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Floods in Bangladesh: A Comparative Hydrological Investigation on Two Catastrophic Events

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Flood becomes regular feature in riverrine Bangladesh. Every year, around 21 percent of land is flooded during monsoon season, however, in severe situation this figure shot up to more than 60 percent of total land. This paper is an attempt to analyze hydrological characteristics of two catastrophic events (1988 and 1998 flood) in the light of flood history in Bangladesh. The analysis demonstrates that the 1998 flood was more severe than the 1988 one. Moreover, the 1998 flood was also prolonged than the 1988 flood due to heavy rainfall inside and outside of the country. Finally, flood management issues in Bangladesh have been analyzed and found that structural solution to mitigate flood is not the only solution. Based on the analysis some possible mitigation options are put forward.

Key words: *Flood, Flood Management, Danger level, Peak floods, Deforestation*

1 INTRODUCTION

Bangladesh is probably the most flood prone country in the world, and some authors are arguing it is the most disaster prone nation in the world (Cutter, 1996, Zaman, 1999). Among natural disasters in Bangladesh, flood is the preeminent one. Every year a large portion of the country becomes flooded due to heavy rainfall and spilling water from the major rivers. It is observed that each year's highest flood record has been broken by the subsequent years and, simultaneously, damage from floods has been surpassed by the following year's damage. For Bangladesh, changes in frequency, magnitude and depth of flooding are very important. On average, 21 percent of the area of the country (31000 km^2) gets inundated by floods annually and 21 percent of the population (assuming uniform population distribution) is vulnerable to annual flooding and, in exceptional cases, more than 60 percent of the country or 70 million people are affected by flooding. For instance, the 1988 flood, engulfed about 60 percent of Bangladesh, and caused damage worth more than 1.3 billion US $ (World Bank, 1990) in a country where the gross domestic product (GDP) was then only US $ 21 billion. Another unprecedented flood occurred in 1998 which considered the worst in memorable time, engulfed 68% of Bangladesh in different magnitude. The extent of damage of this flood was estimated around 2 billion US $ (Siddique and Chowdhury, 2000). Even though flooding is a regular feature in Bangladesh, however, data on flooding is incomplete, inconsistent and partially misleading (Paul, 1997), because floods are assessed by a number of institutions from different points of view (Chowdhury, 2000). The effects of flood are manifold in Bangladesh since flood water remains long time onto the land. For example, all means of communication viz. roads, railways, highways, and even runways become paralyzed due to flooding. It causes widespread damage to crops, stored food grains, domestic animals, homesteads, development infrastructures, and human lives. People remain maroon in water without having food and drinking water until relief arrives. The consequences of such recurring floods are really well beyond the capacity of a developing country like Bangladesh to bear. The factors that contribute to these calamitous inundations are varied and complex and some of these are natural, like heavy monsoon downpour, melting snows in the Himalayas, and geophysical instabilities in the northern regions. But some of the factors that responsible for floods are human work such as deforestation and unplanned development works.

The aims of this paper are, (1) to provide a brief account of the history of flooding in Bangladesh along with its background, (2) to investigate a comparative analysis of hydrology (in terms of rainfall and water level at important gauge stations) of the three major river systems in two catastrophic events such as in 1988 and 1998 and (3) to study different flood control works in Bangladesh.

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2 FLOOD HYDROLOGY IN BANGLADESH

Bangladesh occupies an area of about 147570 km^2 between latitudes 20^0-$30'$ N and 26^0- $45'$ and longitudes 88^0 -$0'$ E and 92^0 -$45'$ East. Bangladesh is surrounded by India except south-east part where it borders with Myanmar. The Bay of Bengal lies on the southern part of Bangladesh. It is well know as 'land of rivers' and there are about 230 rivers network within the country including 54 international rivers flowing across the country and finally reach to the Bay of Bengal. The combined catchment area of three major river systems e.g. the Ganges, the Brahmmaputra and the Meghna is approximately 1500000 km^2 of which only 7.5 percent lies within Bangladesh. Most of the major rivers are originated outside of the country and having their headway in the Himalayas. The Brahmmaputra originates on the Chinese side of Himalayas and after traversing about 1800 km through Tibet and India, enters Bangladesh through the northern border. Within Bangladesh it is called the Jamuna and flows for an additional 275 km up to its junction with the Ganges. The Ganges flows for about 2000 km through India, enters into Bangladesh through Rajshahi district and flows to the south-east for another 250 km to confluence with the Brahmmaputra. The Meghna originates in one of the rainiest regions of the world, the Shillong plateau in Assam in India. The headwaters of the Meghna comprise a number of streams that meander through Assam for about 400 km and then enter into Bangladesh from north-east in the form of two major tributaries e.g. Surma and Kushiyara-which reunite to form the main channel and flows to the Meghna (**Fig. 1**).

