# A HYDROMETEOROLOGICAL STUDY OF THE RAINFALL TREND IN THE GHAGGAR CATCHMENT AREA

*by* V. V. SARMA, *Meteorologist Gr. I, Office of the Director-General of Observatories, Lodi Road, New Delhi*-110003

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The Ghaggar river is an inter-state one flowing across the three States of Haryana, Punjab and Rajasthan. During the recent years there has been a perceptible increase in the discharges downstream requiring construction of additional hydraulic structures. This necessitated an examination of the rainfall trend in this area with a view to eliminate the possibility of any changes in the river hydrology consequent to any climatic change. For this purpose rainfall data for the period 1891 to-date over the catchment and their moving averages have been examined. An intensive study of daily and seasonal rainfall and concurrent discharges for the recent years from 1952 to 1965 were made. Correlation between the two parameters, time lag between heavy rainfall and peak flood and the effects of antecedent precipitation were looked into. Frequencies of daily rainfall have also been determined for the sub-catchments of the river.

The rainfall and runoff trends have been studied by plotting cumulative data of these elements. Results of the study have been discussed.

## INTRODUCTION

The river Ghaggar has its origin from the Sivalik ranges in the foothills of Himalayas near Simla. It passes through Ambala and Hissar districts of Haryana and Patiala district of the Punjab and enters the Rajasthan State in Sri Ganganagar district. Near the Haryana border at Ottu, a diversion weir was constructed in 1896-97 from which two irrigation canals take off.

In the past, the river below Ottu weir used to flow with very low discharges. The trend is apparently reversed in the recent years. There has been a perceptible increase in the discharges of the river downstream. This increased discharge has been inundating area in the downstream plains of the catchment necessitating flood protection works there. With the construction of Bhakra dam in 1957 significant changes have taken place in the irrigation and agricultural practices of this region. The drainage improvement and canalisation of the Ghaggar and its tributaries upstream could have contributed to the higher discharges of the river in addition to any natural changes due to the occurrence of rain storms over the catchment.

A study of the meteorological aspects with special reference to rainfall pattern and trend was undertaken to find out to what extent this can explain the increase in observed discharges of the river. For any such study, it is important to bear in mind the following three distinct epochs of development of irrigation and water management practices in this region:

(*i*) The early period prior to 1957—Pre-Bhakra period.

(*ii*) The intermediate period between 1957 and 1962 when irrigation from Bhakra canal system had been introduced but effective drainage improvement works were not completed—Post-Bhakra to pre-drainage period.

(*iii*) The later period after 1962 when drainage improvements had commenced—post-drainage era.

## NORMAL RAINFALL

Fig. 1 shows the Ghaggar catchment area with the raingauge stations and its four sub-catchments, namely (*a*) Upto Narwana branch crossings, (*b*) Narwana to Khanauri, (*c*) Khanauri to Chandpur, and (*d*) Chandpur to Ottu. Rainfall data for the stations located in the Ghaggar catchment are available for more than 70 years since 1891. For the period 1891 to 1952, the number of raingauge stations was 7 only. A large number of stations were set up thereafter, particularly in the lower basin which is in the plains and receives comparatively less rainfall than the upper catchment. For the present analysis, all available data from the network of 25 stations in and near the catchment were made use of.

The normal annual rainfall isohyets were drawn. It would be seen that rainfall varies considerably between 60 inches in the upper reaches to 12 inches in the downstream portion of the catchment. Table I gives the frequencies of percentage departures of monsoon rainfall in Ghaggar catchment in each decade between 1891 and 1967 under the three categories, viz., normal, excess or deficit. While 50 per cent of the

