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A STUDY OF FLOODS IN THE BRAHMAPUTRA BASIN IN INDIA

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ABSTRACT

During the summer monsoon months June–September, the Brahmaputra River experiences severe floods that occur year after year causing death and destruction in the Assam Valley and neighbouring Bangladesh. During the period 1987–1998, flood data of 21 gauge/discharge sites on the main Brahmaputra River and its 12 major tributaries have been studied with a view to discovering which sites and tributaries experience frequent floods in different monsoon months and how high flood magnitudes are. It is hoped that this study may be useful to planners and water resources engineers for taking the remedial measures against recurring floods in this region. Copyright © 2000 Royal Meteorological Society.

KEY WORDS: Brahmaputra basin; cyclonic disturbances; floods; southwest monsoon; seasonal monsoon trough; trans-Himalayan rivers

1. INTRODUCTION

Although originating in the semi-arid region of south Tibet, the Brahmaputra River experiences severe floods on a yearly basis. This is due to the river's passage through the wettest region of India. These floods bring death and devastation not only to Assam but also to the neighbouring country of Bangladesh. In connection with this, it is worth mentioning what Khosla (1958), one of India's top engineers, said some 40 years ago:

> Floods are an evil in so far as they cause destruction to life and property but floods are potential resources and blessings. This resource can be wasted harmlessly to the sea by suitable engineering works, but of really vital importance is the utilization of these surplus flood waters for purpose of irrigation, power development, navigation, etc. Such utilization can be achieved by conserving the flood supplies in for beneficial use, and thereby eliminating the death and destruction.

In light of this, rainfall and flood study of the Brahmaputra River and its major tributaries in the Assam region has been undertaken with a view that some permanent flood control measures may be taken to conserve the flood waters for beneficial use in the coming years, so that there is overall development of the northeastern region of the country.

2. PHYSIOGRAPHIC FEATURES OF THE BRAHMAPUTRA BASIN

Brahmaputra, as the name implies, means the '*Son of Brahma*', the God of Creation. It is one of three major rivers of the Indian sub-continent, *viz*. the Indus, the Ganga and the Brahmaputra. It has an annual average runoff of 510 000 million m^3 and a total length of about 2900 km, draining an area of 580 000 km^2 in Tibet, India and Bangladesh (Rao, 1975). This river is a trans-Himalayan river as it rises in south Tibet from the glaciers of Mount Kailash at an elevation of about 5150 m asl at 30°31′N, 82°10′E (Burred *et al*., 1934). In Tibet, it is called Tsangpo, and flows eastwards through southern Tibet for about 1600 km, being almost parallel to the Great Himalayan range (Rao, 1975). Figure 1 shows the basin plan of the Brahmaputra River and some of its tributaries.