The climate of Bangladesh is subtropical with three prominent seasons, e.g. winter (Nov-Feb), summer (Mar-Jun) and monsoon (Jul-Oct). Rainfall on average is 2160 mm per annum, of which 1728 mm fall in the monsoon (BWDB et al., 1989). The distribution of rainfall revealed a distinct seasonal regime and gradual increase from west to east. Temperature regimes throughout the country are same with the average highest temperature in the month of July (28-29^0 C) and the lowest in January (17-19^0 C).

3 FLOODS TYPES AND CAUSES

Bangladesh generally experiences four types of floods: flash floods, riverrine floods, rainfall induced floods and storm surges floods, nevertheless, vulnerability to these four types of floods varies according to different regions in the country. This section describes the four main types of floods in order to understand their nature, extent and damage patterns.

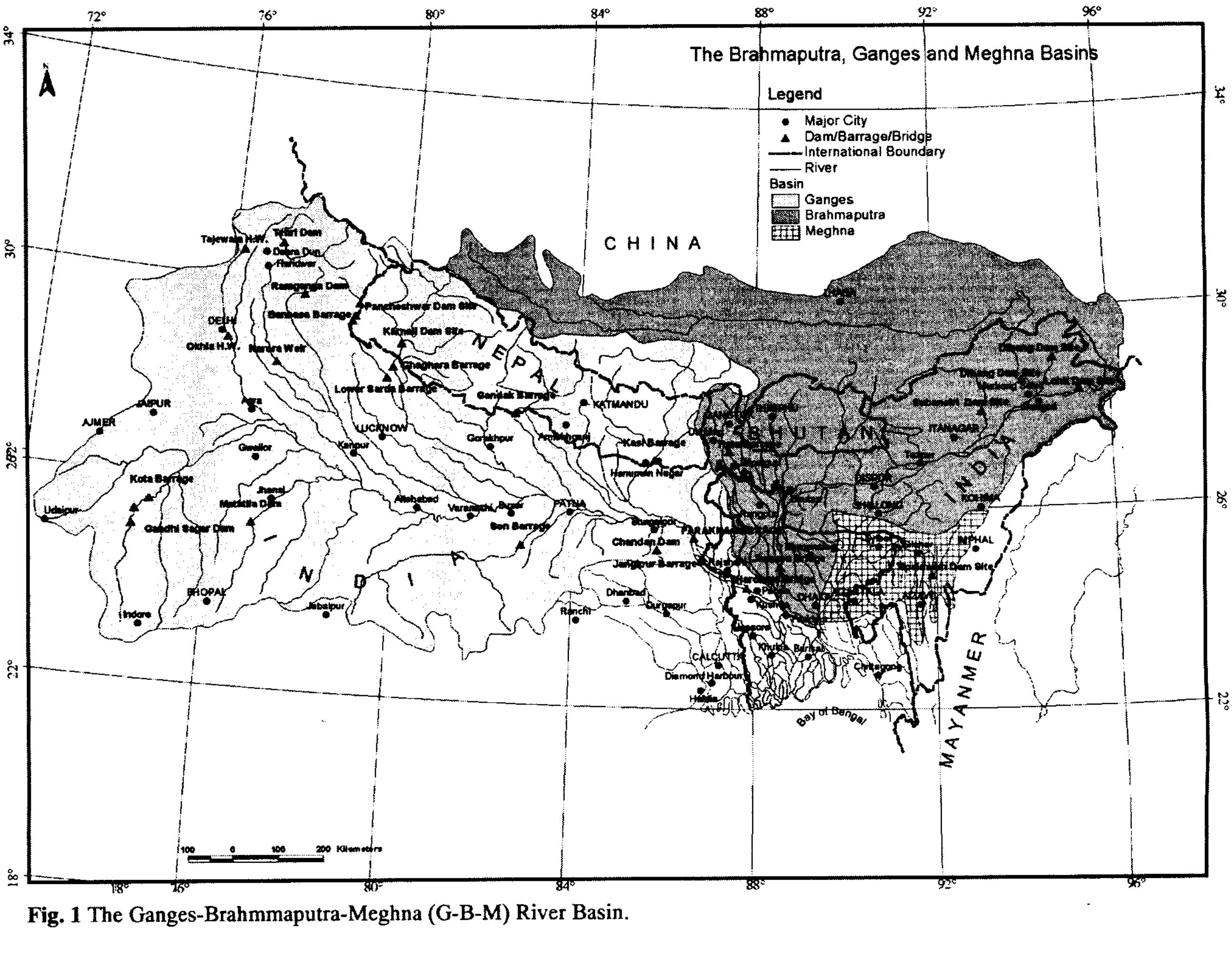

Fig. 1 The Ganges-Brahmmaputra-Meghna (G-B-M) River Basin.