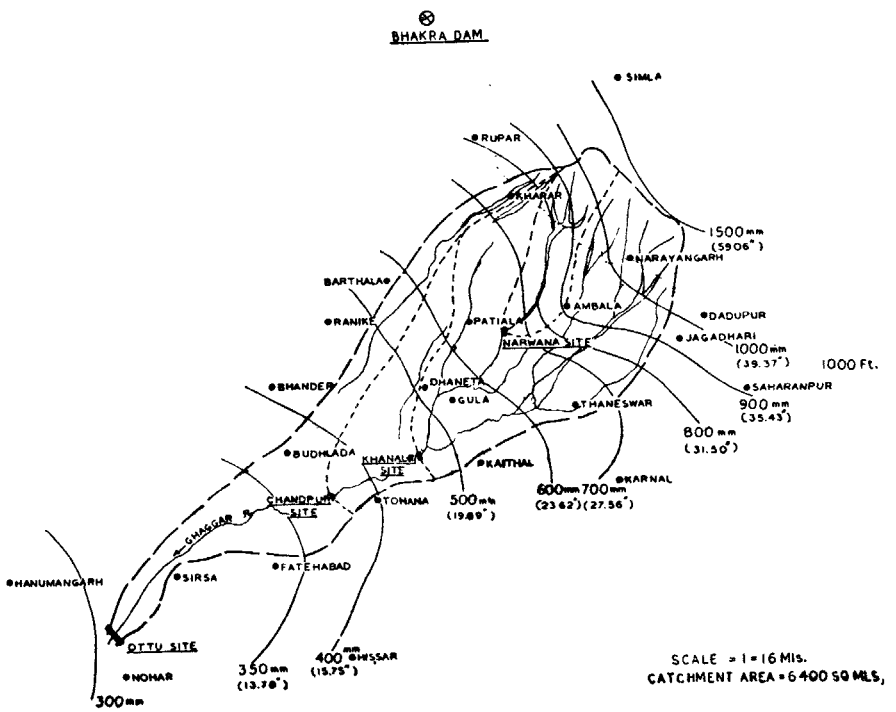


FIG. 1. Ghaggar catchment area upto Ottu site showing normal annual isohyets.

TABLE I

*Frequency of percentage departures of monsoon rainfall of Ghaggar catchment upto Ottu weir*

| Years | Normal ±20% | Excess >20% | Deficit <20% |
|---|---|---|---|
| 1891 to 1900 | 8 | 2 | — |
| 1901 to 1910 | 3 | 1 | 6 |
| 1911 to 1920 | 4 | 2 | 4 |
| 1921 to 1930 | 6 | 1 | 3 |
| 1931 to 1940 | 5 | 2 | 3 |
| 1941 to 1950 | 3 | 4 | 3 |
| 1951 to 1960 | 6 | 4 | — |
| 1961 to 1967 | 3 | 1 | 3 |
| Total : | 38 | 17 | 22 |
| Percentage of number of occasions | 50% | 20% | 30% |

cases show normal rainfall over the catchment the rainfall was below or above normal on 20 per cent and 30 per cent occasions respectively.

## MOVING AVERAGES

Average monsoon rainfall for the Ghaggar catchment have been calculated from 1891 to 1967. Considering such of the stations as existing upto 1952 for the whole period the average works out to 21.2 inches. The 11-years moving averages have also been worked out and plotted (Fig. 2). It is seen that the moving average curve is generally lower as compared to the arithmetic mean for the period prior to 1944. From 1945 onwards the moving average curve lies above the arithmetic average line. It would also be seen that significant positive departures were spaced 5 to 10 years upto the year 1942. Thereafter there was a comparatively wetter period from 1945 to 1953. From 1955 to 1962 the monsoon rainfall was consistently higher than the arithmetic average. Again from 1962 to 1967 the wet spell seems to have abated.

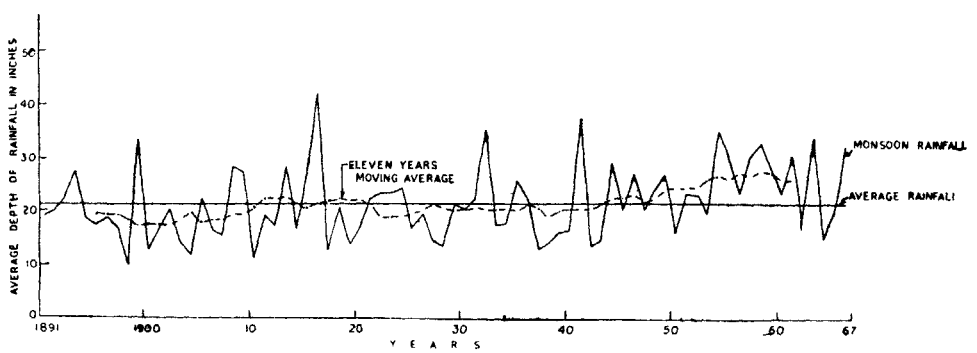


FIG. 2. Monsoon (June–October) rainfall of Ghaggar catchment upto Ottu Weir.

