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Major flood of 1988 in the *Yamuna* river upto Delhi

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सार — इस शोधपत्र में दिल्ली रेलवे स्टेशन के पुल तक यमुना नदी में वर्ष 1988 के दौरान भारी बाढ़ का अध्ययन किया गया है और इसे बाढ़ के विशेष लक्षणों सहित प्रस्तुत किया गया है। वर्ष 1988 के दौरान आई बाढ़ों की कुल संख्या तथा उनकी अवधि और चरमगेज रीडिंग भी इस अध्ययन में बताई गई है।

प्रस्तुत अध्ययन, दिल्ली तक यमुना जलग्रहण क्षेत्र में और उसके आसपास स्थित वर्षामापी स्टेशनों से इकट्ठे किए गए वर्षा के आंकड़ों के विश्लेषण पर आधारित है।

ABSTRACT. The study of the peak flood during the year 1988 in the *Yamuna* river up to Delhi railway bridge has been made and presented in this paper alongwith the special features of this flood. The total number of the floods during the year 1988 with duration and peak gauge readings are also mentioned in this study.

The present study is based on the analysis of the rainfall data collected from raingauge stations lying in and around the Yamuna catchment up to Delhi.

1. Introduction

The study of peak floods in the *Yamuna* river made so far by Dhar (1962), Johri & Veeraraghavan (1976) and Ghosh *et al.* (1982) shows that all time record flood occurred in September 1978 and the second record flood in August 1976. The present study shows that the peak flood of 1988 has become the second record flood during the period 1900 to 1988 and consequently the peak flood of August 1976, the third record flood.

The *Yamuna* river crossed the danger level of 204.83 m at Delhi railway bridge on five occasions — once in July, three times in August and once in September during the year 1988. Table 1 shows the duration of the flood, the maximum gauge reading reached at Delhi railway bridge and time of maximum gauge reading during each flood. This table shows that water level of *Yamuna* river touched the maximum gauge of 206.92 m on 27 September 1988 and remained above the danger level for four days from 26 to 29 September 1988. Wazirabad bridge and old bridge over *Yamuna* river at Delhi were closed for traffic for two days. Although, there were very few casualties, great loss of property and crops during this peak flood of 1988, was, however, reported.

2. Highest peak flood of 1988

2.1. The *Yamuna* crossed the danger level of 204.83 m at Delhi railway bridge at 0230 IST on 26 September and rose progressively thereafter. The peak gauge reading of 206.92 m was attained at 1300 IST on 27 September and, thereafter, the water level receded slowly and came below the danger level at 1630 IST on 29 September.

2.2. The present study has been made on the basis of rainfall data of stations which fall in and around the Yamuna catchment up to Delhi. The Yamuna catchment up to Delhi, keeping in view its orography, is divided into following two parts — (1) The upper catchment from source of the river to Kalanaur, which comprises of parts of Himachal Pradesh and hills of west Uttar Pradesh and (2) the lower catchment from Kalanaur to Delhi railway bridge, which consists of parts of west Uttar Pradesh and Haryana.

There were two rainstorms responsible for the highest flood of September 1988. The first rainstorm was of three day duration (*i.e.*, from 23-25 September) and the second of one day duration (*i.e.*, 27 September) only. The criterion for the purpose of storm selection has been taken as an arithmetic average of at least 2.5 cm of daily rainfall in the catchment (Abbi *et al.* 1970).

2.3. The main system responsible for heavy to very heavy rainfall in the upper and lower Yamuna catchments, was a well marked low pressure area which lay over south Gujarat region and neighbourhood on 22 and 23 September; over north Gujarat and south Rajasthan on 24 September 1988. In association with this system there was also an upper air cyclonic circulation extending up to mid-tropospheric levels moving across Himachal Pradesh. The other system, which helped the above mentioned cyclonic circulation in drawing up copious moisture resulting in heavy to very heavy rainfall, was a westerly trough in mid and upper troposphere with its axis at 500 mb fluctuating between 67°E and 75°E, north of 25°N during the period from 22 to 26 September 1988.

