CAUSES OF FLOODS

In the Indus Basin and the Technique for Forecasting Them

BY

*SIBTE NABI NAQVI

Floods in the Indus Basin, like those of any other big basin result from heavy rainfall or excessive melting of snow or due to some upheaval in the water channel of a particular basin. There can thus be floods of 3 types : —

(1) Those resulting from excessive snowfall in the higher reaches and its melting in spring and summer ;

(2) Those due to heavy rainfall in the catchment area and

(3) Those due to upheavals in the river courses which are accompanied by an on rush of huge quantities of water.

2. All these floolds are greatly modified in their behaviour depending upon the losses due to evaporation of water into the atmosphere and its percolation into soils as the flood water rushes down a particular river.

3. A survey of meteorological and hydrometeorological causes of flood in the Indus Basin was made by S. N Naqvi in the note submitted to the Punjab Flood Commission 1951. Table 5 in that note gave the average frequency of heavy rainfall of 3″ or more in homogeneous parts in different districts for the catchment areas of the various Punjab Rivers, based on data of 30 years and show that Ravi and Chenab are most liable to frequent floods.

4. An examination by S. N. Naqvi of the intensity of heavy rainfall at Lahore (1952) and of heavy rainfall in the catchment of Ravi and Chenab at the time of 1950 floods (1951) would suggest that we have not yet recorded the highest intensity of rainfall and heaviest floods that can be expected.

5. To understand all the types of floods in a river basin, however, we should study not only the characteristics of rainfall and

* Direetor, Meteorological Service Pakistan.

snowfall in a particular catchment, but also the variations of temperature, humidity and wind which control evaporation, and the structure of rocks and soils which determine the possibilities of changes in the course of a stearm and its capacity, as well as percolation.

6. The histograms of average monthly rainfall, heaviest total rainfall in different months and the heaviest rainfall in 24 hours at representative stations in the Indus basin are given in figures 1, 2 and 3. These are based on data upto 1940. A study of rainfall of subsequent years upto 1950 has shown that the characteristics shown by these histograms remain unchanged. Fig. 4 gives isohyetal distribution of the normal annual rainfall which gives an idea of the large variation of rainfall in the Indus Basin.

7. A study of the first 3 figures gives information about the quantities of water that can usually be available in the rivers of the Indus Basin in different months and seasons, but the most important factors to which special attention may be paid are :—

(1) The total amount of winter precipitation in the higher catchments expressed in terms of heights of water appears to be rather small in individual months. But this is very deceptive. Most of this precipitation at heights above 7,000 ft. in the Himalayas and the karakoram ranges is received in the form of snow. The periods of clear weather and copious radiation for melting the snow during the winter season itself cannot be long because on an average 7 to 9 western disturbances affect this region in each winter month and each western disturbance brings cloudy weather for 2 to 3 days on an average. Thus the weather can usually be clear for not more than 10 days in a month and total amount of radiation received on these short winter days is usually not enough to melt away all the accumulated snow. Thus considerable quantities of compacted snow accumulation during winter months remain unmelted at the end of the season—December to March.

(2) The rainfall in Kashmir and the northern districts of Peshawar Division is heaviest in the spring season of April and May. A major part of this also is received in the form of snow, but due to increased amount of radiation received in clearer atmosphere, snow melting is copious and is seen in the form of increased discharges of all the rivers. The average discharges for 10 days periods have been worked out from the daily values for 10 years 1941 to 1950 recorded at different sites on each river in the Indus Basin ; those for Ravi are given in the hydrographs in figure 5 which show the increased discharges in the spring and early summer. They however, do not cause much inundation. On the contrary they increase the supply for irrigation through perennial or inundation canals.

8. The accumulation of snow over western Himalayas at the end of April and May has been found to have a negative significant correlation with the monsoon rainfall as a whole, The negative correlation

between snow accumulation over the Western Himalayas at the end of May and the subsequent monsoon rainfall would show that the years in which the accumulation of snow in the higher reaches of the Indus Basin is more, the monsoon precipitation is generally less. Naturally therefore the snow and ice of the upper catchment of the Indus and its tributaries though important in themselves are not very important factors in causing devastating floods, which are all experienced in the monsoon season, generally towards its end. This is further borne out by the decrease of discharge at the end of May in 10 day normal hydrographs of different sites on Ravi in Fig. 5.

9. The second conclusion which can be drawn from the histograms in Figures 1 to 3 is that the monsoon rainfall is heaviest in the Swaliks, the outer Himalayas and their adjoining plains. It is this rainfall which causes most devastating floods.

