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An analytical study of severe floods of July 1978 in *Bagmati* and *Adhwara* group of rivers

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ABSTRACT. Synoptic and hydrometeorological aspects of severe floods that visited the *Bagmati* and the *Adhwara* group of rivers in north Bihar in July 1978 have been studied in this paper. The floods touched or surpassed the highest flood levels of 1975 in the two rivers, inspite of much less total storm precipitation yield and less favourable antecedent precipitation conditions. This phenomenon has been explained with the help of short duration intensity of the storm rainfall.

1. Introduction

Floods are the recurring annual feature of Bihar State, particularly the areas north of the *Ganga*. Almost in every flood season the rivers of north Bihar witness a few flood waves which cause considerable damage to property and some time even loss of life.

The high incidence of floods in these areas are due to the combined effects of physiographical and meteorological conditions.

The area is traversed by a large number of swift flowing rivers which originate in the southern slopes of the Himalayas, mostly in Nepal. They flow in a north-south direction and join the *Ganga* which flows from west to east through the State. The major tributaries of the *Ganga* in north Bihar are the *Ghaghra*, the *Gandak*, the *Burhi Gandak*, the *Bagmati*, the *Adhwara* group & the *Kamla*, the *Kosi* & the *Mahananda* from west to east. These rivers meet the *Ganga* at various points within Bihar as the *Ganga* progresses eastwards.

An important contributory factor for floods in these rivers is the relative flatness of their basin slopes. The slopes in the mountainous and in the submontane reaches are quite steep but as the rivers debouch into the plains the slope becomes flatter resulting in inefficient drainage of storm discharge through the stream channels. The topography of these areas is also marked by vast bowls of low lands locally known as "Chaurs" which get filled up during the floods and remain stagnant for a considerable period due to poor drainage.

Meteorologically, the upper catchments of these rivers lie in a rain-belt that receives an annual rainfall of about 183 cm on an average, about 147 cm, *i.e.*, 81 per cent of it falls in the monsoon season. The major rain producing conditions in these areas are: (*i*) break in the monsoon, (*ii*) the passages of middle latitude westerly waves across the Himalayas and (*iii*) the occasional northward moving lows or depressions from the Bay of Bengal. Whereas, 'break' are the phenomenon of the mid-monsoon months July and August, the lows and the depressions visit the submontane Bihar in the late monsoon months of September and October.

In the present decade, there have been a number of floods in the major rivers of Bihar including the *Ganga*. In September 1974 and in July-August 1975 floods of severe magnitude occurred in the *Burhi Gandak*. On both the occasions the previous high flood levels were surpassed (Prasad 1977). During July-August 1975, the *Bagmati*, the *Adhwara* group of rivers and the *Kamla* also received heavy floods and attained highest flood levels. There was recurrence of floods in the *Bagmati* and *Adhwara* group in July 1978. The flood levels in 1978 spell touched or surpassed the highest flood levels of 1975 in the two rivers, inspite of much less total storm precipitation yield and less

