Situation Analysis on Floods and Flood Management
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Eklavya Prasad
Nandan Mukherjee

Ecosystems for Life: A Bangladesh-India Initiative
Preface

Bangladesh and India share three major river systems: the Ganga, the Brahmaputra and the Meghna. Along with their tributaries, these rivers drain about 1.75 million sq km of land, with an average runoff of 1,200 cu km. The GBM system also supports over 620 million people. Thus, the need for cooperation on trans-boundary waters is crucial to the future well-being of these millions.

That is precisely the motivation for the Ecosystems for Life: A Bangladesh- India Initiative (Dialogue for Sustainable Management of Trans-boundary Water Regimes in South Asia) project. IUCN wishes to promote a better understanding of trans-boundary ecosystems between Bangladesh and India, by involving civil society in both countries and by providing a platform to discuss issues common and germane to the region. The overall goal is an improved, integrated management of trans-boundary water regimes in South Asia. The Ecosystems for Life is guided by a Project Advisory Committee (PAC) of eminent persons from Bangladesh and India. This four-and-a-half year initiative is supported by the Minister for European Affairs and International Cooperation, the Netherlands.

Ecosystems for Life has been working towards developing longer-term relationships between various stakeholder groups within and between the countries through dialogue and research. The aim is to encourage a common understanding to generate policy options on how to develop and manage natural resources sustainably so that livelihoods, water and food security improve. Inter-disciplinary research studies have been conducted by bringing together experts from various fields from both countries so that relevant issues are holistically grasped.

The initiative centres around five broad thematic areas:
- food security, water productivity and poverty;
- impacts of climate change;
- inland navigation;
- environmental security; and
- biodiversity conservation.

The first step of dialogue and research has concentrated on creating ‘situation analyses’ on each thematic area and related issues. Each analysis set identified core issues, their significance within the India-Bangladesh geographic focus, research gaps and needs and, ultimately, priority areas for joint research. Authors discussed their points of view at a joint exercise; they shared their research. After due PAC review, the ensuing material was further circulated among multiple stakeholders in both countries. All outcomes of this dialogue process are incorporated in the final papers. 16 situation analyses related to the five thematic areas were published in 2012. Further 4 papers have been completed in 2013 and ready for publication. We will also subsequently publish summary briefs, based on these studies. The initiative, thus, has taken a big step; now, the agenda for meaningful joint research is clear.

IUCN hopes these publications will be useful to academics, researchers and practitioners in the GBM region.
### The Ganga/Ganges-Brahmaputra-Meghna (GBM) Region

<table>
<thead>
<tr>
<th>River</th>
<th>Ganga/Ganges</th>
<th>Brahmaputra</th>
<th>Meghna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (km)</td>
<td>2,510</td>
<td>2,900</td>
<td>210</td>
</tr>
<tr>
<td>Catchment (sq km)</td>
<td>10,87,300</td>
<td>5,52,000</td>
<td>82,000</td>
</tr>
</tbody>
</table>

Total area of GBM region: 17,21,300 sq km

Source: 1. Average, based on various data; 2. Joint River Commission figures
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## Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ADB</td>
<td>Asian Development Bank</td>
</tr>
<tr>
<td>AFD</td>
<td>Armed Forces Division</td>
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<tr>
<td>BDRC</td>
<td>Bangladesh Red Crescent Society</td>
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<tr>
<td>BMD</td>
<td>Bangladesh Meteorological Department</td>
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<tr>
<td>BUP</td>
<td>Bangladesh Unnayan Parishad</td>
</tr>
<tr>
<td>BWDB</td>
<td>Bangladesh Water Development Board</td>
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<tr>
<td>CCC</td>
<td>Climate Change Cell</td>
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<tr>
<td>CEGARS</td>
<td>Centre of Academic Research and Studies</td>
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<tr>
<td>CEGIS</td>
<td>Centre for Environmental and Geographic Information Services</td>
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<tr>
<td>CPP</td>
<td>Cyclone Preparedness Programme</td>
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<tr>
<td>CRU</td>
<td>Central Research Unit</td>
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<tr>
<td>DER</td>
<td>Disaster Emergency Response</td>
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<tr>
<td>DMB</td>
<td>Disaster Management Bureau</td>
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<tr>
<td>DMIC</td>
<td>Disaster Management Information Centre</td>
</tr>
<tr>
<td>DMRD</td>
<td>Ministry of Disaster Management and Relief</td>
</tr>
<tr>
<td>DND</td>
<td>Dhaka Narayanganj Demra</td>
</tr>
<tr>
<td>DRR</td>
<td>Directorate of Relief and Rehabilitation</td>
</tr>
<tr>
<td>DTW</td>
<td>Deep Tube Well</td>
</tr>
<tr>
<td>EOC</td>
<td>Emergency Operation Centre</td>
</tr>
<tr>
<td>F0, F1, F2, F3, F4</td>
<td>Land type classification based on normal monsoon season flood depths (0-30cm, 30-60cm, 60-90cm, 90-180cm, &gt;180cm respectively)</td>
</tr>
<tr>
<td>FAP</td>
<td>Flood Action Plan</td>
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<tr>
<td>FCD</td>
<td>Flood Control Drainage</td>
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<tr>
<td>FFWC</td>
<td>Flood Forecasting and Warning Centre</td>
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<tr>
<td>GBM</td>
<td>Ganges–Brahmaputra–Meghna</td>
</tr>
<tr>
<td>GCM</td>
<td>Global Climate Model or General Circulation Model</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>GO</td>
<td>Governmental Organization</td>
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<tr>
<td>GOB</td>
<td>Government of Bangladesh</td>
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<tr>
<td>IPCC</td>
<td>Intergovernmental Panel on Climate Change</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
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<td>---------</td>
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<tr>
<td>ISDR</td>
<td>International Strategy for Disaster Reduction</td>
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<tr>
<td>IWFM</td>
<td>Institute of Water and Flood Management</td>
</tr>
<tr>
<td>LGED</td>
<td>Local Government Engineering Department</td>
</tr>
<tr>
<td>LLP</td>
<td>Low Lift Pump</td>
</tr>
<tr>
<td>MoFDM</td>
<td>Ministry of Food and Disaster Management</td>
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<tr>
<td>MoWR</td>
<td>Ministry of Water Resources</td>
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<tr>
<td>MPO</td>
<td>Master Plan Organization</td>
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<td>NDMC</td>
<td>National Disaster Management Council</td>
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<tr>
<td>NGO</td>
<td>Non-governmental organization</td>
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<tr>
<td>NWMP</td>
<td>National Water Management Plan</td>
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<tr>
<td>NWPo</td>
<td>National Water Policy</td>
</tr>
<tr>
<td>RCM</td>
<td>Regional Climate Model</td>
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<tr>
<td>RENA</td>
<td>Rapid Emergency Needs Assessment</td>
</tr>
<tr>
<td>RIR</td>
<td>Rapid Initial Report</td>
</tr>
<tr>
<td>SAARC</td>
<td>South Asian Association for Regional Cooperation</td>
</tr>
<tr>
<td>SOD</td>
<td>Standing Orders on Disaster</td>
</tr>
<tr>
<td>SPARRSO</td>
<td>Space Research and Remote Sensing Organization</td>
</tr>
<tr>
<td>STW</td>
<td>Shallow Tube Well</td>
</tr>
<tr>
<td>SWC</td>
<td>Storm Warning Center</td>
</tr>
<tr>
<td>UDMC</td>
<td>Union Disaster Management Committee</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nation Development Programme</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>UzDMC</td>
<td>Upazila Disaster Management Committee</td>
</tr>
<tr>
<td>WAPDA</td>
<td>Water and Power Development Authority</td>
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<td>WB</td>
<td>World Bank</td>
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</table>
South Asia is marked by a large population and high incidence of poverty. The region (with 4,482,388 square kilometers (sq km) which includes Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka) is home to more than world’s one fifth of humanity, nearly half of its poor, almost half of its non-literate population and as much the malnourished. It is estimated that between 2 to 16 percent of the gross domestic product (GDP) of different South Asian countries get wasted every year due to natural disasters (Thakkar, 2006).

The countries in this region (Thakkar, 2006) have been struggling to achieve sustainable development and economic prosperity which are often frustrated due to a number of economic and social factors, along with their high vulnerabilities to natural disasters such as floods, droughts, salinity ingress, cyclone, and storm surge. Vulnerabilities to water-related disasters are predominantly due to acute climate variability and extremes which are manifested by both spatial and temporal distribution of water resources available throughout the region.

The most densely populated and the poorest areas in South Asia with the largest concentration of disaster-affected people due to high intensity floods, are located in the eastern part of the Indo-Gangetic Plains (IGP) (Muhammed et al. 2004). Within IGP is the Ganges – Brahmaputra – Meghna riverine region also referred to as GBM river basin (Paura, 2003).

The most densely populated and the poorest areas in South Asia with the largest concentration of disaster-affected people due to high intensity floods, are located in the eastern part of the Indo-Gangetic Plains.
The GBM riverine region is a set of trans-boundary river system with a total area of just over 1.7 million sq km, distributed between India (64 percent), China (18 percent), Nepal (9 percent), Bangladesh (7 percent) and Bhutan (3 percent). Nepal is located entirely in the Ganges river basin and Bhutan is located entirely in the Brahmaputra river basin. Bangladesh occupies only about 7 percent of the catchment area of the GBM system, whereas it discharges over 92 percent of the water volume through it. Such an imbalance in the draining of the regional surface water causes abundance of water in the monsoon months. Furthermore, a decline in drainage gradient along the Ganges and other rivers results in severe drainage congestion close to the estuary. As a result, an estimated average of around 25 percent of the landmass of the country is flooded every year, whereas about 60 percent landmass is prone to flooding. Since the number of people living in the flood prone areas is increasing with increasing population and more assets are being placed in those areas, it is likely that the damages due to floods will increase manifold in future (Muhammad et al. 2004).

The GBM riverine region consists of distinct characteristics and flow through very different terrains for most of their lengths. These three rivers join just a few hundred kilometres upstream of the mouth in the Bay of Bengal. Not only are these three rivers big by themselves, individually, each of them also has tributaries that are important by themselves in social, economic and political terms, as well as for water availability and use. Many of these tributaries are also of transboundary nature. The GBM river system is the third largest freshwater outlet to the world’s oceans, being exceeded only by

Map 1: Ganges – Brahmaputra – Meghna River Basin

Source: IUCN Bangladesh, 2014
the Amazon and the Congo river systems (FAO, 2013). The basin is almost annually ravaged by
floods from June to September. The annual run off in the GBM river system is 1400 billion cubic
metre (BCM), the third largest in the world. The annual sediment load in the system is 1670 million
tonnes (MT). The annual run-off, the annual rainfall, sediment load and the Himalayan Rivers’
response show extreme variability (Thakkar, 2006).

India is the largest country in the South Asian region. It shares most of its
major basins with Pakistan, Nepal, Bhutan and Bangladesh. The annual precipitation, in India,
including snowfall is estimated at 4,000 billion cubic meter (bcm). Out of this, the seasonal rainfall
in monsoon is of the order of 3,000 bcm. The rainfall in India shows great temporal and spatial
variations, unequal seasonal distribution and geographical distribution and frequent departures
from the normal.

In eastern and north-eastern India floods are caused by a number of factors such as
excessive precipitation, inadequate drainage capacity, land use changes, natural denudation,
and excessive siltation (Mohapatra & Singh, 2003). The maximum rainfall in India is recorded in
the Brahmaputra valley, about 2500 millimeters (mm). The Brahmaputra and Barak along with
their tributaries cover Assam and other north-eastern states (Arunachal Pradesh, Meghalaya,
Manipur, Mizoram, Assam, Tripura and Nagaland) and northern portion of West Bengal. The
region is interspersed with a large number of streams that inundate the narrow valley. The north
bank tributaries of the Brahmaputra are very flashy, which bring down heavy loads of sediments,
sometimes even boulders, and have a tendency to change their courses. The hillsides are prone
to earthquakes and are susceptible to landslides and erosions, and these in turn interfere with the
drainage systems. The effect of the 1950 earthquake on the water levels of the Brahmaputra in
India is significant: the lowest water level was reported to have increased by 3 meters (m). Thus,
the main problems of the Brahmaputra and its tributaries in India are those of over-bank spillage,
drainage congestion, bank erosion, landslides, and change of river courses (Muhammad et al.
2004). Floods in the eastern part of India in the recent past are striking examples.

Nepal, the land of Sagarmatha, has about 6000 rivers. Though only a small number of
these rivers are closely linked to the livelihood of the Nepalese, a large proportion of who are
concentrated in the Terai while the rest are dispersed in other parts of the country (Muhammad
et al.). The Sapta Kosi River, which means seven rivers, is the biggest in Nepal. It drains the
eastern part of the country, particularly the eastern region of Gosainsthan (north of Kathmandu)
and west of Kanchenjungha, a region known as the Kosi basin. Altogether the river drains an area
of 71,500 sq km in Tibet, Nepal and north Bihar and has seven major tributaries, the Sun Kosi,
the Indrawati, the Dudh Kosi, the Tama Kosi, the Likhu, the Arun and the Tamor of which the Sun
Kosi, the Arun and the Tamor are the main ones (Dixit, 2009).