10. A history of the floods in the old Punjab shows that some of the most devastating floods have been experienced towards the end of the monsoon period, not in the beginning. This gives a very interesting clue to the effect of channel losses on the intensity of floods. Directly observed data of the losses are not available, but can easily be inferred from the 10 day normals such as those given in Fig. 5.

11. A study of the discharge hydrographs for 10 day normals at the sites along Ravi brings out the following interesting points :—

(1) After the off take of the Upper Bari Doab Canal at Madhopur the form of the hydrographs is significantly changed.

(2) Except for the summer months, April to June, the discharges at lower sites are generally higher and the channel losses are more than made up by the contributions from tributaries, return flows from canals and the under ground flows.

(3) The local contributions are quite important in the monsoon period and can be easily allowed for if stearm gauging of all the tributaries is arranged.

(4) The forms of hydrographs at different sites follow each other closely, showing a high and significant linear relationship.

12. In U. S. A., and other countries much importance is attached to snow cover and the losses due to percolation and evaporation as it should be if flood forecasting is to be attempted throughout the year. In our case we are expected to forecast the flows only in the flood season. In spite of this, those who want to follow blindly the techniques of flood forecasting developed in these countries, and I know there are quite a number of them in our country, would have advised us first to collect these data and only then undertake flood forecasting and warning in the Indus Basin. They forget that the variability factor of these

elements in our region is so great that for collecting reliable statistics in respect of these factors we shall have to wait for a number of years before the data can be used as reliable parameters in flood computations. Besides, in the parts of the catchment which make maximum contribution to flood flows it is not possible to have many places for such observations due to the undeveloped and difficult nature of these parts and the fact that they are under foreign administration.

13. While discussing the parameters for flood computation we should also be clear about the rainfall data needed in this connection. The first point on which we should be quite clear is the accuracy of rainfall data used in flood computation. If we remember that 1 inch of rainfall over one square mile means 2,323,200 cubic feet of water it is easy to form an idea of the possible errors involved. If the catchment area of a river is $100 \times 10 = 1000$ sq. miles, 1 inch of rainfall in 24 hours would mean 2,323, 200,000 cubic feet of water in 24 hours or 26,889 cubic feet every second. This is a tremendous amount and even normal errors of observation would introduce quite large possible errors in the results based on a large number of observations.

14. In computing discharges we assign a factor to each raingauge in the catchment depending upon the area represented by it (on the basis of Thesian Polygons). The whole method of computation by this technique can be reduced to the following form. If there are 'n' rainfall recording stations x_1 to x_n and the area assigned to each station is a_1, a_2, a_3, a_4, etc., a_n and the intensity of rainfall reported in inches per second by each is r_1, r_2, r_3, r_4, etc., r_n. The total amount of water fallen over the catchment in cusecs would be $W = (a_1 r_1 + a_2 r_2 + a_3 r_3 + a_4 r_4 + \ldots\ldots\ldots)$ 26,889 cusecs. A part of this water is lost by percolation or retention and a part is evaporated away. The sum total of these is a very variable quantity, but for computing the flood discharge usually a constant factor depending upon the average conditions for each locality represented by a rainfall recording station is assigned and with the help of this factor the discharge is calculated. In flood computation machines the loss factors are replaced by resistances in the electric circuits. We know from experience, which is absolutely valid even in theory, that the losses in flood flows are much more at the beginning of the monsoon season than those at the end. Naturally therefore if we were to follow the method of unit hydrograph and compute flood discharge by blindly following the techniques developed in other countries the result will be as follows :—

(1) Increase in the number of reporting raingauges will result in an increase of the possible error. No doubt the standard error of estimates of the result will be reduced as the number of observations increases, but again this will depend upon the variability of the amounts recorded in each catchment and the net result will not be much different from that obtained by the simple estimates of the possible errors given above. If however we compute the quantities of water available with

the help of planimeter from isohyetal maps the errors will perhaps be smaller but the time taken in preparation of rainfall charts every day and then computing runoff will be much larger.

(2) The use of an average factor for losses will give results much higher than thoseactually experienced in the beginning of flood season and much less two ards the end of the season.

(3) The computation of losses by traditional methods requires a long p eriod of observations by highly trained scientists. This is not possible for us, particularly for areas in foreign territories.

15. In view of the difficulties and limitations in the application of the method of computation usually adopted, and absence of even the essential facilities I tried to develop a simpler technique for forecasting flood discharges in the Indus besin with a view to give immediate effect to the recommendations of the Punjab Flood Commission 1951.