3.1 Flash Floods

The extent of flash floods is in the northern and eastern parts of Bangladesh. A flash flood is characterized by a very sharp rise of water level of rivers and subsequent overbank spillage with high velocity. It is also marked by a relatively rapid recession of water from the floodplains. In Bangladesh, a flash flood occurs after a heavy downpour in the neighboring hills and mountains. These floods often maul the standing crops at the ripening stage and cause severe damages to the physical infrastructures along river banks.

3.2 Riverrine Floods

Riverrine floods from the major rivers generally rise and fall slowly over 10 to 20 days or more. Spilling by the major rivers and their tributaries and distributaries can cause extensive damage to lives and properties. Flood damage is most extensive when the three major rivers are in peak stage at the same time. It is thought that snow melt in the Himalayas makes a significant contribution to river flooding in Bangladesh (UNDP, 1989). Most of the floodplains in Bangladesh are subject to riverrine floods during Monsoon.

3.3 Rainfall Induced Floods

Rainfall induced floods are caused by high intense local precipitation of long duration in the monsoon. Bangladesh receives, on an average, some 2200 mm rainfall annually, ranging from 1100 mm in the west to 5000 mm or more in the northeast (WARPO, 1998). Local torrential rainfall often induced floods when drainage capacity of basins exceeds its carrying capacity. In Bangladesh, mainly embanked areas are characterized of this flood. However, in each monsoon, rainfall induced localized floods are observed in a number of locations in Dhaka city, the capital of the country.

3.4 Storm Surge Floods

Storm surge floods occur in the coastal areas of Bangladesh which consists of large estuaries, extensive tidal flats, and low lying islands. Storm surges generated by tropical cyclone causes widespread damage to the lives and property of coastal people. During 1960-1992, a total of 35 cyclones hit the Bangladesh coast. Among these, 17 were reported to be deadly (Khalil, 1992). The 1970 cyclone generated a surge height over 9 meters in places and an estimated 220000-400000 people died. The severe cyclone of 1991 killed 138868 people and the surge height was estimated to be between 6-7.5 meters (Ericksen et al., 1996). Tropical cyclones are most likely to occur during pre and post-monsoon periods (April-May and October-November, respectively), and have not been known to coincide with monsoon flood peaks.

The causes of floods in Bangladesh have been studied by many researchers from different perspectives (Islam, 1980, Ahmed, 1989, Khalil, 1990). But the present paper intends to present an abridge overview of the causes of floods in Bangladesh.

a) Extremely flat topography. The average height of the land is 25 feet or 8 meters (Huq 1986),
b) Synchronization of peak flows of the major rivers,
c) Excessive monsoon rainfall in the plains and catchment areas of three major river systems,
d) River bed siltation which is reducing river carrying capacity,
e) Back water or tidal effect from the Bay of Bengal during monsoon which is an impediment to recede water from rivers,
f) Deforestation and ecological imbalance,
g) Increasing population pressure which is resulting encroachment and filling up of lakes and canals,
h) Drainage congestion due to unplanned construction of infrastructures,
i) Flood control activities such as flood wall, embankment, artificial levee, dykes,
j) Probable sea level rise and land subsidence.

4 A BRIEF HISTORY OF FLOOD IN BANGLADESH

As mentioned earlier, accounts on flooding in Bangladesh is somewhat questionable (Chowdhury and Sato, 1996). However, collection of data on flooding has been started in 1955 following two consecutive disastrous floods in 1954 and 1955. Ground observation was the only method to estimate flooding area at that time. In 1959, Bangladesh Water Development Board has been established and until now this is the only official body of water management in Bangladesh. It is found from the available data during 1950-2000, Bangladesh has been hit by more than 28 floods with different magnitudes (BWDB, 1998). Among these, the ones in 1953, 1955, 1956, 1962, 1963, 1966, 1968, 1969, 1970, 1971, 1974, 1976, 1984, 1987, 1988, 1998 and 2000 have been most devastating. Historical records revealed that five major floods occurred in the 19th century (1842, 1858, 1871, 1885 and 1892) and 15 such floods occurred in the 20th century (Rasid and Paul, 1987, Khalil, 1990, Haque, 1997). Two very exceptional floods are in 1987 and 1988 when more than 40% of the country was devastated by consecutive floods (Haque, 1997). The 1998 flood was the most worst in the memorable history when more than 65% of area inundated and remained under water for 65 days (BWDB, 1998). The following Table (**Table 1**) describes a brief account of flood and deaths of people from flood between 1954 and 1998 in Bangladesh.

