International Journal Of
Recent Scientific
Research
ISSN: 0976-3031
Volume: 7(2) February -2016

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THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 2, pp. 8670-8671, February, 2016

International Journal of Recent Scientific Research

ISSN: 0976-3031

RESEARCH ARTICLE

FLOOD FREQUENCY ANALYSIS: USING GUMBEL DISTRIBUTION

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ARTICLE INFO

Article History:

Received 11th February, 2016
Received in revised form 16th February, 2015
Accepted 17rd February, 2016
Published online 28th February, 2016

Key Words:

Flood Frequency analysis, peale discharge Gumbel distribution

ABSTRACT

In the case of small dams, diversion works & other hydraulic structures where structural failure or overtopping will not involve loss of life, it would be seldom economical to design them to withstand the probable maximum flood. A calculated risk is taken to design these structures for a flood lesser than the probable maximum flood.

The Frequency Analysis helps interpret a past record of events to predict the future probabilities of occurrence. Gumbel distribution helps to predict expected flood with different return periods. The present paper discusses one such case for construction of bridge so as to minimise the risk of any kind of problem that may arise in future.

INTRODUCTION

In the case of small dams, diversion works & other hydraulic structures where structural failure or overtopping will not involve loss of life, it would be seldom economical to design them to withstand the probable maximum flood. A calculated risk is taken to design these structures for a flood lesser than the probable maximum flood.

The Frequency Analysis helps interpret a past record of events to predict the future probabilities of occurrence.

Data selection

For any frequency analysis, relevant, adequate & accurate data series is necessary.

Adequate data series refers to length of record. Data with sufficient length & reliability, can yield satisfactory estimates. For the estimation of flood flows of large return periods, it is necessary to extrapolate the magnitude outside the observed range.

The accuracy of the estimate reduces with degree of extrapolation. Some hydrologists set a limit of extrapolation of about twice the length of record i.e. a 50 year data can be used to determine the magnitude of events up to 100 year flood, but not of floods of longer return period. If extrapolated to estimate 1000 year return flood, etc. then degrees of uncertainty involved in estimates have to be mentioned.

Flood Frequency Analysis: Using Gumbel Distribution

Hydrologic flood frequency analysis

Ven Te Chow has proposed the use of

$x = \bar{x} + K\sigma_x$, as the general equation for hydrologic frequency analysis.

where

K = the frequency factor defined by a specific distribution. (Table values can be referred)
x = flood magnitude of given return period T

x = mean of observed / recorded floods
σ_x = std. Deviation of observed / recorded floods

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Gumbel distribution

Gumbel was the first to realise that the annual maximum flood data are the observations of extreme values in different years. Hence they should follow extreme value distribution law viz. Double Exponential Probability Function .

$F(x) = \exp(-e^{-y})$ where $y = \frac{x + a}{c}$, $a = \gamma c - ¶$, $c = \frac{\sigma\sqrt{6}}{\Pi}$,

$\gamma = 0.57721$ = Euler's constant

y = reduced variate , x = magnitude of flood

γc $= 0.57721 * \frac{\sigma\sqrt{6}}{\Pi} = 0.45\,\sigma$

$\therefore \quad y = \frac{[x - ¶ + 0.45\,\sigma]}{\frac{\sigma\sqrt{6}}{\Pi}}$

$= \frac{[x - ¶ + 0.45\,\sigma]}{\sigma * (0.7797)}$

Fitting of Double Exponential Distribution to the frequency distribution of observed data of floods can be checked by collecting records of floods of many rivers in the region & computing a set of skewness coefficients.

Cumulative Density Function (CDF) = F(x) $= \exp(-e^{-y})$, or y = lnln(F(x))

ln = natural log.

In Gumbel's Distribution CDF is F (x) = P (X<=x) $= \exp(-e^{-y})$

T= Return period of Flood, P(X>x) = 1-F(x) = 1- $\exp(-e^{-y})$

i.e. T= 1/ P(X>x) or 1/T = 1- $\exp(-e^{-y})$

or $\exp(-e^{-y}) = \frac{T-1}{T}$

i.e. y = -ln[-ln F(x)]

y = -ln [lnT-ln(T-1)]

$\frac{x + a}{c} = -\ln[\ln T - \ln(T-1)]$

$x = -\frac{\sigma\sqrt{6}}{\Pi}\left[\gamma + \ln\left(\ln \frac{T}{T-1}\right)\right]$

The data of yearly values of maximum peak discharges for a bridge are given in Annex-I. Using above mentioned statistical method, one can estimate the discharge for return period of different magnitudes

RESULTS

Return period	K alue	K	$x = \bar{x} + K\sigma$	
1 in 100 years	K100	3.49	9613.323	m^3/sec
1 in 50 years	K50	2.89	8434.809	m^3/sec
1 in 10 years	K10	1.47	5645.659	m^3/sec

Annex-I

To estimate magnitude of 10, 50, 100 year flood for data of Yearly maximum peak discharges for a bridge.

Year	discharges (x) m^3 / sec. **in descending**	Rank m	Return period **T=(n+1)/ m**	Year	discharges (x) m^3 / sec. **in descending**	Rank m	Return period **T=(n+1)/ m**
1	9025	1	51.00	26	2200	26	1.96
2	7300	2	25.50	27	2175	27	1.89
3	6800	3	17.00	28	2010	28	1.82
4	6775	4	12.75	29	1925	29	1.76
5	6450	5	10.20	30	1800	30	1.70
6	5500	6	8.50	31	1800	31	1.65
7	4700	7	7.29	32	1775	32	1.59
8	4680	8	6.38	33	1700	33	1.55
9	4600	9	5.67	34	1700	34	1.50
10	4325	10	5.10	35	1475	35	1.46
11	3950	11	4.64	36	1375	36	1.42
12	3825	12	4.25	37	1375	37	1.38
13	3650	13	3.92	38	1275	38	1.34
14	3650	14	3.64	39	1225	39	1.31
15	3350	15	3.40	40	1175	40	1.28
16	3200	16	3.19	41	1100	41	1.24
17	2825	17	3.00	42	1100	42	1.21
18	2750	18	2.83	43	1075	43	1.19
19	2525	19	2.68	44	1075	44	1.16
20	2475	20	2.55	45	1075	45	1.13
21	2475	21	2.43	46	1000	46	1.11
22	2475	22	2.32	47	725	47	1.09
23	2475	23	2.22	48	625	48	1.06
24	2450	24	2.13	49	400	49	1.04
25	2200	25	2.04	50	325	50	1.02

K ' value is referred from the table for Gumblel distribution

Mean =	**4177.2**
Std. Dev.	1848.10
Var.	3415465

$K = -\frac{\sqrt{6}}{\Pi}\left[0.57721 + \ln\left(\ln \frac{T}{T-1}\right)\right]$ true for an infinite No. of observations.

Return period	K value	K	x = x+Kσ	
1 in 100 years	K100	3.49	9613.3231	m^3/sec
1 in 50 years	K50	2.89	8434.8091	m^3/sec
1 in 10 years	K10	1.47	5645.6593	m^3/sec

CONCLUSION

A risk is taken to design the structure (bridge) for a flood lesser than the probable maximum flood as mentioned above.

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ISSN 0976-3031