16. Before making any attempt to forecast floods or issue warnings it was considered necessary to make an intensive study of the flow characteristics of different rivers in the Indus Basin. While studying the causes of frequent floods since 1947 the Punjab Flood Commission 1951, had come to the conclusion that slow siltation of the river channels and the gradual rise of their beds were responsible to some extent for the greater frequency and inundation by floods in recent years. With a view to use truly representative data and also to keep them within limits of easy comprehension, the daily data of rainfall and river discharge for the latest 10 years. (1941-1950) then available were used for preliminary studies. Daily hydrographs for August and September-the most flood-ridden months—were drawn for all the sites for each river, for each year on one sheet. These hydrographs showed the flood peaks and the advance of each to different sites along the river.

17. All the rainfall data available for the period 1941-50 were sorted out according to the sectors of the catchment above each gauge or discharge site. From these data the mean daily rainfall for each sector was calculated and weighted according to the area of the sector. These weighted sector rainfall values were plotted on the hydrographs along with the gauge and discharge data.

18. The rise and fall of the river flow on these hydrographs was found, to be closely related with the sector rainfall in the hilly catchment but appeared to be hardly dependent on the sector rainfall over the catchment in the plains. This was later confirmed by the study of statistical correlations.

19. The gauge and discharge values of each flood peak were read out from the hydrographs as it advanced down the river to different sites and the time taken by each flood peak as it moved from one stage to the other was noted down. In this way we collected the data about the flood peaks and their behaviour as they moved down the river. By 1952 I had completed the preliminary study of the floods of river Ravi in the months of August and September.

20. The results of this study of floods in Ravi were discussed by S. N. Naqvi in his paper on "Classification of Floods in Ravi and Correlation between peak discharges at different stages along the River", presented at the Pakistan Science Conference in 1952. The flood peaks of different chances of occurrence at Shahdara, Balloki and Sidhnai obtained in this study are given in Table 1. The annual flood peaks of the first, second and third order were also worked out, and are given in Table II.

21. Along with this study of the characteristics of floods in Ravi, the 10-day averages of gauge and discharge values based on the same data were worked out. These have been shown graphically in fig. 5. These 10-day normals along with the 10-day normals of sector rainfall weighted according to the area of each sector of the catchment above each stage depicted the normal conditions of rainfall and river flows, departures from which were to forewarn a forecaster about the expected behaviour of the river quite a few days ahead.

22. Along with these studies, daily rainfall maps for all the flood situtations for which discharge data were available were drawn to establish the rainfall-runoff relationship. These maps have so far remained unstudied since I left Lahore and planimeters for computing run-off were not available. However, they are expected to give the most essential information about rainfall-runoff relationships needed in any system of flood forecasting.

23. An important requirement for flood warnings is the expected time of advance of a flood peak while travelling down the river from one stage to the other. At the start we expected this to be a simple affair, because the general slope of the river-bed between different stages is known and slight variations in the speed of flow depending upon the state of flood could easily be determined. In actual experience, however, this was found to be a very complicated problem.

24. As mentioned earlier, the time taken in the travel of flood peaks between different stages was read out from the daily hydrographs for each river. The scatter in the time of traval of flood peaks was found to be very large, e.g., between Jassar and Shahdara the time of travel of different peaks was found to vary between about 20 and 50 hours, and it became evident that the time series thus obtained represented a very heterogenous population consisting of different random samples. If the flood warnings were to be organised on a scientific

basis it was essential to find out a way to separate out homogeneous random samples from a heterogenous population. The usual statistical methods did not supply any device for solving this problem. However S.N. Naqvi in his paper "Sorting out homogeneous random samples from a heterogenous population" presented to the All Pakistan Statistical Conference in Dacca in 1952 suggested a method for this purpose which satisfied the statistical tests for randomness of the homogeneous samples obtained by that method. In this study it was found that the hydrographs could be divided into 3 main categories corresponding to the fast moving flood peaks, medium speed flood peaks and slow moving flood peaks.

25. This was just a preliminary attack on the problem which is greatly complicated by the flood peaks of the tributaries joining the main current at different places. Much more work is needed before the problem can be finally solved, and we are going to apply other hydrographic techniques also in future. However by keeping an eye on the current hydrograph a forecaster can roughly estimate whether a particular peak belongs to a fast moving, medium moving or slow moving variety and can decide how the warning should be worded by taking into account the confluence of an advancing flood peak in a tributary.

26. The last and the most important problem in flood warning is the estimation of a flood peak when it reaches a particular stage down the river. The method followed in America and many other countries in which flood warnings are issued is to compute the amount of expected water supply in a particular catchment for each rainstorm based on data of a close network of raingauge stations, by getting reports of intensities and amounts of rainfall, and the times of commencement and cessation of the fall at each station. The losses and the time taken for the flow of any station in reaching the main channel are determained and fully allowed for while preparing a forecasted hydrograph.

