.72
400	5.990213243	4.9029	44849.60

For bamnidhi peak flow was found to be 7731.667m^3/s in 2011 and minimum flow of 346.7351m^3/s was found in 2009.

For jondhra peak flow was found to be 12700m^3/s was recorded in 1994 and minimum flow of 1600 m^3/s was found in 2002.

For Rampur peak flow was found to be 10958.38m^3/s was recorded in 2003 and minimum flow of 90m^3/s was recorded in 1989.

For Seorinarayan peak flow was found to be 22800m^3/s was recorded in 2003 and minimum flow of 1584 m^3/s was recorded in 1989.

And at different Gauging station bamnidhi, jondhra, Rampur and seorinarayan estimated flood for return periods 2,10,25,50,100,200 and 400 was found to be:

Table -5: Computation Table for estimated flood for different recurrence interval

Return Period	Bamnidhi	Jondhra	Rampur	Seorinarayan
2	1889.65	4475.62	1391.82	10106.12
10	5461.83	8783.41	4876.06	19483.68
25	7259.76	10951.57	6629.72	24203.52
50	8593.56	12560.04	7930.69	27704.96
100	9917.51	14156.63	9222.05	31180.55
200	11236.64	15747.39	10508.7	34643.46
300	12007.07	16676.48	11260.17	36665.97
400	12553.37	17335.27	11793.01	38100.09

5.2. Log Pearson TypeIII

For basantpur, using the flood data estimated flood was calculated by this method and results was computed and shown in the table below:

Table -6: Computation Table using Log Pearson type3 for basantpur

year	PEAK FLOOD	PEAK FLOOD IN descending order	order	z=logx	$(z-\bar{z})^2$	$(z-\bar{z})^3$
1988	6001	33087.95	1	4.520	0.268	0.138
1989	2441	23365.9	2	4.369	0.134	0.049
1990	14915	19935	3	4.300	0.088	0.026
1991	14236	17661	4	4.247	0.060	0.015
1992	17201	17201	5	4.236	0.054	0.013
1993	11006	16826.73	6	4.226	0.050	0.011
1994	17661	16117.48	7	4.207	0.042	0.009
1995	15619	15685	8	4.195	0.037	0.007
1996	6300	15619	9	4.194	0.037	0.007
1997	12324	14919.62	10	4.174	0.029	0.005
1998	8789	14915	11	4.174	0.029	0.005
1999	7234	14236	12	4.153	0.023	0.003
2000	5134	12324	13	4.091	0.008	0.001
2001	15685	12200	14	4.086	0.007	0.001
2002	3402.191	12020.52	15	4.080	0.006	0.000
2003	33087.95	11520.71	16	4.061	0.003	0.000
2005	7890.561	11006	17	4.042	0.002	0.000
2006	11520.71	9138.497	18	3.961	0.002	0.000
2004	14919.62	8825.123	19	3.946	0.003	0.000
2007	12200	8789	20	3.944	0.003	0.000
2008	16826.73	7890.561	21	3.897	0.011	-0.001
2009	16117.48	7234	22	3.859	0.020	-0.003
2010	9138.497	6331.108	23	3.801	0.040	-0.008
2011	23365.9	6300	24	3.799	0.041	-0.008
2012	8825.123	6001	25	3.778	0.050	-0.011
2013	12020.52	5134	26	3.710	0.085	-0.025
2014	19935	4281.509	27	3.632	0.137	-0.051
2015	4281.509	3402.191	28	3.532	0.221	-0.104
2016	6331.108	2946.046	29	3.469	0.284	-0.152
2017	2946.046	2441	30	3.388	0.378	-0.232
			Zavg	4.002	2.156	-0.305
	σ_z	0.27264				
	C_s	-0.5569				

Frequency factor for different coefficient of skewness were calculated and the flood with different return periods 2,10,25,50,100,200 and400 were computed shown in the next table.