As stated earlier the number of raingauge stations in the catchment has significantly increased from 1952 onwards. This period of 16 years from 1952 to 1967 has been compared with 16 years periods backwards from 1952. It is found that the arithmetic mean monsoon rainfall 1952 to 1967 works out to 24.7 inches. It progressively decreased to 21.2 inches for the period 1936 to 1951, 21.3 inches from 1920 to 1935, 19.5 inches from 1904 to 1919 and 20.15 inches from 1891 to 1903. There seems to be a gradual upward trend in the mean monsoon rainfall. Rainfall in certain block periods has been higher than the preceding block periods.

## Frequencies of Rainfall Intensities

During the recent past, the pattern of peak discharges in the river shows an increase in the frequencies of number of days when higher discharges are observed. To examine this point further, with reference to the rainfall distribution and any possible correlation with higher rainfall intensities, daily rainfall over the four sub-catchments of the Ghaggar catchment have been computed for the period 1949 to 1967. Frequencies of daily rainfall at one inch intervals have been worked out and the results are tabulated in Table II. The frequency variation over the period as a

Table II

*Frequency of daily rainfall of Ghaggar and its catchments*

| Year | Up to Narwana | | | | Narwana to Khanauri | | | | Khanauri to Chandpur | | | | Chandpur to Ottu | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1949 | 23 | 5 | 2 | — | 16 | 1 | — | 3 | 3 | 1 | — | — | 14 | 1 | — | — |
| 1950 | 50 | 9 | — | — | 20 | 6 | — | — | 13 | 2 | 2 | 3 | 19 | 4 | 1 | — |
| 1951 | 30 | 10 | — | — | 8 | 1 | — | — | 3 | — | — | — | 6 | 2 | — | — |
| 1952 | 45 | 4 | 1 | — | 25 | 4 | 3 | — | 21 | 4 | — | — | 28 | 1 | — | — |
| 1953 | 46 | 13 | — | — | 27 | 6 | — | 1 | 14 | 3 | — | — | 27 | 2 | 1 | — |
| 1954 | 62 | 4 | 1 | — | 25 | 4 | 1 | — | 22 | 2 | — | — | 34 | 2 | — | — |
| 1955 | 43 | 6 | — | — | 22 | 7 | 2 | — | 19 | 5 | 1 | — | 24 | 5 | 1 | — |
| 1956 | 56 | 9 | 4 | — | 12 | 7 | 2 | — | 32 | 4 | — | — | 40 | 3 | — | — |
| 1957 | 55 | 8 | 1 | 3 | 29 | 5 | 3 | — | 19 | 7 | 2 | 2 | 35 | 5 | 1 | 2 |
| 1958 | 48 | 11 | 3 | — | 39 | 8 | 1 | — | 18 | 6 | 1 | 1 | 44 | 4 | 2 | — |
| 1959 | 62 | 12 | 2 | 1 | 32 | 7 | 1 | — | 18 | 4 | — | — | 35 | 2 | — | — |
| 1960 | 54 | 6 | 1 | 1 | 25 | 8 | 2 | 1 | 17 | 7 | — | 1 | 32 | 4 | 1 | — |
| 1961 | 66 | 10 | 1 | — | 28 | 2 | — | — | 17 | 6 | — | 1 | 34 | 2 | — | — |
| 1962 | 48 | 8 | 4 | 1 | 14 | 2 | 1 | — | 19 | 4 | 1 | 1 | 30 | 2 | 2 | — |
| 1963 | 45 | 12 | 3 | 3 | 26 | 2 | — | — | 24 | 3 | — | — | 25 | 2 | 1 | — |
| 1964 | 58 | 11 | 4 | 2 | 32 | 6 | 2 | — | 25 | 7 | 4 | — | 35 | 3 | 2 | 1 |
| 1965 | 48 | 6 | — | 1 | 18 | 1 | 1 | — | 4 | 6 | 1 | 1 | 21 | 1 | 1 | — |
| 1966 | 43 | 4 | 4 | 1 | 27 | 2 | — | — | 15 | 1 | — | — | 34 | 4 | — | — |
| 1967 | 52 | 12 | 2 | 1 | 30 | — | 1 | — | 9 | 2 | — | — | 34 | — | 1 | — |

Note:

1—0.1″ to 0.99″ 2—1.0″ to 1.99″

3; 2.0″ to 2.99″ 4; > 3.0″

whole does not show any significant change in respect of rainfall higher than 1" So far as rainfall upto 1" is concerned, it is seen (Fig. 3) that during the earlier period prior to 1952 the frequencies have been generally low as compared with the period after 1952 for all the sub-catchments. To some extent, this increase in the frequencies of rainfall even though of lesser amounts might have resulted in higher antecedent precipitation index which is more favourable for higher discharges in the river.