The Sapta Kosi cuts through a gorge to reach the Terai in the south. The change in
altitude cuts deep channels formed of coarse materials in the mountainous landscape (Dixit,
2009). All these rivers originate in the Himalayas and feed the Ganges system. The rivers are more
influenced by snow-melt and, therefore, they have significant flows even in winter months. But the
swelling rivers can engulf flood plains when they receive rainfall-runoff in the monsoon. The rivers
traverse through the steep slopes of the mountains and on receiving the heavy monsoon-runoff
generate high kinetic energy devastating the plains in the valleys both in Nepal and in India. The
rivers rising from the Siwalik range in Nepal experience floods caused by burst of rainfall on the
southern slopes. These floods cannot be predicted, but they often bring down voluminous loads
of water that virtually sweep the plains of Nepal and adjacent plains of India. Water levels in the
main channel fluctuate so suddenly that people hardly get any time to move to safer places. All Himalayan rivers carry sediments. These sediments that are deposited in the plains reduce the drainage gradient in the downstream (Muhammed et al. 2004).

It is imperative to include arguments and perspectives from sub regional specificities to capture the diverse social distinctions, thoughts and practices while undertaking a situation analysis of floods. This will help in identifying different existing vulnerabilities confronted by local people and locating the presence of unattended, invisible or unrecognized vulnerabilities. Therefore, this study has combined inputs and analysis from sources that have tried comprehending floods through different standpoints of recurring floods in the region.

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Sub-regional Specificities

Bihar

The name Bihar is derived from the ancient word Vihara (monastery) as there are many monasteries and shrines in this state. It is located in the eastern part of India (between 83°-30' to 88°-00' longitude) and it is an entirely land-locked state mid-way between West Bengal in the east and Uttar Pradesh in the west. It is bounded by Nepal in the north and Jharkhand in the south (Government of Bihar). The total population of the State is 103,804,637 comprising 54,185,347 and 49,619,290 male and female population respectively (Census of India, 2011).

The River Ganges which is the main drainage system for the state, flows in an easterly direction and stretches 432 km across Bihar, bisecting the state. North Bihar, the plain, located north of the Ganges, is interspersed with eight major river basins: the Ghaghra, the Gandak, the Burhi Gandak, the Bagmati, the Adhwara group of rivers, the Kamala, the Koshi, and the Mahananda. Thus, all the rivers in North Bihar share basins either with another Indian state or with Nepal and Tibet (Singh et al. 2009).

With a geographical area of about 94,000 sq km, Bihar is divided into two distinct parts - north Bihar is spread over 53,000 sq km and south Bihar in an area of 41,000 sq km (Government of India, 2008). All rivers of north Bihar drain into the main Ganges stem. Any rainfall occurring in Tibet and Nepal directly affects the flow in these river systems (Government of India, 2008) and with the present flood management mechanism flooding of North Bihar becomes a recurrent phenomenon.
The flat terrain and the huge seasonal variations in water volume in the rivers cause extensive flooding in the North Bihar plains. Gradients vary from 22 cm per km near the Indo-Nepal boundary to 7.5 cm per km near the confluence of the rivers with the Ganges. The difference between the minimum and the maximum flows in the Himalayan rivers is high. In the normal years, the rivers carry between 10 and 20 times more water throughout the monsoon than in winter; during periods of intense rainfall in the catchment areas, they can increase a hundred-fold in volume (Singh et al. 2009).

A considerable portion of the land in Bihar is waterlogged, a phenomenon that has been exacerbated by human interventions: natural drainage has been impeded by embankments, canals, roads, and railway tracks. Official records suggest that nearly one million hectares of land in Bihar, 85 percent of it in North Bihar, is waterlogged. The 835,000 hectares of waterlogged area constitutes about 16 percent of the total area of North Bihar, which has a population of 52.3 million people and an area of 52,312 sq km (Singh et al. 2009).

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West Bengal

West Bengal is also referred to as the state with rich cultural and political heritage. It is situated in the eastern part of the country between 21°20’ and 27°32’ N latitude and 85°50’ and 89°52’ E longitude. The total area of the state is 88,752 sq km which is 2.7 percent of the total area of the country. The state has two distinct natural divisions - the Northern Himalayan region and the Southern Alluvial plains. Teesta, Torsa, and Jaldhaka are the three main rivers in the north. They are tributaries of the Ganges river. The other two important rivers passing through the state are Ganges and Hooghly. The Ganges drains into the Bay of Bengal forming the famous delta of Indian Sundarbans (Government of West Bengal & Government of India, 2011). West Bengal is bordered by Bangladesh to the east, to the northwest by Nepal and in the north by Bhutan. The Indian states of Assam and Sikkim lie to the north and north-east, Orissa in southwest, Jharkhand and Bihar in the west.

The total geographical area of the state of West Bengal is 88,752 sq km. As a part of the Bengal Delta, it has 37,660 sq km flood prone area spread over 111 blocks. The total devastated area crossed 20,000 sq km in four different years, and the flood of medium magnitude, having a measure between 2,000 and 10,000 sq km, occurred on ten occasions (Irrigation & Waterways Department). At present, 42 percent of total area of the State spread over 18 districts is susceptible to flood. The highest affected area of flood as recorded in 1978, is about 30,607 sq km. About 23,970 sq km of area was devastated by flood in 2000 (Choudhary et al. 2010).
The flood problems of the state are of different nature at different regions. The rivers Teesta, Torsa, Jaldhaka, Raidak-I and Raidak-II flowing through the districts of Jalpaiguri and Cooch Behar, originate in the neighbouring country of Bhutan and the state of Sikkim, flow onwards down to Bangladesh, where they meet the Brahmaputra at different points (Irrigation & Waterways Department).

Map 3: Flood prone areas of West Bengal


The rivers (Atrai, Punarbhaba) of the districts of Uttar Dinajpur and Dakshin Dinajpur, originating in Bangladesh passes through these districts and then join the River Ganges-Padma at downstream of Farakka in Bangladesh. Both the places of origin and also the outfall of most of these rivers are in Bangladesh (Irrigation & Waterways Department). The district of Malda in West Bengal through which the river Ganges flows, receives its flood waters from about 11 states and is battered by the run-off flow generated from these vast areas. Ultimately the river flows down to Bangladesh (Irrigation & Waterways Department). Another portion of the Malda district receives floodwaters of the Mahananda, which again originates in the hills of Nepal. It enters India through the neighbouring state of Bihar and then passes through Malda to join the Ganges-Padma also at downstream of Farakka Barrage in Bangladesh (Irrigation & Waterways Department).

... Mahananda and most of the rivers of Uttar and Dakshin Dinajpur districts stop flowing when the Ganges; upstream and downstream of Farakka Barrage, rules high thereby not allowing drainage of flood discharge during that period
Major contributing factors to flood in the northern parts of West Bengal are the local monsoon run-off, discharge from upper river basin areas and also the outfall condition in the neighbouring countries. In addition, Mahananda and most of the rivers of Uttar and Dakshin Dinajpur districts stop flowing when the Ganges upstream and downstream of Farakka Barrage rules high; thereby not allowing drainage of flood discharge during that period.

The flood in this zone becomes voluminous because of the shape of the catchment area, its steep slope starting from a high level plateau area and sloping sharply down to a flat terrain near the outfall of limited capacity. This feature is again adversely affected by tidal condition as is generally noticed in the month of September, the likely month of occurrence of floods.

In other sub-basin areas of the Bhagirathi-Hooghly there are certain distinctive features of drainage condition which give rise to flood situation. Basin-wise there are quite a number of rivers in the west bank of the Bhagirathi-Hooghly which are Pagla-Bansloi, the Dwarka-Bramhani, the Mayurakshi-Babra-Uttarasan, the Bakreswar-Kuye and also the Ajoy. Between them, these rivers drain an area of 17,684 sq km, spread over the state of Jharkhand, and districts of Birbhum, part of Murshidabad (west of Bhagirathi) and Burdwan. They generate flood because of high rainfall in these basins and limited carrying capacity of the river Bhagirathi between the towns of Jangipur and Kalna. In this reach the Bhagirathi has a discharge carrying capacity of maximum 3114.85 cumec. If all these rivers receive rainfall simultaneously in their catchment areas, they can generate run-off volume of any amount between 11 to 16 thousand cumec at their outfall at the Bhagirathi, as it occurred during the flood of September 2000. In this vast tract of land there is one structure which interferes with the natural flow of flood water, the Massanjore Dam over river Mayurakshi. This dam, constructed for irrigation, intercepts about 36.4 percent of the Sidheswari-NoonBeel-Mayurakshi basin area of 5109 sq km. It can discharge or generate only 16 percent of run-off that is likely to be generated in case of simultaneous rainfall in these basins, west of the Bhagirathi, from the Pagla-Bansloi to the Ajoy (including catchment of Ajoy). The flood in this zone becomes voluminous because of the shape of the catchment area, its steep slope starting from a high level plateau area and sloping sharply down to a flat terrain near the outfall of limited capacity. This feature is again adversely affected by tidal condition as is generally noticed in the month of September, the likely month of occurrence of floods (Irrigation & Waterways Department).

On the left bank of the Bhagirathi river system, the Bhairab-Jalangi-Sealmari group of rivers originates from Ganges-Padma at Akherigunj in Murshidabad district and meets the Bhagirathi at Swarupgunj in Nadia District. This system of rivers drains a total area of 4,300 sq km of Murshidabad and Nadia districts. Generally, this area suffers from flood because of three reasons – (1) high intensity rainfall in the basin area (2) inflow of flood water from Ganges-Padma
at its high spate, and (3) drainage congestion at its outfall because of high stage of the Bhagirathi (Irrigation & Waterways Department).

In the Damodar-Barakar Basin System, the rivers originate at Chotonagpur plateau and flows down the plains of West Bengal to meet the Bhagirathi. The catchment area upto Durgapur Barrage is 18,026 sq km as against total catchment of 22,015 sq km. In this catchment area there are only 4 (four) reservoirs having a storage capacity of 1.21 lakh ha.m. The original concept of flood storage was to have an area reserved for storing a volume of 3.58 lakh ha.m. Thus, with this limited flood storage capacity the storage dams at present can modify only the peak flood discharge. Any discharge above 1982.17 cumec down stream of Durgapur Barrage may cause flood depending on the outfall condition of the Mundeswari at Harinkhola(Irrigation & Waterways Department).

The Kangsabati River system (also known as the Kasai and Cossye), rises from the Chota Nagpur plateau in Jharkhand state and passes through the districts of Purulia, Bankura and Paschim Medinipur in West Bengal before draining in the Bay of Bengal. After originating near Jhalda in the Chota Nagpur plateau in Purulia district, it passes by Khatra and Ranibandh in Bankura district, and then enters Paschim Medinipur in the Binpur area. It is joined by Bhairabbanki. At Keshpur the river splits into two. The northern branch flows through the Daspur area as Palarpai and joins the Rupnarayan river. The other branch flows in a south-easterly direction and on joining the Kaliaghai river forms the Haldi River, which flows into the Hooghly River at Haldia.

The Kangasabati Project is situated in drought prone mid-western part of West Bengal. The project comprises two dams across the rivers Kangasabti and Kumari which are located near village Mukutmonipur, [P.S. Khatra] in the district of Bankura. The two dams are connected by a hillock in between forming a continuous barrier with single reservoir, while the valleys of Kangasabati and Kumari being connected by a link channel. The dam is earthen with concrete saddle spillway. The length of the dam is 6.40kms and maximum height of Kangasabati dam is 38.10 m and Kumari dam is 41.15 m. The gross storage capacity of the reservoir is 1053 Mcum and live storage capacity is 916.57 Mcum. The spillway has 11 radial gates with discharge capacity of 5686.58 cumec. The dam has two regulators supplying to a left bank feeder canal of 192 cumec design capacity and a right bank feeder canal of 79 cumec capacity. The left bank feeder after some distance bifurcates into two viz Supur main canal and Khatra main canal. Khatra main canal crosses the river Silabati through a barrage (Silabati barrage) after which it is known as Indpur main canal. The right bank canal crosses the river Bhairabbanki and the river Tarafeni via two barrages (Tarafeni barrage and Bhairabbanki barrage) on these rivers. The total CCA of the project is 3,96,050 ha and annual irrigation is 4,01,890 ha. The dam was completed in 1972 and the canal network completed in 1985. The project benefits districts of Bankura, Hoogly and Midnapur (India - WRIS Wiki 2013).

**The two dams are connected by a hillock in between forming a continuous barrier with single reservoir, while the valleys of Kangasabati and Kumari being connected by a link channel...**
The Mathabhanga-Churni-Ichamati system of rivers originates at the Mathabhanga off-taking from Ganges-Padma downstream of Farakka Barrage in Bangladesh and on reaching West Bengal at Majhdia, in Nadia district, bifurcates in two branches – (1) the Churni flowing in south-westerly direction meeting the Bhagirathi at Ranaghat and (2) the other branch viz. the Ichamati flowing in south-easterly direction to meet Bay of Bengal through the creek of Raimangal. The main flood situation in this area arises because of inflow from Ganges-Padma (when it rules high), rainfall in the own catchment area and also tide lockage. In the flood of 2000 a very unusual situation arose where the Bhagirathi transferred a large volume of its floodwater to this basin area by breaching its embankments at several places (Irrigation & Waterways Department).