Table -7: Computation estimated peak flood using Log Pearson TypeIII for basantpur

recurrence interval	Kz for -0.5	K for -0.6	K for(-1.0234) -0.5569	$K_z\sigma_z$	$Z_T=\bar{Z}+K_z\sigma_z$	X_T=ANTILOG Z_T
2	0.083	0.099	0.092104	0.025111	4.02746	10652.71319
10	1.216	1.2	1.206896	0.329048	4.331397	21448.50989
25	1.567	1.528	1.544809	0.421177	4.423526	26517.08164
50	1.777	1.72	1.744567	0.475639	4.477988	30059.91491
100	1.955	1.88	1.912325	0.521376	4.523725	33398.37125
200	2.108	2.016	2.055652	0.560453	4.562802	36542.8118
1000	2.4	2.275	2.328875	0.634944	4.637293	43380.39279

5.3. Log Normal

Similar to log Pearson standard deviation was done and frequency factor for zero coefficient of skewness were taken. Estimated flood was calculated by this method for different recurrence interval were calculated and results was computed for basantpur and shown in the table below

Table -8: Computation estimated peak flood using Log Normal for basantpur

recurrence interval	K for Cs=0	$K_z\sigma_z$	$Z_T=\bar{Z}+K_z\sigma_z$	X_T=ANTILOG Z_T
2	0	0	4.002349	10054.23
10	1.282	0.349524	4.351873	22483.99
25	1.751	0.477393	4.479742	30181.56
50	2.054	0.560003	4.562352	36504.93
100	2.326	0.634161	4.63651	43302.17
200	2.576	0.702321	4.70467	50660.52
1000	3.09	0.842458	4.844807	69953.04

Similarly, for Bamnidhi, Jondhra, Rampur and Seorinarayan estimated flood using Log PearsonTypeIII and Log normal were calculated and different parameter like mean, standard deviation, standard deviation for z variant were calculated and computed in table below:

Table -9: Different parameter using different station

Gauging Station Parameter	Basantpur	Bamnidhi	Jondhra	Rampur	Seorinarayan
Average($\bar{x}$)	11911.83	2211.408	4863.646	1705.65	10950.797
Standard Deviation (σ)	6717.985	2109.345	2543.710	2057.416	5537.367
Standard Deviation for z variant (σ_z)	0.2728	0.353	0.221	0.48727	0.2870
Coefficient of skew (C_s)	-0.5569	0.6154	-0.0483	-0.2405	-0.9632

