

Flow Characteristics of the Jamuna River: During the 1988 and 1998 Catastrophic Flood Events in Bangladesh

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Abstract

The 1988 and 1998 flood events hit Bangladesh which was more catastrophic in the present study area, Manikganj district. The Jamuna River has great locational influences to cause severe flood situations in the study area. Bangladesh Water Development Board (BWDB) provided the river stage data of the Jamuna for pivot table analysis and drawing hydrographs. The Jamuna River attained its highest peak 10.55 m in August and 10.58 m in September in 1988 flood at Arichaghat station which flowed 141 cm and 144 cm above its danger level (9.14 m). In 1998 flood event, the Jamuna rose up to 10.02 m in July, 10.35 m in August and 10.76 m in September that flowed respectively 88 cm, 121 cm and 162 cm above the danger level (9.14 m). As a whole, the Jamuna flowed above the danger level for 43 days in 1988 and 68 days in 1998 causing the devastating flood in the study area. A total of 2518 people lost their lives and damage to crops fisheries, livestock, was over 120 billion US dollar. About 125 km of local roads, national highways and several hundred bridges, over 250 educational institutions and 140 health structures were affected by the flood events.

Keywords: Flood; Danger level; Water level; Jamuna River; Arichaghat

Introduction

About 30 to 35 percent land surface of Bangladesh is flooded every year during the wet monsoon [1]. But the catastrophic flooding event is the most critical environmental issue which causes untold sufferings to millions of people [2-5]. Actually, flood has become a perennial feature in Bangladesh due to its geographical settings [6,7]. Bangladesh is situated at the confluence of three of the world's mighty rivers, namely, the Ganges, the Brahmaputra, and the Meghna which all originate from the Himalayan system and flow through Bangladesh carrying 2.4 billion tons of sediment into the Bay of Bengal [8,9]. The striking feature of this system is that Bangladesh's territory of only 1,44,000 square kilometers occupies an extremely small part of the system at its lower end [7-9]. About 93 percent of floodwater is discharged from outside its boundaries while only 7 percent is from within its margin [4,9]. About 230 rivers of the country form a perplexing and ever changing pattern [10-12]. All the rivers and streams constitute 24,000 km length covering 7 percent area of country with average 38,000 cubic meters per second water flow during the rainy season [8,9,13].

Flood is a perennial and/or recurring phenomenon in Bangladesh, locally termed as banna. It has been noticed that in 20 years out of 50 annual available records, one-fifth area of the country was flooded. Eighteen major floods occurred in the twenty century and those of 1988 and 1998 were of catastrophic consequences. The widespread floods occurred successively in 1954, 1955, 1956 and 1966 when 26%, 35%, 25% and 23% area of the country went under water but the large area was flooded in 1988 (61%) and 1998 (67%). In 1987, the catastrophic flood occurred throughout July and August and affected 57,491 sq. km. of land, about 40 percent of the total area of the country. In 2000, the flood submerged 24% area of the country and caused loss to life and massive damage to property. The flood of 2004 (38%) and 2008 (23%) was also of devastating consequences. The 2007 flood affected the large part (42%) of Bangladesh (Table 1).

| Year Affected (sq. km) | | Percentage of Total Area | Year | Year Affected Area (sq. km) 1984 28314 19. | | |
|---------------------------|-------|-----------------------------|------|---|-------|--|
| 1954 | 36920 | 25.64 | 1984 | 28314 | 19.66 | |
| 1955 | 50700 | 35.21 | 1985 | 11427 | 7.93 | |
| 1956 | 35620 | 24.74 | 1986 | 4589 | 3.19 | |
| 1960 | 28600 | 19.86 | 1987 | 57491 | 39.92 | |
| 1961 | 28860 | 20.04 | 1988 | 89970 | 61.00 | |
| 1962 | 37440 | 26.00 | 1989 | 6100 | 4.00 | |
| 1963 | 43160 | 29.97 | 1990 | 3500 | 2.40 | |
| 1964 | 31200 | 21.67 | 1991 | 28600 | 19.00 | |
| 1965 | 28600 | 19.86 | 1992 | 2000 | 1.40 | |
| 1966 | 33540 | 23.29 | 1993 | 28742 | 20.00 | |
| 1967 | 25740 | 17.87 | 1995 | 32000 | 22.00 | |
| 1968 | 37440 | 26.00 | 1996 | 35800 | 24.00 | |
| 1969 | 41600 | 28.89 | 1998 | 100250 | 67.00 | |
| 1970 | 42640 | 29.61 | 1999 | 32000 | 22.00 | |
| 1971 | 36475 | 25.33 | 2000 | 35700 | 24.00 | |
| 1972 | 20800 | 14.44 | 2001 | 4000 | 2.80 | |
| 1973 | 29900 | 20.76 | 2002 | 15000 | 10.00 | |
| 1974 | 52720 | 36.61 | 2003 | 21500 | 14.00 | |
| 1975 | 16590 | 11.52 | 2004 | 55000 | 38.00 | |
| 1976 | 28418 | 19.73 | 2005 | 17850 | 12.00 | |
| 1977 | 12548 | 8.71 | 2006 | 16175 | 11.00 | |
| 1978 | 10832 | 7.52 | 2007 | 62300 | 42.00 | |
| 1980 | 33077 | 22.97 | 2008 | 33655 | 23.00 | |
| 1982 | 3149 | 2.19 | 2009 | 28593 | 19.00 | |
| 1983 | 11112 | 7.72 | 2010 | 26530 | 18.00 | |