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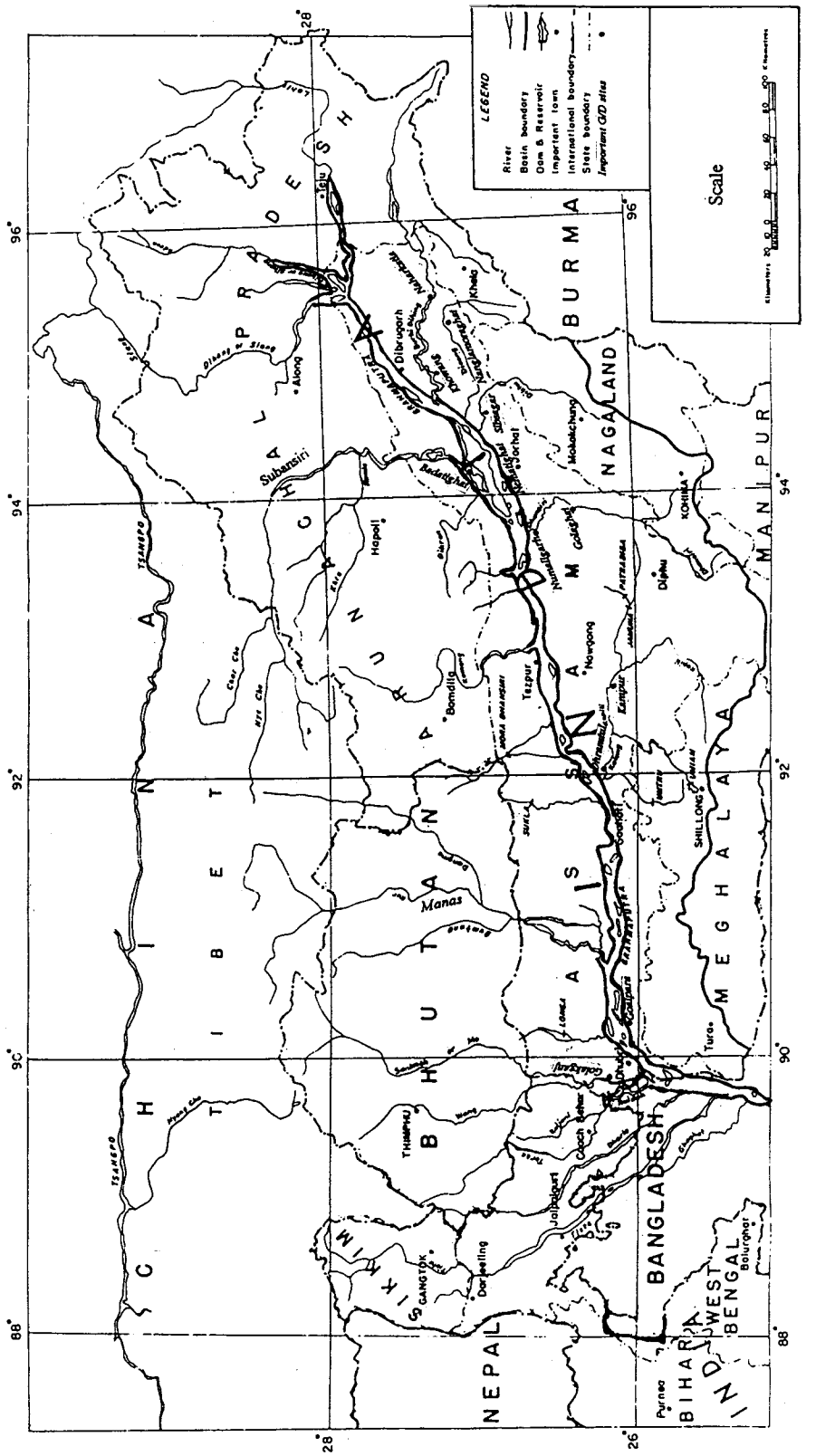

Figure 1. Basin plan of the Brahmaputra River and its tributaries

At its eastern end the river flows in a great loop around Mount Namcha Barwa (7756 m), the highest peak in the Himalayas in this region and then turns to the south after cutting a gorge across the Himalayas known as the 'Great Bend'. At the Great Bend the river falls from about 3000 m in Tibet to 500 m in India in a short stretch and enters the Assam Valley west of Sadiya town (Murthy, 1981). From here it is called 'the Dihang' and is joined by two more tributaries from the northeast and east, *viz*. the Dibhang and the Luhit (see Figure 1). From here onwards the combined course of these three rivers, *viz*. the Dihang, the Dibhang and the Luhit, is called *the Brahmaputra*.

This mighty river flows down the entire Assam Valley between the foothills of the Himalayas to the north and the Khasi and the Garo hills to the south for about 720 km. During its long course in the Assam Valley, it is joined by important tributaries from the Himalayan ranges of Arunachal Pradesh and Bhutan in the north, *viz*. the Subansiri, the Kameng, the Dhansiri and the Manas, and from the south by the Dihing, the Buri Dihing, the Disang, the Dikhu and the Kopili. The river takes a southward course near Goalpara in Assam and enters Bangladesh and flows about 270 km across the alluvial plains of Bangladesh before joining the Padma at Goalundo.

The Brahmaputra occupies eighth position in a list of 34 major rivers of the world on the basis of their annual average runoff (Rao, 1975). The Ganga and Indus occupy tenth and 21st positions, respectively, with the Amazon of South America appearing at the top of the list.

On 15 August 1950, the entire Assam region of northeastern India experienced a severe earthquake, which altered the course and bed levels of many rivers in this region. In the case of the Brahmaputra, the earthquake caused a sudden rise of bed levels at Dibrugarh and many other places by bringing down a large mass of debris, consequently changing the river's morphology.