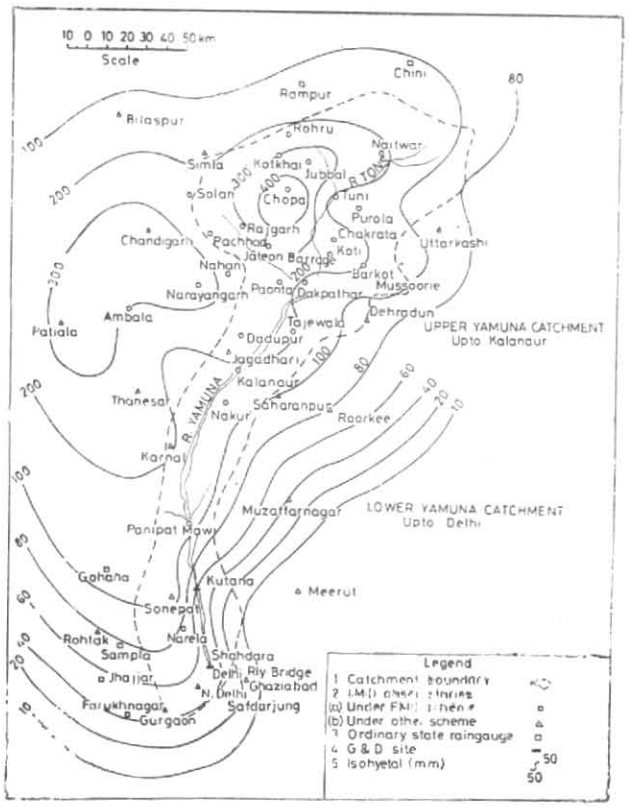

Fig. 1. Three-day isohyetal pattern of 23 to 25 Sep 1988 rainstorm over the Yamuna catchment

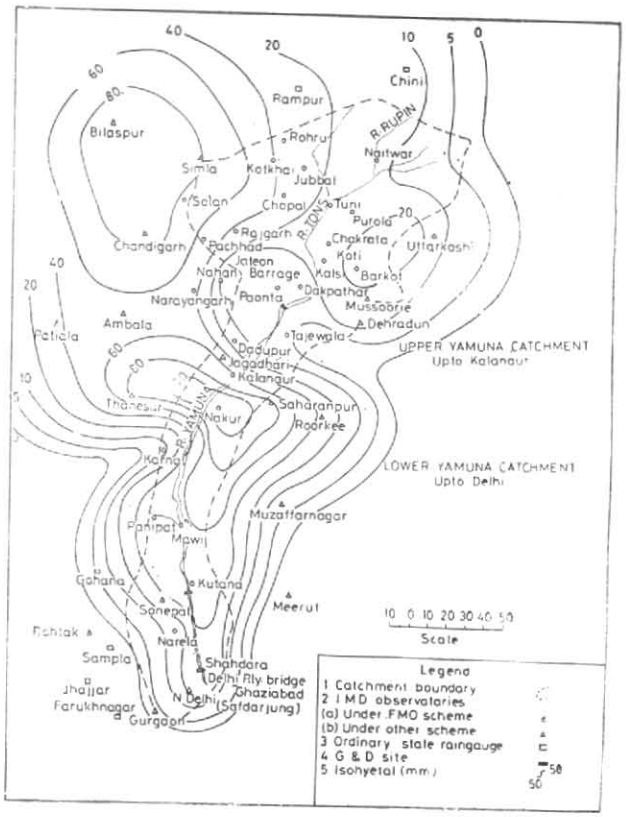

Fig. 2. Isohyetal pattern of one-day rainstorm of 27 Sep 1988 over the Yamuna catchment

TABLE 1

Floods during 1988 in *Yamuna* river

Duration of flood	Time/date of peak gauge at Delhi Rly. bridge (IST)	Peak gauge attained at Delhi Rly. bridge (m)
24-26 July 1988	2400 25 Jul 1988	205.51
1-6 Aug 1988	0100 3 Aug 1988	205.49
9-12 Aug 1988	1500 10 Aug 1988	205.23
16-17 Aug 1988	0300 17 Aug 1988	205.05
26-29 Sep 1988	1300 27 Sep 1988	206.92

