FLOOD FREQUENCIES IN SOAN VALLEY

I. Ahmad, Z. Ahmad* and S. A. Ahmad**

College of Earth and Environmental Sciences, Punjab University, Lahore
*Department of Earth Sciences, Qaid-e-Azam University, Islamabad
**Institute of Geology, Punjab University, Lahore
Corresponding author e-mail: hydromod@yahoo.com

ABSTRACT: Estimation of peak floods in a watershed where industrial and housing development is present always has prime importance to determine extent of flooding and its damage. Such type of estimation guides that these developments are safer during flooding or not. Soan valley is one of the important valley in which major cities like Rawalpindi, Attock and a part of Islamabad is located. This study is based on long term recorded flood data along the Soan river at various locations. Detailed flood frequency analysis was carried to select the best fit frequency models at various locations in Soan river. The data were processed to check its consistency and outliers. The estimated peak of the floods in Soan at Chirah, Rawalpindi and Dhok Pathan for 100 year return period worked out to be 3787, 5752 and 9842 m^3/sec respectively. These results may be helpful for future development along the river by determining the elevation of flood encroachments along the banks.

Key word: Peak floods, flood frequency, outliers, catchment, gauging stations, return period.

INTRODUCTION

Estimation of flooding in Soan valley has great importance, because the river crosses Rawalpindi and Attock districts where a lot of industrial and housing development along the river banks has been made. Soan river is one of the left bank tributary of Indus river. It lies between Longitude 71^0 45' to 73^0 35' and Latitude 32^0 45' to 33^0 55'. This study may be useful to determine the extent of flooding and its damage in the area.

The Cathment Area: Soan valley is a part of Potohar Plateau, lies to the south of northern mountains. (Figure-1). Soan river originates from Muree hills and passing through the steep slopes (about 3.78 %), it enters the plains near Chirah. Simly dam is located 13.9 km upstream of Chirah on Soan river. Rawal dam on Soan is situated near capital Islamabad. Four major streams Ling river, Korang river, Sil river and Lai nullah contributes flood to the Soan River. Total length of main river is 274 km. (Jehanzeb, 2004) The catchment area upto Dhok Pathan gauging station is 6475 sq km.

The area has 305-610 m relief. The landscape is broken terrain characterised by undulations and irregularities. Soan River flows from east to the west and after crossing the region in the north and in the middle respectively; falls in the Indus. Agriculture is dependent on rainfall of 750-1400 mm and on the small dams built in the catchment areas of the streams. Fields of wheat, barley, jowar, bajra and pulses are found in the valley and on the terraced slopes along river banks. The region is also known for its the ancient civilization sites in Soan valley, the capital, Islamabad, which stands north of the old city of Rawalpindi at the southern slops of Murree hills.

Figure 1 Location of study area

METHODOLOGY

Flood frequencies are important parameters to determine the extent of flooding for different return periods (US Water Resources Council, 1981). This may be better choice compared to PMP study (probable maximum precipitation) where the return period of peak flood is not known. In this case instantaneous peak

discharges of the river at various recorded locations were taken from long term data and maximum instantaneous flood of each year was extracted. The data were then processed for outliers and consistency. Outliers are those data points which depart significantly from the trend of the remaining data (Chow et al., 1988). Consistency of data is checked with the help of t-statistics (Kottegoda, 1980). Detail of the methods is not included here to conserve space.

Observed frequency of historic data are required for a comparison with that of theoretical models. Observed frequency (Gringorten, 1963) is computed by choosing one of the following formulas:

	Method	**Formula**
Relative Frequency	n / N	Weibull m / N+1
	Gringorten	(m-0.44) / (N+0.12)
	Hazen	(m-0.50) / N
	Blom	(m-0.375)/ (N+0.25)

Where

N = No. of events in that class

N = No. of data values

M = Rank of data

The four commonly used flood frequency distributions are used in the model to cover all possible aspects employed during a frequency analysis (Chow et al., 1988). These distributions include:

a) Gumbel Extreme Value Type-I

b) Pearson Type-III

c) Log Pearson Type-III

d) Lognormal

The parameters of the distributions can be estimated by 'Method of Moments' or more precisely by 'Method of Maximum Likelihood'. (Haan, 1977, Kite, 1978). To conserve space mathematical description of Gumbel Extreme Value Type-I is presented below:

