NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE
WORKSHOP ON
FLOOD FREQUENCY ANALYSIS

TUTORIAL - 5

REGIONAL FLOOD FREQUENCY ANALYSIS

PROBLEM:

The discharge in cumecs for the eighteen bridges of Mahanadi basin (subzone 3d) are given in Table T. 5.1. Develop a regional curve based on the median ratios of the discharges of different return periods to mean annual peak flood using (i) Least Square approach and (ii] Method of maximum likelihood approach. Also, develop the relationship between mean annual peak flood and the drainage area of different bridge catchments. Give the steps for computing the discharge of different return periods for any ungauged catchment of the homogeneous region using the above two approaches. Assume the data of annual maximum floods at each gauging site to follow Gumbel distribution.

The drainage area for the eighteen bridge catchments are given below :

Sl. No.	Br. No.	Drainage Area (sq. km.)	Sl. No.	Br. No.	Drainage Area (sq. km.)
1	12	665.53	10	40K	115.25
2	148	108.52	11	121	1150.00
3	59 (KGP)	47,00	12	385	194.25
4	66K	154.13	13	332 (KGP)	175.16
5	176	65.79	14	59 (BSP)	135.70
6	308	17.48	15	489	823.00
7	325	26.77	16	154	58.09
8	332 (NGP)	225.00	17	42	49.00
9	698	112.66	18	69	172.78

TABLE-T 5.1 : Discharge in Cumecs for Bridges in Mahanadi Basin for 1958-1980

SL. NO.	BR. NO.	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	12	460	396	490	387	869	822	510	478	836	271	150	220	390	375	410	900	500	710	300	408	310	[illegible]	710
2	48	31	14	40	45	33	153	198	57	94	130‡	13	300	143	130	310	90	150	100	160	93	550	100	[illegible]
3	59(KGP)	40	93	85	101	23	55	105	13	30	240	80‡	24	50	33	54	54	73	[illegible]	[illegible]	62	5	33	[illegible]
4	66K	177	290	283	156	71	156	283	184	105	548	370	135	50	900	640	425	530	145	[illegible]	228	170	395	[illegible]
5	176	40	21	57	85	17	47	30	19	16	140	32	29	53	27	43	241	14	12	90	70	40	101	[illegible]
6	308	60‡	59‡	62‡	57	53	56	25	28	17	80	12	72	92	44	22	56	9	15	27	44	65	30	30
7	325	17‡	17‡	34‡	35‡	7‡	20‡	13‡	6	7	75	75‡	31‡	78	36	56	31	19	24	[illegible]	93	50	110	22
8	332(NL?)	47‡	20‡	56‡	16‡	135‡	130‡	27‡	33	295	291	169	120	[illegible]	292	66	415	33	150	110	300	340	195	[illegible]
9	698	194‡	321‡	304‡	344‡	163‡	225‡	344‡	125	150	279	140	97	70	275	22	272	192	95	530	74	180	500	170
10	40K	228‡	324‡	312‡	210‡	152‡	207‡	300‡	219‡	159	157	164	162	135	475	109	925	34	330	150	450	340	54	250
11	121	230‡	115‡	287‡	80‡	690‡	667‡	138‡	115‡	677	1620	351	1333	1051	1105	505	1651	1440	1700	400	1100	300	320	550
12	385	138‡	101‡	194‡	282‡	97‡	194‡	136‡	97‡	94	244	21	12	50	93	95	20	19	44	[illegible]	120	115	165	152
13	332(KGP)	37‡	21‡	44‡	53‡	35‡	196‡	254‡	35‡	47	53	47	53	13	127	112	151	29	75	41	33	67	65	54
14	59(BSP)	95‡	251‡	221‡	275‡	68‡	142‡	292‡	27‡	73‡	345	5	132	294	244	144	536	213	460	130	200	22	350	115
15	489	153‡	1399‡	1234‡	1523‡	1070‡	741‡	1605‡	92‡	370‡	1254	415	304	1603	334	525	1179	610	800	3000	905	1200	415	830
16	154	102‡	96‡	105‡	97‡	137‡	136‡	110‡	107‡	143‡	89‡	74	127	43	91	103	401	17	73	70	95	50	28	50
17	42	11‡	6‡	15‡	17‡	11‡	69‡	29‡	25‡	4‡	61‡	6‡	105	42	71	45	115	34	57	57	43	32	39	75
18	69	199‡	181‡	211‡	180‡	302‡	294‡	219‡	209‡	327‡	173‡	170‡	150‡	193	196	76	475	254	115	130	400	95	270	130

Note ‡ Indicates Benerted Data

SOLUTION

(I) LEAST SQUARE APPROACH :—The procedure adopted for solving the above problem using this approach is :

(a) Compute annual flood peak values by converting the annual observed peak stage from the available Stage-Discharge curves.

(b) In order to make equal length of records for each of the bridge catchments, generate the missing data using the established relationship between the peak discharges of the missing data site and the nearby gauging site for which the annual peak records for longer period are available. The following steps may be adopted to generate the missing data :

(i) Relate the peak flood at one gauging site with the peak flood at other nearby gauging site having common period of records. Fit a straight line by linear regression.

(ii) Estimate the missing peak flows at the gauging site of shorter record length using the corresponding available records at the other gauging site used in the regression relationship.

(c) Arrange the available annual peak discharge values at each gauging sites in ascending order and calculate their plotting positions using the formula :

$$F_i = \frac{i-0.44}{N+0.12} \qquad \text{(T 5-1)}$$

where :

i is the rank of the event

N is no. of years of data and

F_i is the probability of non-exceedance.

The thus calculated plotting position for peak flow values at the Br. No. 489 is shown in Table T 5.2.

(d) Compute EV-I reduced variate using the relation :

$$y_i = -\ln(-\ln(F_i)) \qquad \text{(T 5-2)}$$

where

Y_i is the EVI reduced variate corresponding to F_i

F_i is the probability of non-exceedance, and ln represents the natural logarithms.

Table T 5.2 also shows the value of EVI reduced variate cprresponding to each peak discharge values of Br. No. 489.

TABLE T 5-2

PLOTTING POSITION AND CORRESPONDING EVI REDUCED VARIATE FOR THE PEAK FLOOD VALUES AT BR. ON. 489

Sl. No.	Year	Observed peak flood (cumecs)	Peak flood arranged in ascending order (cumecs)	Rank	Plotting positions F_i	EV I Reduced variate y_i
1	1958	453*	82*	1	0.02422	—1.314
2	1959	1399*	304	2	0.06747	—0.992
3	1960	1234*	370*	3	0.11073	—0.789
4	1961	1523*	415	4	0.15398	—0.626
5	1962	1070*	453	5	0.19723	—0.485
6	1963	741*	535	6	0.24048	—0.354
7	1964	1605	554	7	0.28374	—0.231
8	1965	82*	610	8	0.32699	—0.111
9	1966	370	615	9	0.37024	0.006
10	1967	1254	741*	10	0.41349	0 124
11	1968	615	805	11	0.45675	0.244
12	1969	304	820	12	0.50000	0.367
13	1970	1603	830	13	0.54325	0.494
14	1971	554	1070*	14	0.58651	0.628
15	1972	535	1158	15	0.62976	0.771
16	1973	1158	1200	16	0.67301	0.926
17	1974	610	1234*	17	0.71626	1.097
18	1975	820	1254	18	0.75952	1.291
19	1976	3000	1399*	19	0.80277	1.516
20	1977	805	1523*	20	0.84602	1.788
21	1978	1200	1603	21	0.88927	2.143
22	1979	415	1605	22	0.93253	2.661
23	1980	830	3000	23	0.97578	3.708

*Indicates the estimbed peak values.