27. To begin with, the flood forecast is prepared on the basis of forecasted amounts of precipitation in each sector of the catchment and it continues to be corrected as reports of rainfall actually recorded are received. For speedy computations electric computors have been made in U.S.A. In these machines the contribution factors for each raingauge station and factors for losses in each sector are provided. In Japan the computations are done mostly by abacus and the method, though basically the same, differs slightly wherever needed to meet the variations in local conditions.

28. In the Indo-Pakistan sub-continent no precedents were available for forecasting floods. The irrigation authorities had organised a system of telegraphically reporting the values of high discharges to concerned authorities down stream and these have all along been termed as flood warnings, but in scientific terminology these are only the reports which do not give any correct indication of the time when a particular

peak would reach different stages down stream, nor do they show the state of a peak when it reaches them. These reports serve as only a rough indication of the impending danger, but nothing more. This was fully known to the members of the Punjab Flood Commission when the development of a new technique was recommended by them, because the old system was not considered satisfactory.

29. Now our position is very difficult indeed. In case of Sutlej, Ravi, Chenab and Jhelum and even Indus, the sectors of catchment areas, which make maximum contribution to the flood flows, are situated in India or India-held Kashmir, where we cannot establish the observatories of the type required for flood forecasting. Even if we held these areas, it would have been practically impossible to provide the required facilities for observations and communications at as many points as are necessary to compute the discharges correctly.

30. Under the present circumstances if we had waited for the ideal conditions for flood computation, as conceived and practised in other advanced countries, we would have waited for very very long indeed. I therefore decided to make the best of the difficult situation in which we are placed. We tried to get reports from the raingauges existing in the Indian territory for the Ravi catchment, but Dalhousie is the only raingauge station in the catchment. In the Sutlej and Beas catchments there are some 4 or 5 raingauge stations but all of them have not got telegraph offices and we could manage to get reports from Dalhousie and Simla and one or two other stations in the Sutlej catchment. Correlation between the contemporary rainfall of Dalhousie and other parts of the catchment as obtained by drawing isohyetal maps of daily rainfall showed that the floods in Ravi are not due to sporadic rainfall in small patches and that they occur only when there is wide-spread and heavy rainfall over the whole catchment, in association with depressions from the Bay of Bengal. The rainfall is particularly heavy and accompanied with devastating results when there is a depression over north Rajasthan, East Punjab and the adjacent parts of West Pakistan, and when in the west there is a wedge of high pressure protruding from Kashmir to the Rawalpindi and Lahore Divisions. The isohyetal maps of rainfall drawn for all the floods for which discharge data are available show the type of rainfall distribution which causes floods in Ravi and the Chenab.

31. This study claerly showed that when Dalhousie receives rainfall, practically the whole of the upper catchment of Ravi gets rainfall of the same order. Further, whatever be the rainfall, the only flow channel for all the rainwater is through Madhopur headworks. In the discharges measured at this point all the losses in that sector of the catchment are fully allowed for. It is sufficiently farther away from the Pakistan border to forewarn for the impending floods. The best way of starting the flood computations would have been to estimate the rainfall runoff relationships for each basin on the basis of the daily rainfall data which had been plotted for all the floods. But this work could not be started for lack of planimeters for which orders were placed abroad and

which have been received now a few weeks back. Meanwhile, to allow fully for the rainfall factor in the catchment, Dalhousie rainfall was used in computing the flood discharges. On the above basic considerations the following correlation coefficients have been worked out :—

1. Rainfall at Dalhousie and discharge at Madhopur :—
   (a) on the same day.
   (b) one day after Dalhousie rain.
   (c) 2 days after Dalhousie rain.
   (d) 3 days after Dalhousie rain.
   (e) 4 days after Dalhousie rain.

2. Dalhousie rainfall and : —
   (a) Jassar gauge on the same day.
   (b) Jassar gauge 1 day after Dalhousie rain.
   (c) Jassar gauge 2 days after Dalhousie rain.
   (d) Jassar gauge 3 days after Dalhousie rain.
   (e) Jassar gauge 4 days after Dalhousie rain.

3. Jassar sector rainfall weighted for area and :—
   (a) Jassar gauge 1 day after the sector rainfall.
   (b) Jassar gauge 2 days after the sector rainfall.
   (c) Jassar gauge 3 days after the sector rainfall.
   (d) Jassar gauge 4 days after the sector rainfall.

4. Discharge at Mukesar and Shahdara in the same flood peaks :—

5. Dalhousie rainfall and :—
   (a) Shahdara discharge the same day.
   (b) Shahdara discharge 1 day after Dalhousie rain.
   (c) Shahdara discharge 2 days after Dalhousie rain.
   (d) Shahdara discharge 3 days after Dalhousie rain.
   (e) Shahdrara discharge 4 days after Dalhousie rain.