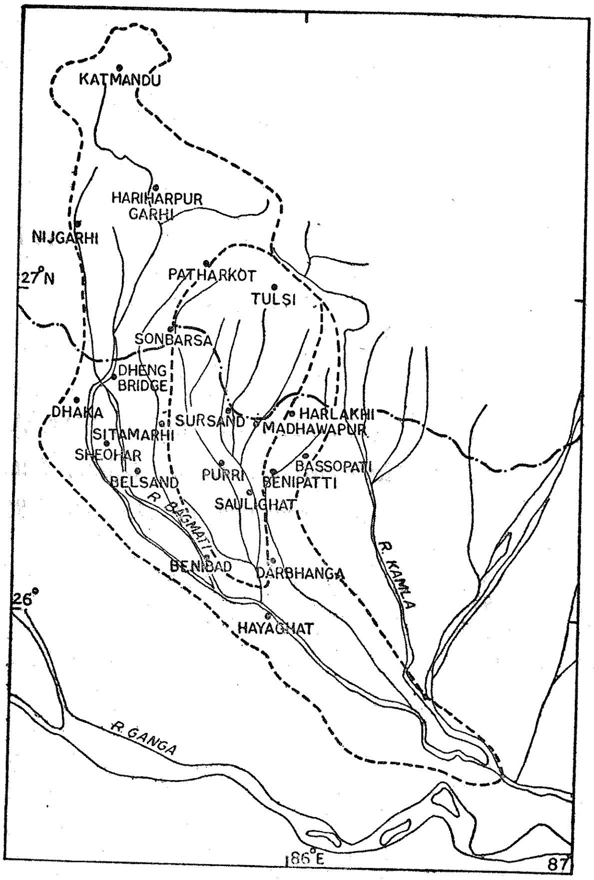


Fig. 1. Bagmati and Adhwara sub-catchment

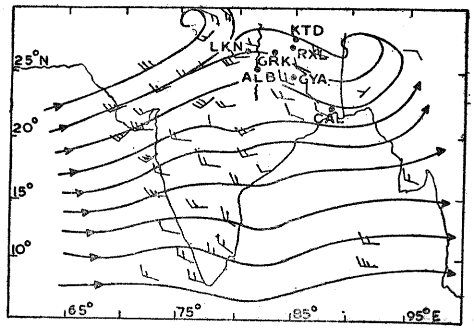


Fig. 2. Upper wind flow patern at 900 m asl on 19 Jul 1978 at 00 GMT

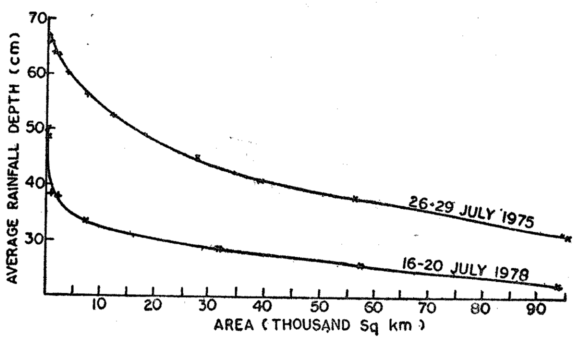


Fig. 3. Depth-area curves

favourable antecedent precipitation conditions. This paper contains the meteorological and hydrometeorological aspects of the floods of 1978 alongwith a comparison of these aspects with those of 1975.

2. The Bagmati and the Adhwara basins and their flood problems

2.1. *Bagmati Basin*

The *Bagmati* is a perennial river. Originating from the Sheopuri range of hills near Kathmandu in Nepal, it has its outfall into the *Kosi* near village Bormo in Monghyr district. It is joined by two tributaries — the *Lakhandai* and the *Lalbakya,* also having their source region in Nepal. Its total catchment area is approximately 13400 sq. km and the total length is 589 km of which 193 km lies in Nepal. It enters India about 25 km upstream of the Railway Bridge No. 89 at Dheng.

2.2. *Adhwara Basin*

The Adhwara basin is vast tract of alluvial plains lying between the rivers *Bagmati* and the *Kamla.* The basin is traversed by a number of smaller tributaries known as the *Adhwara* group of rivers. These tributaries are the *Adhwara, Jamua, Sikao, Burhand, Khiroi, Singhi, Marcha, Rato, Dhaus, Thomane* and *Darbhanga Bagmati.* These originate in Nepal at elevations ranging between 600 & 750 m and join together before finally meeting *Bagmati* near Hayaghat. These rivers have a very short run in the hills. The *Adhwara* basin is a sub-basin of the *Bagmati.*

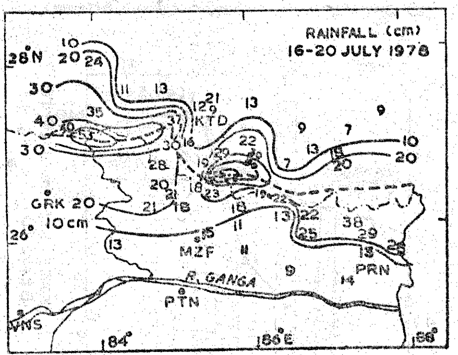
Adhwara basin is very flat. Hardly does any ridge exist between any two rivers. The total catchment area of the *Adhwara* group of rivers is approximately 4960 sq. km of which about 2360 sq. km lies in Nepal.