(e) Plot the Peak discharge values against their corresponding EVI reduced variate on ordinary graph paper for each gauging site and draw a line either by eye judgement or by linear regression excluding the generated peak values as they are only used for assigning the plotting positions (Here line is drawn by linear regression). In case EVI probability paper is available, the peak discharge values may be plotted against their plotting positions F_i without going for the computation of EVI reduced variates. These plots are known as frequency curves as shown in figure T 5-1 for the peak flow values at Br. No. 489.

(f) Compute the upper and lower limit of 95% confidence level on regression line using the following steps.

(i) Let $\overline{Q'_k} = a + by_k$ is a regression line

where $\overline{Q'_k}$ is the predicted k_{th} mean value of peak discharge,

y_k is the EVI reduced variate corresponding to kth observation computed from equation T 5-2 and

a and b are the parameters to be estimated by the linear regression.

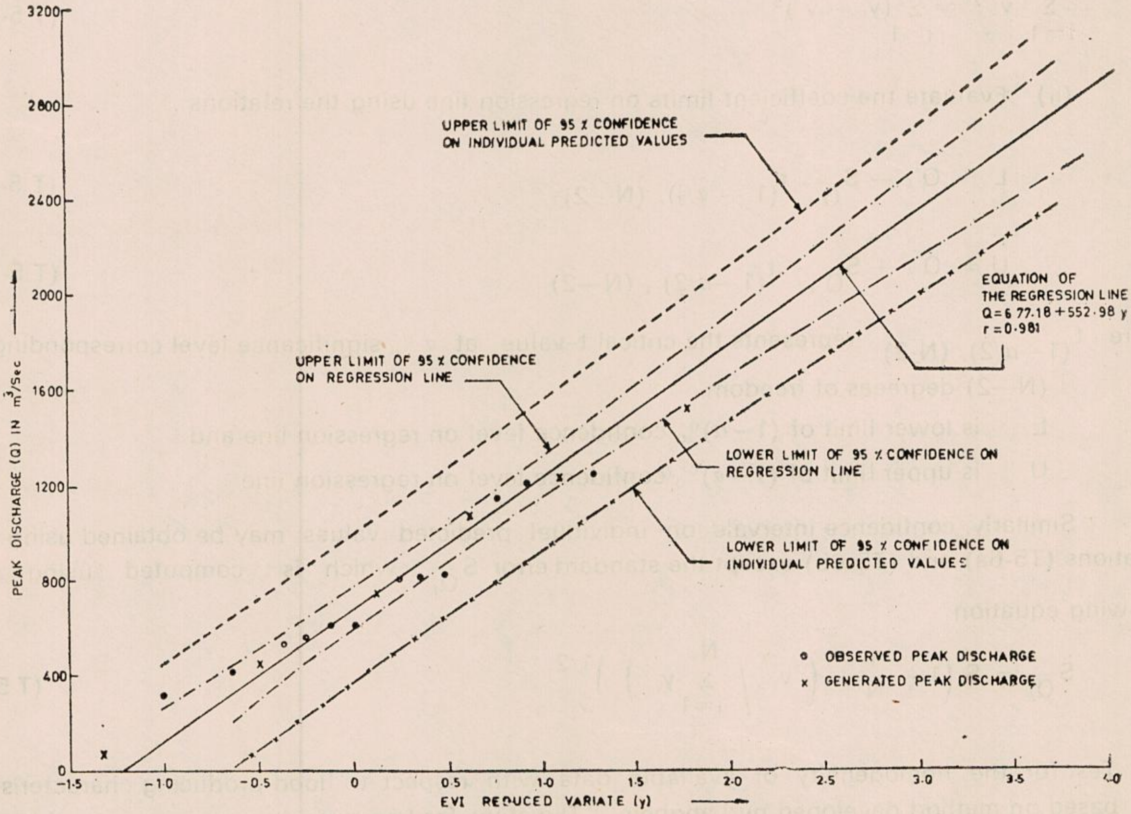

Fig. T 5-1. Plot Between Peak Discharge and EV1 Reduced Variate for BR. No. 489

Estimate the standard error of Q_k using the relation

$$S_{\overline{Q'_k}} = S\ (1/N + y_k'^2 \Big/ \sum_{i=1}^{N} y_i'^2)^{1/2} \qquad \text{(T 5-3)}$$

where,

$S_{\overline{Q'_k}}$ is the standard error of $\overline{Q'_k}$

S is the standard error of regression equation evaluated from

$$S = \sqrt{\sum_{i=1}^{N} (Q_i - Q_i')^2 \Big/ (N-2)} \qquad \text{(T 5-4)}$$

Q_i is the itn value of observed peak flood series;

Q'_i is the ith value of computed peak flood;

N is the no. of observations considered for regression ;

y_k is the kth value of EVI reduced variate, and;

$\bar{y}$ is the mean of the N values of EVI reduced variate.

$$y'_k = (y'_k - \bar{y}) \qquad \text{(T 5-5a)}$$

$$\sum_{i=1}^{N} y_k'^2 = \sum_{i=1}^{N} (y_i - \overline{y})^2 \qquad \text{(T 5-5b)}$$

(ii) Evaluate tne coefficient limits on regression line using the relations :

$$L = \overline{Q'_k} - S_{\overline{Q'_k}}\ t_{(1-\alpha/2),\ (N-2)} \qquad \text{(T 5-6a)}$$

$$U = \overline{Q'_k} + S_{\overline{Q'_k}}\ t_{(1-\alpha/2)\ ,\ (N-2)} \qquad \text{(T 5-6b)}$$

where $t_{(1-\alpha/2),\ (N-2)}$ represents the critical t-value at α % significance level corresponding to (N—2) degreees of freedom.

L is lower limit of $(1-\alpha)$% confidence level on regression line and

U is upper limit of $(1-\alpha)$% confidence level on regression line.