The probability density function is given by:

$$f(x) = \frac{1}{\alpha} \exp\left[-\left(\frac{x_i - \mu}{\alpha}\right) - \exp\left(-\frac{x_i - \mu}{\alpha}\right)\right]$$

Where

$$\alpha = \frac{\sqrt{6}}{\pi} S_x$$

$$\mu = \bar{x} - 0.5772\,\alpha$$

S_x = Standard Deviation

$\bar{x}$ = Mean

x_i = Data Values

The goodness of fit of these frequency models to the observed data depends upon the standard error, 95% confidence limits and Chi-Square test (Kite, 1978).

The Chi-Square test procedure tabulates a variable into categories and computes a chi-square statistic. This goodness-of-fit test compares the observed and expected frequencies in each category to test either that all categories contain the same proportion of values or that each category contains a user-specified proportion of values. Standard error of an estimated value is a measure of the standard deviation of the estimated event magnitudes computed from samples about the true event magnitude. In its general form, it may be expressed as:

$$S_e = \left[\frac{\Sigma\,(x_i - \bar{x}_i)^2}{n}\right]^{1/2}$$

Where

S_e = Standard Error

x_i = Observed Value

$\bar{x}_i$ = Estimated Value

RESULTS AND DISCUSSION

For estimation of flood frequency, long term flow data of Soan river was collected from WAPDA and processed. The main Soan river is gauged at the three Chirah, Rawalpindi and Dhok Pathan as shown in Figure-2. At these control points, catchment area of Soan, their ground elevation and year of start of flow measurements are presented in Table-1.

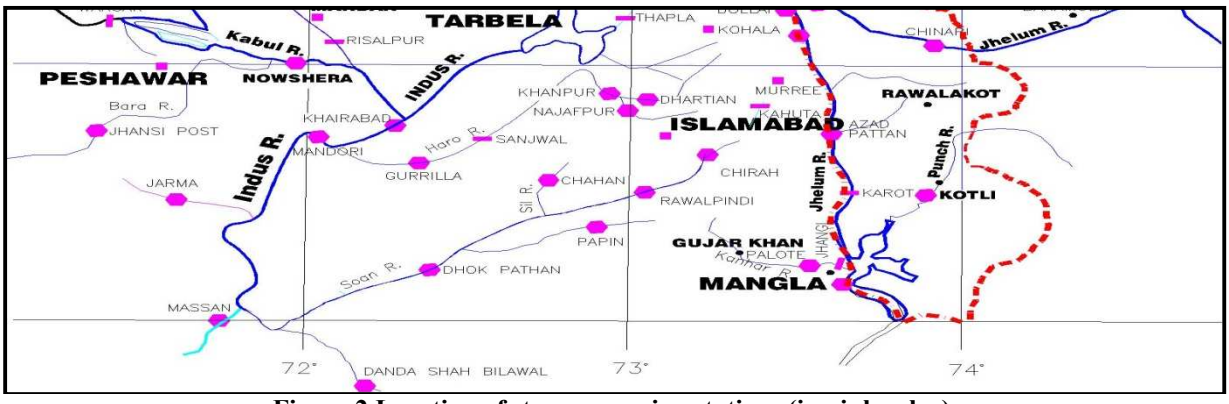

Figure 2 Location of stream gauging stations (in pink color).

Table 1 Hydrometeorological Stations

Station	River	Latitude			Longitude			Catchment Area (km^2)	Elevation (m)	Station Started in year
		0	'	"	0	'	"			
Chirah	Soan	33	39	25	73	18	15	326	562	1960
Rawalpindi	Soan	33	33	05	73	06	05	1684	419	1960
Dhok Pathan	Soan	33	07	32	72	20	05	6475	305	1963

Source: WAPDA, Lahore, (2000)

The instantaneous annual peak discharge of each station was prepared and processed for any outliers and its consistency. The graph showing peak discharges at the three control points are shown in Figure-3.