Table 1 Coverage of Inundation and Deaths in Major Floods, 1954-1998.

Year	Flooded Area (km^2)	Percentage of Total Area	Number of Deaths
1954	36920	25	112
1955	50700	34	129
1956	35620	24	NA
1962	37440	25	117
1963	43180	29	NA
1968	37300	25	126
1970	42640	28	87
1971	36475	24	120
1974	52720	35	1987
1984	28314	19	553
1987	57491	38	1657
1988	77700	52	2379
1998	100000	68	1050

NA: Not Available

5 A COMPARATIVE ANALYSIS OF FLOOD 1988 AND 1998

This section presents a comparative analysis on two major events e.g. 1988 and 1998 flood characteristics in terms of rainfall and water level.

5. 1 RAINFALL

Rainfall is one the major determinants of flood severity in Bangladesh. It is believed that recent floods have turned into catastrophe due to huge water flow from the upstream point and, at the same time, regional rainfall acted as an auxiliary factor which accelerates the situation to be worst (Elahi, 1988). For example, the 1987 flood was predominantly caused by local rainfall (Miah, 1988). The three major river catchments area are also one of the rainiest areas of the world where every year on average, the Ganges Basin receives 140 cm, Brahmmaputra basin receives 210 cm and Meghna basin receives 400 cm rainfall respectively (Mirza, 1998). However, their spatio-temporal variation differs basin to basin (Ahmed, 1989). To understand how local rainfall played a significant role in creating the deluge, we tried to compare the rainfall pattern of 1988 and 1998 at most important rainfall measuring points in the three river basins in Bangladesh. Comparative statements of rainfall in two big events have been presented in **Table 2** and **Table 3**. Analysis of rainfall pattern revealed that many stations experienced heavy rainfall in 1998 compare to 1988 floods. From July to the middle of September continuous and heavy intermittent rainfall occurred both inside and outside of the country. As a result, flood situation prevailed from July to September in different places in different magnitudes in the country in 1998.

Table 2 Comparative Rainfall Statistics of Major Stations in Bangladesh during 1988 Flood.

St. Name	June			July			August			September		
\	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)
Kurigram	527	666.5	139.5	455	666.3	211.3	297	722.5	425.5	296.5	333	37
Jamalpur	457	953.5	496.5	440	375.8	-64.2	363	484.2	131.2	256	267	14
Dhaka	376	538	162	360	253	-107	333	168	-165	234	187	-47
Rajshahi	233	662.4	429.4	334	343.2	9.2	241	362.6	121.6	221	84	-137
Kustia	268	464.5	196.5	311	299.6	-11.4	292	274.1	-17.9	200	128	-72
Faridpur	375	483.6	108.6	337	227.4	-109.6	300	263.9	-36.1	244	190	-54
Sunamgonj	1270	1000.5	-269.5	1410	1726	316	1079	2514.7	1435.7	596	1093	497
Bhairab Bazar	463	503.4	40.4	432	438.9	6.9	325	333.6	8.6	266	291	25
Chandpur	414	379.1	-34.9	380	332	-48	320	276.3	-43.7	235	156	-79
Noakhali	582	746.8	164.8	629	526	-92.6	595	884.4	88.4	418	631	213
Chittagong	612	540.7	-71.3	680	789.3	118.3	568	414	-154	294	224	-70
Bandarban	562	604.2	42.2	612	578.6	-33.4	424	419.9	-4.1	270	430	160

Source: Flood Forecasting and Warning Center, BWDB, 1998.

Table 3 Comparative Rainfall Statistics of Major Stations in Bangladesh during 1998 Flood.

St. Name	June			July			August			September		
	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)	Normal (mm)	Actual (mm)	Deviation from Normal (+/-)
Kurigram	502	471	-30.8	519	532.5	13.5	291	492.6	201.6	348	355.1	7.1
Jamalpur	455	190.2	-264.8	489	438.4	-50.6	361	516.8	155.8	312	270.7	-41.3
Dhaka	376	89	-287	360	515	155	337	563	226	232	224	-8.0
Rajshahi	251	63	-188	345	362.5	17.5	251	160.5	-90.6	253	194.2	-58.8
Kustia	251	187.5	-63.5	297	421.5	135.2	268	241.3	-26.7	197	333.1	131.1
Faridpur	366	165.5	-200.5	335	312	-23	289	350.6	61.6	269	226	-43.0
Sunamgonj	1060	1025	-35	1402	1591	189	1089	1841.5	752.6	733	378	-355
Bhairab Bazar	411	87	-324	404	613.2	209.2	337	292	-45	276	239	-37
Chandpur	393	76.2	-316.8	373	735.9	362.9	304	538	204	235	108.9	-126.1
Noakhali	597	204.6	-312	703	864	161	616	977.8	361.8	438	232	-205.1
Chittagong	613	80	-533	816	1247	431.4	548	1308	758	275	139.6	-135.4
Bandarban	576	291.6	-284.4	706	897.4	176.4	464	689.5	225.4	247	189.3	-57.7