Table 1: Year-wise flood affected areas in Bangladesh.

The catastrophic flood events in 1988 and 1998 caused untold sufferings to millions of people, and result in human deaths, loss of livestock, spread of diseases and hunger, damaged standing crops, destroyed physical and economic infrastructures [3,4,14-16]. Rainfall, together with synchronization of very high flows of all the three major rivers of the country in only three days aggravated the flood situations [4,13,17]. The floodwater inundated about 89,970 sq. km of land area that is estimated about 61 percent of the country and duration of the flood varied from 15 to 34 days in respect of time and place [7,18-20]. The 1998 flood occurred from July 12 to September 14, with duration of 68 days, and affected about 67 percent area of the country [12,21]. Copulation of excessive rainfall within and outer boundary of the country and synchronization of peak flows of the major rivers

contributed to cause the flood. The prolonged situation was caused due to solar eclipse retards the outflow of water drainage by raising the tidal level [22]. The effects of EL-Nino and synchronization of high tide are the causes of long duration in 1998 flood [21,23].

Geographical setting of study area

The geographical settings and hydrological characteristics of the major rivers are the ground causes of flood in Bangladesh (Figure 1) as well as the present study area (Figure 2). Three mighty rivers the Brahmaputra-Jamuna, the Ganges and the Padma all have originated from the Himalayan systems carrying huge discharges and put pressure to occur the devastating floods in Bangladesh (Table 2).

| Parameters | Jamuna | Ganges | Padma |
|---|--------|--------|-------|
| Drainage area (103 km²) | 570 | 1000 | 1573 |
| Average annual rainfall within the drainage area (mm) | 1900 | 1200 | 1450 |
| Average annual discharge (m ³ /s) | 20000 | 11000 | 30000 |
| Maximum discharge (m ³ /s) | 100000 | 78000 | - |
| Average width (km) in Bangladesh | 11.8 | 5.3 | 10.3 |
| Average slope (cm/km) in Bangladesh | 7.5 | 5 | 5 |
| Average bed material size (D50)(mm) | 0.20 | 0.15 | 0.12 |

Table 2: Key characteristics of the Jamuna, the Ganges and the Padma Rivers.





The study area, Manikganj district is located (23038/ and 24003/ N latitudes and 89041/ and 90016/ E longitudes) in the middle part of Bangladesh (Figure 2). The Jamuna River has been flowing from northwest to south-east through the western part of the district and the entire area has been crisscrossed by the distributaries of the Jamuna. Four main physiographic units have been recognized in the district of which floodplain is dominant [8,24]. The study area is almost flat with very gentle slope and low-lying flood plain area is the major cause of seasonal flood [8,12].



Considering the gravity of influence, this study has analyzed the hydrological behavior of the Jamuna River during the monsoon (June-September) months. The two prime objectives of this study are as follows:

a. To analysis the flow characteristics of the river in respect of danger level; and

b. To draw hydrographs for visualizing the flood intensity.