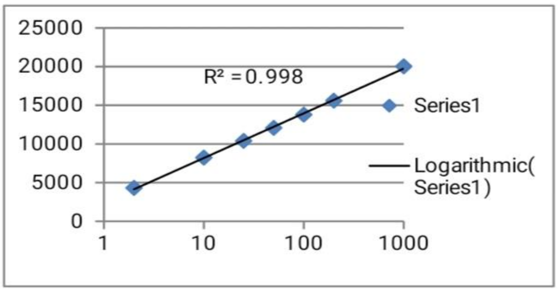

Fig -3.1:(a) Gumbel's method

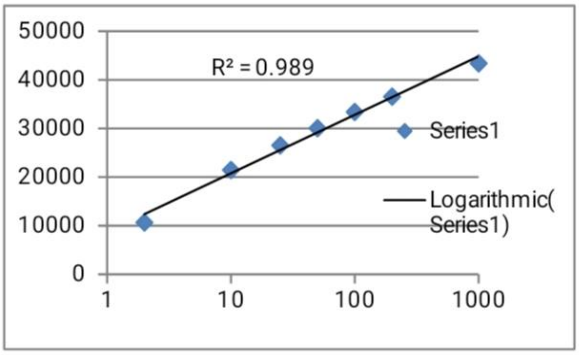

Fig -3.1:(b) Log Pearson-TypeIII

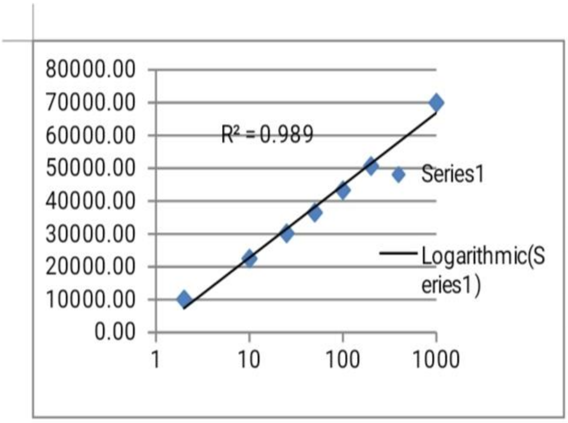

Fig -3.1:(c) Log Normal

Above graph is plot between estimated peak discharge (m^3 /s) in Y-axis and recurrence interval (year) in X-axis for Basantpur.

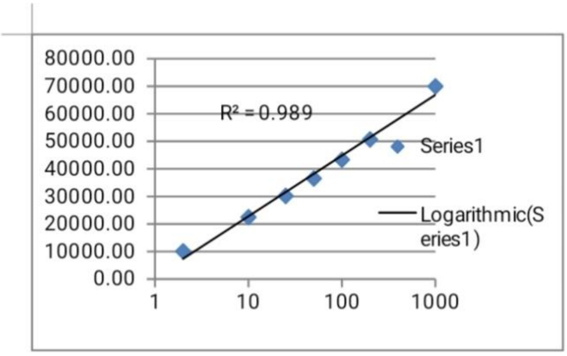

Fig -3.2:(a) Gumbel's method

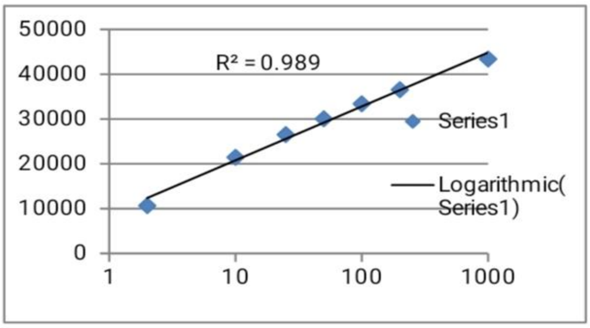

Fig -3.2:(b) Log Pearson-TypeIII

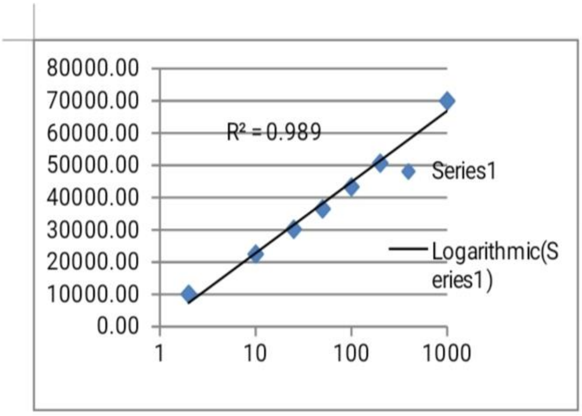

Fig -3.2:(c) Log Normal

Above graph is plot between estimated peak discharge (m^3 /s) in Y-axis and recurrence interval (year) in X-axis for Baminidhi.

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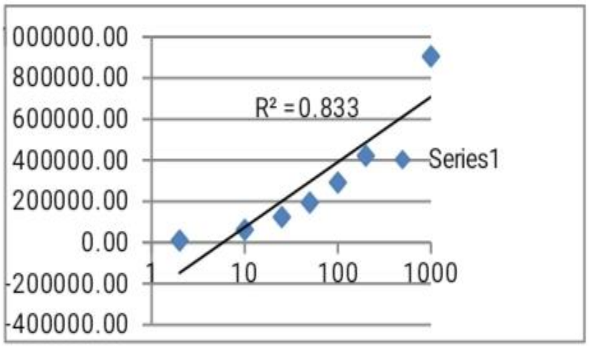