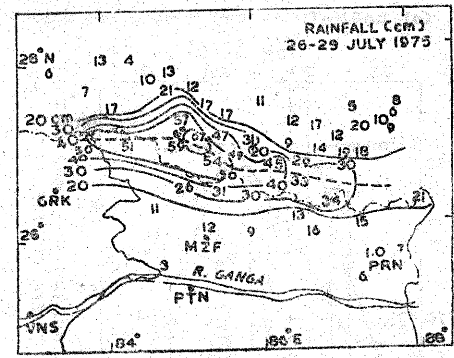
These river systems are shown in Fig. 1.

3. Synoptic conditions of floods in Bagmati and Adhwara group of rivers in 1978 and 1975

Synoptic situations

(a) *July 1978* — Following the northwestwards movement of a deep depression from the northwest Bay of Bengal to the southeast Rajasthan through Orissa & M.P. during 12 to 14 July 1978 the eastern end of the monsoon trough at sea level was passing through submontane Bihar in the morning of 15th. The lower tropospheric winds over Bihar and U.P. had a strength of 20-25 kt with a southerly component. In this situation the catchments of *Burhi Gandak, Bagmati & Adhwara* group received heavy to very heavy rainfall. Heavy





- - - - - - AXIS OF THE ISOHYETAL PATTERN

Fig. 4. Storm isohyetal chart (16-20 Jul 1978)

Fig. 5. Storm isohyetal chart (26-29 Jul 1975)

rainfall extended well also into Bihar plains. The break monsoon conditions persisted for the next four days, *i.e.*, upto 20th, but due to the gradual weakening of the lower tropospheric winds over east U.P. and Bihar, the rainfall in submontane Bihar decreased considerably after 16th. There was, however, a spurt in rainfall in this area between 19th & 20th. It is noticed that a north/south ridge in the lower tropospheric westerlies (900 m asl) was running along about 82 deg. E with the corresponding trough along 90 deg. E on 19th (Fig. 2). The surface convergence due to the monsoon trough situated close to the foothills was apparently augmented by the lower tropospheric convergence between the ridge and the down wind trough at 900 m asl resulting in this increased rainfall. It is admitted (Fig. 2) that the curvature to the east of the ridge is rather small. While there may be small amount of convergence due to the curvature term, some contribution of the shear term to the total magnitude of convergence is likely as is indicated by light winds at Bahraich.

The total storm isohyetal pattern from 16 to 20 July 1978 is shown in Fig. 4.

(b) *July 1975* — The floods of July 1975 were associated with break monsoon conditions from 25 to 27 July 1975, synchronous with the discernible movement of a wave disturbance in the middle latitude westerlies (500 mb) across Tibet (Prasad 1977). The total storm isohyetal chart for the period from 26 to 29 July 1975 is shown in Fig. 5.

It will be seen from Figs. 4 & 5 that in the submontane region of Bihar, the realised rainfall amounts in the break situation of 1975 were much higher than in 1978. These observations are further supported by the depth-area-curves of total storm duration, *i.e.*, 26 to 29 July 1975 and 16 to 20 July 1978 as performed in Fig. 3.