Materials and Methods

This study has selected the Arichaghat station for analysis river stages of the Jamuna because the station is within the district territory. The Aricha station has been indicated with the number of 50.6. The Danger Level (D.L.) of the Jamuna at Aricha station is 9.14 m. The Bangladesh water development Board (BWDB) monitors and records the water levels regularly (8 hours intervals) and writes down in a resister book. This research work has collected water levels of the Jamuna River from the BWDB. The river stages of 1988 and 1998 flooding years have been arranged for pivot table analysis. The water levels of the river for four months (June-September) have been tabulated and compared with the danger level that has precisely indicated when the river crossed the danger level and attained its highest peak flow. The comparison between water level and danger level provided what above the river flowed from the danger mark. The study has also given a detailed figure of changing of the river stages over a period of only three months (July to September) because real world flooding situations exist during this period. The dummy table data of water level and danger level of the three months have been processed with the help of Microsoft Excel sheet in drawing hydrographs that have indicated the flood intensity and flood magnitude. The water level data has been processed for drawing graphs under Excel software program.

Results and Discussion

The river stages of 1988 flood

The Jamuna at Aricha station crossed the danger level on 13 July and was above the danger level for 3 days on 13, 14 and 15 July. The river rose up to 10.55 m on 31 August that was flowing 141 cm above the D.L. (9.14 m) on this date (Table 3). The Jamuna attained its peak at Aricha was 10.58 m (Table 1) on 2 September at 12:00 hrs, which was 144 cm above its danger level (BWDB, 2015). As a whole, the Jamuna at Aricha was above the danger level for 34 days in 1988 (July 3 days, August 16 days and September 15 days) which have been illustrated in Figures 3-5.

| Date | Danger Level | June | | July | | August | August | | September | |
|------|-----------------|-------|------|------|------|--------|--------|-------|-----------|--|
| | | H.L. | L.L. | H.L. | L.L. | H.L. | L.L. | H.L. | L.L. | |
| 1 | 9.14 | 7.30 | 7.25 | 7.17 | 7.14 | 8.98 | 8.97 | 10.56 | 10.55 | |
| 2 | 9.14 | 7.36 | 7.32 | 7.15 | 7.12 | 9.03 | 9.00 | 10.58 | 10.55 | |
| 3 | 9.14 | 7.31 | 7.25 | 7.15 | 7.11 | 9.08 | 9.05 | 10.53 | 10.4 | |
| 4 | 9.14 | 7.19 | 7.10 | 7.22 | 7.17 | 9.00 | 8.96 | 10.42 | 10.35 | |
| 5 | 9.14 | 7.02 | 6.90 | 7.39 | 7.33 | 8.86 | 8.84 | 10.27 | 10.20 | |
| 6 | 9.14 | 6.81 | 6.73 | 7.73 | 7.59 | 8.82 | 8.78 | 10.14 | 10.07 | |
| 7 | 9.14 | 6.64 | 6.55 | 8.00 | 7.80 | 8.75 | 8.73 | 9.98 | 9.93 | |
| 8 | 9.14 | 6.45 | 6.41 | 8.29 | 8.22 | 8.77 | 8.74 | 9.87 | 9.87 | |
| 9 | 9.14 | 6.45 | 6.41 | 8.65 | 8.40 | 8.81 | 8.80 | 9.79 | 9.75 | |
| 10 | 9.14 | 6.39 | 6.33 | 8.90 | 8.83 | 8.80 | 8.79 | 9.70 | 9.65 | |
| 11 | 9.14 | 6.29 | 6.24 | 9.09 | 9.05 | 8.80 | 8.77 | 9.60 | 9.56 | |
| 12 | 9.14 | 6.28 | 6.27 | 9.15 | 9.10 | 8.86 | 8.82 | 9.53 | 9.48 | |
| 13 | 9.14 | 6.31 | 6.28 | 9.19 | 9.16 | 8.96 | 8.92 | 9.44 | 9.37 | |
| 14 | 9.14 | 6.56 | 6.47 | 9.19 | 9.17 | 9.08 | 9.02 | 9.32 | 9.26 | |
| 15 | 9.14 | 6.64 | 6.58 | 9.16 | 9.12 | 9.15 | 9.12 | 9.23 | 9.16 | |
| 16 | 9.14 | 6.80 | 6.64 | 9.08 | 9.02 | 9.20 | 9.17 | 9.08 | 9.01 | |
| 17 | 9.14 | 6.85 | 6.83 | 8.95 | 8.87 | 9.20 | 9.25 | 893 | 8.85 | |
| 18 | 9.14 | 6.87 | 6.84 | 8.82 | 8.75 | 9.35 | 9.32 | 8.76 | 8.66 | |
| 19 | 9.14 | 7.04 | 6.93 | 8.72 | 8.60 | 9.39 | 9.37 | 8.56 | 8.48 | |
| 20 | 9.14 | 7.20 | 7.15 | 8.56 | 8.52 | 9.40 | 9.39 | 8.37 | 8.29 | |
| 21 | 9.14 | 7.27 | 7.22 | 8.51 | 8.46 | 9.42 | 9.40 | 8.17 | 8.08 | |
| 22 | 9.14 | 7.35 | 7.33 | 8.46 | 8.41 | 9.40 | 9.38 | 8.04 | 7.97 | |
| 23 | 9.14 | 7.39 | 7.37 | 8.43 | 8.42 | 9.35 | 9.38 | 7.94 | 7.88 | |
| 24 | 9.14 | 7.51 | 7.47 | 8.50 | 8.45 | 9.57 | 9.50 | 7.33 | 7.78 | |
| 25 | 9.14 | 7.58 | 7.49 | 8.60 | 8.52 | 9.70 | 9.63 | 7.74 | 7.71 | |
| 26 | 9.14 | 7.45 | 7.41 | 8.70 | 8.65 | 9.93 | 9.83 | 7.67 | 7.65 | |
| 27 | 9.14 | 7.48 | 7.43 | 8.73 | 8.72 | 10.15 | 10.05 | 7.65 | 7.62 | |
| 28 | 9.14 | 7.45 | 7.40 | 8.78 | 8.75 | 10.30 | 10.24 | 7.67 | 7.65 | |
| 29 | 9.14 | 7.40 | 7.30 | 8.82 | 8.80 | 10.40 | 10.35 | 7.80 | 7.71 | |
| 30 | 9.14 | 7.26 | 7.19 | 8.90 | 8.87 | 10.48 | 10.45 | 7.85 | 7.83 | |
| 31 | 9.14 | n. a. | n.a. | 8.95 | 8.93 | 10.55 | 10.50 | n.a. | n, a, | |