Similarly, confidence intervals on individual predicted values may be obtained using the equations (T5-6a) and (T5-6b) except the standard error $S_{\overline{Q_k}}$ which is computed using the following equation :

$$S_{\overline{Q_k}} = S\left(1 + \frac{1}{N} + \left(y_k'^2 \Big/ \sum_{i=1}^{N} y_i' \right) \right)^{1/2} \qquad \text{(T 5-7)}$$

(g) Test for the homogeneity of available data with respect to flood producing characteristics based on method developed by Langbein. The steps for homogeneity test are :

(i) Compute the EVI reduced variate carresponding to 10 year return period flood using the relaltion :

$$Y_T = -\ln\left(-\ln\left(1-\frac{1}{T}\right)\right) \quad \text{(T 5-8)}$$

for example $Y_{10} = -\ln\left(-\ln\left(1-\frac{1}{10}\right)\right)$

$= 2.25$

(ii) Compute the 10 year flood by putting Y_{10}=2.25 in the linear regression equations developed at Step (e) for the different catchments.

(iii) Repeat Step (i) and (ii) to compute 2.33 year flood which is the annual mean flood for EVI distribution.

(iv) Compute the ratio ef 10 year flood to annual mean flood ($Q_{2\cdot33}$) at each gauging site The ratio is known as the frequency ratio.

(v) Average the frequency ratios of all the gauging sites to obtain the mean 10 year frequency ratio for the subzone as a whole (Table 5-3).

TABLE T 5-3

COMPUTATION OF FREQUENCY RATIO ($Q_{10}/Q_{2\cdot33}$) FOR DIFFERENT BRIDGE CATCHMENTS OF MAHANADI BASIN

S. No.	Br. No.	Stream	Equation of the regression line	Mean annual flood $Q_{2\cdot33}$ (m^3/sec)	10 year flood Q_{10} (m^3/sec)	$Q_{10}/Q_{2\ 33}$ $= a$
1	12	Nilagarh	Q_T = 376.32 + 165 35 y_T	472	748	1.58
2	48	Barjnora	Q_T = 84.90 + 130 47 y_T	160	378	2.36
3	59 (KGP)	Lahardonga	Q_T = 45.19 + 36.46 y_T	66	127	1 92
4	66 K	Malania	Q_T = 214.27 + 178.70 y_T	318	616	1.94
5	176	Sildha	Q_T = 36.44 + 40.04 y_T	60	126	2.11
6	308	Kolera	Q_T = 33.54 + 17.98 y_T	44	74	1.68
7	325	Kujanjnor	Q_T = 23.90 + 23.11 y_T	37	76	2.05
8	332 (NGP)	Parri	Q_T = 96.09 + 114.09 y_T	162	353	2.18
9	698	Bisra	Q_T = 164.43 + 108,72 y_T	227	409	1 80
10	40 K	Sagar	Q_T = 193.14 + 162.96 y_T	287	560	1.95
11	121	Kelo	Q_T = 538.04 + 422.07 y_T	782	1488	1.90
12	385	Sandyl	Q_T = 93.29 + 60.45 y_T	128	229	1.79
13	332 (KGP)	Pithakalia	Q_T = 44.64 + 36.15 y_T	66	126	1.91
14	59 (BSP)	Jetha	Q_T = 145.35 + 141.75 y_T	227	464	2.05
15	489	Karo	Q_T = 677.18 + 552.98 y_T	997	1921	1.93
16	154	Ahera	Q_T = 91.58 + 67.86 y_T	131	244	1.86
17	42	Barjhora	Q_T = 41.99 + 29.99 y_T	59	109	1.86
18	69	Barai	Q_T = 172.43 +78.74 y_T	218	350	1.60

Mean a = 1.92

(vi) Determine the EV1 reduced variate corresponding to the product of annual mean flood and the average 10 year frequency ratio from the linear regression equations developed at Step (e). (Table T 5-4).

TABLE 5-4

RETURN PERIOD PEAK FLOWS FOR DIFFERENT BRIDGE CATCHMENTS OF MAHANADI BASIN USING MEAN FREQUENCY RATIO ($\bar{\alpha}$) OF 10 YEAR FLOOD

S. No.	Br. No.	$Q_T = \bar{\alpha}\, Q_{2.33}$ (cumec)	Equations for the conputation of y_T	y_T	T (years)	Period of record available (Years)
1	12	906.24	$y_T = (Q_T - 376\ 32)/165.35$	3.205	25.16	23
2	48	307.20	$y_T = (Q_T - 84.90)/130.47$	1.704	6.01	22
3	59 (KGP)	126.72	$y_T = (Q_T - 45.19)/36.46$	2.236	9.86	22
4	66 K	610.56	$y_T = (Q_T - 178.70)/214.24$	2.218	9.70	23
5	176	115.20	$y_T = (Q_T - 36.44)/40.04$	1.967	7.66	23
6	308	84.48	$y_T = (Q_T - 33.54)/17.98$	2 833	17.50	20
7	325	71.04	$y_T = (Q_T - 23.90)/23.11$	2.0398	8.20	14
8	332 (NGP)	311.04	$y_T = (Q_T - 96.09)/114.09$	1.884	7.09	16
9	698	435.84	$y_T = (Q_T - 164.43)/108.72$	2.496	12.64	16
10	40 K	551.04	$y_T = (Q_T - 193.14)/162.96$	2.196	9.50	15
11	121	1501.44	$y_T = (Q_T - 538.04)/422.07$	2.283	10.31	15
12	385	245.76	$y_T = (Q_T - 93.29)/60.45$	2.522	12.96	15
13	332 (KGP)	126 72	$y_T = (Q_T - 44.64)/36.15$	2.271	10.19	15
14	59 (BSP)	435.84	$y_T = (Q_T - 143.35)/141.75$	2.049	8.27	14
15	489	1914.24	$y_T = (Q_T - 677.18)/552.98$	2.237	9.87	14
16	154	251.52	$y_T = (Q_T - 91.58)/67.86$	2.357	11.07	13
17	42	113.28	$y_T = (Q_T - 41.99)/29.99$	2.377	11.28	12
18	69	418.56	$y_T = (Q_T - 172.43)/78.74$	3.126	23.29	11

(vii) Plot the EV1 reduced variate obtained from Step (vi) against the effective length of records for that station on a test graph where upper and lower regional limit of 95% confidence are already plotted using the following co-ordinate pairs (Fig. T 5.2).

Sample size	*Lower limit*	*Upper limit*
5	—0.59	5.09
10	0.25	4.25
20	0.83	3.67
50	1.35	3.15
100	1.52	2.88

As the points for all stations lie between the 95% confidence limits as shown in fig. T 5-2 they are considered homogeneous.