Fig -3.3:(a) Gumbel's method

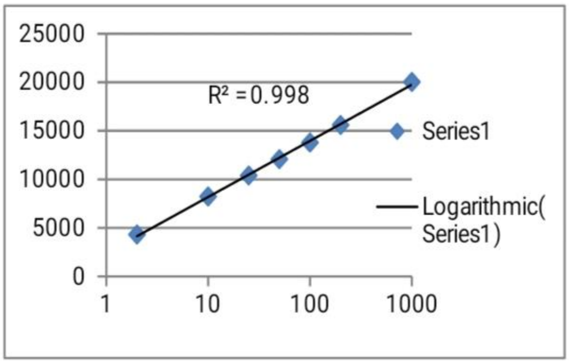

Fig -3.4:(a) Gumbel's method

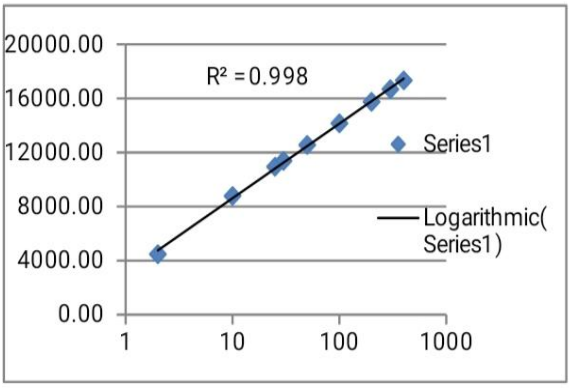

Fig -3.3:(b) Log Pearson-TypeIII

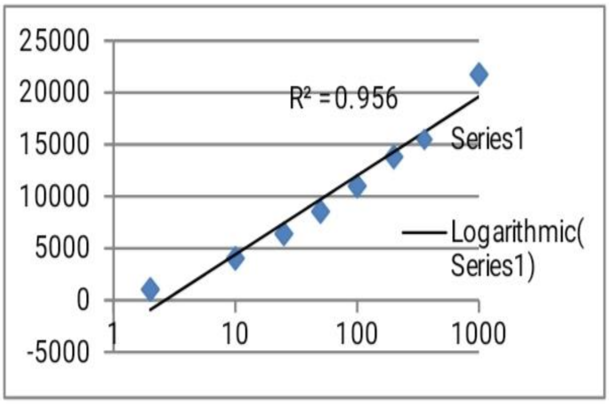

Fig -3.4:(b) Log Pearson-TypeIII

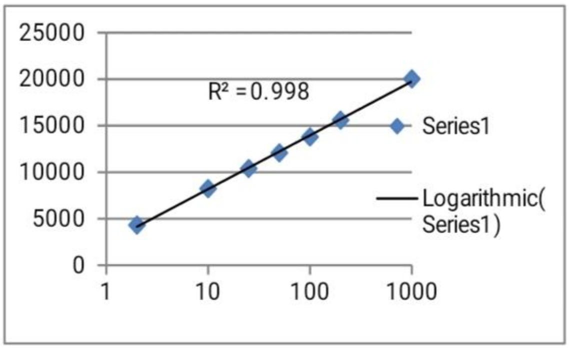

Fig -3.3:(c) Log Normal

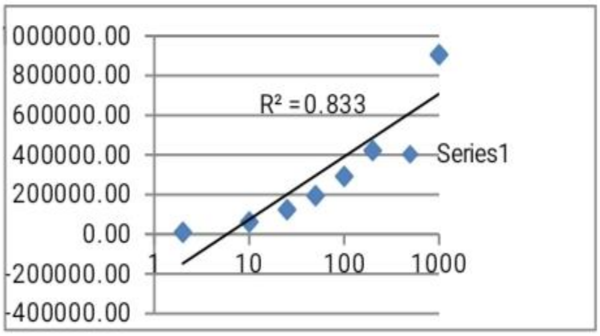

Fig -3.4:(c) Log Normal

Above graph is plot between estimated peak discharge (m^3/s) in Y-axis and recurrence interval (year) in X-axis for Jondhra.

Above graph is plot between estimated peak discharge (m^3/s) in Y-axis and recurrence interval (year) in X-axis for Rampur.