3. RAINFALL DISTRIBUTION OVER THE BRAHMAPUTRA BASIN

Normally the monsoon sets in over the Assam region during the first week of June and withdraws by the second week of October. The two Indian stations that receive the heaviest rainfall, viz. Cherrapunji and Mawsynram, are located just to the south of the Brahmaputra basin (not shown in Figure 1). The southwest monsoon is responsible for causing the bulk of rainfall (this being the order of 165 cm) which is about 65% of the annual rainfall over the basin in Assam. Most of the runoff of this river is derived from heavy rainfall of 510–640 cm in the Abor and Mishmi hills in Arunachal Pradesh and 250–510 cm in the Brahmaputra plains (Murthy, 1981).

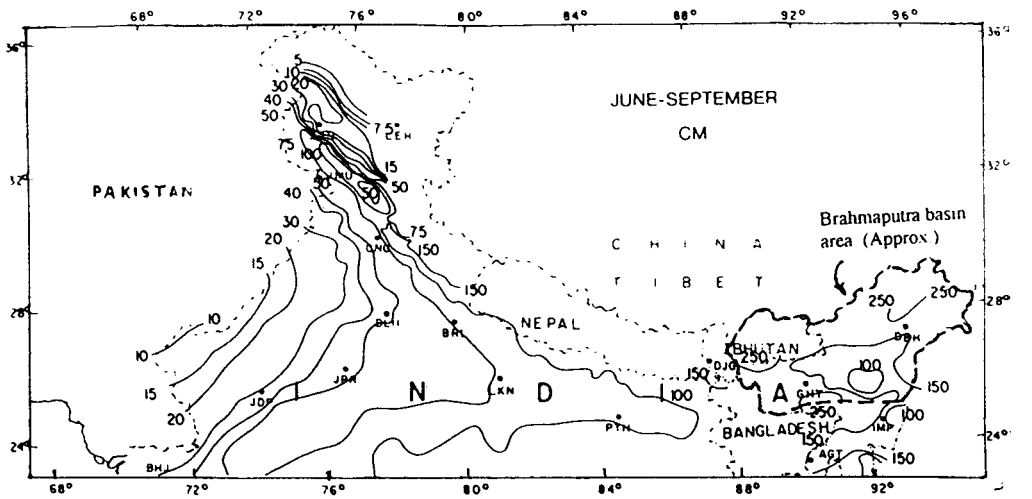

Figure 2. Monsoon isohyetal map of north India with special reference to the Brahmaputra basin in northeast India

Table I. Stations that recorded 40 cm or more in the Assam Valley

Station	Rainfall (cm)	Date of occurrence
Lakhimpur	49	25 May 1954
Nematha	69	30 May 1893
Goalpara	71	8 June 1970
Upper Shilong	44	20 June 1934
Bardgur	42	20 June 1934
Shillang	41	20 June 1934
Bijim	49	9 July 1895
Pasighat	47	11 July 1948
North Lakhimpur	51	22 September 1956
Tezu	64	30 September 1972

Variability of annual rainfall over this region is low, in the order of 10–15%. Before the onset of the monsoon, there is considerable thunderstorm activity over the region in the month of May due to the incursion of moisture in the region from the neighbouring Bay of Bengal. On examination of the annual isohyetal map of this region prepared by India Meteorological Department (IMD, 1986) it can be seen that maximum rainfall (about 250–500 cm) occurs in the northwestern and southwestern parts of this basin with a minimum of about 150 cm in the southeastern side of the basin in the Lanka-Dimapar area (see Figure 2).

A close examination of daily rainfall data for stations in the Assam Valley has shown that the stations listed in Table I recorded rainfall of 40 cm or more in one day during the recent past.

4. METEOROLOGICAL SITUATIONS CAUSING HEAVY RAINFALL OVER THE BASIN

Dhar and Changraney (1966), Pant *et al.* (1970) and Ramaswamy and Rao (1979) studied the meteorological situations responsible for causing heavy rainfall in and around this basin. It has been observed by them that heavy rainfall is mostly caused when the eastern end of the monsoon trough shifts northwards to the Assam Valley or during the periods when 'Break' monsoon situations set in over the country with a northward shift of the monsoon trough to the foot of the Himalayas. These two particular meteorological situations are responsible for causing heavy rainfall on about 65% of occasions. Cyclonic circulations cause very heavy rainfall over the Assam region. Such systems cross the Orissa–Bengal Coast and move in a northwesterly or northerly direction, or recurve in a northerly or northeasterly direction. It has been seen that rainstorms over this region normally have a duration of 2–3 days, but there have been occasions when rain spells of 6–7 days in duration have also occurred.