Assam

Assam is the gateway to the northeastern part of India and is also known as the land of the red river and blue hills. Situated between 89° 42’ E to 96° E longitude and 24° 8’ N to 28° 2’ N latitude, it has an area of 78,438 sq km, constituting 2.4 percent of the country. Assam is bordered in the North-West and North-East by the Kingdom of Bhutan and the Indian state of Arunachal Pradesh. Along the south lie the states of Nagaland, Manipur and Mizoram. Meghalaya lies to her South-West, West Bengal and Bangladesh to her West (Raatan 2005). The total population of Assam is 31,169,272 comprising 15,954,927 and 15,214,345 male and female population respectively (Census of India, 2011).

Map 4: Flood prone areas of Assam


Assam is situated in a high rainfall area with an average annual rainfall of 2,546 mm. About 60 to 70 percent of the monsoon rain is received within a span of 3 to 4 months - May to
August (Hazarika, 2006). For a population of 31 million in Assam, where 3/4 of the total number of districts remain under flood water every year from June to September, flood has become an annual event of life and factored in their yearly account of activities. The two rivers Brahmaputra and Barak with their tributaries drain the valley and bring untold miseries to the people while the ferocity of the floods has increased every year.

The Brahmaputra is a major international river with a drainage area of 580,000 sq km, 50.5 percent of which lies in China, 33.6 percent in India, 8.1 percent in Bangladesh, and 7.8 percent in Bhutan. Its basin in India is shared by Arunachal Pradesh (41.9 percent), Assam (36.3 percent), Nagaland (5.6 percent), Meghalaya (6.1 percent), Sikkim (3.7 percent), and West Bengal (6.5 percent). The first 1,625 km of the Brahmaputra lies in Tibet, the next 918 km in India, and the remaining 337 km in Bangladesh. The basin lies between latitudes 23°N and 32°N and longitudes 82°E and 97°E, and is of irregular shape with the maximum east-west length being 1,540 km while the maximum north-south width is 682 km. The average width of the valley is about 86 km, of which the river itself often occupies up to 20 km. Throughout its course in India, the Brahmaputra is highly braided, with some well-defined stable banks where the river width is narrow. All along its course, abundant wetlands and back swamps are common in the floodplain (Mahanta, 2006).

The river enters the plains of Assam near Pasighat after traversing nearly 226 km of mountainous course. At Kobo, 52 km south of Pasighat, Dihang meets two rivers called Dibang and Lohit. Thereafter, it is called the Brahmaputra. This happens to be the only male river in the female-river dominated area (Phukan, 2005).

The Brahmaputra basin, one of the most flood-prone basins in India, spreads over nearly 58 million hectares covering Tibet, India, Bhutan and Bangladesh. It originates from the great glaciers of Kailash range and traverses nearly 1100 km across Tibet before entering India through Eastern Arunachal Pradesh. In Tibet, it is known as Tsangpo and in Arunachal Pradesh as Dihang or Siang. The river enters the plains of Assam near Pasighat after traversing nearly 226 km of mountainous course. At Kobo, 52 km south of Pasighat, Dihang meets two rivers called Dibang and Lohit. Thereafter, it is called the Brahmaputra. This happens to be the only male river in the female-river dominated area (Phukan, 2005).

The Barak basin covers parts of India, Bangladesh and Myanmar. In India it spreads over states of Meghalaya, Manipur, Mizoram, Assam, Tripura and Nagaland having an area of 41,723 sq km which is nearly 1.38 percent of the total geographical area of the country. The basin extends between 89°50’ to 94°0’ east longitudes and 22°44’ to 25°58’ north latitudes with maximum length and width of 460 km and 350 km. It is bounded by the Barail range separating it from the Brahmaputra basin on the north, by the Naga and Lushai hills on the east and by Mizo hills and territory of Bangladesh on the south and west.
The Barak River rises from the Manipur hills, south of Mao in Senapati district of Manipur at an elevation of 2,331 m. It flows then along the Nagaland-Manipur border through hilly terrains and enters Assam. It flows further and enters Bangladesh where it is known by the name of the Surma and the Kushiyara and later called the Meghna (Meghna is formed inside Bangladesh by the joining of different rivers originating from the hilly regions of eastern India) before receiving the combined flow of the Ganga and the Brahmaputra. The length of the Barak River from its origin upto the border of Assam along the Kushiyara is 564 km. The principal tributaries of Barak joining from north bank are the Jiri, the Chiri, the Modhura, the Jatinga, the Harang, the Kalain and the Gumra whereas the Dhaleswari, the Singla, the Longai, the Sonai and the Katakhal joins from south bank. The major part of basin is covered with forest accounting to 72.58 percent of the total area and only 1.92 percent of the basin is covered by water bodies.(India -WRIS Wiki 2013)

An average annual surface water potential of 585.6 cubic kilometers has been assessed in this basin. Out of this, 24 cubic kilometers is utilizable water. The average annual yield of the Barak at Lakhipur has been calculated at 14,077 million cubic meters while monsoon and non-monsoon averages are 12,073 and 2,004 million cubic meters respectively (Brahmaputra Board 1988). Floods are an annual threat also in the Barak basin where the maximum flood-prone area is about 4.33 million hectares. The annual average rainfall is 3,400 mm, with a highest recorded total of 4,194 mm in 1989. The cultivable area of the basin is about 13.04 million hectares, which is 7.1 percent of the total cultivable area of the country (Mahanta, 2006).

### Impact of Floods in the Region

There are abundant authentic indicators to prove that over the years, the nature and impact of floods have become far more catastrophic and wide-ranging. According to the information published by different government agencies, flood prone area in India has been increasing dramatically. According to RBA’s assessment in 1980, the flood affected area in the country was 40 million ha. The sum of maxima of flood affected areas in any year considered by RBA upto 1978 as 33.516 million ha has now gone upto 49.815 mha by 2010. However, there is no credible data base maintained by the States as required by a judicious criteria based on frequency of flooding, duration and depth of inundation etc. The flood damages reported by States from 1953 to 2010 have been projected at 2011 price level as Rs. 812,500 crore approximately (Planning Commission 2011).

*There are abundant authentic indicators to prove that over the years, the nature and impact of floods have become far more catastrophic and wide-ranging. According to the information published by different government agencies, flood prone area in India has been increasing dramatically*
Table 1: Flood affected area compiled by Eleventh Plan Working Group on Water Resources

<table>
<thead>
<tr>
<th>Name of States</th>
<th>Area Liable to Floods as assessed by RBA (million ha)</th>
<th>Flood affected area as compiled by Eleventh Plan Working Group (million ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arunachal Pradesh</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>Assam</td>
<td>3.15</td>
<td>3.82</td>
</tr>
<tr>
<td>Bihar</td>
<td>4.26</td>
<td>6.88</td>
</tr>
<tr>
<td>Manipur</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>0.02</td>
<td>0.09</td>
</tr>
<tr>
<td>Mizoram</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>Nagaland</td>
<td>-</td>
<td>0.009</td>
</tr>
<tr>
<td>Sikkim</td>
<td>-</td>
<td>0.02</td>
</tr>
<tr>
<td>Tripura</td>
<td>0.33</td>
<td>0.33</td>
</tr>
<tr>
<td>West Bengal</td>
<td>2.65</td>
<td>3.76</td>
</tr>
</tbody>
</table>

Source - (Planning Commission 2011)

Table 2: State-wise Maximum Areas Affected by Floods in any year during 1953-2010

<table>
<thead>
<tr>
<th>Name of States</th>
<th>Maximum Area Affected (million ha)</th>
<th>Year of maximum Area Affected (million ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arunachal Pradesh</td>
<td>0.207</td>
<td>2003</td>
</tr>
<tr>
<td>Assam</td>
<td>3.820</td>
<td>1988</td>
</tr>
<tr>
<td>Bihar</td>
<td>4.986</td>
<td>2004</td>
</tr>
<tr>
<td>Manipur</td>
<td>0.080</td>
<td>1989</td>
</tr>
<tr>
<td>Meghalaya</td>
<td>0.095</td>
<td>1987</td>
</tr>
<tr>
<td>Mizoram</td>
<td>0.541</td>
<td>1993</td>
</tr>
<tr>
<td>Nagaland</td>
<td>0.009</td>
<td>1993</td>
</tr>
<tr>
<td>Sikkim</td>
<td>1.170</td>
<td>2000</td>
</tr>
<tr>
<td>Tripura</td>
<td>0.330</td>
<td>1963</td>
</tr>
<tr>
<td>West Bengal</td>
<td>3.080</td>
<td>1978</td>
</tr>
</tbody>
</table>

Source - (Planning Commission 2011)

**Problem of Tal areas** - natural depressions where water accumulates during monsoon for a longer period are known as Tal areas. Generally, they hamper normal activity affecting the Kharif crop. Mokama group of Tal in Bihar is known for its flood problem. Water gets accumulated in these areas during monsoon and remains stagnant up to September/October (Mohapatra & Singh, 2003).
**River bank/bed erosion** - All natural rivers are with mobile bed flows. Therefore, depending on the flow phenomenon, there may be aggradations and/or degradation in the river banks and beds. A river erodes its banks due to various reasons causing considerable loss of arable and productive land, deterioration of the river regime and sometimes account for huge losses during floods. Rivers in Brahmaputra-Barak and Ganges basins are prone to severe erosion. The erosion is governed by the discharge in the river, bed slope, sediment flow and composition of bed and bank materials. The river behaviour causes new riverine landmass to be built up, but these become productive after many years and cannot compensate the land-loss due to erosion. Erosion in the Majuli Island, the largest river-island in the world, is the most appropriate example to showcase the severity of the problem. The Brahmaputra Board has estimated that in the Majuli Island, the annual loss of land due to erosion could be about 3.9 sq km and an economic loss of about Rs. 31.5 million per annum (Mohapatra & Singh, 2003).

**Sediment transport by rivers** - one of the problems associated with the floods in the region is the transport of sediments by rivers during floods. Himalayan rivers originating from Nepal bring a lot of sediment during floods to the alluvial plains in the valley. Transport of sediments (suspended and bed load) has a major role on river behaviour and river morphology. Thus, the flood problem and its management measures depend a lot on sediment transport. As recorded by CWC, the total live and gross storage capacity created in India is about 177 and 217 cubic km, respectively. Based on the sedimentation data of 144 reservoirs, the weighted average annual loss in gross storage due to silting computed is 0.44 percent. Thus, the likely annual loss in the total gross storage of 217 cubic km is 0.95 cubic km. Similarly, the annual loss in live storage is 0.31 percent based on the data of 42 reservoirs. Thus, the likely annual loss in the total live storage is 0.55 km³. Considering the average density of 1.137 tonnes/m³, based on the data of 13 reservoirs, the weight of the total of all the reservoirs in India is 1,080 million ton annually (Mohapatra & Singh, 2003).

**Dam break flows** - flooding due to dam break is a mega-disaster as it is associated with huge loss of life and property. An unusual high peak in a short duration and presence of a moving hydraulic shock/bore make it a different problem as compared to other natural floods. In India, historical events for dam break floods are common. Sometimes, blockage of water due to deposits caused by a landslide takes place. When this natural blockage fails due to increased amount of water at the upstream, huge flooding occurs. The behavior of this flood is similar to that of dam break floods (Mohapatra & Singh, 2003).

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**Rivers in Brahmaputra - Barak and Ganges basins are prone to severe erosion. The erosion is governed by the discharge in the river, bed slope, sediment flow and composition of bed and bank materials. The river behaviour causes new riverine landmass to be built up, but these become productive after many years and cannot compensate the land-loss due to erosion. Erosion in the Majuli Island, the largest river-island in the world, is the most appropriate example to showcase the severity of the problem.**
Flash floods - flash floods are characterized by sudden rise and recession of flow of small volume and high discharge which causes damages because of suddenness. They generally take place in hilly regions where the bed slope is very steep (Mohapatra & Singh, 2003).

Impacts of flood in the east and north-east India apart from having a regional identity encompass the following areas of commonality.

- **Food insufficiency** occurs because a. the stored food grains are destroyed during floods; b. loss of grains are not proportionately compensated; c. there is no constant supply of food grains as per the requirement, and d. the effected population neither know of any source nor have the capital to acquire food grains.
- Housing always emerges as one of the basic and most common problem requiring immediate intervention. Villages that come in the midst of the flood course, suffer the maximum damage.
- **Livestock** remains as the supplementary source of income for the rural population. As a consequence of the floods, a huge population of livestock succumb to the fury of floods. As a result, access to milk becomes a major problem in the region.
- Drinking water sources get covered by silt or are destroyed during floods. The quality of drinking water gets affected too. As a result, the region faces acute **drinking water problem**. In the absence of safe drinking water source, the affected population has to depend on flood water for their daily requirement. The newly installed drinking water facilities are often not proportionate to the displaced population, hence a lot of time and energy is consumed for accessing drinking water.
- Changed landscape often poses a new problem and that is of **sanitation**, especially for women and adolescent girls. Open defecation too becomes a challenge in such circumstances.
- Lack of adequate food, safe drinking water and sanitation facilities coupled with stressed living environment often results in **psychological and physiological infirmity**. The problem gets further aggravated due to lack of financial capability to address the problem.
- **Sand casting** creates an enormous problem for agriculturists, as they neither have the financial capacity nor the technical expertise for removing the silt/sand from their respective fields. Formation of ‘moyan’ (signifying a crater) in the agricultural fields further deteriorates the scope of agricultural activities in the region.
- **Loss of standing crops** along with the stored ones, result in enormous loss for the farmer community.
- **Unemployment increases** at an alarming rate. The situation remains the same until certain well designed and contextual development interventions are carried out in the region, creating opportunity for people locally.
- Damaged canal network and sand- cast borings results in total destruction of **irrigation facilities** in the region. To revive agriculture, resurrection of canal facilities and deep borings becomes imperative.
- **Loss of agricultural equipments, seeds and fertilizers** during floods worsens an already precarious status of agriculture in the region. Unavailability of capital to procure the lost agricultural support systems mars the future prospects of agriculture locally.
• The **community infrastructure facilities** (roads, schools, health centers, community centre, public drinking water sources, community sanitation units) are totally destroyed during the floods. The only hope for its restoration rests on the respective state governments.