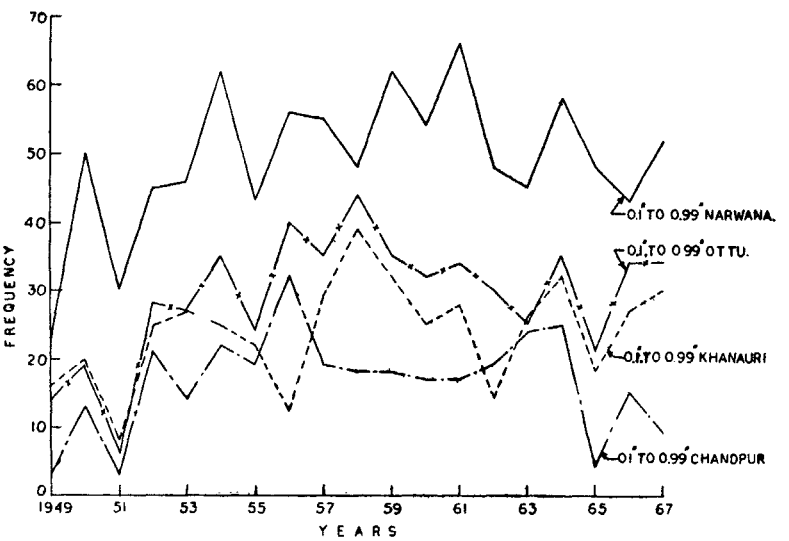


FIG. 3. Variation in frequency of rainfall of different amounts over the sub-catchments of Ghaggar river.

## RAINFALL AND RUNOFF

An attempt was made to correlate qualitatively the observed runoff in the river at Ottu with the rainfall over the four sub-catchments. For this purpose, histograms of the daily rainfall were plotted together with the concurrent discharge curve for a period of 10 years representing the three epochs 1949–51 and 1959 in pre-Bhakra period, 1959–61 in post-Bhakra to pre-drainage period and 1964–66 in the post-drainage period.

A detailed examination of the curves reveals the following noteworthy features. The time lag between peaks of rainfall and discharges varies considerably. Generally it is about 4 to 10 days, but there are a few cases in which discharge peak is registered after an interval of 14 days of any significant rainfall in the catchment. On a few occasions heavy rainfall in the upper region followed by heavy rainfall downstream 3 or 4 days later has given rise to peak inflows. There are many occasions particularly late in the month of October, when there is consistent flow without any heavy rain. Mention may also be made of the rainfall occurrence over one or more of the sub-catchments without resulting in any contribution to the inflow. The highest recorded peak of 20,700 cusecs observed on 3rd September, 1964 could not be adequately ex-

plained from the rainfall distribution in that year. One of the favourable factors that can be seen in this period is the high antecedent precipitation index conducive to high flow but certainly not of the order of the extreme high value recorded in that year. These features could not be associated with any particular epoch but they are common to all the three epochs for which the data have been examined. It has thus been not possible to arrive at any conclusive pattern regarding the rainfall runoff relationship from these curves during the different periods. The poor correlation is apparently due to limitations of the discharge data affected by increased human activities as a result of development in the area particularly the upstream utilisation, infiltration, decreased pondage etc.

## Cumulative Rainfall and Runoff

In Fig. 4 cumulative rainfall has been presented from 1891 to 1967. It is seen that the plot generally coincides with the 45° line up to 1947 whereafter it acquires a