Table 3: Water level of the Jamuna (in m) at Aricha, 1988. Note: H.L.=Highest Level and L. L.=Lowest Level.







Figure 4: Water level of the Jamuna at Aricha, August 1988.





The river stages of 1998 flood

In 1998, the Jamuna first crossed the Danger Level (9.14 m) on 12 July (Table 4). From this date the river rose gradually and attained its highest level of 10.02 m on 28 July which was 88 cm above the danger level (9.14 m). The Jamuna flowed above the danger mark throughout the August. The river stage rose up to 10.35 m on 23 August at 18:00 hrs which flowed 121 cm above the danger level. At Aricha, the Jamuna attained its highest peak of 10.76 m on 9 September at 18:00 hrs which was 162 cm above the danger level (Table 4).

| Date | Danger | June | | July | | August | | September | |
|------|--------|-------|------|-------|-------|--------|-------|-----------|-------|
| | Level | H.L. | L.L. | H.L. | L.L. | H.L. | L.L. | H.L. | L.L. |
| 1 | 9.14 | 6.34 | 6.30 | 8.31 | 8.30 | 9.77 | 9.72 | 10.10 | 10.09 |
| 2 | 9.14 | 6.27 | 6.24 | 8.32 | 8.31 | 9.64 | 9.60 | 10.13 | 10.12 |
| 3 | 9.14 | 4.20 | 4.17 | 8.36 | 8.35 | 9.55 | 9.54 | 10.15 | 10.14 |
| 4 | 9.14 | 6.12 | 6.12 | 8.42 | 8.40 | 9.52 | 9.49 | 10.22 | 10.17 |
| 5 | 9.14 | 6.22 | 6.16 | 8.50 | 8.47 | 9.47 | 9.45 | 10.34 | 10.28 |
| 6 | 9.14 | 6.39 | 6.25 | 8.56 | 8.52 | 9.46 | 9.46 | 10.50 | 10.43 |
| 7 | 9.14 | 6.56 | 6.50 | 8.67 | 8.63 | 9.44 | 9.42 | 10.61 | 10.55 |
| 8 | 9.14 | 6.70 | 6.64 | 8.76 | 8.70 | 9.40 | 9.39 | 10.72 | 10.70 |
| 9 | 9.14 | 6.70 | 6.69 | 8.86 | 8.80 | 9.38 | 9.37 | 10.76 | 10.74 |
| 10 | 9.14 | 6.72 | 6.69 | 8.96 | 8.92 | 9.40 | 9.39 | 10.73 | 10.70 |
| 11 | 9.14 | 6.83 | 6.77 | 9.08 | 9.04 | 9.42 | 9.42 | 10.63 | 10.60 |
| 12 | 9.14 | 7.22 | 7.00 | 9.16 | 9.12 | 9.48 | 9.44 | 10.48 | 10.40 |
| 13 | 9.14 | 7.69 | 7.50 | 9.27 | 9.24 | 9.61 | 9.54 | 10.28 | 10.18 |
| 14 | 9.14 | 7.90 | 7.80 | 9.41 | 9.35 | 9.65 | 9.64 | 10.04 | 9.95 |
| 15 | 9.14 | 8.04 | 8.00 | 9.54 | 9.48 | 9.70 | 9.68 | 9.77 | 9.70 |
| 16 | 9.14 | 8.07 | 8.04 | 9.62 | 9.60 | 9.75 | 9.73 | 9.54 | 9.40 |
| 17 | 9.14 | 7.97 | 7.97 | 9.66 | 9.65 | 9.90 | 9.82 | 9.33 | 9.23 |
| 18 | 9.14 | 7.80 | 7.75 | 9.60 | 9.56 | 10.00 | 9.98 | 9.10 | 9.00 |
| 19 | 9.14 | 7.68 | 7.65 | 9.48 | 9.47 | 10.10 | 10.06 | 8.88 | 8.80 |
| 20 | 9.14 | 7.70 | 7.72 | 9.45 | 9.44 | 10.20 | 10.15 | 8.70 | 8.65 |
| 21 | 9.14 | 7.79 | 7.75 | 9.50 | 9.47 | 10.25 | 10.23 | 8.56 | 8.50 |