• Last but not the least, floods completely destroy the **boundaries of individual agricultural land** and all of it seems to be one huge portion of land. The problem gets further complicated and time consuming when the updated land records too get destroyed in the floods. There is a provision for land records to be maintained at the district and commissionerate levels, but in the absence of updated records, this problem can assume enormous proportions.

### State-wise Impact of Floods

#### Bihar

Floods and Bihar are synonymous. Every year, the state (largely north Bihar) faces the vagaries of floods and water logging. Total flood prone area of the state is 6.88 million hectares which is 73.06 percent of its total geographical area and 17.2 percent of the total flood prone area in the country (Government of India, 2008).

A substantial proportion of the total cropped area, nearly 41 percent gets frequently affected by floods (Government of India, 2008). Almost 806,000 hectares (ha) of land, (roughly 15 percent of the region) in north Bihar remains permanently waterlogged, as to say, covered by stagnant water that has no way out (Government of India, 2008). In addition, the impact of floods has always been catastrophic. In 2007, floods devastated 25 million people; in 2004 it created havoc in lives of 21 million people; in 1987 it affected 28.2 million population; in 1974 it disrupted lives of 16.39 million people (SANDRP, 2007). In 2008, a total of 3.3 million population was affected (Government of Bihar, 2008).

North Bihar has an additional season in the form of floods within a calendar year, which is clearly identified by the misery, destruction, and fatality accompanying it (Prasad, 2009). For centuries this season was considered and dealt by the local people as ‘a way of life’. The transformation of ‘a way of life’ to an assured devastation has transformed the self-sufficient communities to being entirely dependent on external help for survival during floods.

In 1954, the devastation caused by the floods limited to North Bihar only. The flood affected an area of 2.46 million ha and a population of 7.61 million (out of 18.393 million). This flood affected 8119 villages (out of 21,107 villages) of North Bihar leading to the loss of standing crops of over 1.59 million ha. A record of 1,79,451 houses were destroyed and 63 persons lost their lives in this flood. In 1944 cattle had also perished in the floods. The flood loss was valued at Rs 500 million (Mishra, 2007).

The impact of 1974 floods was felt south of the Ganges also in the districts of Munger and Santhal Parganas (now Jharkhand) and had a spread area of 3.182 million ha. It had hit a population of 16.39 million and crops over 1.751 million ha were lost. A total of 5,16,353 houses were destroyed in this flood that killed 80 persons and 288 cattle. The total losses were put at Rs. 3545.9 million (Mishra, 2007).
Flood of 1987 was the worst recorded flood of the 20th century, the records set by that flood have not been broken so far (2007 included). This flood had not only mauled North Bihar, its impact was felt in South Bihar as well as in Jharkhand (a part of then Bihar). The flood hit an area of 4.668 million ha of present day Bihar and a population of 28.23 million. It engulfed 23,852 villages and destroyed crops of over an area of 2.51 million ha. It further destroyed 1,682,059 homes and recorded 1373 deaths (Mishra, 2007).

Flood in 2004 was spread over 20 districts of North Bihar with an area over 2.772 million ha and a flood-hit population of 21 million. This flood had engulfed 9,346 villages, destroyed crops in an area of 1.399 million ha and swept away 929,773 homesteads and caused death of 885 persons (Mishra, 2007).

For centuries this season was considered and dealt by the local people as ‘a way of life’. The transformation of ‘a way of life’ to an assured devastation has transformed the self-sufficient communities to being entirely dependent on external help for survival during floods.

<table>
<thead>
<tr>
<th>Year of flood</th>
<th>Affected districts</th>
<th>Affected population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>20</td>
<td>6.9 million</td>
</tr>
<tr>
<td>2008</td>
<td>5</td>
<td>3.3 million</td>
</tr>
<tr>
<td>2007</td>
<td>22</td>
<td>25 million</td>
</tr>
<tr>
<td>2004</td>
<td>20</td>
<td>21 million</td>
</tr>
<tr>
<td>1987</td>
<td>30</td>
<td>28 million</td>
</tr>
<tr>
<td>1974</td>
<td>-</td>
<td>16.39 million</td>
</tr>
</tbody>
</table>


In whole, habitation in the flood prone areas has become far more vulnerable, complicated and distressing as compared to erstwhile period. There is a common saying in Bihar “Chauvan ke phele ka badh char dino ka aur chauvan ke baadh chaar mahinon ka – Floods before 1954 used to be for 4 days and post 1954 floods remained for 4 months.” For many, the reason for the change in the character of floods in Bihar, is the construction of the embankment on Kosi river initiated in 1952.
There is a common saying in Bihar “Chauvan ke phele ka badh char dino ka aur chauvan ke baadh chaar mahinon ka”– Floods before 1954 use to be for 4 days and post 1954 floods remained for 4 months”

West Bengal

West Bengal has three major river basins namely, Ganges, Brahmaputra and Subarnarekha where 80 percent of the state is within the Ganges basin, 13 percent within the Brahmaputra basin and less than 5 percent within the Subarnarekha basin. The districts of Darjeeling and Cooch Behar in the northern most part of the state are within the Brahmaputra basin. The Medinipur district in south-western part of the state is within the Subarnarekha and rest of the entire state is within the Ganges basin. The Ganges River system with its tributaries and sub tributaries meanders widely due to which many abandoned channels, oxbow lakes and swamps have formed in the floodplain [the deltaic plain]. In addition, the region has numerous low-lying areas, which get flooded during and after the monsoon and remains water logged due to the natural inadequate drainage outlets for the receding floodwaters (Ministry of the Rural Development of the Asian Development Bank, 2008). About 42 percent of the state area is flood prone.

In West Bengal, only five years between 1960 and 2000, have been identified as the flood free years. During this period only less than 500 sq km of area was inundated. After the 1978 major flood, the State suffered consecutively in 1998, 1999 and 2000. In terms of loss of life and property, the flood of 2000 was almost comparable to the 1978 flood. Seventy two hours of continuous and concentrated rainfall over the western river basin areas of the Bhagirathi - that would be from the Pagla-Bansloi to the Ajoy- generated such a huge flood volume that all embankments on the eastern side of the Bhagirathi were almost washed away and the whole of Nadia and larger part of Murshidabad and northern areas of North 24 Parganas were flooded and remained underwater for the entire two months (August-October) Ray, n. d.).

Floods can be due to excess water carried over from transnational and inter-state borders. For example, floods are caused in north of West Bengal by flood waters received through rivers Teesta, Torsa, Jaldhaka, Raidak from Sikkim and Bhutan; in Uttar and Dakshin Dinajpur by flood waters in the rivers (originated in Bangladesh) passing through these two districts, and in Malda by flood waters received from Nepal through Mahananda, and through Ganges which carries flood waters from about 11 States in India (Government of West Bengal & Government of India, 2011). Extreme rainfall, relating to late monsoon cloud bursts also lead to floods here. The infrastructures such as roads and railways with inadequate culverts cause escalation of floods. Poor drainage is also a cause due to which the flood spreads (Government of West Bengal & Government of India, 2011). On the other hand, accumulation of silt over the years has raised the riverbeds and reduced drainage capacity. The 1996 flood affected 10 districts of the state. It destroyed 203,987 dwellings, and caused deaths of 48 people. In the flood of 2000, 17.5 million people were affected, 700 were reported dead or missing. Vast areas of Kolkata were inundated. This was West Bengal's worst flood in 20 years, caused by a week of torrential rain that began on September 17, 2000. Nine of the 17 districts in West Bengal were affected (Info Change India, n. d.).
Seventy two hours of continuous and concentrated rainfall over the western river basin areas of the Bhagirathi - generated such a huge flood volume that all embankments on the eastern side of the Bhagirathi were almost washed away and the whole of Nadia and larger part of Murshidabad and northern areas of North 24 Parganas were flooded and remained underwater for the entire two months (August-October 2000)

Assam

Floods have been another exogenous source of constraint to the development of Assam. Floods in the Brahmaputra and Barak valleys of Assam cause serious erosion, sand casting, loss of human life and livestock, and heavy damage to infrastructure and property and impede agricultural productivity. It also disrupts communications and poses health hazards. The damage to crops, cattle, homes and utilities in Assam due to the floods between 1953 and 1995 is estimated at Rs.44 billion with a peak of Rs.6.64 billion in a single bad year. The assessed flood prone area in the state is estimated at 3.15 m ha (million hectares) or 92.6 percent of the cultivated land as in 1992-93, almost half of which (1.63 m ha) do not have any flood management structures. Even the limited flood management structures that exist are poorly maintained. The master plan prepared by the Brahmaputra Board estimates Rs.1848 crore at 1995 prices for short time measures and Rs.50,000 crore for long-term measures up to 2050 (Government of India,2002). The Brahmaputra has 28 northern tributaries and 16 southern tributaries. CWC records indicate that the area affected by flood ranges from 4.22 million hectares in 1988 to a low of 0.19 million hectares in 1961. In normal years about 2000 villages are affected. Out of nearly 21995 villages in Assam, the numbers of villages affected by flood were (Phukan, 2005) as such:

Table 4: Villages affected by floods in Assam between 1982-88

<table>
<thead>
<tr>
<th>Year</th>
<th>Total number of villages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>3600</td>
</tr>
<tr>
<td>1983</td>
<td>4403</td>
</tr>
<tr>
<td>1984</td>
<td>4699</td>
</tr>
<tr>
<td>1985</td>
<td>3006</td>
</tr>
<tr>
<td>1987</td>
<td>7290</td>
</tr>
<tr>
<td>1988</td>
<td>8770</td>
</tr>
</tbody>
</table>

Source: Phukan 2005

No data is available on the total number of villages affected during floods after 1988. In Assam, floods result from natural, ecological and anthropogenic factors. These factors, combined with climatic factors like the depression over Bay of Bengal, high transport of sediment (monsoon sediment discharge of the Brahmaputra is nearly 2.12 MT of sediments per day), deforestation,
shifting cultivation, earthquake and landslide, affect the flood discharge. Physical parameters of a watershed such as drainage characteristics, infiltration, sediment transport and even the stream discharge, change with time. These changes are difficult to be monitored continuously and as a result, error creeps in often in the flood flow estimation, extreme value analysis and partial series analysis. This partially accounts for inadequate flood drainage provided by the organizations, like the Railways, by using classical formulae used elsewhere in the country without modification. In addition to the above, the high rate of population increase has forced people to encroach on the riverine areas resulting in constricted waterway, reduced conveyance capacity and increased sediment production due to deforestation (Phukan, 2005).

The high rainfall in a limited time span causes major problems in the form of floods, erosion, and drainage congestion in the plains districts of the Brahmaputra and Barak valleys. The recurring floods have extensively damaged the rural economy of the state, with extensive sand casting of once-fertile lands, especially on the north bank of the Brahmaputra, and riverbank erosion throughout the state is among the factors forcing many rural families to migrate to towns (Hazarika, 2006).

In Assam, floods result from natural, ecological and anthropogenic factors. These factors, combined with climatic factors like the depression over Bay of Bengal, high transport of sediment (monsoon sediment discharge of the Brahmaputra is nearly 2.12 MT of sediments per day), deforestation, shifting cultivation, earthquake and landslide, affect the flood discharge

Understanding Local Vulnerabilities

The transformed vulnerability quotient in the flood prone region of east and northeast India is yet to be comprehended in its totality. Policy makers often do not understand the concept of vulnerability and frequently use the term as a substitute for poverty or the state of being poor. Vulnerability means not just lack or need but defenselessness, insecurity, and exposure to risks, shocks, and stress. The perception of vulnerability within the project area differs according to the location of the embankment and income levels and is integrally linked to net assets. Marginalized communities within the project area who have few or no assets feel that their vulnerability is caused by their poor asset base, especially with respect to land (Singh et al. 2009).
Policy makers often do not understand the concept of vulnerability and frequently use the term as a substitute for poverty or the state of being poor. Vulnerability means not just lack of or need of but defenselessness, insecurity, and exposure to risks, shocks, and stress. The perception of vulnerability within the study area differs according to the location of the embankment and income levels and is integrally linked to net assets.

The unpredictable nature of the rivers, floods and their management strategy has caused insecurity and a sense of defenselessness among the local population, but despite these limitations they continue to confront and survive the recurring floods year after year on their own terms and understanding, especially in the absence of any external help or support. For any outsider to project, promote and prescribe solutions, safeguards and interventions for overcoming the local problems during and post floods, the basic principle to follow would be to interact with different groups and to comprehend the different responsibilities handled by different groups within the affected society. The sum of all efforts help in understanding gaps in managing survival, and in developing arguments and intervention of overcoming the problems as well. In the absence of it, neither any research nor intervention will be complete and inclusive. Therefore, without proper local knowledge about perception and definition of the floods, along with categorical understanding about the externally defined and assumed non-contextual local survival knowledge and techniques, working on easing flood related consequences will be futile. The remoteness embedded with the flood prone area inhibits the local population to connect with the adaptation discourse and strategies defined by the external sphere, though they continue to survive the wrath of the ever changing character of flood over the years. The local survival techniques and adaptive measures therefore, become extremely crucial to be explored, identified, understood and documented. The effort will help in not only sustaining the body of local knowledge but might assist in developing it with the changing character of the flood.