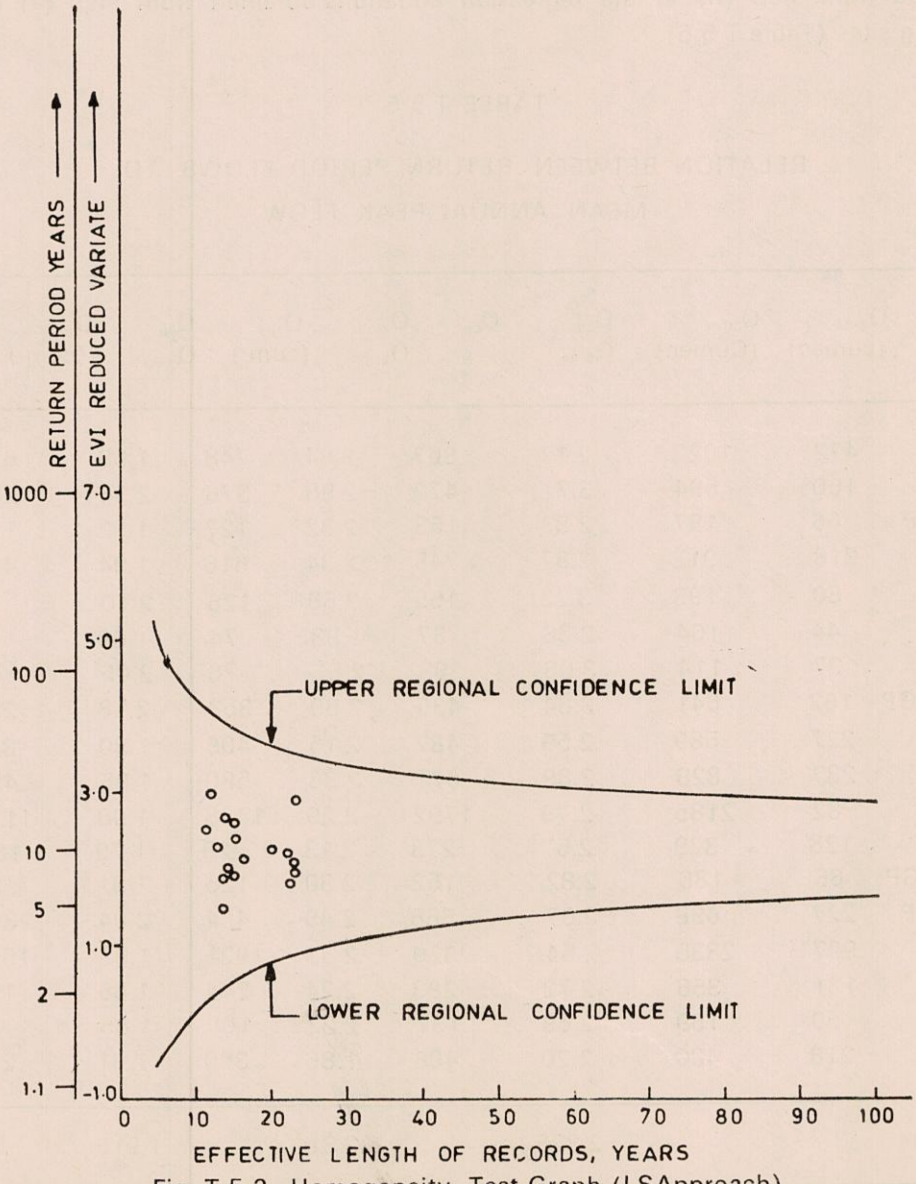

Fig. T 5-2. Homogeneity Test Graph (LSApproach)

(h) Compute the EV 1 reduced variate corresponding to 50, 20, 10, 5, and 2.33 years return period using the equation T 5-8 and they are listed below :

Return period (years) (T)	EVI reduced variate (Y_T)
2.33	0.500
5	1.50
10	2.25
20	2.97
50	3.90

(i) Compute the flood of 50, 20, 10, 5 and 2.33 years using the values of EVI reduced variate obtained from step (h) in the regression equations obfained from step (e) for different gauging sites (Table T 5-5).

TABLE T 5-5

RELATION BETWEEN RETURN PERIOD FLOWS TO MEAN ANNUAL PEAK FLOW

Sl. No.	BR. NO.	$Q_{2\cdot33}$ (cumec)	Q_{50} (Cumec)	$\frac{Q_{50}}{Q_{2\cdot33}}$	Q_{20}	$\frac{Q_{20}}{Q_{2\cdot33}}$	Q_{10} (cum.)	$\frac{Q_{10}}{Q_{2\cdot33}}$	Q_5 (cum.)	$\frac{Q_5}{Q_{2\cdot33}}$
1	12	472	1022	2.17	867	1.84	748	1.58	624	1.32
2	48	160	594	3.71	472	2.95	378	2.36	281	1.76
3	59 KGP	66	187	2.83	153	2.32	127	1.92	100	1.52
4	66 K	318	912	2.87	745	2.34	616	1.94	482	1.52
5	176	60	193	3.22	155	2 58	126	2.10	97	1.61
6	308	44	104	2.36	87	1.98	74	1.68	61	1.39
7	325	37	114	3.08	93	2.51	76	2.05	59	1.59
8	332 NGP	162	541	3.34	435	2.69	353	2.18	267	1.65
9	698	227	589	2.59	487	2.15	409	1.80	328	1.44
10	40 K	287	829	2.89	677	2.36	560	1.95	438	1.53
11	121	782	2185	2.79	1792	2.29	1488	1.90	1171	1.50
12	385	128	329	2.57	273	2.13	229	1.79	184	1.44
13	332 KGP	66	186	2.82	152	2.30	126	1 91	99	1.50
14	59 BSP	227	698	3.07	566	2.49	464	2.04	358	1.58
15	489	997	2835	2.84	2320	2.33	1921	1.93	1507	1.51
16	154	131	356	2.72	293	2.24	244	1.86	193	1.47
17	42	59	159	2.69	131	2.22	109	1.85	87	1.47
18	69	218	480	2 20	406	1.86	350	1.61	291	1.33
Median values				2.825		2.31		1.915		1.51

(j) Compute the frequency ratios of floods of 50, 20, 10 and 5 years to annual mean flood ($Q_{2.33}$) as listed in table T 5-5.

(k) Work-out the median values of the frequency ratios and draw the regional frequency curve taking these median values of the frequency ratios against the EVI reduced variate (return periods) as shown in Fig. T 5-3.

(l) Correlate the computed logarithm of annual mean flood values for each gauging sites with their corresponding logaritem of catchment area and draw the best fit line either by eye judgement or by linear regression (Fig. T 5-4). Here the line is linear regression.

(m) Compute the discharge of different return period for any ungauged catchment in the subzone using the following steps :

(i) Find out the drainage area from areal survey or toposheets.

(ii) From Fig. T 5-4 read the value of the annual mean flood peak ($Q_{2.33}$) for the corresponding drainage area of the site of interest.