Source: Flood Forecasting and Warning Center, BWDB, 1998.

5.2 WATER LEVEL

The following section describes a comparison of the water level during 1988 and 1998 floods in three major gauge stations in three basin areas in Bangladesh.

(1) *The Brahmmaputra Basin*

The Brahmmaputra above Bahdurabad has a length of approximately 2900 km and a catchment area about 583000 km^2. It rises in the northernmost range of the Himalayas and flows east far above half its length across the Tibetan plateau. Bangladesh enjoys only 45658 km^2 of its total area. A comparison of water level of Brahmmaputra River (in Bangladesh part it is known as Jamuna) at Bahdurabad station during 1988 and 1998 floods has been presented in **Fig. 2.** It is found that in 1988 Jamuna River has crossed its danger level* for twice. It crossed its danger level for first time on 08.07.1998 and the second did occur on 12.08.1998. However, water level at this station continued to be on danger level for 59 days whereas in 1988 the days above danger level was only 27 days. The same river at Sirajgonj station continued for 49 days above danger level and in 1988 it was for 30 days. The Buringanga river, a distributory of the Jamuna remained 58 days above danger level at Dhaka station in 1998 and 23 days in 1988 respectively. These records demonstrated that the 1998 flood was more severe in terms of magnitude compare to 1988 flood in Brahmmaputra basin in Bangladesh. It is believed that due to heavy rainfall in the month of July, August and first part of September within Bangladesh and at the upstream point in the catchment area this basin experienced prolonged and severe flooding in 1998.

* In Bangladesh danger level at a river location is the level above which it is likely that the flood may cause damages to nearby crops and homesteads. In a river having no embankment, danger level is about annual average flood level. In an embanked river, danger level is fixed slightly below design flood level of the embankment. The danger level at a given location needs continuous verification as e.g. embankments may be breached, but it is not done continuously by Flood Forecasting and Warning Center (FFWC), whereby some danger levels may be not precise.

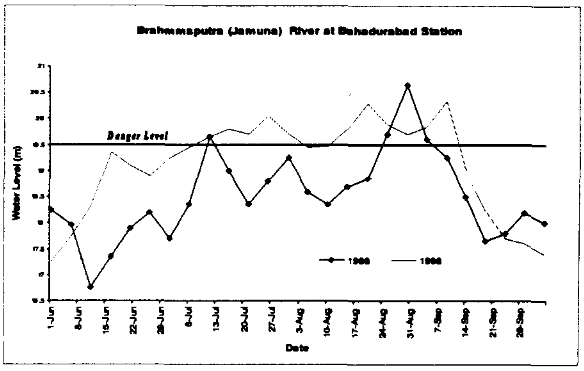

Fig. 2 Hydrographs of the Brahmmaputra (Jamuna) River at Bahdurabad station showing the extent of the flood level during 1988 and 1998.

(2) *The Ganges Basin*

The Ganges has a total length of about 2600 km to its confluence with the Brahmmaputra and a catchment area of approximately 907000 km^2 of which Bangladesh has only 49250 km^2. This is not a braided river like Brahmmaputra, meanwhile, the Ganges is vital for the ecological balance of the south-west region of Bangladesh. The Ganges after its confluence with the Jamuna at Goalondo, the river, also known as Padma. In Chandpur, the Padma is joined by the Meghna from whence it flows to the sea and is fully under the influence of tides.

In the Ganges Basin, few important gauge stations statistics on water level have been considered for analysis during two flood events. Records on water level of Mahanada river at Chapainawabgonj station of the Ganges Basin shows that on 25th of July it crossed its danger point and consistently remained on this level for 61 days. On the other hand, the Ganges at Hardinge Brindge crossed its danger level on 9th of September and remained for 23 days above danger level. In the downstream part of the Ganges Basin, Padma river at Goalonda and Bhagaykul point were 67 and 73 days above danger level. In 1988, flood level data shows that the Mahananda was 32 days, Ganges was 23 days above danger point. Similarly, Padma at Goalonda and Bhagayakul remained 41 and 47 days respectively. A comparison of 1998 and 1988 water level of the Ganges river at Hardinge Bridge point has been presented in **Fig. 3**.