4. Rainfall and flood situation in 1978 and 1975

Day to day progression of the gauge levels in the rivers *Bagmati* at Dheng and *Benibad* and *Adhwara* at Sonbarsa and Saulighat (Fig. 1) in 1978 and in 1975 are shown in Figs. 6 & 7. The daily average rainfall for the storm periods, 16 to 20 July 1978 and 26 to 29 July 1975 are also depicted therein. The average rainfall has been taken in both the situations, as the arithmatic average of 24 hr point rainfall recorded at stations located in the portion of the catchment upstream of the respective gauge sites. The day to day progress of the gauge levels of *Bagmati* at Hayaghat during the situations in 1978 and 1975 are shown in Fig. 8.

It will be seen that in 1978, before the onset of the rainstorm the *Bagmati,* both at Dheng and Benibad were in falling stage implying that the river was emptying the discharge. This is further supported by the falling tendency at the downstream site Hayaghat. The *Adhwara,* both at Sonbarsa and Saulighat were, however, in a steady state. Again, the contribution of the rainfall to the run-off at Dheng after 16th was not significant enough as can be seen from the general falling tendency of the gauge, till the small rise between 19th & 20th. This rise is attributable to the second spurt in rainfall, the probable explanation of which has been discussed.

At Dheng, the river responded immediately to the rainstorm of 16 July 1978 and the flood peak was attained within 12 hours. At Benibad, the beginning of the rainspell arrested the falling tendency. Then rising gradually the flood peak was attained after three & half days of the rain peak.

This immediate response at the upstream site, Sonbarsa, the greater lag in attaining the peak at the dowstream site Saulighat were also seen in the *Adhwara* river.

On the other hand, in 1975, the river *Bagmati* before the onset of the rainstorm was rising at Dheng, Benibad and Hayaghat implying the passage of a flood wave along the entire reach. The *Adhwara* was, however, in a steady state. It will be seen that the gauge peaks were realised in both *Bagmati* and *Adhwara* from rain of four days duration, substantially heavier than the rainfall of 5 days (16-20th) duration in the