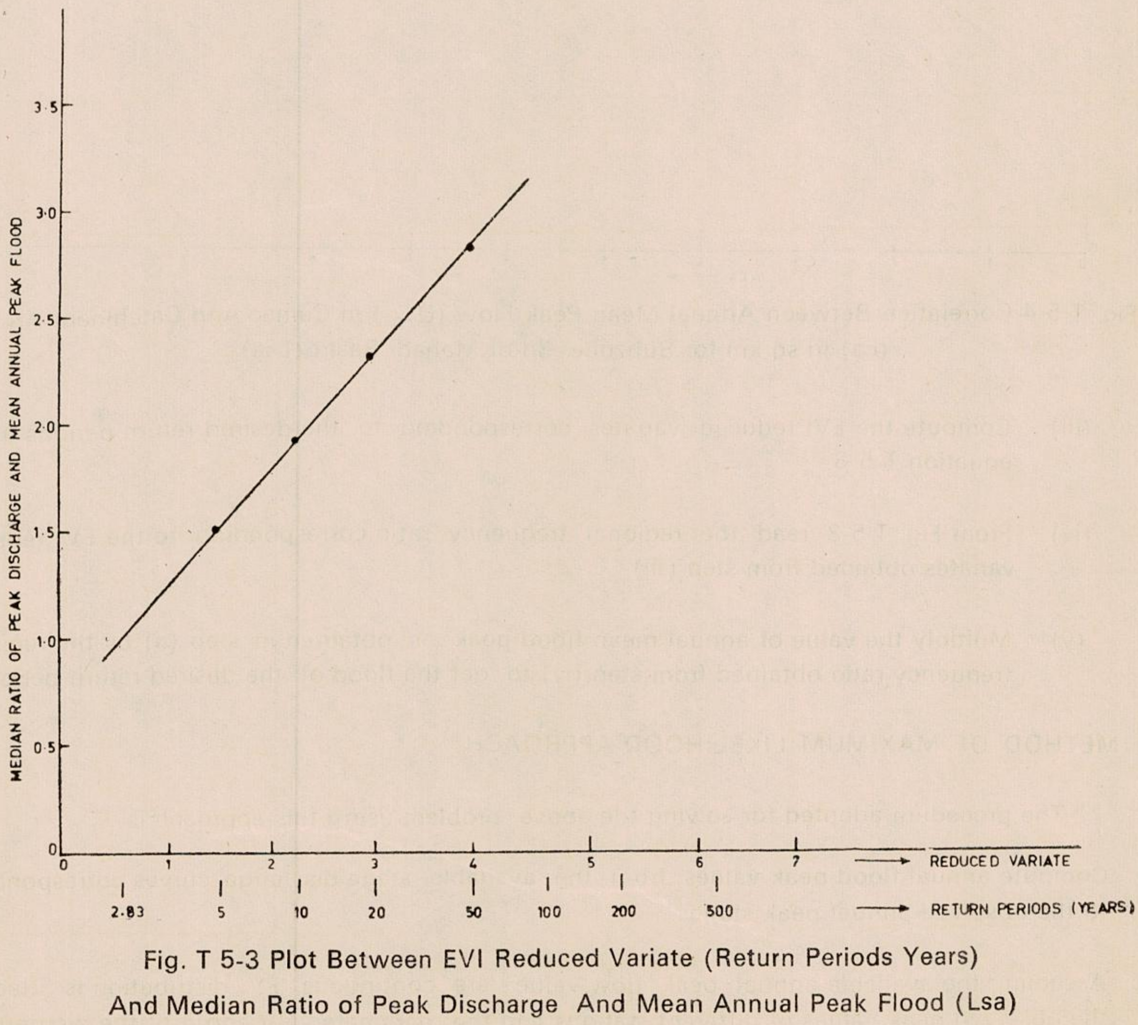

Fig. T 5-3 Plot Between EVI Reduced Variate (Return Periods Years)
And Median Ratio of Peak Discharge And Mean Annual Peak Flood (Lsa)

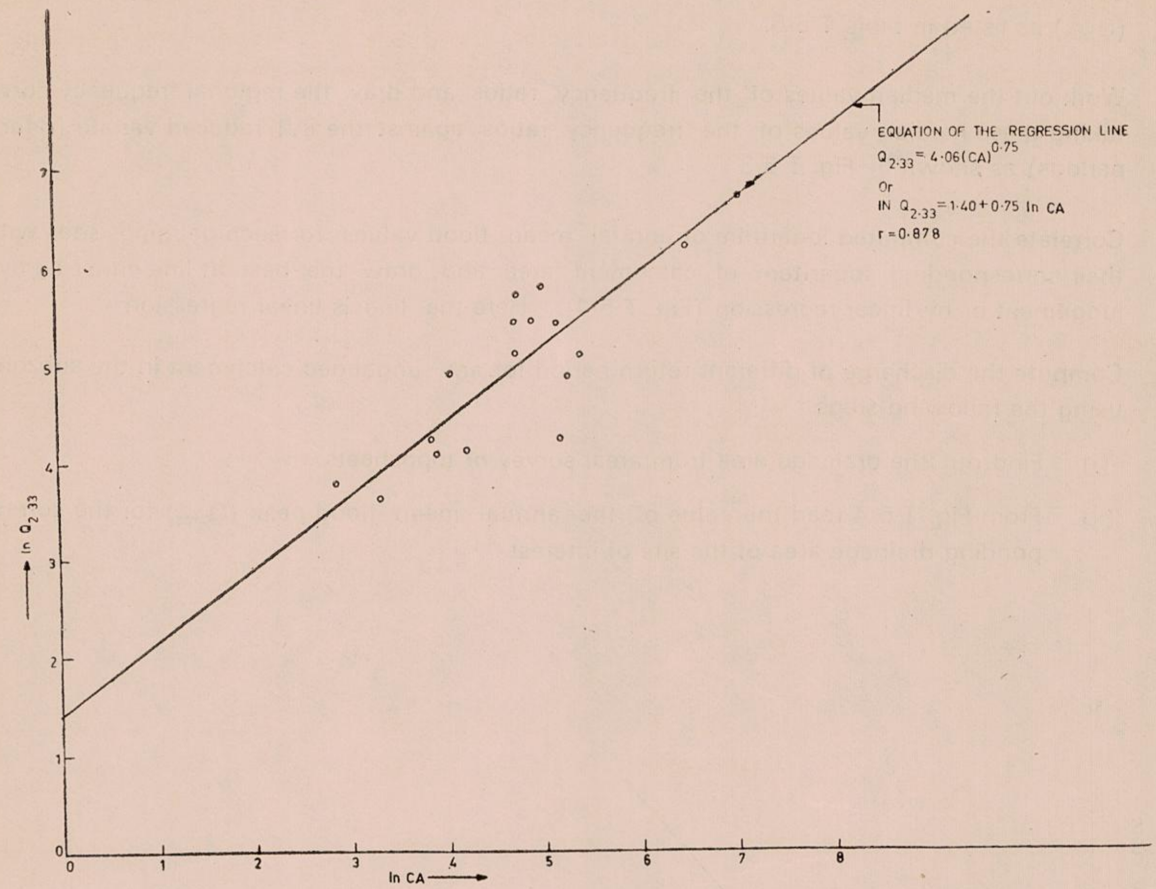

Fig. T 5-4 Correlatien Between Annual Mean Peak Flow ($Q_{2\cdot33}$) in Cumec And Catchment Area (ca) in sq km for Subzone 3d of Mahadi Basin (Lsa)

(iii) Compute the EVI reduced variates corresponding to the desired return periods using equation T 5-8.