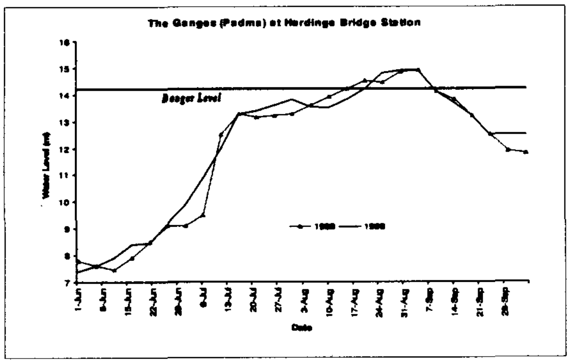

Fig. 3 Hydrographs of the Ganges River at Hardinge Bridge station showing the extent of the flood level during 1988 and 1998.

(3) *The Meghna Basin*

The Meghna system originates in the hills of Shillong and Meghalaya of India. The main source is the Barak river, which has a considerable catchment in the ridge and valley terrain of eastern Assam bordering Burma. On reaching the border with Bangladesh at Amalshid in Sylhet district, it bifurcates to form the Surma and the Kushiyara rivers. In Bangladesh, 12 gauging stations are available to monitor flood level in the basin, however, for convenience of this study we analyzed two important stations water level comparison in order to visualize flood characteristics in the basin. For example, Meghna river at Bhairab Bazar station crossed its danger point on 20th July (**Fig. 4**) and consistently remained at this position for 70 days while the same river at Chandpur station where it meets with Padma and Jamuna remained above danger level for 49 days during 1998 Flood. On the other hand, in 1988 Meghna river at these points were 68 and 45 days above danger level.

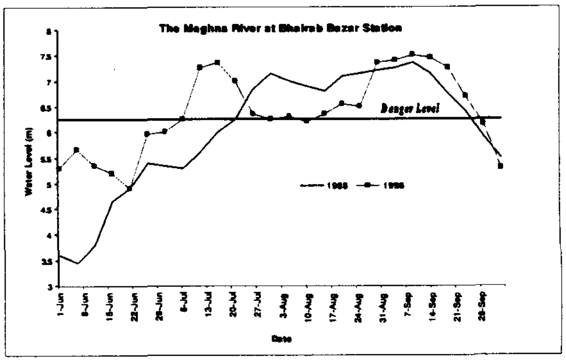

Fig. 4 Hydrographs of the Meghna River at Bhairab Bazar station showing the extent of the flood level during 1988 and 1998.

The following table (**Table 4**) is shown a vivid picture of flood magnitude in two different years.

Table 4 Water Level of nine major points above Danger Level during 1998 and 1988 Floods.

River	Station Name	Water Level Above Danger Point (Days)	
		1988	1998
Jamuna	Bahadurabad	27	59
Jamuna	Sirajgonj	31	49
Bhuriganga	Dhaka	23	58
Shitalkhya	Narayangonj	36	72
Mahananda	Chapainawabgonj	32	61
Ganges/Padma	Rajshahi	24	29
Padma	Bhagyakul	47	73
Padma	Goalondo	41	67
Meghna	Bhairab bazaar	68	70

Source: Flood Forecasting and Warning Center, BWDB, 1998.

Analysis of the above table depict that the central part of the country has experienced sever flood in 1998 compare to 1988. All stations show almost similar trend of flooding in 1998 except the Meghna at Bhairab Bazar point. To understand the spatial pattern of inundation in Bangladesh flood maps have been incorporated which is clearly demonstrating the extent and magnitude of flood during 1988 and 1998 catastrophic events (**Fig. 5 & 6**).

What were the causes of severe flooding in 1998 compare to 1988 flood? This is not a simple answer to say. As many researchers have been putting their effort to find out the causes and best solutions of flooding in Bangladesh after 1988 event nonetheless, it is still in myth. If we look at the causes of 1988 floods there are some arguments can be found in the literature. They are rapid elimination of forest in the upper catchments area in India (Shahjahan and Hossian, 1990), however, there is debate with this argument and Hamilton (1987) and Hofer (1998) argued that deforestation in Nepal has very little effect on flood problem in Bangladesh. In addition, Miah (1990) and Islam (1989) established that the bulk of the 1988 floodwater originated from areas adjacent to the Bangladesh border rather than the upper reaches in Nepal and China. Other causes are believed to be human activity such as embankments, dykes and other flood related engineering schemes along upstream reaches of the rivers reduce the basins' storage capacity which leads to higher flood peaks and a steeper rise in downstream water level (Haque, 1997). The causes of 1998 flood severity are also not clear. For example, it is believed that El Nino Southern Oscillation (ENSO) induces strong monsoons in the Indian Subcontinent (Choudhury, 2000). Synchronization of the peaks of the Brahmmaputra and the Ganges occurred within a span of 24 hours (Matin, 1998). High tide in the Bay of Bengal is believed to be one of the causes of flood severity in 1998 because of lunar effect which impend water to recede at slower rate (Ahmed and Mirza, 2000).