Normally the month of June experiences average rainfall of about 48 cm over Assam and neighbouring areas. The other monsoon months of July, August and September receive about 45, 40 and 32 cm of rainfall, respectively (IMD, 1971). Examination of past records dating back to 1901 revealed that the region's most severe rainstorms occurred in the periods 9–12 August 1902 and 18–21 June 1934. Both these rainstorms were caused by the northward shifting of the eastern end of the monsoon trough. The average rain depths caused by these two rainstorms over 67 700 km^2 for a 4-day duration are as follows (Pant *et al.*, 1970):

Rainstorm duration	Average rain depths (cm)	Centre of the rainstorm
9–12 August 1902	30	Mawsynram
18–21 June 1934	28	Mawsynram

Prasad (1974) studied the diurnal variation of rainfall at four stations in the Assam Valley, *viz*. north Lakhimpur, Dibrugarh, Tezpur and Ganhati stations and observed that rainfall maxima at all these four stations occur during early morning hours, i.e. 00:00–06:00 h and minima occur during the afternoon hours, i.e. 12:00–18:00 h. He attributed this to a mountain wind effect in the valley.

Using all the available long-period rainfall data of about 103 rainfall stations in and around the Brahmaputra basin, Dhar and Kamte (1973) estimated extreme point rainfall, also called probable maximum precipitation (PMP), using Hershfield's (1965) statistical technique. They found that 1-day extreme point rainfall over the valley varied from 30 to 75 cm. By using the same technique, but a longer and more up-to-date network of stations, the Indian Institute of Tropical Meteorology, Pune (IITM, 1989) found that the extreme point rainfall of 1-day duration varied from 40 to 80 cm.

5. FLOODS IN THE BRAHMAPUTRA AND ITS TRIBUTARIES

Here, an attempt has been made to study the flood level data of 21 gauge/discharge (G/D) sites (Central Water Commission (CWC), 1987–1998) over the main Brahmaputra River and its 12 important tributaries during the monsoon seasons of 1987–1998. Before looking at the actual flood events on the Brahmaputra and its tributaries, mention will be made of how floods are defined in India. It should also be stated that, floods that have occurred in the rivers joining the Brahmaputra outside Assam, like the Torsa, the Teesta, etc., have not been considered in this study, as they do not cause floods in the Assam Valley.

5.1. Flood definitions

A flood is defined by various workers in different ways. According to Chow (1956), a flood is a relatively high stage of a river that overtakes the natural channel provided for its flow. According to Ward (1978), a flood is a body of water that rises to overflow land which is not normally submerged.

In India, a river is said to be in flood when its water level crosses the danger level (DL) at that particular site. CWC, New Delhi, which is the nodal agency in India for the development of water resources, has fixed DLs at important G/D sites on most of the rivers in consultation with State Government Engineers. As such, when water level in a river touches or exceeds the DL at a particular G/D site, the river at that site is said to be in flood. Major floods are those when water level is 1 m or more above the DL and if it is 5 m or more above the DL, that flood is said to be catastrophic. In India, up to 1997, about 30 G/D sites over 17 rivers recorded catastrophic floods (Dhar and Nandargi, 1998). So far, the highest deviations from DL are considered, it has been observed that on the Teesta river (in northeast India) it was of the order of 18.10 m on the 4 October 1968 at the Anderson Bridge G/D site and 17.87 m on the Narmada River at G/D site, Garudeshwar on 6 September 1970 (Dhar and Nandargi, 1998).

5.2. Catalogue of highest floods in the Brahmaputra

Table II gives the catalogue of highest floods recorded in the Brahmaputra basin in the Assam Valley during 1987–1998 at 21 G/D sites during the monsoon months June–September. July and August experience the worst floods of the monsoon season while this river starts experiencing floods right from June, which is the first month of the monsoon season. The reason for this is that during May, the Assam Valley experiences widespread thunderstorm activity. This causes considerable rainfall all over Assam, consequently causing quick runoff in its tributaries as well as in the main river.

The catalogue shows that the highest flood occurred on 20 June 1993 in the Puthimari River, a tributary of Brahmaputra (at N.H. Crossing G/D site) when the deviation between DL and flood level was 4.65 m (see Table II). If the six G/D sites on the main Brahmaputra River are considered, it is seen from Table II that deviations between the highest flood level and DL during the 12-year period (1987–1998) ranged from 1.02 to 2.28 m.

