RESEARCH PAPER | Engineering | Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X

Flood Frequency Study For Kadana Reservoir Projectby Gumbel's Frequency Distribution Method

KEYWORDS: Basin, Frequency Analysis, Statistics, Time Series, Trend, Variations

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ABSTRACT *Water is a vital natural resource which forms the basis of all life. It is very important tool for human development, a key resource in all economic activities ranging from agriculture to industry. Hydrologic phenomena are extremely complex. Rainfall is usually the main input to the hydrological system. Its magnitude, variation and distribution plays important role in hydrological response of the area. Rainfall studies are of utmost utility for understanding nature & hence the behaviour of climate changes.*

In the present paper flood frequency study of Kadana Reservoir Project have been carried out. Considering data for pre construction and post construction period.

INTRODUCTION
Kadana Dam is located in gorge cut by Mahi River through a low range of hills in Dahod of Gujarat State just near the border with Rajasthan. The catchment area up to this project is 25,520 sq.km. and catchment area intercepted at Banswara in Rajasthan is 6149 sq.km. The dam is composite earth fill and masonry gravity structure rising 58 m above the stream bed with the top length of dam about 1551 m with main spillway of 406 m in river gorge portion and 113 m long additional spillway in right bank. The effective storage capacity of Kadana reservoir is 1203 $Mm^{3.}$ The benefits of this project include irrigation facilities for 12795 ha and Hydro - Power generation by installation of 4 Nos Reversible turbines of capacity 60 M.W. each, with a total capacity of 240 M.W.

Table.1 Main Salient Features of Kadana Project

Location	Village: Kadana, Tal: SantrampurDist: Panchmahals
Purpose	Irrigation, Hydro-Power & Flood Protection
River	Mahi
Area of catchment	25520 km^2
Mean annual runoff in the catchment	7696 Mm^3
Mean annual rainfall	760 mm
Year of commencement of construction work	1969
Year of completion	1979
Maximum observed flood (Cumecs)	32925.00

Source:http://guj-nwrws.gujarat.gov.in/ showpage. aspx?contentid=1576&lang=English

CONCEPT OF ANALYSIS
Surface run off due to rain fall is called flood flow or only flood. Generally run-off flows in river within its natural banks. But during heavy rain in short time water of the river overflows its banks and inundates the marginal country. This river inundation is called flood.

Floods cause much loss of life and property disruption of communication etc. and the subsequent famine. The process of preventing floods from inundating the marginal and is called flood control. Exact flood calculation is difficult but probable flood can be find out and flood control measures can be taken to minimize the losses to human life and property.

Different rivers have different flood characteristics and hence require different methods to control floods in them. Estimation of flood can be done by various methods like.

1. By flood discharge formula

a. Fanning's formula

b. Fuller 's formula

c. Dicken 's method

d. Inglis formula

e. Nawab jangbahadur formula

2. By flood frequency studies using Gumbel's method.

3. By unit hydrograph

4. By physical introduction of past floods.

FLOOD FREQUENCY STUDIES
Since the exact sequence of stream flow for future years cannot be predicted, probability concepts must be used to study the probable variations in flow so that the design can be completed on the basis of a calculated risk.

Flood frequency.It is the like hood of flood being equalled or exceeded. A 10% frequency (F) means that the flood has 10 out of 100 chances of being equalled or exceeded.

Recurrence interval.It is the number of years in which a flood can be expected once. This is usually denoted by a symbol T_r and is given by

$$T_r = \frac{100}{F}$$

DETERMINATION OF RECURRENCE INTERVAL
If record of annual flood for *N* number of years is given, then arrange them in the deceasing order of there magnitude and mark their serial order. Thus, the highest flood should be placed atop and should be given number 1. next highest should be given number 2 and so on. The lowest flood will be at the bottom with a serial number *N*. If a particular flood has a serial numbers m in the order mentioned above its recurrence lateral can be found by many methods like Californian Method, Hazens method and Gumble's method

Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X

To find any design flood of desired frequency, a plot of Q versus T_r (or F) is prepared on a probability paper. From this plot, unknown flood for any value of T_r can be found out. This method does not give good results for obtaining the values of higher discharges for value of such recurrence interval which exceed the number of years of records available.