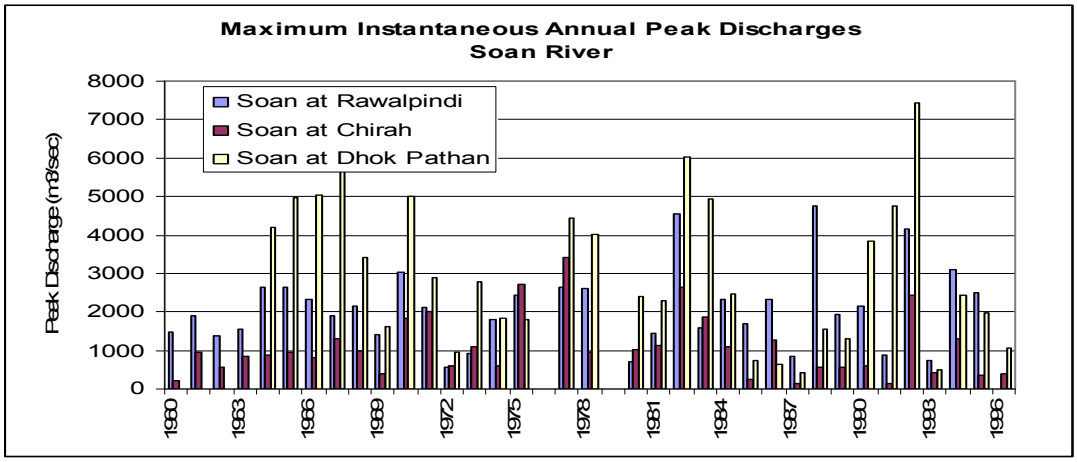

Figure 3 Maximum annual instantaneous peak discharges in Soan river

Table 2 Quality of Hydrological Data

		Outliers		Data	
Station	**River**	**Low**	**High**	**Consistency**	**Remarks**
Chirah	Soan	Nil	Nil	Inconsistent	Not Discarded
Rawalpindi	Soan	Nil	Nil	Consistent	
DhokPathan	Soan	Nil	Nil	Consistent	

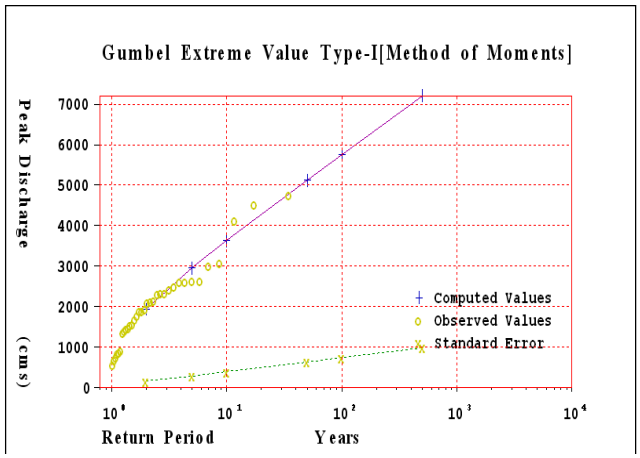

Figure 4 Sample curve showing computed and observed values of peak discharge with its standard error for Soan at Rawalpindi

***Computer Simulation*:** Computer model "Design Flood" (Ahmad and Ahmad, 2003) has been used for the flood frequency analysis. Details about the program may be cited in the User's manual of "Design Flood". (Ahmad, 2000). Each data set is verified for the quality of data. The computer runs gave the following results.

The model is rerun for generating the flood frequency curve for each four distributions with two different methods. In this way total of 24 curves for 3 stations were derived. Sample curve showing computed and observed values of peak discharge with its standard error for Soan at Rawalpindi is presented in Figure-4.