The local survival techniques and adaptive measures, therefore, become extremely crucial to be explored, identified, understood and documented. The effort will help in not only sustaining the body of local knowledge but might assist in developing it with the changing character of the flood.
Flood Management Strategy of the Government of India and the State Governments

As per Compendium of Guidelines in the field of Flood Management prepared by Ganga Flood Control Commission (GFCC), Patna, the floods have been classified as under.

- **Low flood**: If water level in the river during monsoon rises higher than usual in other seasons of the year and results in overflow of bank once in every two years; submerges the adjoining fields but generally does not prevent flow of drainage of fields; also does not create drainage congestion in the nearby populated area, it is termed as low flood situation. In such situation, the water level always remains at least 1 m below plinth level of township as fixed by the Civil Authorities for civil construction of industrial Complexes and residential areas.

- **Medium flood**: When the water level in the river rises to the extent that crops in the adjoining areas are submerged and populated areas are encircled with flood waters and the flood waters overflow the river bank, with flood frequency of 1 in 10 years; submerges agricultural areas and enters in the residential areas blocking the drainage systems for not more than 6 hours; waters in the residential areas and industrial complexes remain just below the plinth level as fixed by the Civil Authorities.

- **High flood**: Any flood level of the river, which is higher than the danger level and corresponds to return period of more than 10 years.

GFCC, Patna has further defined the following:

- **Danger Level**: A level of the river depicting the stage of the river, which if crossed by the flood waters, will start damaging crops and property and will affect the daily life of population. This level is to be taken as medium flood level or 0.3 m below the plinth level of residential areas and industrial complexes as fixed by the Civil Authorities, whichever is less.

- **Warning Level**: A flood level 0.6 m to 1.0 m below the danger level depending upon the lead time available.

- **Highest Flood Level**: The highest flood level of the river ever recorded at the place.

- **Very high flood**: Any flood which exceeds 1 in 100 years frequency.

- **Flood Plain**: Land adjoining the channel which is inundated only during floods.

Devastation by floods is a recurrent annual phenomenon in India. Almost every year, some or the other part of the country is affected by floods. Floods cause enormous damage to life, property (public and private) and disruptions to infrastructure, besides psychological and emotional instability amongst the people. Based upon the statistics of a 59-year period (1953 to 2011), average annual flood damage in the country is more than about Rs. 1800 crore. It was decided by the GOI to provide Central Government assistance to the concerned State Governments to redress the problems (Brahmaputra Board Ministry of Water Resources).
Floods cause enormous damage to life, property (public and private) and disruptions to infrastructure, besides psychological and emotional instability amongst the people.

Due to unprecedented floods of the year 2004 in Assam, Bihar and West Bengal, the Ganges and Brahmaputra rivers crossed their highest flood levels at several places resulting in heavy loss of lives and properties. Ministry of Water Resources (MoWR), GOI constituted a Task Force on Flood Management / Erosion Control to look into the problems of recurring floods in Assam and neighbouring states as well as Bihar, West Bengal and Eastern Uttar Pradesh. The Task Force, headed by the Chairman of the Central Water Commission, submitted its final report on December 31, 2004. It recommended a number of flood management works under (a) Immediate Measures, (b) Short Term-I Measures and (c) Short Term-II Measures. Part of these works was taken up by enlarging the ongoing scheme (a) Critical Anti-erosion Works in Ganges Basin States and (b) Critical Anti-erosion Works in Brahmaputra and Barak Valley States.

The four schemes, as mentioned above, have been merged together and a restructured scheme named Flood Management Programme under the State Sector in the Central Plan has been launched by the GOI for Eleventh Plan period. Under this scheme, central assistance would be provided to the State Governments in order to take up works related to river management, flood control, anti-erosion, drainage development, flood proofing, restoration of damaged flood management works and anti-sea erosion to the extent of Rs. 80 billion (Brahmaputra Board Ministry of Water Resources).

All the flood management measures fall broadly into two categories:

- structural: involving construction of embankments, reservoirs, detention basins, inter-basin transfer of water, raising of villages, etc.
- non-structural: including flood plain zoning, watershed management, flood forecasting, disaster mitigation and preparedness, etc. (Sinha, 2008).

Both are complementary to each other and not mutually exclusive.

The engineering methods of flood protection, which do not reduce the flood flow but reduce spilling, are:

- embankments which artificially raise the effective river bank and thereby prevent spilling, and
- channel and drainage improvement works, which artificially reduce the flood water level so as to keep water confined within the river banks and thus prevent spilling.

**Structural Interventions**

Structural intervention confines the flood flows and prevent spilling, thereby reduce the damage. These are generally cheap, quick and most popular methods of flood protection and have been constructed extensively in the past. These are reported to have given considerable protection at comparatively low costs, particularly in the lower reaches of large rivers. In many places,
embankments may be the only feasible method of preventing inundation. By March, 2011, a total of about 35,200 km of embankments has been constructed.

Embankments are generally designed and constructed to protect against floods of a certain frequency and intensity or against the maximum floods recorded till the time of their planning only (in the absence of detailed hydrological data for longer periods) depending upon the location protected and their economic justification. Apart from the raising and strengthening works, erosion along the embankments and natural banks of the river systems has been a serious problem on which considerable expenditure has been incurred in the past. Particular mention could be made of the erosion problem of the embankment systems in Assam, Bihar, and West Bengal.

The embankments, under serious wave action by the major rivers and their tributaries, have to be suitably protected by spurs, pitching and other appropriate anti-erosion measures. On many embankment systems like the Kosi embankment and Piprasi-Pipraghat embankment on the Gandak in Bihar, the river wave action is so severe that the required protection measures cannot be covered under the normal maintenance works. Therefore, special maintenance programmes need to be drawn for such cases and adequate funds for the purpose should be earmarked by the State Governments. Some embankments have provided positive benefits by ensuring sustained protection against floods and river spills while on the other hand, some embankments have, in certain reaches of the river, aggravated the flood problem by raising river bed levels, decreasing their carrying capacity, causing drainage congestion in the countryside and distorting the levels/gradient of the outfall points.

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A number of Committees constituted in various countries as well as in India have deliberated upon the utility of embankments as a means for flood protection. Extreme views have emerged out of these. Many NGOs have voiced serious criticism about existing embankments. One is that problems of flood can be solved by removal of all the existing embankments and the other, diametrically opposite, being that construction of more and more lengths of the embankments and their raising and strengthening is the only practicable medium/short term solution for the flood problems. The reason for such wide divergence in opinion is obviously due to the inadequacy of sufficient number of performance evaluation studies of existing embankments and the divergent
views on their performance. Construction of embankments with proper roads on its top has been
perceived as useful communication linkages and reliable surface network for areas that are liable
to stand completely cut off during floods and thereafter. They could provide quick communication
for facilitating better supervision and maintenance of the flood protection works and provide all
weather communication facilities to the adjoining habitats. As such, they are often deemed as
the life line during floods. It is also recognized that apart from the benefits mentioned above,
the embankments also have adverse effects such as interference with drainage, and inability to
stand erosion which should be considered before planning this measure for flood management.
As such, this method of flood management may be undertaken only after carrying out detailed
hydrological and other studies including adverse effects (Planning Commission, 2011).

The method of developing the channel by improving the hydraulic conditions of the river
channels by de-silting, dredging, and lining to enable the river to carry its discharges at lower
levels or within its banks has been often advocated but adopted on a very limited extent because
of its high cost and other problems.

Dredging operations of the Brahmaputra, which were undertaken in the early seventies
on an experimental basis, were discontinued because of their prohibitive cost and limited benefits.
Dredging in selected locations may perhaps be considered as a component of a package of
measures for channel improvement to check the river bank erosion subject to techno-economic
justification. It may be economically justifiable as a method for channel improvement where
navigation is involved. Dredging is also at times advocated for clearing the river mouth or narrow
constrictions of the river, if any (Planning Commission, 2011).

Bihar

In Bihar flood management works implemented so far comprise construction of 3,455 km of
embankments, 365 km of drainage channels and 47 town/village protection works. It is claimed
that these measures have helped in affording reasonable protection to 2.949 million ha out of
6.88 million ha flood-prone areas in the state. It is important to mention here that the Second
Bihar State Irrigation Commission (1994) analysed the flood damage data for the period 1968 to
1991 and on this basis observed, “Although quite significant flood management works have been
implemented in Bihar till March 1992, it is apparent from the reported figures of damages in all
the 11 flood-prone basins that the damages have increased gradually and significantly in recent
years”(Sinha, 2008).

The state government of Bihar has planned to construct 1,604 km of new embankments
over the next five years to protect 2.045 million hectare of arable land from floods. Water Resources
Department (WRD) aim is to contribute its share of value to the state’s agriculture road map by
creating new irrigation potential and restoring the lost irrigational potential. According to WRD
“Embankments have provided multi-pronged help to farmers in increasing crop yield, apart from
protecting their land from floods,” adding that the state today has 3,643 km of embankments.
WRD had planned to construct 406 km of additional new embankments during the financial year
ending on March 31 2013. “In a few cases, land acquisition is the problem. In others, clearance
has to be sought from Ganges Flood Control Commission (GFCC). Getting the GFCC clearance
would not be difficult. The land acquisition, however, remains a problem,” confirmed WRD. The
new embankments to be constructed by March 31 2013 would give protection to arable land from
the floods caused by the Budhi Gandak, Bagmati, Mahananda, Adhwara Jhimi and the Chandan.
The new embankment concerning the Budhi Gandak would be of 73 km in length; the one related to Mahananda, 167 km in length; that concerning the Adhwara Jhimi, 52 km in length, and the protection from Chandan would involve construction of a 78 km of embankment. The other embankments to be constructed include the ones associated with the Kamla and the Tirmohan Kursela. The construction of 406 km of new embankments would involve an expenditure of Rs 9.61 billion from the plan fund. During the current financial year, another chunk of plan fund worth Rs 12.31 billion would be spent on works pertaining to the irrigation sector - that is, creation of new irrigation potential and restoration of the lost irrigation potential. The department would be able to utilize the plan fund earmarked for the current financial year even as the plan fund allotment had increased to Rs 21.92 billion. “It is the highest allotment made in the last 20 years,” according to WRD, adding that the planned fund utilization was Rs 18.70 billion in 2011-12 and Rs 13.65 billion in 2010-11 (Singh, 2012).

West Bengal

Construction of embankments is the only structural measure available with the Irrigation Department of the State Government of West Bengal to give relief to the people for the damages and losses suffered due to flood. In the northern part of West Bengal, Chengmari-Premgunj Embankment and Bibigunj-Jharsingeswar Embankment, Helapakri Embankment with extension upto Indo-Bangladesh borders on the river Teesta, Dharaikuri Embankment, and Giriya embankment on the river Jaldhaka exist. In the southern part, the Ajoy Left embankment on river Ajoy upto railway line and on both the right and left embankment upto Nutanhat, construction of marginal embankments in Kaliachak and Manikchak on river Ganges, circuit embankment at Bhutnidiara and embankments on the upper reaches of Dwarka, Brahmani and Mayurakshi System have been taken up. Some of the important embankments of this region are the Bhagirathi embankment from Bhagirathi to Palassey and the Ganges embankment.

In addition, the Sundarbans comprises an area of 7910 sq km out of which 4170 sq km are under reserved forest including creeks, channels and rivers within the Forest Zone. Out of remaining 3740 sq km recovered from forest about 2590 sq km are under cultivation which is now protected by about 3500 kilometers of marginal embankments. Out of the remaining 1150 sq km within non-Forest habitable zone, 891 sq km is water surface and balance 259 sq km is uninhabited foreshore land or low newly formed islands (Irrigation & Waterways Department).

Assam

Flood control activities in Assam started after announcement of National Policy for Flood in 1954 by the GOI. Though there was short term and long term measures envisaged in National Flood Policy of 1954, to get the immediate relief to the flood ravaged state, construction of embankments as short term measures had been widely adopted. In the State as a whole, the total area eroded by the Brahmaputra, Barak and their tributaries since 1954 is 3.86 lakh hectares, which constitute seven percent of the total area of the State. The ‘Rashtriya Barh Ayog’ has identified 31.05 lakh hectares of flood prone area in the State of which Water Resource Department has protected 16.50 lakh hectares of flood affected land through implementation of various projects (Economic Survey, Assam, 2010-11).
Accordingly, during the Tenth Plan (Flood Management Program, 2009) the following four schemes were sanctioned to provide central assistant to the flood prone states to take up flood control and river management works in critical areas-

- Critical Anti-erosion works in Ganges Basin States (a Centrally Sponsored Scheme)
- Critical Flood Control and Anti-erosion Schemes in Brahmaputra and Barak Valley States (a State Sector Scheme)
- Improvement of Drainage in Critical areas in the country (a State Sector Scheme), and
- Critical Anti-erosion Works in Central and other than Ganges Basin States (a State Sector Scheme) (Brahmaputra Board Ministry of Water Resources)

An amount or Rs. 150 crore was sanctioned for Critical Flood Control and Anti-erosion Schemes in Brahmaputra and Barak Valley States for completion during the Tenth Plan through MoWR. The achievements of Water Resources Department, Government of Assam in terms of infrastructures development, at a glance, are (Economic Survey, Assam, 2010-11).