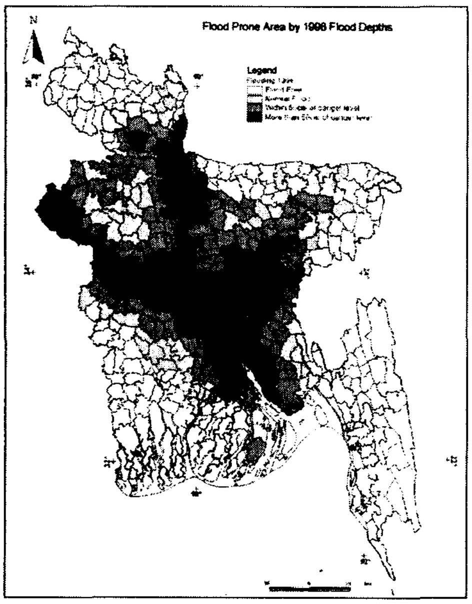

Fig. 5 Spatial Extent of Flooding in Bangladesh in 1998.

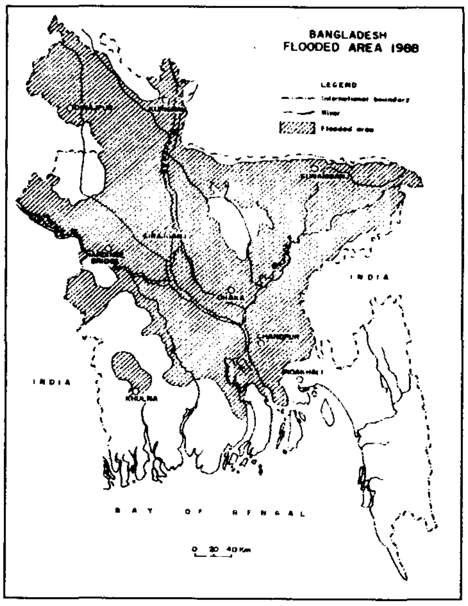

Fig. 6 Spatial Extent of Flooding in Bangladesh in 1988.

6 FLOOD DAMAGE IN BANGLADESH

It is very difficult task to present a complete statistics on damage reports from flooding in Bangladesh because data on damage has not been collected systematically. Even though data can be found but they have lack of consistency and reliability since each organization calculates flood damage from their own point of view (Paul, 1997, Chowdhury and Sato, 1996). This study is used to collect data from ample literatures and tries to provide a realistic statistics on flood related damages in Bangladesh during different flooding years. An overview of flood damage in Bangladesh during 1953-1998 has been shown in the following Table (**Table 5**).

Table 5 Flood Damage in Bangladesh, 1953-1998.

Year	Crop Damage (million tons)	Total Financial Loss (million Taka*)
1953	0.6	-
1954	0.7	1500
1956	0.5	1580
1962	1.2	1500
1966	1.0	600
1968	1.1	1200
1969	1.0	1100
1970	1.2	1000
1974	1.4	20000
1980	0.4	4000
1984	0.7	4500
1987	1.5	35000
1988	3.2	40000
1998	4.5	142160

*1 Taka = 57 US $

7 AN OVERVIEW OF FLOOD PROTECTION MEASURES IN BANGLADESH

The flood management issue in Bangladesh did not receive much attention before 1954 and 1955 disastrous floods. After two consecutive big events, the then East Pakistan government sought the assistance of the United Nations to tackle flood problem. A team of experts headed by Mr. J.A. Krug, former USA Interior Secretary visited the then East Pakistan and formulated a report on flood control plan. Following the recommendations of this report, the Water and Power Development Authority (WAPDA), presently known as Bangladesh Water Development Board (BWDB) was established in 1959 to conduct all types of water resource development works. In 1964, a Master Plan was drawn up by the US International Engineering Company Inc. (IEC) under the aegis of WAPDA, proposing large scale flood control, drainage and irrigation (FCDI) programs. These programs were based on the experience gained in a century of flood protection works on the lower Mississippi river. Three types of projects were envisaged on the Master plan such as flood embankment with gravity drainage; flood embankments with sluice drainage and flood embankments with pump drainage. As a consequence, WAPDA took the task of constructing flood embankments across the country. The pioneers of the Master Plan did not take into consideration the fact that, in Bangladesh one has to deal with a system of more than one river, having the forces and volumes even exceeding those of the Mississippi.