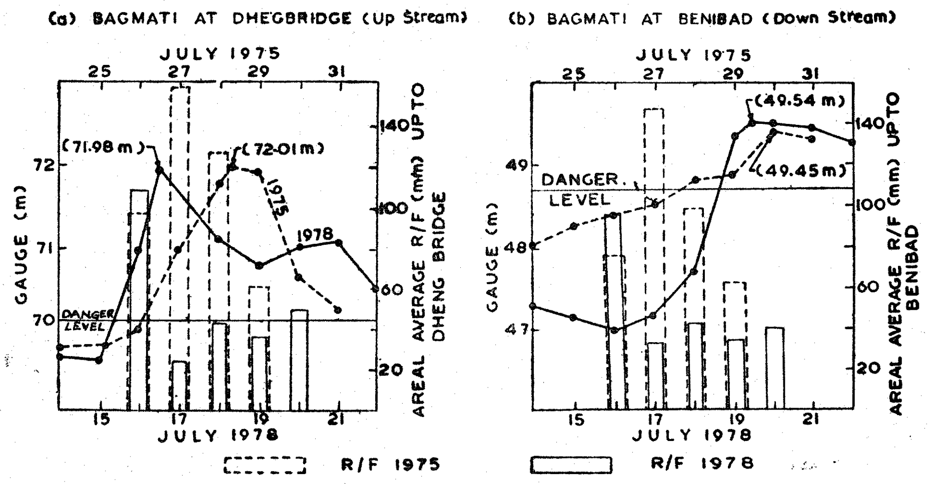


Fig. 6. Gauge curves and areal average rainfall in Bagmati catchment

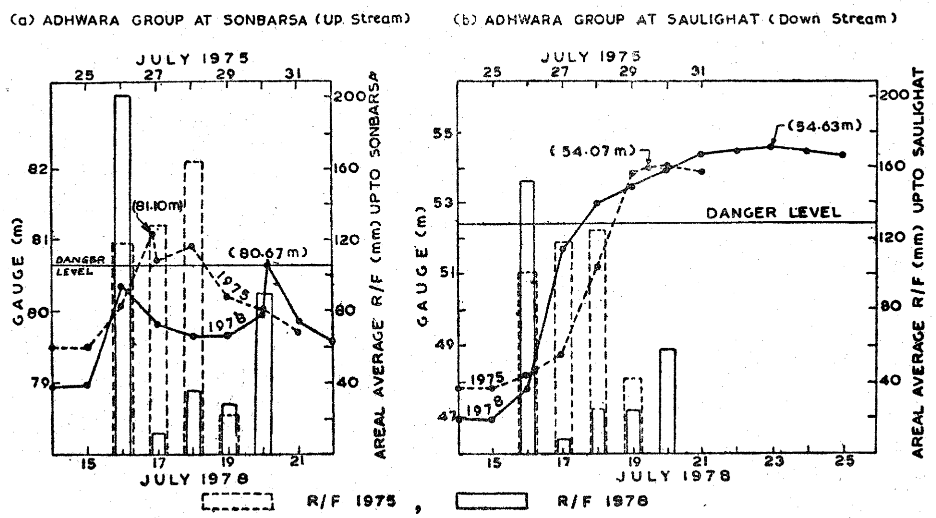


Fig. 7. Gauge curves and areal average rainfall in Adhwara catchment

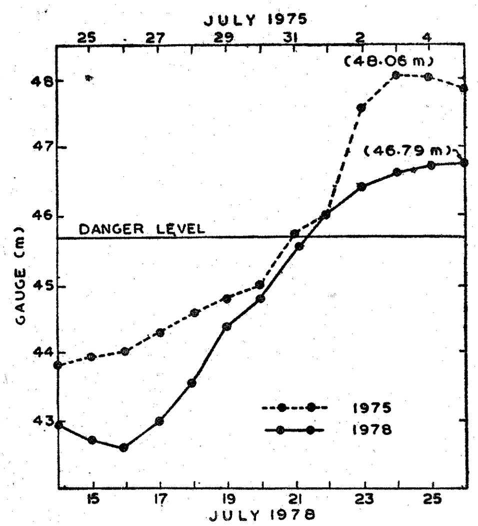


Fig. 8. Gauge curves of river *Bagmati* at Hayaghat

flood occasion of 1978. The initial river levels before the commencement of the rainstorm were lower at Dheng, Benibad and Hayaghat in the *Bagmati* and also at Sonbarsa and Saulighat in the *Adhwara* in 1978 compared to 1975.

The water surface slopes before the commencement of the rainstorm in the *Bagmati* between Dheng and Benibad and in the *Adhwara,* between Sonbarsa and Saulighat were steeper in 1978 compared to those in 1975. One of the reasons of lesser water surface slopes in the rivers in 1975 appears to be the backwater effect downstream. Hayaghat was at a much higher level in 1975 compared to 1978.

Informations on the comparative states of the rivers, rainfall amounts and the gauge levels are presented in Table 1 for ready reference.

TABLE 1

Comparative states of the rivers, rainfall amounts and gauge levels in the *Bagmati* and *Adhwara* group during July 1975 and July 1978 flood spells