Table 5: Achievements of Water Resources Department, Government of Assam

<table>
<thead>
<tr>
<th>Works</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of embankment</td>
<td>4465.85 km</td>
</tr>
<tr>
<td>Drainage Scheme</td>
<td>854.19 km</td>
</tr>
<tr>
<td>Anti erosion / protection works</td>
<td>746</td>
</tr>
<tr>
<td>Sluice</td>
<td>86 (major) and 539 (medium and minor)</td>
</tr>
</tbody>
</table>

Source: Economic Survey, Assam, 2010-11

The flood problem in Assam is critical and enormous as recurrence of flood apart from inflicting damages in the protected area, damages existing vital infrastructure facilities, the core sector of development. In order to combat/reduce flood problems, the Water Resource Department had chalked out an action plan as follows, for implementation during the 11th Five Year Plan

- Raising and strengthening of existing embankment system, so as not to cause any decrease in already protected area
- New embankment to be taken up to increase the safe and benefited area in present flood prone region
- Anti-erosion works and protection works to safeguard fertile lands, important towns and industrial areas
- Removal of drainage congestion to bring more areas under protective arena
- Flood proofing programme, such as raised platforms etc
- Dredging of selective reaches, particularly in the tributaries and at the outfalls
- Annual scientific collection of flood damage data, basin wise preparations of flood risk maps and flood plain zoning
- River morphological studies through satellite imageries for study of bank migration
to find out probabilities of areas likely come under attack of erosion and take cost effective and timely preventive measures

- The north bank tributaries originating from Bhutan, create acute flood problem in the lower Assam Districts particularly Barpeta, Kokrajhar and Dhubri due to sudden onrush of flood discharge, particularly with breach of artificial dams caused by huge landslides in the upper catchments in Bhutan territory, along with flow of huge sediment loads. Frequent monitoring by the Joint Group of Experts Committee may be given priority to tackle the problem

- The existing flood forecasting and flood warning network is to be further augmented, particularly bringing tributaries flowing down from Bhutan and Tibet (China) under the umbrella of this network

- Water shed management in selected hilly catchments of Northern tributaries, which have deteriorated in recent times very fast, due to varied reasons, should get priority, so that the functioning of flood management structures have desired results.

Non-structural Interventions

The non-structural methods endeavour to mitigate the flood damages by:

- Facilitating timely evacuation of the people and shifting of their movable property to safer grounds by having advance warning of incoming flood i.e. flood forecasting, flood warning in case of threatened inundation

- Discouraging creation of valuable assets/settlement of the people in the areas subject to frequent flooding i.e. enforcing flood plain zoning regulation.

Providing absolute protection to all flood prone areas against any magnitude of floods is neither practically possible nor economically viable. Such an attempt would involve stupendously high cost for construction and for maintenance. Hence a pragmatic approach in flood management is to provide a reasonable degree of protection against flood damages at economic cost through a combination of structural and non-structural measures.

Flood Forecasting

The work of flood forecasting and warning in India is entrusted with the Central Water Commission (CWC). Flood forecasting and flood warning in India was commenced in a small way in the year 1958 with the establishment of a unit in the Central Water Commission (CWC), New Delhi, for flood forecasting for the river Yamuna at Delhi. Presently, there are 878 Hydrological and Hydro-meteorological sites being operated by CWC across the country covering 20 river basins for gauge, discharge, sediment and water quality observations. The formulation of a forecast requires effective means of real time data communication network from the forecasting stations and the base stations (380 stations at present, approximately). Wireless Communication system installed in almost 550 stations is the backbone of the communication system required for flood forecasting activities. The activity of flood forecasting comprises of Level Forecasting and Inflow Forecasting. The level forecasts help the user agencies in deciding mitigating measures like evacuation of people and shifting people and their movable property to safer locations. The Inflow Forecasting is used by various dam authorities in optimum operation of reservoirs for safe passage of flood downstream as well as to ensure adequate storage in the reservoirs for meeting demand during
non-monsoon period. Presently, flood forecasts are issued by CWC at 175 stations (28 Inflow Forecast Stations + 147 Level Forecast Stations). Annually, about 6000 flood forecasts are issued by CWC during floods (Government of India, 2011).

Table 6: Basin-wise existing flood forecasting stations in East and North-east India

<table>
<thead>
<tr>
<th>Name of River System</th>
<th>Number of flood forecasting stations</th>
<th>Level</th>
<th>Inflow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganges and Tributaries</td>
<td>77</td>
<td>10</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Brahmaputra and Tributaries</td>
<td>27</td>
<td></td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Barak System</td>
<td>05</td>
<td></td>
<td>05</td>
<td></td>
</tr>
<tr>
<td>Eastern Rivers</td>
<td>08</td>
<td>01</td>
<td>09</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>117</strong></td>
<td><strong>11</strong></td>
<td><strong>128</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: Government of India, 2011

Table 7: State-wise existing flood forecasting stations in East and North-east India

<table>
<thead>
<tr>
<th>Name of State</th>
<th>Number of flood forecasting stations</th>
<th>Level</th>
<th>Inflow</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assam</td>
<td>24</td>
<td>00</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Bihar</td>
<td>32</td>
<td>00</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Tripura</td>
<td>02</td>
<td>00</td>
<td>02</td>
<td></td>
</tr>
<tr>
<td>West Bengal</td>
<td>11</td>
<td>03</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>69</strong></td>
<td><strong>03</strong></td>
<td><strong>72</strong></td>
<td></td>
</tr>
</tbody>
</table>

Source: Government of India, 2011

**Flood Plain Zoning (Government of India, 2011)**

Flood-plain zoning is a concept central to flood plain management. This concept recognises the basic fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity therein must recognise the river’s ‘right of way’. Flood-plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimised, if not avoided. However, while all, in principle, generally endorse this approach, scant attention is given to it in actual practice, leading to increased flood damages. CWC has been continuously impressing upon the states for the need to take follow-up action to implement the flood plain zoning approach. A model draft bill for flood plain zoning legislation was also circulated by the Union Government in 1975 to all the States. There has been resistance on the part of the states to follow up the various
aspects of flood plain management including possible legislation. The State of Manipur had enacted the flood plain zoning legislation way back in 1978 but the demarcation of flood zones is yet to be done. The state of Rajasthan has also enacted legislation for flood plain management in the State but enforcement thereof is yet to be done. The Government of Uttar Pradesh has decided to take suitable measures for regulating the economic/development activities in the flood plains. The Government of Bihar initiated action to prepare flood plain zoning maps, which are essential before any executive measures could be undertaken. The Government of West Bengal had intimated that a draft bill on flood plain zoning was under process. Other States are yet to take action for enactment of legislation.

**Flood-plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones, so that whenever floods actually occur, the damage can be minimised, if not avoided. However, while all, in principle, generally endorse this approach, scant attention is given to it in actual practice, leading to increased flood damages.**

**Flood Proofing (Government of India, 2011)**

Flood proofing measures adopted in India in the past, consisted of raising a few villages above pre-determined flood levels and connecting them to nearby roads or high lands. Under this programme, several thousand villages were raised in Uttar Pradesh in the fifties. In West Bengal and Assam also land-fills were attempted in villages to keep houses above flood levels even though nearby agricultural lands were liable to inundation. During Tenth Plan, the Government of Bihar with Central assistance, had also constructed, the raised platforms for safety of the people in flood prone areas of North Bihar.

**Institutional Mechanism for Flood Management**

As per constitutional provisions, the subject Flood Management falls within the purview of the States. The flood control and management schemes are planned, investigated and implemented by the State Governments with their own resources as per priority within the State. The Union Government renders assistance to States which is technical, advisory, catalytic and promotional in nature. Therefore, a two tier system of flood management exists in India as briefly described below:
**State Government Mechanism**
The State Level Mechanism includes the Water Resources Departments, State Technical Advisory Committee and Flood Control Board. In some States, the Irrigation Departments and Public Works Departments look after flood matters.

**Central Government Mechanism**
The Union Government has set up following organizations and various expert committees to enable the State Governments in addressing flood problems in a comprehensive manner:

- Central Water Commission (CWC) – The Government of India set up Central Water Commission in 1945 for achieving the goal of furthering and promoting measures of flood control, conservation and utilization of water resources throughout the country in the areas of beneficial uses, irrigation and hydropower generation, flood management and river conservation.

*The CWC plays direct role in real time collection of flood data, flood forecasting and dissemination of flood forecasts to the local administration for planning suitable administrative measures including evacuation of people from flood affected areas to the safer locations.*

As a national apex engineering organisation in the field of water resources development, the CWC with its vast experience gained in its strides towards progress in more than six decades, has developed considerable know-how in planning, investigation, management and design of water resources development schemes and made valuable contribution in the country’s remarkable progress in this field besides sharing the expertise with developing nations of the world. The CWC plays direct role in real time collection of flood data, flood forecasting and dissemination of flood forecasts to the local administration for planning suitable administrative measures including evacuation of people from flood affected areas to the safer locations.

Brahmaputra Board – The Government of India set up the Brahmaputra Board under Brahmaputra Board Act, 1980 (46 of 1980) under the then Ministry of Irrigation (now Ministry of Water Resources) The jurisdiction of Brahmaputra includes all northeast States including Sikkim and northern area of West Bengal. The main functions of the Brahmaputra Board are as under:

- To conduct survey and investigations in Brahmaputra and Barak valley
- Preparation of master plans to control floods, bank erosion, improvement of drainage system
- Preparation of Detailed Project Reports (DPRs) for dams and other projects
- Standard specifications for construction, operation and maintenance of dams
- Construction of multipurpose dams and maintenance, thereof
- Any other function for implementation of Brahmaputra Board Act-1980.
- Brahmaputra Board prepared master plans for Brahmaputra under Phase-I, Barak under Phase-II and under Phase-III 38 tributaries of Brahmaputra, 8 rivers of Tripura
and 3 south flowing rivers of Meghalaya.

- The Board has also proposed to prepare master plans for the remaining parts of NE Region, south flowing rivers in Sikkim and Northern parts of West Bengal in Brahmaputra Basin.
- the Board has continued survey and investigations for preparation of master plans for tackling the problems of flood, erosion and drainage congestion including DPRs for multipurpose projects.
- The Board identified 21 multipurpose projects for investigation and preparation of DPRs out of which Pagadiya Dam Project was approved by GOI.
- Out of 34 drainage developments identified by the Board, 10 schemes have been approved by the Ministry of Water Resources for execution. The Harang Drainage Development Scheme is near completion and other eight drainage development schemes are proposed to be completed during Eleventh Plan.

Ganges Flood Control Commission - The Ganges Flood Control Commission (GFCC) was set up by Government of India in 1972 for preparation of comprehensive plan of flood control for Ganges Basin and to draw out a phased coordinated programme of implementation of works and monitoring and appraisal of flood management schemes of Ganges basin States. The GFCC has prepared comprehensive plans of flood management of the 23 sub-basins in the Ganges Basin besides developing a phased implementation programme of the planned works as per regulated standards, examination and monitoring of various flood management schemes in the Ganges Basin States.

National Disaster Management Authority (NDMA) - For prevention and mitigation of effects of disasters including flood disasters and for undertaking a holistic, coordinated and prompt response to any disaster situation, the Government of India has set up a National Disaster Management Authority (NDMA) in 2005 under the Chairmanship of Hon’ble Prime Minister of India. The functions of the NDMA are to:

- lay down policies on disaster management
- approve national Plan
- approve plans prepared by the Ministries or departments of the Government of India in accordance with the National Plan
- lay down guidelines to be followed by the State Authorities in drawing up the State Plan
- lay down guidelines to be followed by the different Ministries or departments of the government of India for the purpose of integrating the measures for prevention of disaster or the mitigation of its effects in their development plans and projects
- coordinate the enforcement and implementation of the policy and plan for disaster management
- recommend provision of funds for the purpose of mitigation
- provide such support to other countries affected by major disasters as may be determined by the central Government
- take such other measures for the prevention of disaster, or the mitigation, or preparedness and capacity building for dealing with the threatening disaster situation or disaster as it may consider necessary
- lay down broad policies and guidelines for the functioning of the National Institute of Disaster Management.
The NDMA has issued guidelines in January, 2008 for management of floods and the roles of various Central and State agencies have been specified for the preparation of flood mitigation plans and taking relief measures during flood disasters.

Institutional Reforms

The following institutional reforms are suggested for effective flood management in the country (Government of India, 2011)

- Expedite setting up of River Basin Authorities – The issue of setting up of River Basin Authorities has been raised by the Expert Committees long back. However, action in this regard is yet to be taken both by Central as well as State Governments. The primary action is to be taken up by the State Governments but so far no concrete action from their side has been taken for initiating a proposal for setting up of the River Basin Authorities. Integrated water resources management including integrated flood management can be addressed with collaborative efforts of all agencies / mechanisms involved in this gigantic task. Therefore, our efforts need to be concentrated for setting up of River Basin Authorities with top managerial skills and with appropriate delegation of powers and to complete this task in a time bound manner in the interest of sustainable management of India’s water resources and addressing flood problems in a holistic manner.