(iv) From Fig. T 5-3 read the regional frequency ratio corresponding to the EVI reduced variates obtained from step (iii).

(v) Multiply the value of annual mean flood peak as obtained in step (ii) by the regional frequency ratio obtained from step (iv) to get the flood of the desired return period.

II. METHOD OF MAXIMUM LIKELIHOOD APPROACH

The procedure adopted for solving tde above problem using this approach is :

(a) Compute annual flood peak values from the available stage discharge curves corresponding to the observed annual peak stages.

(b) Assuming the available annual peak flow values are continuous, EVI distribution is fitted for the observed peak values of different stations and the parameters, u and α of the distribution are estimated using method of maximum likelihood. The values of the parameters, u and α for the eighteen gauging sites are given in table T 5-6.

(c) Test for the homogeneity of available data with respect to flood producing characteristics based on the method developed by Lengbein. The steps for homogeneity test are :

(i) Compute 10 year flood using the following equations for each gauging site ;

$$Q_{10} = u + \alpha Y_{10} \tag{T 5-9a}$$

$$Y_{10} = -\ln\left(-\ln\left(1 - \frac{1}{10}\right)\right) \tag{T 5-9b}$$

$$= 2.25$$

Therefore

$$Q_{10} = u + 2.25\,\alpha \tag{T 5-9c}$$

(ii) Compute 2.33 year flood using the equations :

$$Q_{2.33} = u + \alpha Y_{2.33} \tag{T 5-10a}$$

$$Y_{2.33} = -\ln\left(-\ln\left(1 - \frac{1}{2.33}\right)\right) \tag{T 5-10b}$$

$$Q\,2.33 = u + 0.5785\,\alpha \tag{T 5-10c}$$

TABLE 5-6

PARAMETERS OF EVI DISTRIBUTION FOR DIFFERENT GAUGING SITES (MML)

S. No.	Bridge No.	Stream	Parameter values	
			u	α
1	12	Nilagarh	375.51	156.75
2	48	Barjhora	93.71	91.73
3	59 (KGP)	Lahardorya	46.63	30.43
4	66 K	Malania	215.46	155.12
5	176	Sildha	38.94	29.84
6	308	Kolera	30.45	18.44
7	325	Kujanjhor	30.27	23.61
8	332 (NGP)	Parri	148.24	105.47
9	698	Bisra	137.49	96.63
10	40 K	Sagar	181.95	159.45
11	121	Kelo	757.64	431.79
12	385	Sandyl	75.30	57.85
13	332 (KGP)	Pithakalia	49.57	24.45
14	59 (BSP)	Jetha	171.47	146.00
15	489	Karo	716.95	395.29
16	154	Ahera	69.59	41.53
17	42	Barjhora	57.48	22.36
18	69	Barai	161 73	83.23

(iii) Compute the ratio of 10 year peak flood to annual mean flood ($Q_{2\cdot33}$) at each gauging site. The ratio is known as the frequency ratio.

(iv) Average the frequency ratios of all the gauging sites to obtain the mean 10 year frequency ratio for the subzone as a whole (Table T 5-7)

(v) Determine the return period corresponding to the product of annual mean flood and the average 10 year frequency ratio (Q') using the following equations :

$$y_T = \frac{Q' - u}{a} \tag{T 5-11a}$$

$$T = \frac{1}{1 - \exp(-\exp(-y_T))} \tag{T 5-11b}$$

The values of these return periods are given in column (9) of the table T 5-7.

(vi) Plot the return periods (or corresponding EVI reduced variate y_T) obtained from step (v) against the effective length of records for that station on a test graph where upper and lower regional limit of 95% confidence are already plotted using the following pairs of coordinates.

TABLE 5-7

RETURN PFRIOD PEAK FLOWS FOR MAHANADI BASIN (SUB 3d)

Sl. No.	Stream	Bridge No.	Drainage area (Sq. Km.)	Mean annual flood $Q_{2\cdot33}$ (cumecs)	10 yr. flood Q_{10} (cum.)	Ratio $Q_{10}/Q_{2\cdot33} = Q_r$	$Q' = Q_r\,Q_{2\cdot33}$ (cumecs)	T for Q' (yrs.)	Period of record available (yrs.)
1	2	3	4	5	6	7	8	9	10
1.	Nilagarh	12	665.53	466.0	728	1.56	834	19.14	23
2.	Barjhora	48	108.52	147	300	2.04	263	6.84	22
3.	Lahardonga	59KGP	47.00	64	115	1.80	115	9.96	22
4.	Molania	66K	154.13	305	565	1.85	546	8 93	23
5.	Sildha	176	65.79	56	106	1.89	100	8.25	23
6.	Kolera	308	17.48	41	72	1.76	73	10.56	20
7.	Kujanjhor	325	26.77	44	83	1.89	79	8.39	14
8.	Parri	332 (NGP)	225.00	209	386	1.85	374	9.02	16
9.	Bisra	698	112.66	193	354	1.83	346	9.16	16
10.	Sagar	40K	115.25	274	541	1.97	490	7.42	15
11.	Kelo	121	1150.00	1007	1729	1.72	1802	11.73	15
12.	Sandyal	385	194.25	109	205	1.88	195	8.43	15
13.	Pithakalia	332 (KGP)	175.16	64	105	1.64	115	15.03	15
14.	Jetha	59 (BSP)	135.70	256	500	1.95	458	7.62	14
15.	Karo	489	823.00	946	1607	1.69	1693	12.32	14
16.	Ahera	154	58.09	94	163	1.73	168	11.20	13
17.	Barjhar	42	49.00	70	108	1.54	125	20.99	12
18.	Barai	69	172.78	210	349	1.66	376	13.63	11

Mean $Q_r = 1.79$

Sample size	Lower limit		Upper limit	
	EVI Reduced variate	Return period	EVI Reduced variate	Return period
5	—0.59	1.2	5.09	160
10	0.25	1.8	4.25	70
20	0.83	2.8	3.67	40
50	1.35	4.4	3.15	24
100	1.62	5.6	2.88	18

The points for all stations lie between the 95% confidence limits (shown in fig. T 5-5).