Description	Bagmati				Adhwara			
	Dheng Bridge		Benibad		Sonbarsa		Saulighat	
	1975	1978	1975	1978	1975	1978	1975	1978
State of the river before commencement of rain	Rising	Falling	Rising	Falling	Steady	Steady	Steady	Steady
Cumulative areal average rainfall (mm) upto	449mm (26-29 Jul)	259mm (16-20 Jul)	398mm (26-29 Jul)	245mm (16-20 Jul)	334mm (26-29 Jul)	368mm (16-20 Jul)	397mm (26-29 Jul)	267mm (16-20 Jul)
Gauge level before commencement of rain	69.78m (25 Jul)	69.63m (15 Jul)	48.26m (25 Jul)	47.17m (15 Jul)	79.50m (25 Jul)	78.96m (15 Jul)	47.84m (25 Jul)	46.93m (15 Jul)
Gauge level at peak	72.01m (28 Jul)	71.98m (16 Jul)	49.45m (30 Jul)	49.54m (19 Jul)	81.10m (27 Jul)	80.67m (20 Jul)	54.07m (29 Jul)	54.63m (23 Jul)
Magnitude of rise in river gauge from commencement to peak	2.23m	2.35m	1.19m	2.37m	1.60m	1.71m	6.23m	7.70m
River surface slope before the commencement of rain from Dheng to Benibad (Bagmati) and Sonbarsa to Saulighat (Adhwara)	21.52m (1975)		22.46m (1978)		31.66m (1975)		32.03m (1978)	

5. Antecedent soil moisture conditions

It is well known that the initial soil moisture deficiency of the basin at the onset of the rain-storm influences substantially the transformation of the rainfall into run off. The moisture condition in the soil based on the antecedent precipitation index is represented by: $I_1 = KI_0$ where I_1 the API on any day is the product of the recession factor K & the value of API, I_0 on the preceding day (Linsley *et al.* 1958).

The values of the antecedent precipitation indices for July 1975 and July 1978 flood spell worked out on the basis of day to day average rainfalls for the zone comprising the *Bagmati* and the *Adhwara* sub-basins. The initial value of API was taken as the rainfall on a day exactly one calender month prior to the commencement of rainstorms in July 1975 and July 1978, *i.e.*, the rainfall of 26 June 1975 and 16 June 1978 respectively. The values of recession factor was taken as 0.9.

The values of antecedent precipitation indices worked out in the above scheme were 73.2 mm for July 1975 flood spell and 58.6 mm for July 1978 flood spell.

6. Discussion

From above analysis it will thus be seen that despite falling tendency, lower water levels in the rivers before commencement of rain, lower API values and also lesser rainfall amounts (cumulative) realised in the catchment area, *Bagmati* in 1978 attained nearly the same peak level as in 1975 at Dheng and crossed the peak of 1975 at Benibad. Again, with lower water levels initially, lower API values and much less realised rainfall in the catchment area in 1978, the *Adhwara* at Saulighat crossed the peak of 1975 though the peak attained at Sonbarsa remained below 1975 level. The attainment of higher peak levels in 1978 were better manifested in the lower reaches of both the rivers. Further, it will be seen from Table 1 that the overall magnitudes of rise from the stage of commencement of rise to peak in 1978 exceeded those of 1975 in both rivers at both the sites. Down-stream at Hayaghat (*Bagmati*) and Ekmighat (*Adhwara*) also, though the peak river gauges in 1978 stayed below the 1975 levels, the overall magnitudes of rise from commencement to peak were higher in 1978 being 4.16 m in 1978 against 4.12 m in 1975 at Hayaghat and 4.25 m in 1978 against 3.41 m in 1975 at Ekmighat.

It will be further seen from Figs. 6 and 7 that the maximum 24-hr rise in the river gauges on any day during the flood spell was much sharper in 1978 than in 1975 in both rivers at both the sites.

Comparative figures of maximum 24-hr rise in the two rivers are shown in Table 2.

It is clear from the foregoing discussion that from all accounts the floods of 1978 were of a more severe nature than of 1975 inspite of lesser cumulative areal average rainfall in the catchment and less favourable API conditions. The most prominent feature of the 1978 floods was the flash rise of rivers as evident from data in Table 2. This appears to be the main contributory factor in the rivers touching or overtopping the 1975 levels.