- Strengthening of Organizations under MOWR – The Organizations, namely, Central Water Commission, GFCC and Brahmaputra Board under the Ministry of Water Resources are required to play vital roles in the preparation of master plans for specific river basins and CWC plays important role at national level in coordinating the efforts made by various agencies in overall water resources management including flood management in an integrated manner. The need for strengthening of these Organizations, in order to play advisory and coordinating roles, has been emphasized by various expert committees on flood management in the past as well as in the Committee of Secretaries meeting in 2007. The strengthening of CWC is required in a time bound manner in view of the expansion of its hydrological and flood data collection network, flood data transmission and management of floods. Therefore, it is recommended that the actions at all concerned levels for time bound strengthening of these Organizations may be expedited so that flood mitigation efforts are properly coordinated in the country. The needs of these organizations regarding infrastructural facilities and vehicles required for flood data collection, flood forecasting, flood management and related inspection, supervision and coordination, are recommended to be addressed appropriately.

…it is recommended that the actions at all concerned levels for time bound strengthening of these Organizations may be expedited so that flood mitigation efforts are properly coordinated in the country
• Strengthening of NWA Pune – The National Water Academy (NWA) located at Pune is presently involved in providing training to the engineers / officers of the Central / State Governments. Although the coverage of the training is exhaustive as per needs of the officers involved in various facets of water resources management, efforts may be made to convert NWA, Pune into a Centre of Excellence for international training programmes on matters pertaining to flood mitigation so that up-to-date globally available know-how could be shared under such training programmes. The NWA, Pune may also be suitably strengthened to meet the requirement of NDMA for conducting trainings on disaster risk reduction programmes.

• Strengthening of State Flood Control Departments – As per Constitutional provision the subject of flood management falls within the purview of the State Governments. Therefore, project-specific planning and their implementation are to be ensured by the State Governments. However, the present structure of the State level flood control departments needs to be revamped to discharge their role as prime flood managers in the State. The specific needs of human resources and their skill development are required to be addressed suitably. However, while making such revamping proposals, proper evaluation of the available strengths and the requirements of the departments to shoulder the responsibilities of flood management would need to be made.

• Dispensing with the concept of ‘Plan’ and ‘Non-Plan’ - There are nagging problems in ensuring proper maintenance of the assets created by the State Governments mainly because the assets are, as per existing financial procedures, arranged under various plan schemes. The sophisticated equipment and the works undertaken with plan funds suffer maintenance when the plan schemes are closed and their maintenance is shifted from Plan to non-Plan Heads of Expenditure. In order to overcome these bottlenecks, it may be appropriate to dispense with the concept of plan and non-plan in Government procedures and the funds to central agencies / departments may be provided by the Planning Commission / Ministry of Finance to the central / state agencies on continuation basis.

• No restriction on Recruitment of new Staff - Presently, there have been restrictions on recruitment of staff under the Central agencies but the important activities like collection of hydrological data, field survey works, flood forecasting and also many other functions being performed by central agencies suffer due to shortage of staff as a result of reduction in strength due to retirement / death of the employees. Therefore, it is recommended that there should not be any restriction on new recruitment of staff required for such emergent field works.

• Providing adequate Infrastructural Facilities – The central agencies performing field activities related to flood management are facing various difficulties including inadequacy of infrastructural facilities for accommodating the field staff and shortage of inspection vehicles for carrying out field job, inspection and supervision. These nagging problems need to be addressed appropriately in order to enhance their output both in terms of quality and quantity.

• Capacity Building Programmes – In order to have well planned and effective flood management measures with state of the art knowledge based inputs, it is recommended that specialized in-house and foreign training may be imparted to the officers/staff of Central/State Governments in all areas of flood management
including hydrological data collection and its management, survey and investigation, planning and design, hydrological studies, preparation of techno-economically sound DPRs, flood forecasting, inundation forecasting, construction, equipment operation maintenance, use of latest GIS based technologies in decision making, etc. The specific training programmes may be drawn by respective organisations and adequate funds for the purpose may be provided.

**Institutional Mechanism for Flood Management Studies (National Institute of Hydrology)**

In order to deal with the specific hydrological problems of different regions of the country and for providing effective interaction with the States, the National Institute of Hydrology has established following two Centre for Flood Management Studies and four Regional Centres:

**Centre for Flood Management Studies, Patna**

The Ganges Plains North Regional Centre (GPNRC) was established in May, 1991. Realizing the importance of Flood Management Studies for Ganges Basin, the Ministry of Water Resources, Government of India restructured the GPNRC as NIH Centre for Flood Management Studies in June 2001. The Centre is now mainly concentrating on flood related studies of the region covering eastern Uttar Pradesh, Bihar, Jharkhand and West Bengal.

The research activities of the Centre are presently concentrating on the following aspects:

- Flood estimation
- Flood routing
- Structural and non-structural measures of flood management
- Application of remote sensing and geographical information system (GIS) in flood studies
- Waterlogging and drainage congestion
- Integrated watershed management
- Development of hydrological database
- Tai problems and its management
- Field and laboratory based studies on soil properties and water quality
- Technology transfer activities

**Centre for Flood Management Studies, Guwahati**

The North Eastern Regional Centre (NERC), Guwahati catering for the seven N-E States, Sikkim and parts of West Bengal (Teesta basin) was established in August 1988 at Guwahati and was working for various water resources problems of the region. Since its inception, the centre has been actively interacting with the various water resources organizations in the states covered under the region while carrying out its studies and research within the framework of recommendations of the Regional Coordination Committee in the areas of representative basin studies, remote sensing application, water quality studies, floods, watershed management etc.

Considering flood as the major problem in the region, Ministry of Water Resources, Govt. of India decided to focus the activities of the centre towards the problem of floods in the Brahmaputra Basin and renamed it as NIH Centre for Flood Management Studies for the Brahmaputra Basin (NIH-CFMS). As per the action plan the centre has to work in the following thrust areas of research:
- Flood estimation and routing
- Structural/non structural measures for flood management
- Integrated watershed management for flood control
- Hydrological data base management system
- Drainage congestion and erosion problems
- Water quality problems
- Socio-economic aspect of flood disaster and
- Technology transfer

In addition, Flood Management Information System (FMIS), Bihar finds its genesis in the brainstorming meeting on Jan 18, 2006 in which the Government of Bihar (GoB) and the World Bank agreed on a water sector partnership matrix and action plan in three time horizons. In the short term it was proposed to improve the technical and institutional capacity of the State of Bihar for flood management, introducing the extensive use of modern information technologies developing and implementing a comprehensive FMIS in priority areas.

Role of Traditional Knowledge Systems in Coping with Recurring Floods

The Indian sub continent comprising India and the other countries is one of the oldest human civilization and it has a vast saga of history ranging from ancient to modern eras. Its long history has helped in developing its unique culture. The region is characterized by multiple religious beliefs and practices, languages and traditions. This rich heritage of culture has been percolated down from the mythological time to the period of Vedas and the invasions by the Mughal Empire to the colonization by the British and these have greatly impacted on each and every community inhabiting in this sub continent. The geographical features further add onto this diversity. The different geographic zones are populated by numerous tribes and ethnic groups maintaining their distinctive cultural identity. And each community has developed a system of knowledge through which they try to find the meaning and answer to every unexplainable phenomenon like the beginning of the universe or the cosmology, origin of the human race and the natural hazards which could destroy the natural creations (Disaster Management Centre, New Delhi, 2008).

People have been living in flood-prone areas of east and northeast India for centuries. They have, inevitably, devised their own methods for protecting themselves and their livelihoods. These methods are based on their own skills and resources, as well as their experiences. Their knowledge systems, skills and technologies are usually referred to under the heading of ‘indigenous knowledge’ (Phukan, 2005). Indigenous knowledge is wide-ranging. It includes economic / material, technological, social/organizational and cultural. It is crucial to recognize that traditional knowledge systems are often used in sequence to respond to different stages of adversity or crisis as observed during disasters such as floods.

**Economic activities and material buffer** - Members of a rural household engaged in agriculture tend to undertake other works, based on their traditional skill sets such as making and selling handicrafts, carpentry, building or blacksmithing as a back up support for survival in the flood prone areas. In addition, vulnerable households try to store up a ‘buffer’ of food, grain, livestock and cash that they can draw on in difficult times. During periods of floods, the local habitants manage food supply and consumption as per requirement and availability. Such
practices have a strong cultural and historical context attached. If a crisis becomes acute, people begin to sell their assets, but sale of livelihood assets (e.g. animals, tools, seeds for planting next year’s crop or even land) is seen as a last resort. Even having a large family is seen as part of an economic coping strategy because it gives a household additional labour (Twigg, 2004).

**Technology** – Technological adaptation with regard to land management systems, building materials and construction methods is based on indigenous knowledge systems. Land use strategies also include making habitation flood secure as far as possible for building a home, and keeping the livestock. To check erosion and flooding during the monsoon, villagers in the hills of Nepal convert hillsides into level terraces, create outlets to manage water overflow from one terrace into another, make networks of ponds to slow rainwater run-off and save it for the dry season, and build stone-works and plant trees to stabilise slopes and prevent erosion of gullies (Twigg, 2004).

Indigenous technological approach is adopted to ensure houses withstand the ferocity of floods to best possible extent, or else common innovations include constructing houses at a height on plinths or platforms of mud so that floodwaters can enter the habitation. For instance, people of Bangladesh have a range of methods for dealing with abnormally high or prolonged monsoon floods. These are based on accommodating themselves to the flooding rather than trying to prevent it. They include building on mounds or mud plinths, having homes of light-weight materials that can be dismantled and moved, building false roofs where goods can be stored and people can live, using beds as a living area when water enters the house, hanging belongings from the roof in jute nets, and investing in movable assets such as animals and boats (Twigg, 2004).

**Social groups** – The indigenous organizations provide mutual support in countering disasters: kinship networks, mutual aid groups, neighbourhood villages. Systems of mutual rights and obligations are part of every household and community’s social structure, forming what is sometimes called a ‘moral economy’ (Twigg, 2004). During the initial period of floods immediate help comes from villages in the same district that have not been affected by floods (Twigg, 2004). This was witnessed during the famous Kosi floods of 2008 as food supplies was initially provided by villagers to overcome food shortage in many flood affected areas of Supaul district. Labour and food sharing during crises is standard in many societies (Twigg, 2004). The family is a fundamental social mechanism for reducing risk. Extended kin relations are networks for exchange, mutual assistance and social contact. In times of stress, relatives living outside the immediate community can become particularly important (Twigg, 2004).

**Cultural** - Cultural factors include risk perception and indigenous knowledge, which are frequently connected. Understanding how people view, confront and accommodate risk is particularly important. The accumulation and application of knowledge are directed by vulnerable people’s perceptions of the risks they face. Communities have their own way of defining when conditions have worsened so much that they constitute a crisis or disaster. This threshold varies between communities, according to their vulnerabilities and the threats they face. Seasonal flooding is not necessarily seen as a disaster in some places. Crop growing may depend on it, and poor families may supplement their diets with fish that are more readily caught as flood water spreads from the rivers over the fields (Twigg, 2004). Culturally, women view floods as a disaster and not as destiny, which normally is the way in which men explicate floods. For women floods both as an occurrence and duration is far more intense and stressful in comparison to their normal existence. Constant and consistent multi-tasking for four months either to lead normal life or
overcome challenges makes the span extremely perilous for them, whereas for men it is a destiny as it defines their future course of action.

The nuances hidden within the sub regional traditional knowledge system if unearthed will help in comprehending the local survival mechanisms and will also contribute towards developing a more authentic way forward.

### Way Forward

The business of flood management in India — the ability to predict, prepare, respond and recover from flood induced catastrophe is the responsibility of the State Government. Though non-state actors (aid agencies, independent research institutions, civil society, philanthropist and advocacy groups, and the people affected) can play a part in flood management, but the formal responsibility generally rests with the state-run irrigation or water resources departments. Other agencies, like state disaster management and local governments, also play a key role in flood management. This situation analysis clearly highlights the different responsibilities that the State performs. However, the flood management in India requires inclusive deliberations to highlight essentials and gaps in the existing system. Firstly, the efficacy, limitations and dangers of the present prescribed flood control measures (structural and non-structural) should be detailed through debate and documentation at various levels. There are constitutional and administrative provisions made for central and state governments in India to adopt flood management in totality. More often than not, structural flood control measures are given preferences in the vulnerable region, and that too in the absence of ecological and social impact appraisal of the past and present flood control measures. Comparative and separate assessment of structural and non-structural interventions respectively as flood control measures have not been undertaken to understand, highlight, advocate, modify and innovate the present practices. The present situation necessitates a review of different structural and non-structural interventions in flood management for disseminating realities in the public domain and facilitating improved and effective way forward. An effort for trans-boundary documentation on flood management strategies must be attempted to create opportunities for cross boundary learnings and adaptations.