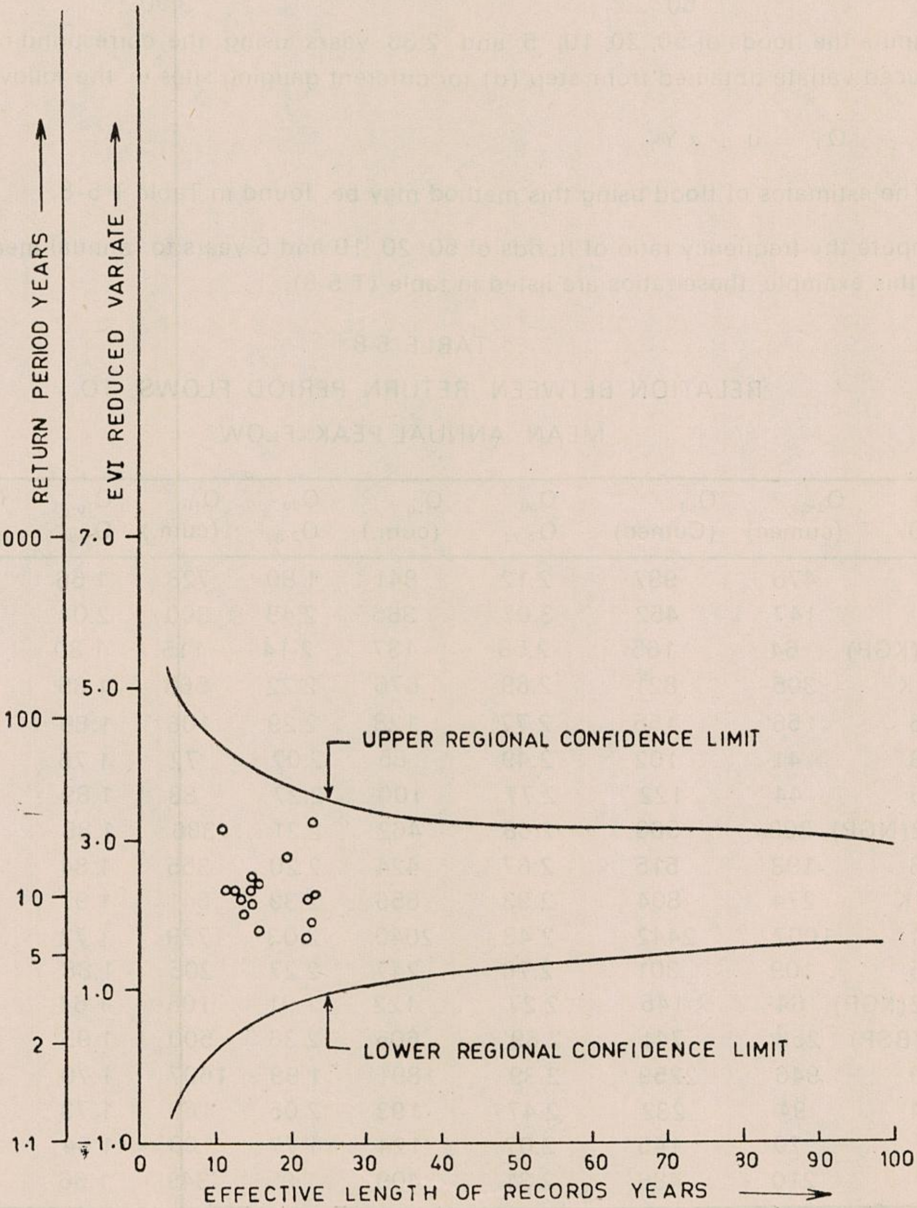

Fig. T 5-5 Homogeneity Test Graph (Maximum Likelihood Method)

(d) Compute the EVI reduced variate corresponding to 50, 20, 10, 5 and 2.33 years return period using the equation T 5-8.

The values of EVI reduced variate corresponding to the return periods are

Return period (years) (T)	EV1 reduced variate (y_T)
2.33	0.50
5	1.50
10	2.25
20	2.97
50	3.90

(e) Compute the floods of 50, 20, 10, 5 and 2.33 years using the corresponding values of EVI reduced variate obtained from step (d) for different gauging sites in the following equation :

$$Q_T = u + \alpha Y_T \qquad (T\ 5\text{-}12)$$

The estimates of flood using this method may be found in Table T 5-8.

(f) Compute the frequency ratio of floods of 50, 20, 10 and 5 years to annual mean flood ($Q_{2\cdot 33}$). For this example, these ratios are listed in table (T 5-8).

TABLE 5-8

RELATION BETWEEN RETURN PERIOD FLOWS TO MEAN ANNUAL PEAK FLOW

Sl. No.	BR. NO.	$Q_{2\cdot 33}$ (cumec)	Q_{50} (Cumec)	$\frac{Q_{50}}{Q_{2\cdot 33}}$	Q_{20} (cum.)	$\frac{Q_{20}}{Q_{2\cdot 33}}$	Q_{10} (cum.)	$\frac{Q_{10}}{Q_{2\cdot 33}}$	Q_5 (cum.)	$\frac{Q_5}{Q_{2\cdot 33}}$
1	12	476	987	2.12	841	1.80	728	1.56	611	1.31
2	48	147	452	3.07	366	2.49	300	2.04	231	1.57
3	59(KGP)	64	165	2.58	137	2.14	115	1.80	92	1.44
4	66 K	305	821	2.69	676	2.22	565	1.85	448	1.47
5	176	56	155	2.77	128	2.29	106	1.89	84	1.50
6	308	41	102	2.49	85	2.07	72	1.76	58	1.41
7	325	44	122	2.77	100	2.27	83	1.89	66	1 50
8	332(NGP)	209	560	2.68	462	2.21	386	1.85	306	1.46
9	698	193	515	2.67	424	2 20	355	1.84	282	1.46
10	40 K	274	804	2.93	656	2.39	541	1.97	421	1.54
11	121	1007	2442	2.43	2040	2.03	1729	1.72	1405	1.40
12	385	109	301	2.76	247	2.27	205	1.88	162	1.49
13	332(KGP)	64	145	2.27	122	1.91	105	1 64	86	1.34
14	59(BSP)	256	741	2.89	605	2.36	500	1.95	390	1.52
15	489	946	2259	2.39	1891	1.99	1607	1.70	1310	1.38
16	154	94	232	2.47	193	2.05	163	1.73	132	1.40
17	42	70	145	2.07	124	1.77	108	1.54	91	1.30
18	69	210	486	2.31	409	1.95	349	1.66	287	1.37
Median values				2.625		2.17		1.03		1.45

(g) Work out the median values of the frequency ratios and draw the regional frequency curve taking these median values of the frequency ratios against the EVI reduced variate return periods (as shown in Fig. T 5-6).

(h) Correlate the computed annual mean flood values of each gauging site with their corresponding catchment area and draw the best fit line either by eye judgement or by linear regression (Fig. T 5-7). Here the line is drawn after performing the linear regression.

(i] Compute tha discharge of different return period for any ungauged catchment in the subzone using the following steps :

(i) Find out the drainage area from areal survey or toposeeets.

(ii) From fig. T 5-7 read the value of the annual mean flood peak ($Q_{2 \cdot 33}$) for the corresponding drainage area of the site of interest.