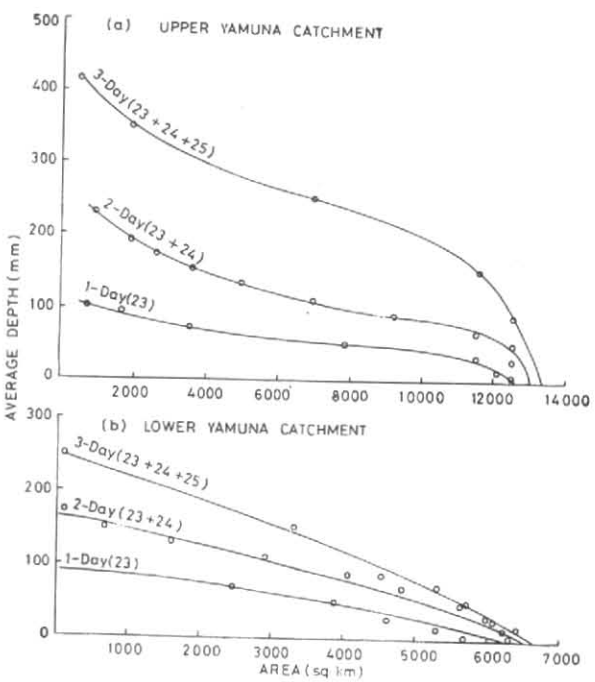

Fig. 3. Depth-duration (DD) curves of Sep 1988 rainstorm over the Yamuna catchment up to Delhi

TABLE 2

Weighted average raindepth (cm) of rainstorms during September 1988 in Yamuna catchment

Catchment	First rainstorm (23-25 Sep)				Second rainstorm 27 Sep
	23 Sep	24 Sep	25 Sep	Total	
Upper	4.9	6.2	11.5	22.6	2.2
Lower	3.9	5.5	3.8	13.2	4.9

TABLE 3

API (Antecedent Precipitation Index) of *Yamuna* river catchment during the flood months of 1988

Catchment	July	August	September
Upper	18.01	22.39	24.00
Lower	14.90	13.54	15.00

TABLE 4

Average accumulated isohyetal raindepth in river *Yamuna*, which caused the three peak floods

	Period of flood	Accumulated isohyetal average raindepth	
		Upper catchment	Lower catchment
1st record peak flood	01-10 Sep 1978	26.5 (4 days)	19.3 (3 days)
2nd record peak flood	26-29 Sep 1988	22.6 (3 days) 2.2 (1 day)	13.2 (3 days) 4.9 (1 day)
3rd record peak flood	19-25 Aug 1976	12.4 (2 days)	14.9 (2 days)

TABLE 5

Dates of maximum API for the years of peak floods

	Period of flood	Values of maximum API with date			
		Upper catchment		Lower catchment	
		API value	Date	API value	Date
1st record peak flood	01-10 Sep 1978	38.5	03 Sep 1978	24.2	03 Sep 1978
2nd record peak flood	26-29 Sep 1988	24.0	25 Sep 1988	15.0	27 Sep 1988
3rd record peak flood	19-25 Aug 1976	20.7	20 Aug 1976	21.8	19 Aug 1976

A third system contributing to this heavy rainfall was an upper air cyclonic circulation extending up to mid-tropospheric levels over north Rajasthan and adjoining Haryana on 25 and 26 September 1988.

2.4. The rainfall data of the two rainstorms was plotted separately and their isohyetal analysis was done. In Fig. 1, the accumulated rainfall amounts for three days (23 to 25 September 1988) are taken for the purpose of isohyets, as the rainstorm was of three days duration; whereas in Fig. 2, a one day (27 September 1988) rainfall amounts are taken, as the rainstorm was of one day period only. These isohyetal charts were planimetered and the weighted mean rain depths of each rainstorms for both the catchments were calculated and are shown in Table 4.

2.5. From the gauge readings at gauge sites at Kalanaur and Delhi Railway bridge, it is seen that peak gauge of 267.95 m at Kalanaur was attained at 1300 IST on 25 September and peak gauge of 206.92 m at Delhi Railway bridge was attained at 1300 IST on 27 September 1988, when there was heavy to very heavy rain in both the catchments of *Yamuna* river.