Table II. List of highest recorded floods at different gauge/discharge sites on the Brahmaputra River and its tributaries (1987–1998)

Sr. no.	River	Gauge site	DL (m)	Highest flood level (m)	Date of occurrence	Deviation from DL (m)	Total no. of floods
1	Brahmaputra	Dibrugarh	104.24	106.41	04.09.98	2.17	136 (43)
		Nematighat	85.04	87.32	11.07.91	2.28	112 (20)
		Tezpur	65.23	66.58	27.08.88	1.35	63 (5)
		Guwahati	49.68	51.37	29.08.88	1.69	43 (4)
		Goalpara	36.27	37.29	29.08.88	1.02	11 (1)
		Dhubri	28.50	30.18	28.08.88	1.68	89 (11)
2	Burhi Dihing	Naharkatia	120.40	121.11	13.08.95	0.71	5 (—)
		Khowang	102.11	103.85	26.08.88	1.74	83 (25)
3	Desang	Nanglamoraghat	94.46	96.45	07.09.98	1.99	35 (13)
4	Dikhaw	Sibsagar	93.30	94.66	24.06.90	1.36	12 (3)
5	Subansiri	Badatighat	82.53	83.69	26.08.88	1.16	34 (3)
6	Dhansiri	Golaghat	89.50	91.12	31.10.86	1.62	11 (1)
		Numaligarh	77.42	79.68	11.10.86	2.24	115 (29)
7	Jaibareilly	N.T. Rd. Crossing	77.00	78.04	11.07.98	1.04	78 (1)
8	Kopili	Kampur	60.50	61.54	08.07.88	1.04	28 (3)
		Dharamtul	56.00	57 54	09.07.88	1.54	29 (6)
9	Puthimari	N.H. Crossing	51.81	56.46	20.06.93	4.65	56 (20)
10	Beki	Road Bridge	44.38	45.89	01.09.98	1.51	158 (18)
11	Pagladiya	N.T. Rd. Crossing	52.75	54.38	15.08.95	1.63	26 (8)
12	Manas	N.H. Crossing	47.56	49.76	11–17.07.97	2.20	94 (35)
13	Sankosh	Golakganj	29.51	30.58	22.07.93	1.07	64 (2)

Rivers are arranged in alphabetical order, no. 1 is the main river and nos. 2–13 are the major tributaries in the Assam Valley. The figure in brackets (column 8) gives frequency of floods when deviation from danger level is 1 m or more.

Table II also gives the total number of floods which were recorded during the 12-year period at each G/D site. It can be seen that G/D site Road Bridge on the Beki River experienced maximum number of floods of the order of 158, which included 18 floods which were higher than 1 m or more above the DL. It can also be seen from Table II that Dibrugarh and Nematighat sites on the Brahmaputra River, Numaligarh on the Dhansiri River and Road Bridge on the Beki River have experienced floods on more than 100 occasions during the 12-year period. Generally, most of the G/D sites have experienced flood levels which were within 3 m above the DLs, except the G/D site, N.H. Crossing on the Puthimari River which stood at 4.65 m.

5.3. Monthwise and yearwise frequency of floods at G/D sites

In Figure 3 monthly and yearly flood frequencies in the Brahmaputra River and its tributaries are shown. It can be seen that the maximum number of floods have occurred in July, followed by the months of August and September. This is also supported by the monthly frequency of floods at different G/D sites (see Figure 4). Although the rainfall is at a maximum in the month of June, floods have not been occurring as frequently as in the other monsoon months.

So far as the yearly frequency of floods at different G/D sites is concerned, it can be seen that the Road Bridge site on the Beki River and Dibrugarh site on the main Brahmaputra River have been experiencing maximum floods year after year (Figure 5). These two G/D sites may be called 'Cherrapunjies' of floods so far as the occurrence of maximum number of floods in this region are considered.