6. Jassar Sector rainfall and :—
   (a) Shahdara discharge on the same day.
   (b) Shahdara discharge 1 day after Jassar sector rain.
   (a) Shahdara discharge 2 days after Jassar sector rain.
   (d) Shahdara discharge 3 days after Jassar sector rain.
   (e) Shahdara discharge 4 days after Jassar sector rain.

7. Jassar gauge and Shahdara discharge for the same peak.
8. Shahdara discharge and Balloki discharge for the same peak.
9. Shahdara discharge and Sidhnai dischargefor the same peak.
10. Balloki discharge and Sidhnai discharge for the same peak.

32. The partial and multiple correlation coefficicnts for appropriate factors among the above have also been worked out and those of them which were found significant were used for estimating flood flows. Regression equations were developed to give discharges at different sites from various parameters found significant and ready reckoner type of tables computed for use of the forecasters. All these tables can be used for estimating the flood flows but the forecasters are expected to study closely the previous and current hydrographs and to choose a particular table after allowing for the peculiarities of each catchment and the weather situation e.g., the position of the depressions, the precipitable amounts of water vapour in the atmosphere and the heavy rainfall reported from or expected in different corners of the catchment.

33. The above technique appears to be rather empirical in which the personal judgement of the forecaster plays a very important role, but this is not much different from how we had started forecasting weather. Even today when the science of meteorology has much developed, the personal factor of the forecaster plays a predominent part in the accuracy of weather forecasts. Regular use as forecasting aid of persistence of weather and of forecasting track of depression and storms by simple extrapolation are purely empirical techniques which still play an important role in weather forecasting.

34. The reports received by me indicate that when the technique developed by us to give immediate effect to the Punjab Flood Commission recommendations was quite new, there had been an undercurrent of mistrust and hostility in some quarters. In spite of this, I had been getting flood forecasts prepared everyday during the flood season in the Regional Forecast Centre, Lahore. These are written down in a register and verified with the actual discharge figures reported at the end of the forecast period. These forecasts have been prepared by a set of persons not fully convinced of the validity of the technique and in some cases even hostile, but the results obtained are on the whole as accurate as those claimed in U.S.A. and some other countries. The results of verification of the flood forecasts prepared at Lahore in 1956 are given in Table III.

35. It will be seen from this Table that the forecasted values agree closely and consistently with actuals in a very large number of cases and some of high flood forecasts have been simply remarkable. In some cases, however, the forecasted values differ from actuals by large margins, but in this daring experiment without any precedent and even in the

absence of essential facilities I had expected much worse results, and it was on my suggestion that the Punjab Flood Commission had recommended that the Government should protect itself by proper legislation against the blunders which are bound to be committed while developing a new technique. I am glad to observe that such an eventuality has not arison in the last four years.

36. Some people might suggest that we should first perfect the technique and than start flood warnings. In the field of science, this is absurd as perfection can neither be attained nor maintained. Access to a high peak in scientific effort opens out a new panorama of problems still to be solved. We have, however, just started on the track. The long journey is bound to be full of many thrills and pitfalls which should neither elate nor discourage us unduly.

37. The Government have created an organisation and the technique will go on changing and perfecting as we move forward and gain experience. I can, however, assure you that we are in touch with the latest developments in the field. After long efforts we have succeded in getting a mobile Dacca Storm Warning Radar and intend to examine the possibility of using the rainfall echoes obtained from this set for determining the distribution and intensity of rainfall in different catchments. The main difficulties in the use of this equipment which I can visualise now will be :—

1. The echoes of the mountains in outer ranges will make it impossible to get information about the rainfall in the hilly catchments, whose contribution in flood flows is maximum.
2. The maximum range of this equipment is only 250 miles but the catchments extend far beyond this range from our territory. If we take the Saanner to some out-of-the-way place near the border it will be impossible to keep in touch with the forecasting office and to use the information.
3. The 3 cm wave length radar which is being used may not give echoes even beyond 50 miles in the heavy intensities of rainfall which really cause floods.

38. However, all these points will be examined from the Storm Warning Radar that we have obtained and I am sure that we shall be able to use our resources to the maximum advantage.

Table I

Minimum discharge in flood peaks of specified percentage chance of occurrence at Shahdara, Balloki and Sidhnai.