Comparison of results derived by this procedure is presented in Table-3 through 5. Graphical comparison in Figure-5 through 7 shows that frequency models were more sensitive at the tails of curves. Based on the minimum value of Chi Square test, 95% confidence

limits and standard errors, the best fit distribution comes to be Gumbel Extreme Value Type-I for the stations Soan at Rawalpindi and Soan at Dhok Pathan while Pearson Type-III was suited for Soan at Chirah.

Table 3: Summary Results of Flood Frequency Analysis

Soan at Chirah						(m3/sec)
Recurrence	**Gumbel**	**Pearson**	**LogPearson**	**Lognormal**	**Gumbel**	**Lognormal**
Interval	**EV Type-I**	**Type-III**	**Type-III**		**EV Type-I**	
(Years)	MM Method	MM Method	MM Method	MM Method	ML Method	ML Method
2	942	863	863	853	924	840
5	1741	1590	1601	1494	1533	1567
10	2270	2108	2132	2003	1936	2148
50	3434	3283	3328	3350	2824	3694
100	3927	3787	3830	4017	3199	4463
500	5064	4964	4967	5800	4067	6527
1000	5553	5476	5441	6679	4440	7549
10000	7176	7200	6948	10151	5678	11598
Chi Square	11.00	4.14	-	4.71	8.14	4.71

Table 4: Summary Results of Flood Frequency Analysis

Soan at Rawalpindi						(m3/sec)
Recurrence	**Gumbel**	**Pearson**	**LogPearson**	**Lognormal**	**Gumbel**	**Lognormal**
Interval	**EV Type-I**	**Type-III**	**Type-III**		**EV Type-I**	
(Years)	MM Method	MM Method	MM Method	MM Method	ML Method	ML Method
2	1935	1908	1950	1882	1926	1932
5	2957	2840	2891	2770	2837	2855
10	3634	3445	3458	3392	3440	3453
50	5123	4725	4544	4839	4767	4744
100	5752	5248	4946	5485	5328	5287
500	7207	6430	5767	7069	6624	6550
1000	7832	6929	6082	7793	7182	7102
10000	9909	8568	6990	10405	9032	8991
Chi Square	3.06	3.06	7.18	10.12	7.18	7.18

Table 5: Summary Results of Flood Frequency Analysis

Soan at Dhok Pathan						(m3/sec)
Recurrence	**Gumbel**	**Pearson**	**LogPearson**	**Lognormal**	**Gumbel**	**Lognormal**
Interval	**EV Type-I**	**Type-III**	**Type-III**		**EV Type-I**	
(Years)	MM Method	MM Method	MM Method	MM Method	ML Method	ML Method
2	2734	2834	2642	2567	2696	2635
5	4637	4515	4588	4148	4402	4457
10	5897	5507	5801	5333	5532	5719
50	8670	7446	8083	8287	8019	8625
100	9842	8194	8888	9682	9070	9912
500	12551	9813	10435	13264	11500	13047
1000	13716	10474	10984	14969	12544	14470
10000	17583	12564	12407	21428	16012	19571
Chi Square	2.87	4.16	-	11.90	6.74	4.16