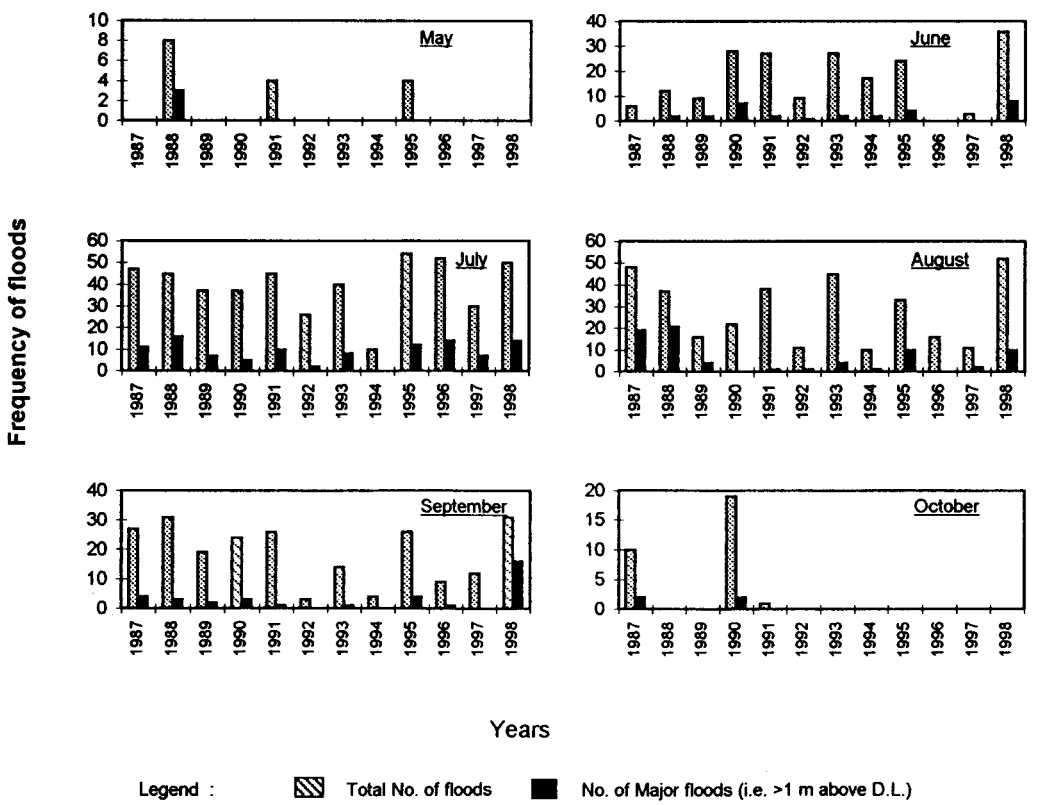

Figure 3. Monthwise and yearwise frequency of floods on the Brahmaputra River and its tributaries (May and October data are incomplete)