Percentage chance of flood peak	Minimum Peak discharge at		
	Shahdara	Balloki	Sidhnai
	10^3 cusecs	10^3 cusecs	10^3 cusecs
90	4·8	4·0	3·0
80	9·5	8·8	5·8
70	14·5	13·5	8·8
60	19·2	18·8	12·0
50	26·0	24·0	15·3
40	33·0	30·5	19·5
30	42·5	37·8	25·0
25	49·0	43·5	28·5
20	57·0	51·0	33·0
15	68·0	63·0	38·0
10	84·0	83·5	45·8
5	128·0	122·0	56·5
1	197·0	175·0	77·0
0·5	210·0	189·5	86·5
0·1	232·0	210·0	101·0
0·01	243·0	218·0	112·0
Average discharge (August	27·231	26·577	20·452
Average discharge (September	14·809	14·708	13·562

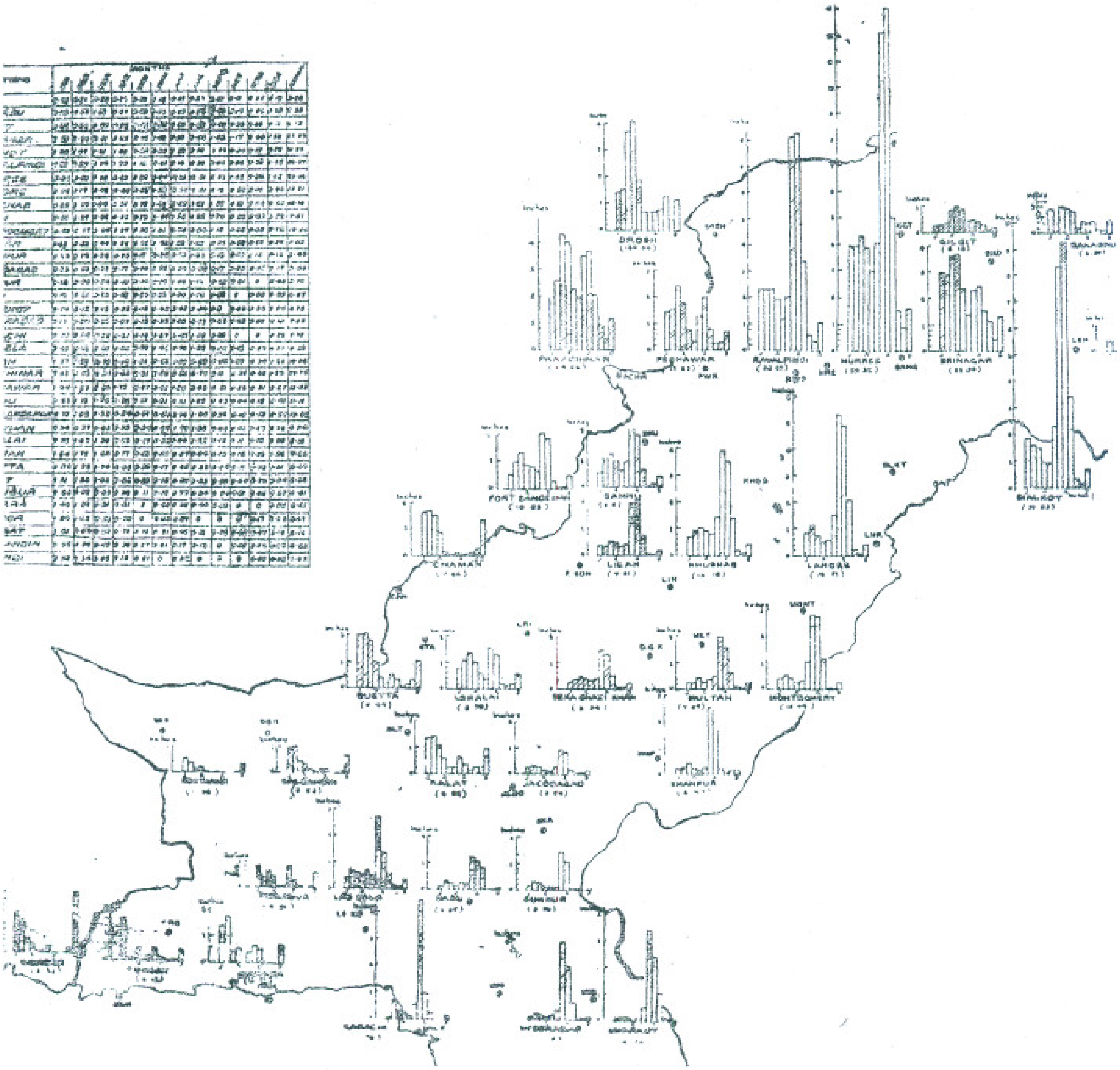
Table II

Annual Flood Peaks in Ravi of the First, Second and Third orders based on data of 1941-50.