Gumbel's method

This Method is useful for obtaining values of food discharges for a high recurrence interval.

If Q_1, Q_2 .... Q_n compares a series of extreme value of floods, the probability of occurrence of value equal to or less then *Q* is given by

$P = e^{-z}$ ...(*a*)

where $Z = e^{-y}$ ...(*b*)

such that $Y = A(Q - Q_f)$ ...(*c*)

where Q_f = value of flood discharge having highest frequency,

$= Q_{av} - 0.45$

$= Q_{av}$ = Average value of discharge.

$$\text{and} \quad \sigma_x = \sqrt{\frac{\Sigma(Q_1 - Q_{av})^2 + (Q_2 - Q_{av})^2 \ldots (Q_n - Q_{av})^2}{N}}$$

$$\text{and} \quad a = \text{constant} = \frac{1.28}{\sigma_x}$$

The recurrence interval of Q in year is T_r given

$$T_r \frac{1}{1 - P}$$

for given date, find , Q_{av} and calculate Q_f.

From Eq. (*a*), (*b*) and (*c*) plot *P* and T_r for various values of *y*. Then, for any desired value of T_r, Q can be found out by extrapolating the line.

ANALYSIS

Data is available since 1959-1994 long before construction of Kadana project to considerable years after project. Data available is divided in to two groups (i) data before Kadana reservoir construction, this covers data for 21 years i.e. from 1959 to 1979 (ii) data after Kadana reservoir for 15 years i.e. from 1980 to 1994. Frequency analysis is carried out for both pre construction phase and post construction phase.

Table.2 Year wise Maximum Discharge Pre Kadana Period

SR.NO.	DATE AND YEAR	DISCHARGE IN CUMEC
1	15/09/1959	20839.02
2	10/08/1960	6800
3	27/09/1961	12869.04
4	21/09/1962	18994.48
5	07/09/1963	5870.03
6	25/07/1964	1289.25
7	30/07/1965	1046.3
8	08/09/1966	1814.81
9	02/09/1967	10450.8
10	01/08/1968	19149.37
11	17/08/1969	8510.83
12	06/09/1970	11116.23
13	30/07/1971	7102.65
14	19/08/1972	5712.19
15	07/09/1973	40662.6
16	21/08/1974	8110.21
17	12/09/1975	14364.43
18	30/08/1976	26533.77
19	08/08/1977	13265.47
20	30/08/1978	16876.68
21	18/08/1979	7333.99

Source: Kadana Dam Flood Control Cell

Table.3 Year wise Maximum Discharge Post Kadana Period

SR.NO.	DATE AND YEAR	DISCHARGE IN CUMEC
1	31/08/1980	6592.78
2	16/08/1981	21510.55
3	19/08/1982	3055.78
4	16/08/1983	4066.83
5	20/08/1984	16500.07
6	09/10/1985	50.12
7	16/08/1986	10912.5
8	26/08/1987	14269.21
9	06/08/1988	11593.66
10	02/09/1989	1140.31
11	24/08/1990	29294.52
12	01/08/1991	15395.36
13	08/08/1992	29.08
14	17/07/1993	14726.35
15	02/08/1994	21260.31