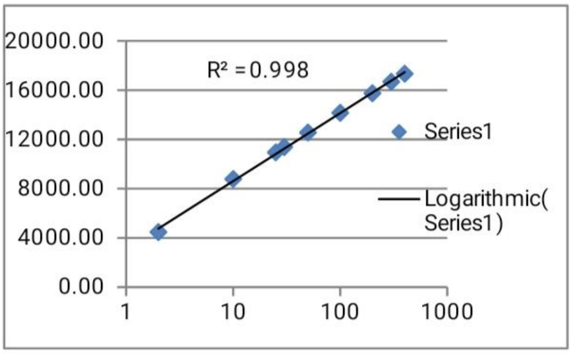

Fig -3.5:(a) Gumbel’s method

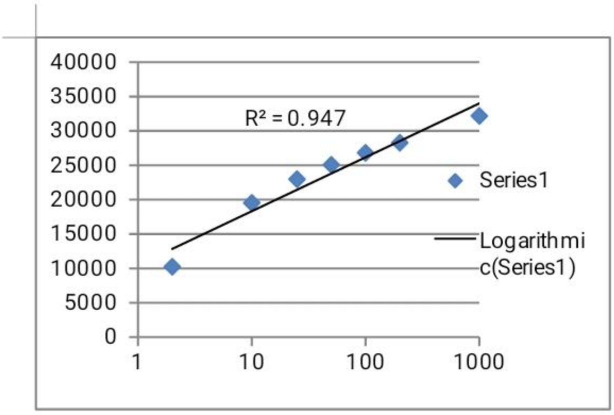

Fig -3.5:(b) Log Pearson-TypeIII

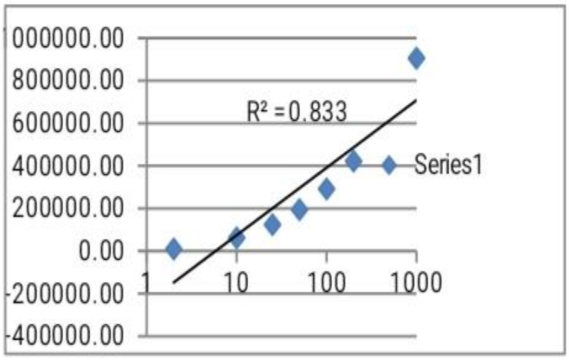

Fig -3.5:(c) Log Normal

Above graph is plot between estimated peak discharge (m^3/s) in Y-axis and recurrence interval (year) in X-axis for Seorinarayan.

To check the best fitted probability distribution out of gumbel’s methods, Log PearsonTypeIII and Log Normal D-index test was used. D-index value were calculated using annual peak flood and corresponding estimating peak flow at different return period 2,10,25,50,100.200.300 and 400 were computed.The minimum D-index is considered as the suitable method for estimation.

Methods➡ Gauging Station⬇	Gumbel's method	LogPearson TypeIII	Log normal
Basantpur	1.178	1.023	2.823
Baminidhi	1.266	4.636	3.585
Jondhra	0.638	1.358	1.419
Rampur	6.522	4.922	8.490
Seorinarayan	0.744	1.066	2.390

6. CONCLUSIONS

From the Flood Frequency Analysis which was carried out for middle Mahanadi River considering 30 year’s annual peak flow data. using D-index test, It has been found that

- LogPearsonTypeIII is suitable for basantpur
- Gumbel’s method is suitable for bamnidhi, Rampur, jondhra and seorinarayan.

Flood inundation modelling of the middle Mahanadi River was done using HEC-RAS, Arc GIS 10 extension models, and HEC-GeoRAS. To arrange and interpret geometric input data from the DEM and outline the floodplain map, HEC-GeoRAS was used. Mahanadi River's flood frequency assessments were conducted in order to evaluate the river's flood magnitude.

The Gumbel method was used to calculate annual peak discharge with 25year return periods (2013), yielding 12020.52,718.65, 6528.57, 850, 12473.6m3/s for Basantpur, Bamnidhi, Jondhra, Rampur and Seorinarayan respectively. Maximum flood in 2013 was found in the month of August.

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