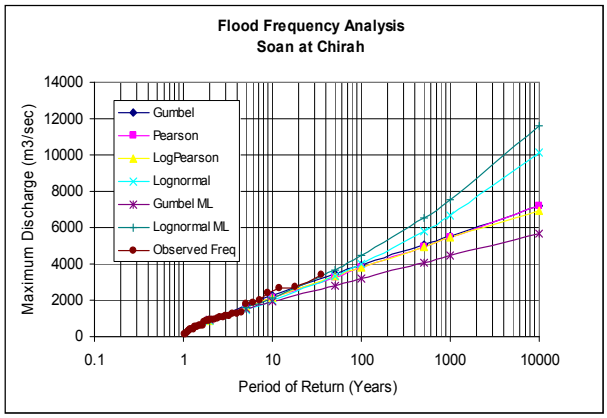

Figure 5 Flood frequency analysis, Soan at Chirah

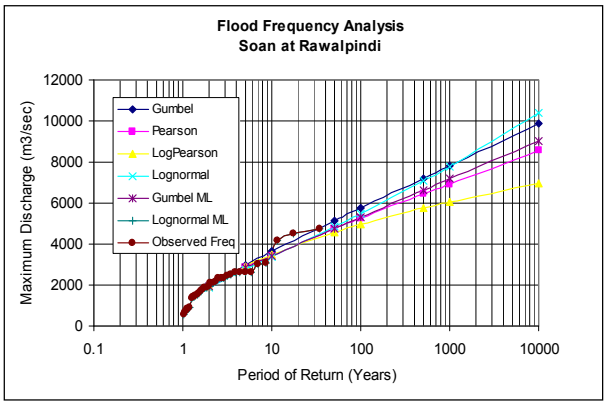

Figure 6 Flood frequency analysis, Soan at Rawalpindi

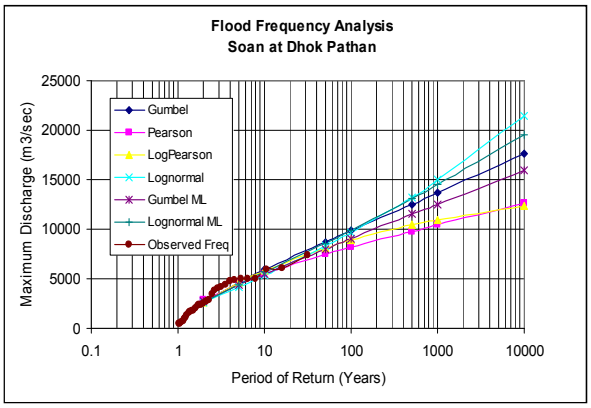

Figure 7 Flood frequency analysis, Soan at Dhok Pathan

Conclusions: Based on the above results and their discussions following flood frequencies have been determined for the Soan valley at its three locations. These results may be used for preliminary design and extent of flooding along the river banks in the valley. The proposed procedure is found to be effective for the test case. It is important to verify the theoretical frequency models with the help of statistical test describe herein. In this way selected best fit model will give the accurate results for estimating the flood frequencies.

Table 6 Summary Results (m^3/sec)

Location	Soan at Chirah	Soan at Rawalpindi	Soan at Dhok Pathan
Recurrence Interval	Pearson Type-III	Gumbel EV Type-I	Gumbel EV Type-I
(Years)	MM Method	MM Method	MM Method
2	863	1935	2734
5	1590	2957	4637
10	2108	3634	5897
50	3283	5123	8670
100	3787	5752	9842
500	4964	7207	12551
1000	5476	7832	13716
10000	7200	9909	17583
Chi Square	4.14	3.06	2.87

REFERENCES

Ahmad, I. Design Flood, Hydrologic Software, WAPDA, Lahore, pp. 4-19 (2000).

Ahmad, I. and Z. Ahmad. Peak flood estimation using computer model "Design Flood", Pakistan Journal of Environmental Science, Lahore, 2(2):23-30 (2003).

Chow, V.T., D. R. Maidment, and W. Larry. Applied hydrology. McGraw-Hill Book Company, New York, U.S.A., pp. 380-405 (1988).

Gringorten, I. I. A plotting rule for extreme probability paper. Journal of Geophysical Research, 68(3):813-814 (1963).

Haan, C. T. Statistical methods in hydrology. The lowa State University Press/Ames., U.S.A., pp. 149-165 (1977).

Jehanzeb, Evaluation of flooding hazards of Soan river in Rawalpindi area, M.Sc. Thesis, CEWRE, University of Engineering and Technology, Lahore, pp. 32-56 (2004).

Kite, G. W. Frequency and risk analysis in hydrology. Water Resources Publications, U.S.A., pp. 92-109 (1978).

Kottegoda, N. T. Stochastic water resources technology. The Macmillan Press Ltd., pp. 38-46 (1980).

US Water Resources Council (USWRC), Guidelines for determining flood flow frequency, Bulletin No. 17B, Washington, pp.16-30 (1981).

WAPDA, Surface Water Hydrology Project (SWHP), River discharge data yearly reports, Lahore, pp. 106-118 (1960-2000).