Source: Kadana Dam Flood Control Cell

Table.4 Frequency Analysis by Gumbel's Method for Pre Kadana Period

Date & Year	Annual Maximum Flood (x) cumecs	Order Number (m)	Return Period T=(N+1) /m 'yrs'	Probability P=m/ (N+1)	x^2
9/7/1973	40662.6	1	21.00	4.76	1653447038.76
8/24/1990	29294.52	2	10.50	9.52	858168902.03
8/30/1976	26533.77	3	7.00	14.29	704040950.41
8/16/1981	21510.55	4	5.25	19.05	462703761.30
8/2/1994	21260.31	5	4.20	23.81	452000781.30
9/15/1959	20839.02	6	3.50	28.57	434264754.56
8/1/1968	19149.37	7	3.00	33.33	366698371.40
9/21/1962	18994.48	8	2.63	38.02	360790270.47
8/30/1978	16876.68	9	2.33	42.92	284822327.82
8/20/1984	16500.07	10	2.10	47.62	272252310.00

Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X

8/1/1991	15395.36	11	1.91	52.36	237017109.53
7/17/1993	14726.35	12	1.75	57.14	216865384.32
9/12/1975	14364.43	13	1.62	61.73	206336849.22
8/2/1997	14356.51	14	1.50	66.67	206109379.38
8/26/1987	14269.21	15	1.40	71.43	203610354.02
8/8/1977	13265.47	16	1.31	76.16	175972694.32
9/27/1961	12869.04	17	1.24	80.65	165612190.52
8/6/1988	11593.66	18	1.20	83.33	134412952.20
9/6/1970	11116.23	19	1.12	89.29	123570569.41
8/16/1986	10912.5	20	1.10	90.91	119082656.25
∑X =	364490.13			∑X² =	7637779607.24

$$Xbar = \frac{\Sigma X}{N} = \frac{364490.13}{20} = 18224.51$$

$$\frac{\Sigma x^2}{N} = \frac{7637779607.24}{20} = 381888980$$

$$S = \sqrt{\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2}$$

$$S = \sqrt{381888980 - 18224.51}$$

$$S = 7053.82$$

Table.5 Computations of Flood Discharge for Period Before Kadana Reservoir Project

Return Period 'T' (Yrs.)		S	K from table	KS	Flood Discharge X = +KS (cumecs)
1000	18224.51	7053.82	6.01	42365.24	60589.75
100	18224.51	7053.82	3.84	27058.45	45282.96
75	18224.51	7053.82	3.56	25132.76	43357.27
50	18224.51	7053.82	3.18	22424.09	40648.60
25	18224.51	7053.82	2.52	17754.46	35978.97
20	18224.51	7053.82	2.30	16237.89	34462.40
15	18224.51	7053.82	2.02	14269.88	32494.39
10	18224.51	7053.82	1.63	11462.46	29686.97

Table.6 Frequency Analysis by Gumbel's Method

Date & Year	Annual Maximum Flood (x) cumecs	Order Number (m)	Return Period T=(N+1)/m 'yrs'	Pro-bality P=m/(N+1)	x²
8/24/1990	29294.52	1	16.00	6.25	858168902.03
8/16/1981	21510.55	2	8.00	12.50	462703761.30
8/2/1994	21260.31	3	5.33	18.75	452000781.30
8/20/1984	16500.07	4	4.00	25.00	272252310.00
8/1/1991	15395.36	5	3.20	31.25	237017109.53
7/17/1993	14726.35	6	2.67	37.50	216865384.32
8/26/1987	14269.21	7	2.29	43.75	203610354.02
8/6/1988	11593.66	8	2.00	50.00	134412952.20
8/16/1986	10912.5	9	1.78	56.25	119082656.25
8/31/1980	6592.78	10	1.60	62.50	43464748.13
8/16/1983	4066.83	11	1.45	68.75	16539106.25
8/19/1982	3055.78	12	1.33	75.00	9337791.41
9/2/1989	1140.31	13	1.23	81.25	1300306.90
10/9/1985	50.12	14	1.14	87.50	2512.01
8/8/1992	29.08	15	1.07	93.75	845.65
∑X =	170397.4			∑X² =	3026759521.30