Order of flood peak	Shahdara		Balloki		Sidhnai	
	Discharge	% Chance	Discharge	% Chance	Discharge	% Chance
	10^3 Cusecs.		10^3 Cusecs.		10^3 Cusecs.	
First Order	95·4	8	85·9	10	46·7	9
Second Order	69·8	14	62·4	15	39·1	13
Third Order	42·9	30	39·0	29	25·4	30
Highest First Order Peak	208·0 (1950)	0·5	197·0 (1950)	0·5	86·0 (1950)	0·5
Highest Second Order Peak	183·0 (1950)	2	172·0 (1950)	1	77·0 (1950)	1
Highest Third Order Peak	57·0 (1943)	20	61·0 (1948)	15	64 (1948)	4
Lowest First Order Peak	39·0 (1941)	29	32·0 (1941)	39	9·0 (1941)	70
Lowest Second Order Peak	29·0 (1941)	45	26·0 (1941)	48	8·0 (1941)	72
Lowest Third Order Peak	20·0 (1941)	60	18·0 (1941)	60	6·5 (1941)	78

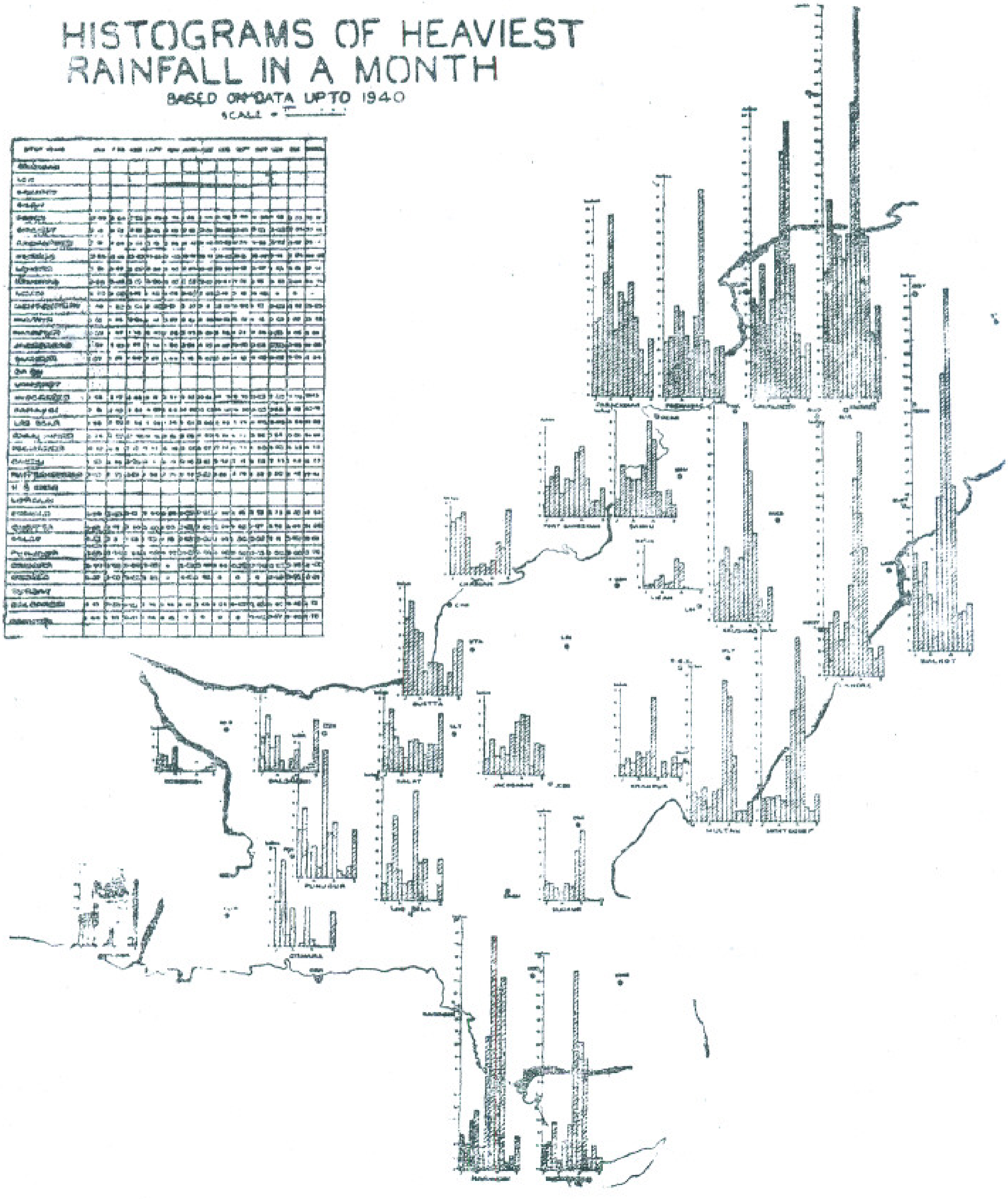
HISTOGRAMS OF MONTHLY NORMAL RAINFALL

BASED ON DATA UPTO 1940
(ANNUAL RAINFALL GIVEN IN FIGURES WITHIN BRACKETS)
VERTICAL SCALE OF MONTHLY RAINFALL
IN WEST PAKISTAN - IN EAST PAKISTAN