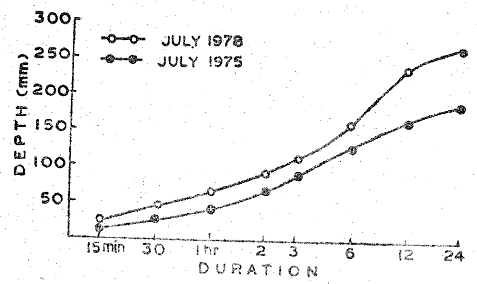


Fig. 9. Depth-duration curve at Sonbarsa

TABLE 2

Maximum 24-hr rise on any day during the flood spells of July 1975 and July 1978

River	Check point	Gauge level (m)	Date Jul'75	Gauge level (m)	Date Jul'78
Bagmati	Dheng	0.98	26 to 27	1.37	15 to 16
	Benibad	0.55	29 to 30	1.63	18 to 19
Adhwara	Sonbarsa	1.01	26 to 27	1.42	15 to 16
	Saulighat	2.63	28 to 29	3.89	16 to 17

The short duration temporal distribution of storm rainfall in the upper catchments of *Bagmati* and *Adhwara* group was examined with the help of autographic records of Sonbarsa. This station is located centrally in upper *Bagmati-Adhwara* system (Fig. 1) and, therefore, may be taken to represent both the subcatchments. The depth-duration plot (duration on log-scale) of the storm rainfall of Sonbarsa for durations 15-min, 30-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr and 24-hr maximum is presented in Fig. 9. The maximum storm rainfall depth for various durations were obtained by computing the running totals of 15-min interval rainfall. It will be seen that curve of 1978 is substantially higher than that of 1975, in fact much higher for durations 6-hr and above, implying that the short duration intensities of rainfall in July 1978 flood spell were higher than in 1975.

It is a well known fact that the volume and peak of runoff outflow from a drainage area of smaller size, such as the one under consideration, and the consequent gauge rise at a stream gauging site, depends to a large extent upon the short duration intensity of rainfall. Higher intensity storm rainfall would evidently result in prompt surface runoff and flash gauge rise.

It is, therefore, apparent that the higher short duration intensity of storm rainfall during 1978 played a decisive role and accounted for the higher gauge rises in July 1978 flood spell even though the total storm precipitation yield was much lower as compared to 1975.

It is realised that the peak attained at the downstream gauge is a combined effect of the outflow from the upstream, the local effects of the rain and the local inflow from the tributaries on the mainstream flow between the upstream and the downstream gauges. Contribution of the local inflow is an important parameter and the total volume of the local inflow as well as the timings of their entry into the mainstream have to be taken into consideration to determine the resultant gauge value at the downstream sites from the observed readings of the gauges at the upstream sites. In rainstorm situations with widespread rain over large areas the tributaries are also in state of floods. Most of the tributaries of the *Bagmati* and of the *Adhwara* group join the mainstream between the gauge sites considered. It is, therefore, reasonable to assume that those tributaries contributed considerable volumes of flow into their respective mainstreams both in 1975 and 1978. But the pertinent information on the inflow volume and the timing of entry is not available for accounting in this study.

7. Conclusions

(*i*) A comparative study of the hydrological and hydrometeorological features of flood spells of July 1975 and July 1978 in rivers *Bagmati* and *Adhwara* group has revealed that with much less rainfall amounts, less favourable antecedent conditions and lower initial gauge levels, the flood peaks were higher in 1978 than in 1975 in the downstream reaches of the rivers. *Bagmati* nearly touched the 1975 HFL at the upstream site Dheng with only one-day rainfall as against four-day rainfall in 1975.

The high intensity of short duration rainfall of the 1978 flood spell contributed significantly to the rivers registering higher gauge rises and overtopping the 1975 HFL at the downstream sites inspite of the total storm rainfall yield and other factors being less favourable. The study has thus brought out the importance of short duration rainfall intensity in formulation of flood forecasts for smaller catchments.

(*ii*) Superimposition of a minor wave disturbance in the lower tropospheric wind flow on prevailing break conditions seem to favour enhancement of rainfall activity in the wave disturbance.

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