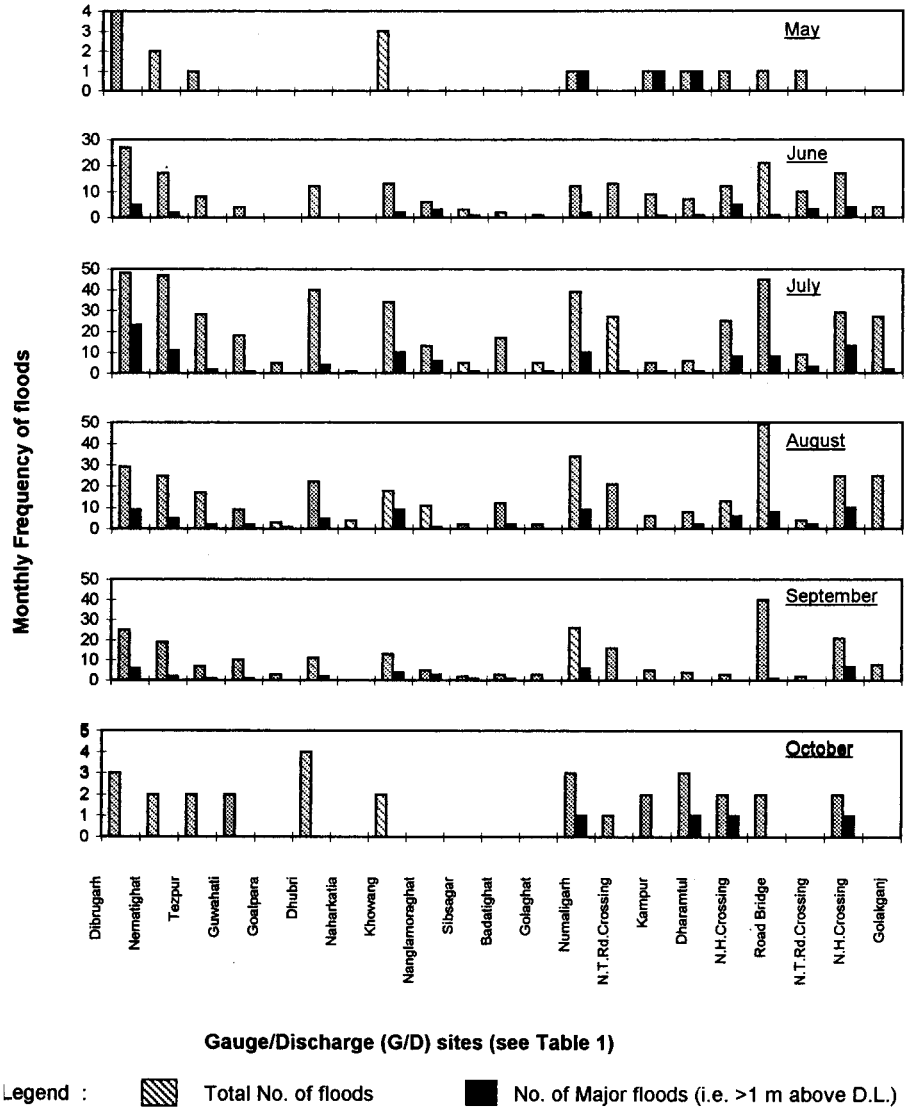

Figure 4. Monthwise frequency of floods at different gauge/discharge sites of the Brahmaputra River and its tributaries (May and October data are incomplete)

6. AVERAGE MONSOON RAINFALL AND FLOODS IN THE BRAHMAPUTRA VALLEY

Area-weighted average rainfall for the monsoon periods of the years from 1987 to 1998 was calculated for the entire northeast region constituting the sub-divisions of (i) Assam and Meghalaya and (ii) Manipur, Mizoram and Tripura. The percentage departures from normal for the rainfall over the monsoon season of each year are given below:

Year	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
% Departure from normal	−9	+17	+10	0	−5	−23	+12	−25	+4	−14	−4	+1