| 22 | 9.14 | 7.86 | 7.82 | 9.54 | 9.50 | 10.31 | 10.29 | 8.42 | 8.35 |
| 23 | 9.14 | 7.94 | 7.90 | 9.64 | 9.59 | 10.35 | 10.34 | 8.30 | 8.22 |
| 24 | 9.14 | 7.99 | 7.97 | 9.72 | 9.67 | 10.35 | 10.34 | 8.18 | 8.15 |
| 25 | 9.14 | 7.97 | 7.96 | 9.84 | 9.80 | 10.32 | 10.31 | 8.10 | 8.08 |
| 26 | 9.14 | 7.95 | 7.94 | 9.94 | 9.90 | 10.28 | 10.25 | 8.05 | 8.02 |
| 27 | 9.14 | 7.98 | 7.95 | 10.00 | 9.98 | 10.23 | 10.21 | 7.96 | 7.90 |
| 28 | 9.14 | 8.07 | 8.04 | 10.02 | 10.00 | 10.20 | 10.19 | 7.90 | 7.85 |
| 29 | 9.14 | 8.16 | 8.13 | 10.01 | 9.99 | 10.21 | 10.20 | 7.87 | 7.84 |
| 30 | 9.14 | 8.26 | 8.23 | 9.97 | 9.92 | 10.18 | 10.16 | 7.85 | 7.84 |
| 31 | 9.14 | n. a. | n.a. | 9.87 | 9.82 | 10.14 | 10.12 | n.a. | n.a. |

Table 4: Water level of the Jamuna (in m) at Aricha, 1998.

Figures (6-8) indicate that flood occurred from July 12 to September 18, with duration of 68 days (July 19 days, August 31 days and September 18 days). According to the IECO Report [25], the slope of the Brahmaputra from Bahadurabad to Goualanda is 0.35 ft/mile. The low gradient of the Jamuna is 0.25 ft/mile at this point influence the flow of excessive water from upper catchments area [26]. The synchronization of peak flows of the Ganges and the Brahmaputra-Jamuna rivers was the cause of severe flood at the study site. The 1998 flood submerged the district entirely, inundated about 67 percent area of the country, and turned into a prolonged one in the history of Bangladesh [12,21].





Figure 7: Water level of the Jamuna at Aricha, August 1998.



Conclusion

The flow characteristics of the Jamuna River were very noticeable during the two flooding events. The river attained highest water level that submerged the study area in deep water. After crossing the danger level, the water level did not come down under the danger level which contributed to the prolonged flooding situations of 34 days in 1988 and 68 days in 1998. Actually, the study area has particular locational influences in occurrences the catastrophic flooding situations in terms of duration, depth and magnitude. The two catastrophic flooding events had the devastating consequences upon the study area. The siltation in the river bed and up and in boundary water influences the flow characteristics of the river. The danger level should be reassessed to understand the actual flow characteristics and real world flooding situations.

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