The Master Plan failed to deliver expected benefits and was entangled with faulty design and construction, poor maintenance of the structures and implementation delays. Noting the failure of the Master Plan the World Bank got involved with the agriculture and water development programs and suggested a shift in strategy from large scale embankment to small scale Flood Control Development projects (FCD) like low lift pump, shallow tubewell and improved cropping practices. Such small scale projects continued until Bangladesh was again devastated by the successive floods of 1987 and 1988.

Soon after the catastrophic floods of 1988, the Government of Bangladesh requested the World Bank (WB) to coordinate and formulate plans that could mitigate the flood problems of Bangladesh. Accordingly, the World Bank prepared a Flood Action Plan, which incorporated structural and non-structural options of flood control, but the structural measures formed the basis for long-term comprehensive flood protection. The implementation of the plan has not progressed as expected due to various delays and controversies over the engineering controls to be the best solution for flood protection in Bangladesh (Alam, 1990). So far, Bangladesh has spent a good amount of foreign aid and internal resources in the construction of the engineering controls. The major types of water control projects constructed so far in Bangladesh are (1) Flood embankments along the river which are constructed in the form of roads and railways, (2) Submersible flood embankment, (3) Polders with drainage regulators, (4) Polders with pump irrigation and drainage, (5) Gravity irrigation projects with pumping stations along the major rivers.

But the planning of the flood control structures in Bangladesh is entangled with various technical problems. The types of problems which engineering controls in Bangladesh usually faces are
(a) Breaching of embankment due to river bank erosion,
(b) Poor design standard, planning and construction,
(c) Poor operation and maintenance,
(d) Construction of embankments with uncompacted and poor soil material,
(e) Unauthorized breaching of embankments during floods. A study revealed that 15 embankments out of 25 were failed due to breaching, seepage and sliding, overflow, erosion and cutting by the public (Islam, 1991 cited in Hoque and Siddique, 1995). Besides the problems related to the efficiency of the embankments, the embankments themselves are imposing problems at different places, these problems are basically (1) Riverbed sedimentation, (2) Water logging, (3) Deterioration of soil productivity, (4) Decline in fishery and wildlife habitats particularly due to FCD projects (Mirza and Ericksen, 1996).

There is always a risk with regard to the structural plans for a country like Bangladesh located in an active tectonic zone, with a growing population of which 70% are below poverty level. It can be mentioned here that, from 1965 to 1990, BWDB has constructed 437 projects to ensure flood free land, however, most of them failed to provide the security (Hoque and Siddique, 1995). Another study (Choudhury, 2000) evaluated the performance of Dhaka-Demra-Narayangonj embankment using computer simulation and found that it was threatened to be overtopped and breached by the floods of 1988 and 1998 for several times. But the collective efforts of BWDB and local people saved that from collapsing during the hazardous floods. Furthermore, no plan can substantiate the strength and durability of flood protection structures against the massive forces of floods. The problems of the embankments are faced with, if not solved and attended, would turn out to be an expensive investment which most probably would fail to produce fruitful results during time of floods.

8 CONCLUDING REMARKS

Floods have been and continue to be one of the most consistently destructive natural hazards and the increasing development in floodplains results in a continuous upward trend in damages as the effect of floods is aggravated, if not actually caused, by men unwise activities and occupation of flood plains. This upward trend occurs in spite of increasing investment in structural solutions to control flooding. Experience indicates that a comprehensive approach to the problem of flooding is required. In the beginning, the problem must be placed in perspective, in technical, economic, social, environmental and political terms with other hazards. Then, a comprehensive program must be planned. It should incorporate elements, such as flood forecasting and warning and structural works to reduce damages and loss of life for existing floodplain development and elements, such as flood risk mapping and land use restriction to reduce damage to future floodplain development. The mapping element or program should be considered, it must be planned in relation to other related programs such as land use restrictions, acquisitions, flood insurance, structural works etc. although these programs may be administered by different governmental departments and agencies, liaison and coordination is essential so that an optimum solution is attained. All flood mitigation measures should be compatible with water and land resources development plans and policies. The people of communities are to be involved with the flood mitigation initiatives. They should also adopt to those activities before, during and after the flood events to minimize flood losses based on the acceptance of the fact that flooding is an inevitable event.

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