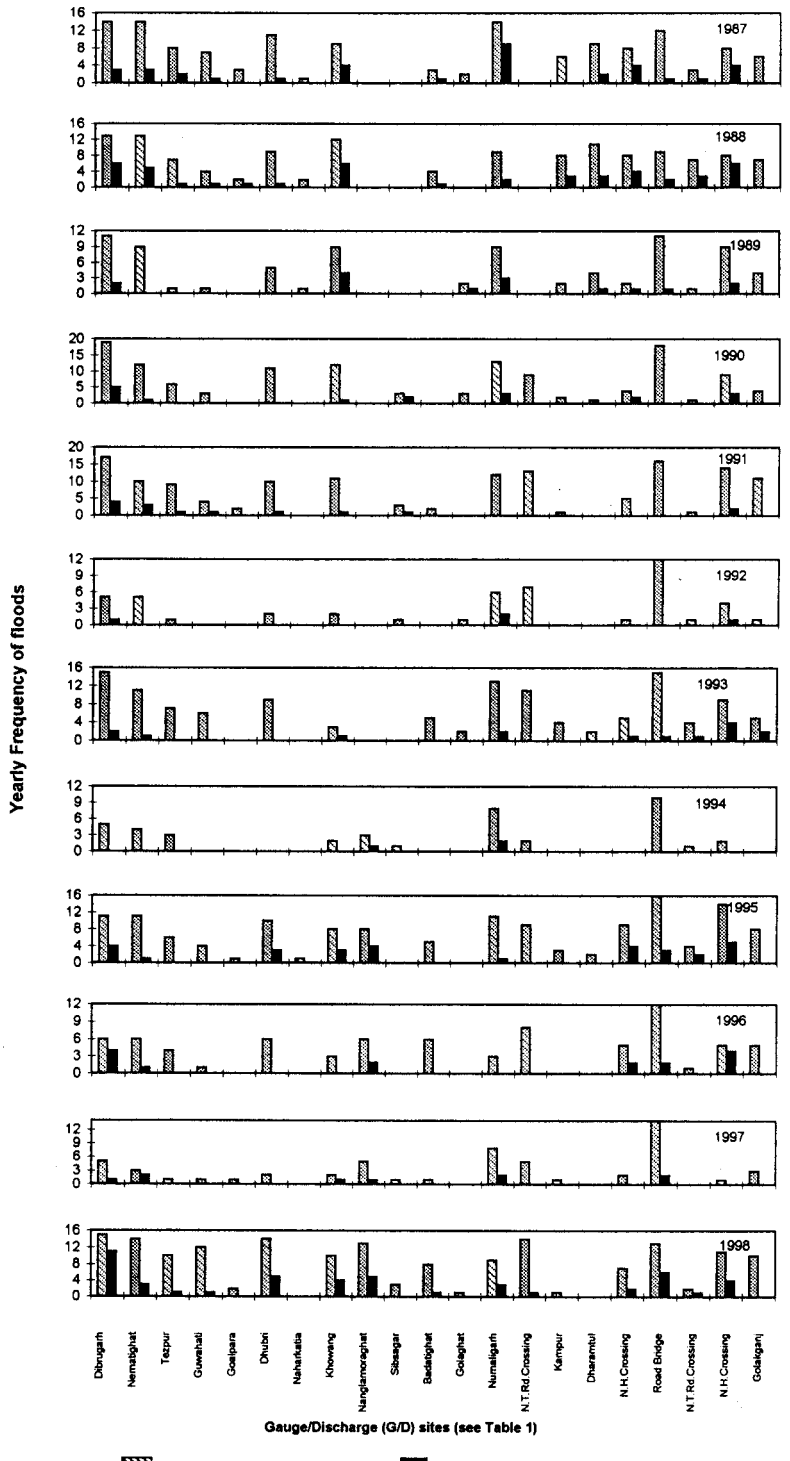

Figure 5. Frequency of floods at different gauge/discharge sites of the Brahmaputra River and its tributaries during the monsoon period 1987–1998

Figure 5 shows the frequency of floods at different G/D sites during the monsoon period of different years. It is evident from this figure that years of above normal monsoon rainfall do produce a larger number of floods as happened in the years of 1988, 1989, 1993, 1995 and 1998. It can also be seen that in years of deficient rainfall like 1987, 1991, 1992, 1994, 1996 and 1997 there were floods at some G/D sites but their frequency was considerably lower, except in the deficient year of 1987.

It was observed in the 1987 monsoon season that rainfall at individual stations, particularly in the sub-divisions of Arunachal Pradesh and Meghalaya, was 20–50% above normal. In these two sub-divisions, rainfall was above normal for 10–15 weeks out of 18 weeks during the monsoon period of 1987 (Dhar and Nandargi, 1989). Perhaps, this heavy rainfall in these two sub-divisions was responsible for causing a large number of floods in the Assam Valley as is seen in Figure 5, although the entire country was experiencing severe drought conditions.

7. SUMMARY AND CONCLUDING REMARKS

The Brahmaputra basin is one of the largest river basins in the northeast region of India, i.e. Assam and neighbourhood. This is the region of highest rainfall in India. The main meteorological situations that cause heavy rainstorms over the Brahmaputra basin are due to the shifting of the eastern end of the seasonal monsoon trough to the foothills of Himalayas in the north and 'Break' monsoon situations during the monsoon season. The mean annual rainfall over this region is of the order of 250 cm (IMD, 1971) with a low co-efficient of variability, this being of the order of 10–15%.

It has been shown that the highest flood deviations from DL at G/D sites over the main Brahmaputra River vary from 1 to 2.28 m during 1987–1998. The two G/D sites at Dibrugarh and Nematighat in upper Assam have experienced high flood levels year after year as well as a high frequency of floods of the order of 112–136 during the 12-year period. Except the Goalpara G/D site, all the other five G/D sites on the Brahmaputra River have been experiencing high flood levels (i.e. 1 m and above their respective DLs), and also the frequency of floods at these sites has been between 40 and 90 during the 12-year period.

Among the Brahmaputra's 12 major tributaries in Assam, the Puthimari River has recorded the highest deviation from DL of 4.65 m in June 1993, while the Beki River has experienced the highest frequency of floods of the order of 158 in the 12-year period.

At present, the enormous water resources of the Brahmaputra River are not fully utilized and practically most of its flood water is being lost into the Bay of Bengal through Bangladesh after causing enormous damage by way of ravaging floods in Assam and Bangladesh. Although there is not much scope for increasing irrigation facilities in the Assam valley beyond a certain limit due to a lack of proper storage sites (especially in the main river and some of its tributaries) there is enormous potential for hydroelectric power generation in this region especially at the 'Great Bend' of the Dihang River when it enters India from Tibet and in some of its tributaries. All this has to be tapped fully if the northeast region as well as the country at large is to advance in the coming years as far as power generation and agriculture are concerned. This, of course, requires full co-operation of the neighbouring countries of Tibet (China), Bhutan and Bangladesh for the development of water resource projects of this entire region.

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