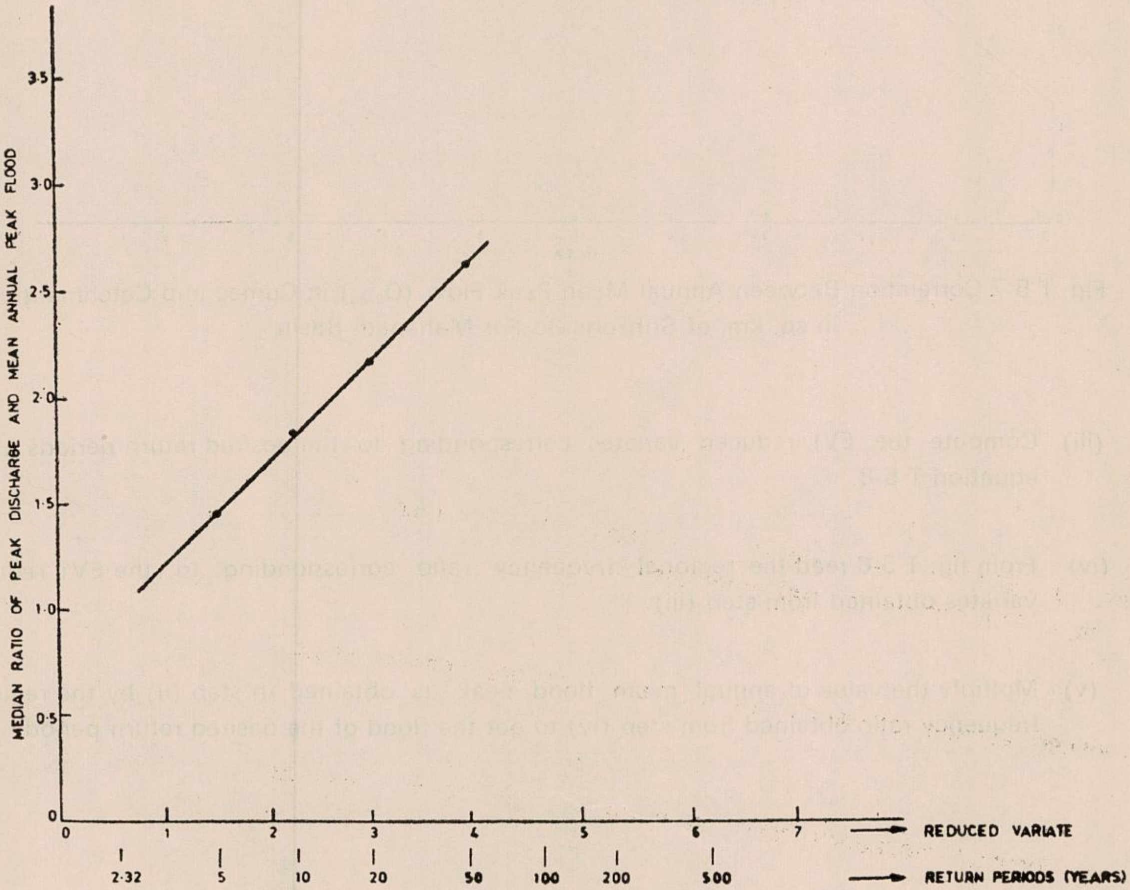

Fig. T 5-6 Plot Between Ev1 Reduced Variate (Return Periods, Years) And Median Ratio of Peak Discharge And Mean Annual Peak Flow (Mlh)

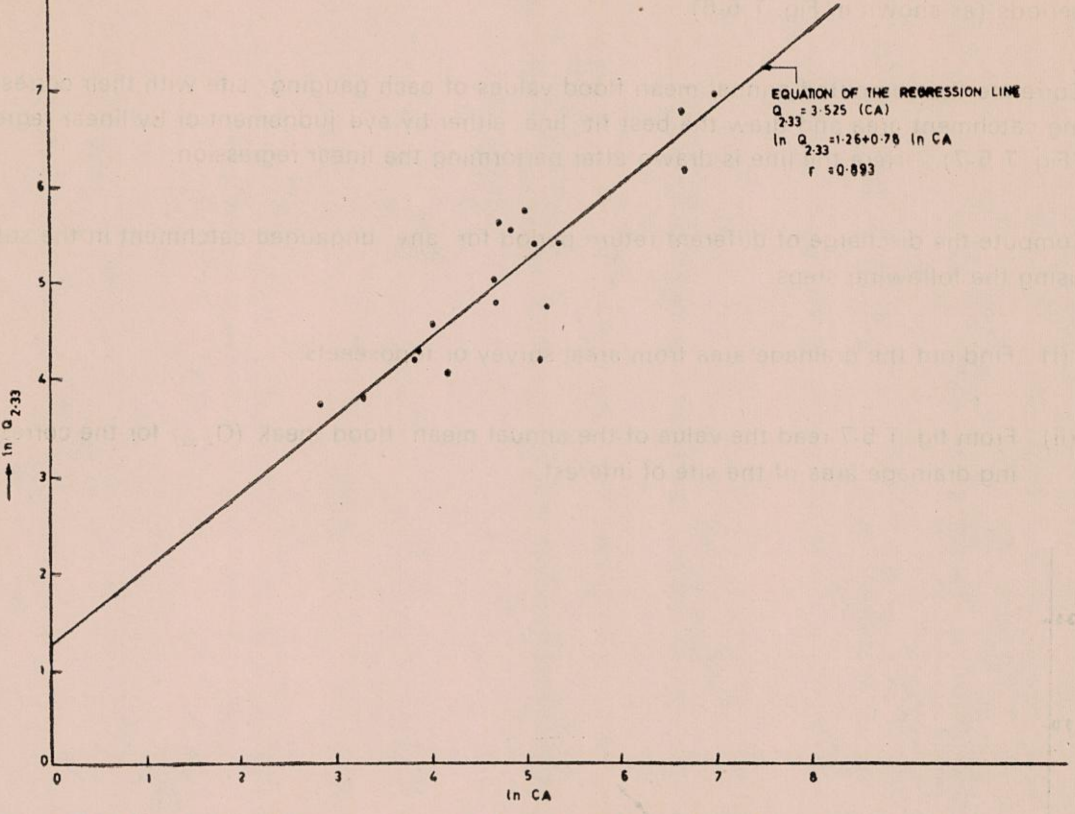

Fig. T 5-7 Correlation Between Annual Mean Peak Flow ($Q_{2\cdot33}$) in Cumec and Catchment in sq. km. of Subzone 3d For Mahanadi Basin

(iii) Compute the EVI reduced variates corresponding to the desired return periods using equation T 5-8.

(iv) From fig. T 5-6 read the regional frequency ratio corresponding to the EV1 reduced variates obtained from step (iii).

(v) Multiply the value of annual mean flood peak as obtained in step (ii) by the regional frequency ratio obtained from step (iv) to get the flood of the desired return period.