2.6. The Antecedent Precipitation Index (A.P.I.) for upper and lower catchments of *Yamuna* river up to Delhi has been calculated for all the three months in which floods occurred in 1988 by the common technique (Chow 1964). The monthwise maximum API for the months July, August and September are given below in Table 3 for the catchments separately.

2.7. Depth area duration curves for the upper and lower catchments have been plotted for 23 September, 23 and 24 September and 23 to 25 September and are shown in Fig. 3.

2.8. The isohyetal average raindepths of the rainstorms in the upper and lower Yamuna catchments which are responsible for the three peak floods (Aug 1976, Sep 1978 and Sep 1988) at Delhi Railway bridge is given in Table 4.

2.9. The maximum values of API for upper and lower Yamuna catchments for the three years in which the three peak floods (Aug 1976, Sep 1978 and Sep 1988) occurred is given in Table 5.

3. Summary and conclusions

3.1. It has been observed from Table 1 that maximum number of floods occurred during the month of August, but the flood of maximum intensity occurred in the last week of September during 1988. The peak floods of 1978 and 1947 also occurred in September and peak flood of 1976 occurred in August. Thus, it can be said that out of four major floods of 1947, 1976, 1978 and 1988; seventy five per cent of major floods occurred in the month of September and twenty five per cent in August.

3.2. The flood of August 1976 has been listed as the second highest record flood in *Yamuna* river (Ghosh *et al.* 1982) during which the peak gauge at Delhi

railway bridge was recorded as 206.70 m. The peak gauge during the flood of September 1988 exceeded the second record gauge of 206.70 m and attained the level of 206.92 m; but remained below the all time high record gauge of 207.49 m during the flood of September 1978. Thus the flood of September 1988 has become the second record flood during the period from 1900 to 1988.

3.3. All the major floods of 1924, 1947, 1976 and 1978 in *Yamuna* river were caused directly or indirectly by depressions either from Bay of Bengal or Arabian Sea (Ghosh *et al.* 1982) but as stated in Sec 2.3 the flood of September 1988 was caused due to a low pressure area over Gujarat region and adjoining Rajasthan. This was associated with upper air cyclonic circulation extending up to mid-troposphere. Thus, it can be said that the major flood in the *Yamuna* (up to Delhi) occur due to heavy to very heavy precipitation in upper and lower catchments associated with not only depressions from the Bay of Bengal or Arabian Sea, but also due to a well marked low pressure area over Gujarat region and adjoining Rajasthan, moving towards north/northnortheast.

3.4. It is noted that the peak gauge during this major flood was recorded, when the API of the catchment was maximum. From Sec 2.5 of this study, it is further observed that peak gauge at Delhi railway bridge is attained after two days' (48 hr) of the peak gauge at Kalanaur gauge site.

3.5. It is observed that September 1988 flood was caused due to heavy to very heavy rainfall continuously for three days in both the catchments. The upper catchment, however, recorded twice the amount of rainfall recorded by the lower catchment. It is thus concluded that major floods in the *Yamuna* occur only when the rainfall amounts were very high in the upper catchment and this confirms the results of the earlier workers on this subject.

3.6. Figs. 1 and 2 show that pattern of isohyets of both the rainstorms is more or less similar and resembles the general pattern of isohyets for the catchment of *Yamuna* up to Delhi.

3.7. From Table 3, it is observed that maximum API of 24.00 and 15.00 was observed in upper and lower catchments respectively in the month of September, out of all the three months, *i.e.* July, August and September during which floods occurred in 1988. The maximum API in upper catchment was on 25 September when the gauge at Kalanaur was maximum and maximum API in lower catchments was on 27 September, when the gauge reading at Delhi was maximum.

3.8. From Table 4, it is observed that the highest flood of September 1978 had the highest accumulated isohyetal average raindepth (*i.e.*, 26.5 cm in upper Yamuna catchment and 19.3 cm in the lower Yamuna catchment) and the second highest flood of September 1988 had the second highest accumulated isohyetal average raindepths in the upper and lower catchments.

3.9. From Table 5, it is seen that the highest flood of September 1978 was having the highest API in both the catchments. In second highest flood of September 1988, the API in upper catchment was more than the third highest flood of 1976 but the API value of lower catchment of second highest flood was less than the third highest flood of 1976.

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