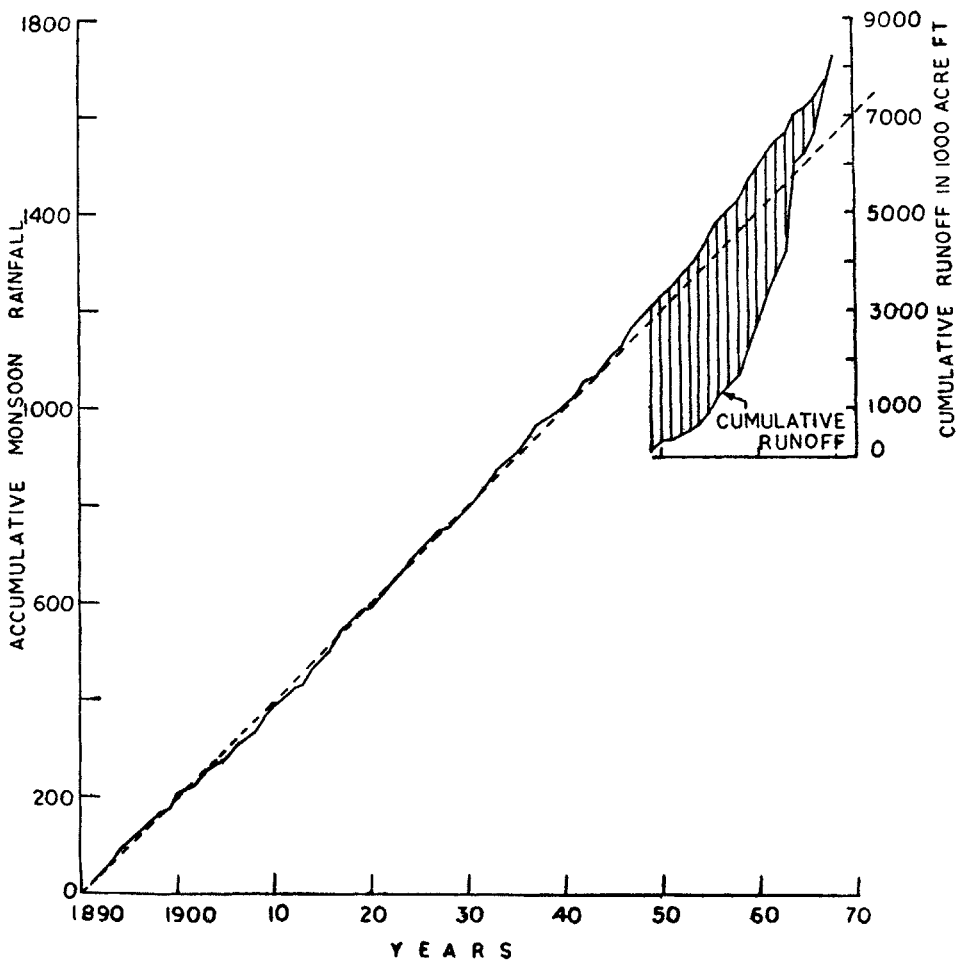


Fig. 4. Cumulative rainfall and run-off figures.

steeper gradient indicating an increasing trend. Runoff figures are available from 1949 onwards and have also been plotted. The cumulative plot for runoff shows rapidly increasing gradient from 1955 onwards. This gradient is steeper than that of the cumulative curve for rainfall. It may be added that 1955 was a year of heavy rainfall in Punjab causing widespread floods and waterlogging. Again during the period 1958 to 1960 and 1962 there was heavy rainfall. The reference to the data of water-logged areas from 1957 to 1966 indicates that water-logged area increased from 1.27 lakh acres in 1957 to 4.4 lakh acres in 1968. Up to 1964 it fluctuated between 3.4 lakh acres to 8.1 lakh acres whence it declined to 2.75 lakh acres in 1964 and 1.89 lakh acres in 1966. It can be envisaged that a steeper gradient of these cumulative curves could be partly due to this fact.

## SUMMARY

On the basis of the present examination, it is only possible to state that the higher rainfall with positive departures from normal during the recent years is just one of the cyclic phases in the periodical variation of rainfall in the region. It is necessary to collect more data for shorter periods and subject them to rigorous statistical analysis and tests for periodicity after eliminating noises. With the modern facilities of computor and machine processed data, it is possible to undertake spectral analysis of the rainfall data and conclusively prove the trend pattern and periodicity.

In this connection, it may be recalled that the excavation at a site near Kalibangan over the river Ghaggar reveal a number of dessicated valleys suggesting a system of rivers which once reached the sea as a tributary of the river Indus during the Harappan era. It has been observed (Das 1968) that history in this region is one of extreme fluctuations with periods of intense cultivation followed by period of dry and semi-arid conditions.

It is not known how the hydraulic structures at Ottu were designed and constructed in the later part of the nineteenth century. No doubt, the heavy rainfall during the year 1893 to 1894 may have something to do with this. It may be that a spell of wet years preceeding 1891 that was responsible for this design, but for want of data prior to this period, nothing can definitely be indicated.

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