HISTOGRAMS OF HEAVIEST RAINFALL IN A MONTH

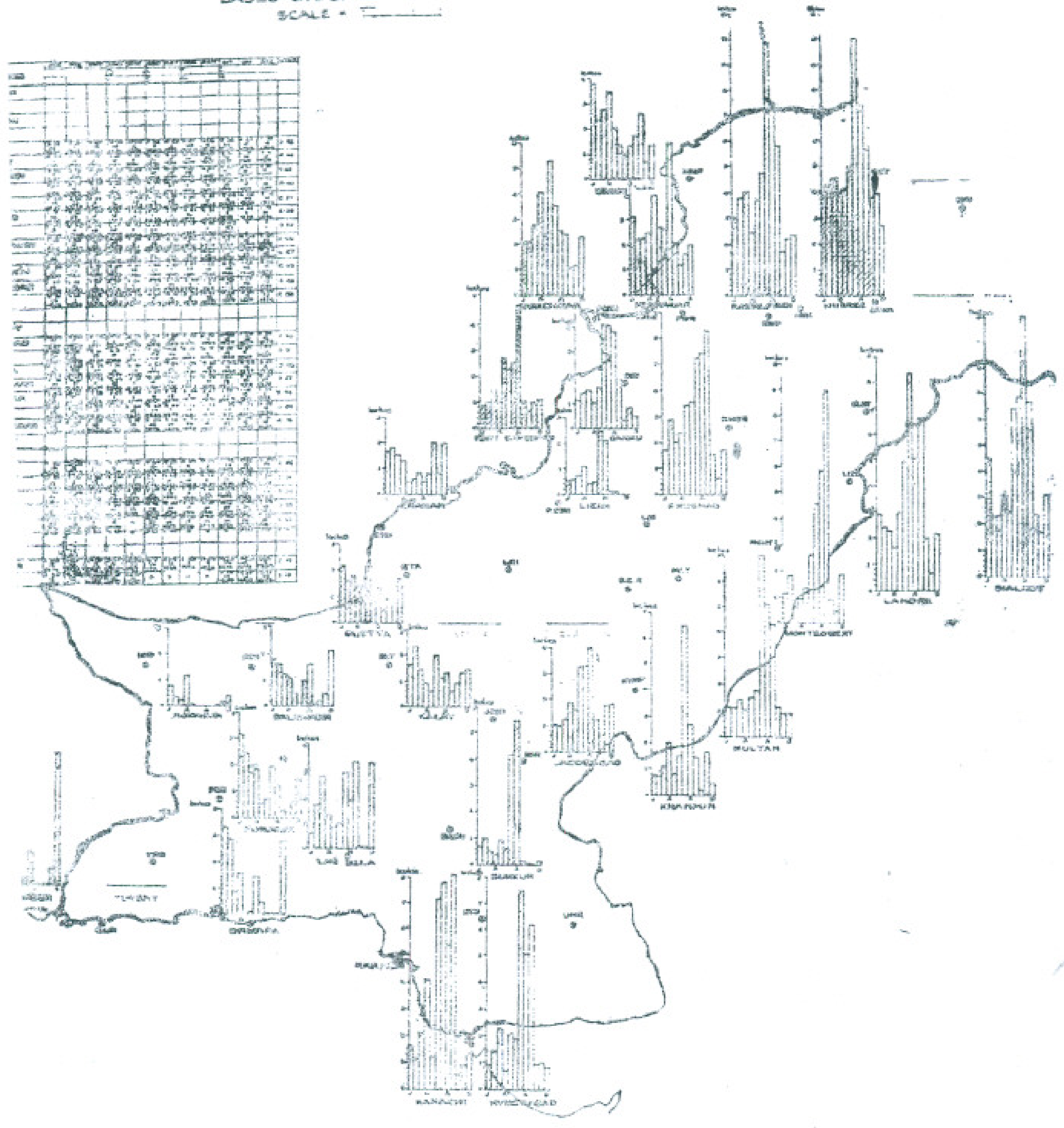
BASED ON DATA UPTO 1940



STOGRAMS OF HEAVIEST RAINFALL IN 24 HRS

BASED ON DATA 1891 TO 1940

SCALE =



5-DAY NORMALS OF DISCHARGE AT DIFFERENT SITES ON THE RAVI