$$Xbar = \frac{\Sigma x}{N} = \frac{170397.4}{15} = 11359.83$$

$$\frac{\Sigma x2}{N} = \frac{3026759521.30}{15} = 201783968.09$$

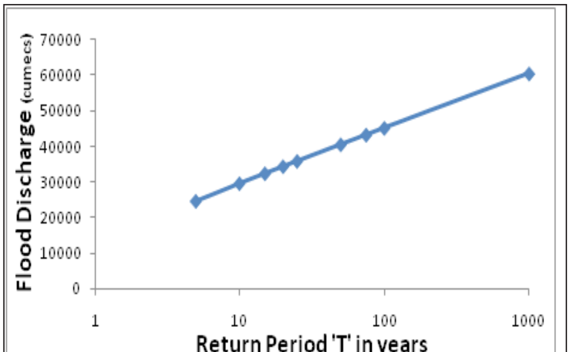
$$S = \sqrt{\frac{\Sigma x^2}{N} - \left(\frac{\Sigma x}{N}\right)^2}$$

$$S = \sqrt{\frac{3026759521.30}{15} - (11359.83)^2}$$

$$S = 8528.67$$

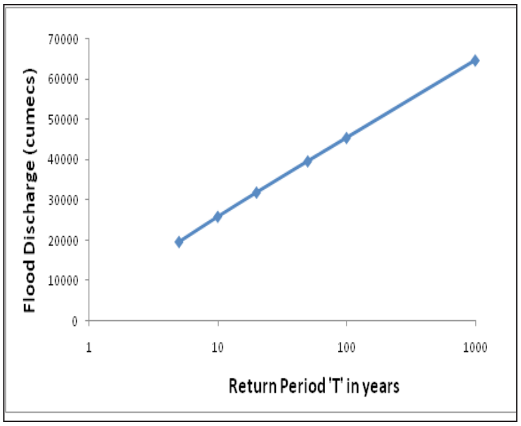
Table.7 Computations of Flood Discharge for Period after Kadana Reservoir Project

Return Period 'T' (Yrs.)		S	K from table	KS	Flood Discharge x= +KS (cumecs)
1000	11359.83	8528.67	6.265	53432.12	64791.95
100	11359.83	8528.67	4.005	34157.32	45517.15
50	11359.83	8528.67	3.321	28323.71	39683.54
20	11359.83	8528.67	2.41	20554.09	31913.92
10	11359.83	8528.67	1.703	14524.33	25884.16
5	11359.83	8528.67	0.967	8247.224	19607.05

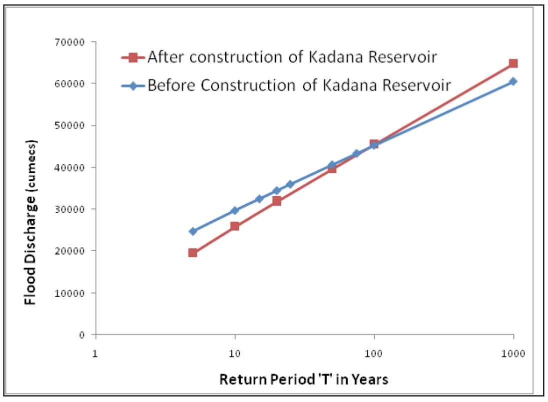


Graph.1 Flood Discharge v/s Return Period before Kadana Reservoir Project

Volume : 4 | Issue : 1 | Jan 2014 | ISSN - 2249-555X



Graph.2 Flood Discharge v/s Return Period after Kadana Reservoir Project.



Graph.3 Graph Indicating Comparative Study for Flood Discharge before and after Kadana Reservoir Project

CONCLUSION

Flood estimation is of crucial importance and themajor aspectof hydrologicdesign. Past flood data, its consistency and validity is very important for accuracy in analysis. Here data availability is comparatively of small range however we can observe from analysis that for the return period less than 100 year frequency plot suggests flood value lesser in post construction period compared to pre-construction period of Kadana Reservoir Project. Post-construction plot line is steeper than pre construction period giving high flood values for return period more than 100 years.

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