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Flood preparedness needs to be filled with concrete and contextual measures such as
understanding of local adaptation measures, gendered experiences of and coping with floods. In order to do so, identification of existing knowledge base about the coping strategies and mitigating responses of the local community becomes extremely crucial. More often than not, it has been observed that the deliberations with regard to floods have been polarized either through technical arguments or relief and rehabilitation discourse (on behest of developmental partners and government agencies). Non-comprehendible knowledge and arguments introduced by external sources tend to easily prevail over the existing local sagacity of living with floods. For example, the issue of durability as a factor has been used to replace the existing local flood adaptive dwelling design with a new one without realizing that the existing design and layout are based on accessibility, availability and affordability to local resources. The local design is far more feasible in the flood context. On the other hand, the new design, though definitely more durable, remains impractical for flood prone areas. The building materials are brought from outside, which alone becomes difficult for remote locations, and its reconstruction is beyond the ability of majority population owing to the additional resources. On the other hand, attempts have been made to understand the local knowledge system and techniques of living with floods, but that too has been a part of larger discourse on floods and its impact. Therefore, attempts have been made to understand the sub-regional nuances of flood coping mechanisms (during all three stages – before, during and after) specifically from the perspective of building knowledge domain for the region.

The developmental partners need to understand the different character of floods in the east and northeast India. For instance, floods in Bihar have been considered a disaster as many others, and the measures taken have been inappropriate in terms of the context and social situation. A consistent and a willing effort of understanding of the area along with respect for local expertise should be the basis of any intervention with the intent of benefiting the local affected population.

It is crucial to understand vulnerability within the sub-regional context, which is made up of multiple risks including conflicts and not just the threat of hazards. Local risk perceptions become necessary as they all vary greatly between and within communities according to culture, experience and (for poor people especially) the pressure to secure their livelihood.

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It is very difficult to gain understanding of local views of risk. Simply asking questions or indirectly approaching the issue under the pretext of understanding or deciphering floods and its impact and about how risk is perceived does not always produce useful insights, because outsiders and local communities are likely to think about and describe risk in very different ways. It is often more constructive to talk to communities about what they do to manage a particular hazard than to discuss risks in general, provided that the full range of risks facing a community is covered in this way. But even this method is likely to miss a great deal (Twigg,
By spending long periods in communities, talking about and observing their daily lives, anthropologists can sometimes acquire a good understanding of the subject. Observation is valuable, as people’s statements of their views can sometimes give a misleading impression of their actual risk perception and risk-avoiding behaviour. There is a common assumption among disaster management professionals, researchers, technologists, development professionals etc that many people are fatalistic, regarding disasters as acts of God that cannot be prevented. In many cases, this may not be true. Statements of belief in divine power are not incompatible with taking actions to reduce risk (Twigg, 2004).

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There is a wide array of broad and specific issues that needs to be deciphered prior to working on floods at a sub-regional level. Lifestyle transformations and gender based challenges and inequalities during and post floods are important segments which have not been explored in totality at the sub-regional and regional level. Local beliefs and practices (based out of religious beliefs and festival, local knowledge about environmental signals and animal behavior, folk tales, flood narratives with experienced past) are key survival strategies adopted by the affected population in predicting weather, rain and floods and developing their own safeguards accordingly. Behavioral changes before, during and after floods amid the diverse habitants also needs to be understood as it remains a dominant coping and adaptation strategy in the flood prone areas. The essentiality of local indigenous technology, economic practices, cultural and social factors, and social capital as support systems requires further exploration to comprehend its potential and relevance and to disseminate such practices on the wider canvas for it to be adequately incorporated in the flood discourse.

Behavioral changes before, during and after floods amid the diverse habitants also needs to be understood as it remains a dominant coping and adaptation strategy in the flood prone areas.
Adaptive indigenous agricultural practices, housing technologies, and other adaptive technologies that help in generating community response to floods, coping during floods, and recovery after floods is yet another crucial survival technique that requires attention, understanding and contextualization. Perceptions among the women of the community, and other sections is fundamental for comprehending the process of exploring, identifying and adopting local solutions. In addition, it is also necessary to compile key findings and analysis of the strength and weakness of the indigenous knowledge practices for survival of the affected population in the eastern and northeastern India.

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Finally, there are few local challenges that exist in the flood vulnerable areas that require understanding, attention and work for streamlining the present flood management practices locally. Some of them have been indicated below:

Flood induced conflicts
It has been claimed that a catastrophe like a flood impacts all without differentiating between social groups. However, on assessing the nature, intensity and duration of the devastating impact (both in rural and urban contexts), a specific impact trend emerges. Assessments have indicated that the vulnerability of the population depends on several social factors like age, gender, economic status, social construct, population density, health status, race/ethnicity, residential status, culture, etc.

In rural areas, another factor affecting vulnerability is caste and social discrimination. The vulnerability quotient of floods is possibly linked with the very causal factors of floods. However, it is crucial to further explore the linkages between the vulnerability quotient and the causal factors of recurrent and unprecedented floods in India in order to identify the common space that could be the breeding ground for flood induced conflict. As floods impact different sections of society to different extents, it is essential to delve into these differences to develop a comprehensive understanding of the issue at a local level.

Conflict in the context of floods can be defined as contradictory perceptions (between centre and state; state and non-state actors; vulnerable and secure groups; and amongst vulnerable groups) about the course of action to overcome the calamity. What actions are taken and how they are taken in the aftermath of a flood provides the immediate context of flood induced conflicts. Conflicts also proliferate because of factual disagreements between individuals, groups and institutions with different values, priorities, interests, resources, survival mechanisms and hopes. Flood induced conflicts take place between groups, displaced communities, within and outside the embankment, states, regions, and nations.
The issue of flood induced conflicts is not limited to what happens after the flood takes place. In fact, there are conflicting perceptions about structural measures like dams and embankments to either prevent or mitigate floods. It is as though the solution itself is leading to problems.

Water conflicts engendered by floods might correlate with the very reason for and scale of the devastation; extent of inundation; degree of exploitation and deprivation; resource crunch and allocation; inadequacy in attending to the immediate and long duration problems; inaccurate damage assessment leading to misplaced allocation of rehabilitation packages; forced compromise to accommodate the needs of other dominant groups; gender specific inequality and inaccessibility; constrained livelihood options; resettlement of displaced population; damage compensation; flood induced migration; political provocation; etc. Many other factors might have remained unexplored. The issue of flood induced conflicts is not limited to what happens after the flood takes place. In fact, there are conflicting perceptions about structural measures like dams and embankments to either prevent or mitigate floods. It is as though the solution itself is leading to problems. Also, there are differences in worldviews about how one conceptualises rivers and floods, and the limit to “tame” rivers. There are differences in the epistemology itself. This difference in worldviews and epistemology get carried through what needs to be done to prevent floods. For example, the viewpoint that it is “natural” for rivers to flood gives rise to conceptualisations of “living with floods”. Cortesi calls these epistemological contestations over floods as ‘struggles of knowledge’. (Prasad et al, 2012).

Human resources
For proper planning of local flood management interventions, human resource base needs to be detailed for effective execution of identified interventions locally. As these are not merely engineering solutions but entail an extremely complex social engineering over large vulnerable areas hence the understanding of the area becomes a prerequisite. Professionals and local representatives will be able to undertake specific research and it will help in taking this task further.

Social engineering
Spread across several panchayats and villages spanning hectares of land, the traditional flood management system in east and north-east India needs to be revisited and revived. However, this would imply a very massive task of research and documentation across and within flood prone regions of the states concerned.

Problems of special communities
It is a known fact that problems of special communities get exacerbated by the recurring floods across regions and states. A process needs to be developed through which the plight of the special communities with regard to their needs and limitations can be understood and acted upon across the flood prone region of east and northeast India. This exercise will highlight the existing problems, interests, knowledge and opportunities that exist within the special communities that
have been long ignored. In addition, a nuanced understanding through mapping of different typologies of flood prone area will help in effectively underlining and addressing the problems of special communities.

**Safeguarding against erroneous policies**

Very often while dealing with a disaster like flood, the entire attention gets concentrated on the structural interventions and aftermath of the disaster. Policies that perpetuate such happenings remain unaddressed, which in turn continue to have fatal impact on the population living in the flood prone region. With a large population of poor and landless families inhabiting the region, steps such as review of policies related to flood control, management, displacement and rehabilitation becomes essential. The purpose behind this exercise will be to prevent non-contextual policies to administer, control and guide the flood control and management measures in India.

**Very often while dealing with a disaster like flood, the entire attention gets concentrated on the structural interventions and aftermath of the disaster. Policies that perpetuate such happenings remain unaddressed, which in turn continue to have fatal impact on the population living in the flood prone region**

Clearly, the established understanding amidst different collaborators surrounding flood control and management can only be addressed adequately through a systemic and challenging argument building process which can be accomplished through detailed national and transboundary documentation of various facets encompassing floods thereby creating space for local survival arguments and mechanisms.

This situation analysis has brought forth the distinct character, state and regional level impacts and complexities surrounding floods and its management in the eastern and north-eastern states of India. This exercise was undertaken to highlight flood related issues at the state and regional level, its relevance at the national and regional level as well as to identify research gaps and needs and future priority joint research areas in east and north east India as well as the regional level.

The exercise will hopefully lead to identification of core issues related to floods, flood management and flood conflicts. Finally, it will give a clear way forward as to the common/transboundary issues to be taken up for joint research/action within the India-Bangladesh sub region.

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Retrospective Perspective on History and Climate Change

Nandan Mukherjee

The usual water-related natural hazard in a deltaic floodplain such as Bangladesh is flood. Over a period of three decades (1986-2007), Bangladesh has faced 24 flood events in different parts of the country. More than 7500 people lost their lives; more than 36 million people were affected from a single incident (2004 flood); more than 5 million settlements were fully damaged, and more than 15 million acres of crop land were destroyed completely. These are some of the snapshots of flood damages over the stipulated period (CDMP’s disaster database). A complex sequence of dynamics yearning of causes and effects, results in flooding in the region. The factors include huge inflow of water from upstream catchment area, overlapping with heavy monsoon rainfall in the country along with a low floodplain gradient and congested drainage channels, major rivers congregating, and tides. Furthermore, storm surges in coastal areas and polders increase the intensity of floodwater outside protected area. Thus, diverse amalgamations of the various aspects give rise to the different types of flooding (Ahmed and Mirza, 2000).

An ecosystem, which depends on a critical balance of various factors and components, can be affected due to sudden impact of a flood. While the flood affect mainly dry lands, the excess runoff due to flood can have consequences, both positive and negative, for all types of aquatic and terrestrial ecosystem components including the flora and fauna. The human population that is the central component of the ecosystem is particularly at risk because of flood due to sudden exposure of morbidity, mortality and loss of livelihood assets.

The Ecosystems for Life project is an initiative taken to promote better understanding of managing ecosystem resources and services in Bangladesh and India. Understanding the current context, the project has initiated a desk study of flood situation analysis in Bangladesh. Similarly the
A desk review has elaborated different spatial and temporal dimensions of flood in the regional context. It has also illustrated different types of flooding, hydro-meteorological reasoning behind mega flood events, impact of climate change on monsoon flooding, flood management measures in Bangladesh and a few set of recommendations for further studies.

An ecosystem, which depends on a critical balance of various factors and components, can be affected by the sudden impact of a flood which can have consequences, both positive and negative. The human population that is the central component of the ecosystem is particularly at risk because of flood due to sudden exposure of morbidity, mortality and loss of livelihood assets.

Rationale

Bangladesh experiences mainly four types of natural floods: river or monsoon floods, flash floods, rainwater floods, and coastal floods stimulated by storm surges (Ahmad et al., 1994; Ahmad et al., 2000). Investigation of past floods patterns suggest that, about 26% of the country is endangered by annual flooding and another additional 42% is at risk because of floods with varied intensities (Ahmed and Mirza, 2000). The average flood accounts all categories of floods and intensities, including the severe flood incidents. Nonetheless in reality, average floods, which inundate area from 10,000 to 25,000 hectares, can seldom be observed since the mid-1970s. The average flood accounts all categories of floods and intensities, including the severe flood incidents. Nonetheless in reality, average floods, which inundate about 10,000 to 25,000 hectares, can seldom be observed since the mid-1970s. Only the minor and high intensity floods have been observed in the last three decades (Agrawala et al. 2003). Moreover there is high distribution in inter-annual variability of flooded areas. The timing and location of flooding varies proportionally according to the variability of rainfall in the Ganges-Brahmaputra-Meghna Basin area. In the event of catastrophic floods, it has been anticipated that about two-thirds of the country can get affected (Ahmad et al., 2000). All the different types of flood are affected directly or indirectly by climate change variables such as temperature, sea level, precipitation and storm surges.

The estimated increase in rainfall during monsoon season is perceived to be within the flow regimes of the rivers of Bangladesh. Moreover, expected consequences of increased rainfall from warmer and wetter conditions may result in increased flooding and drainage congestion. Flood runoff depth may increase by of 18 – 22% due to 10% increase in monsoon precipitation (Qureshi and Hobbie, 1994). Since it has been observed that monsoon precipitation is expected to rise between 11 to 20%, correspondingly surface runoff could tend to increase by 20 to 45% (Ahmed and Alam, 1998). It has been noted that, an additional 14.3% of the country will
become exceptionally susceptible to floods by the year 2030. Thereby, already vulnerable area are left in order to endure higher levels of further flooding. Furthermore, even if the banks of the major rivers are embanked, further non-flooded area will become even more susceptible to flooding by the year 2075.

The rise in sea level along the coastal belt will not only inundate its low-lying areas, it would also create a favorable condition for saline waters to overtop the flood protecting coastal embankments, especially when induced by strong winds (CEGIS, 2006). Breach of existing coastal embankments will also inundate land with saline waters.

Mirza and Dixit (1997) estimated that a 2°C warming combined with a 10 percent increase in precipitation would increase runoff in the Ganges, the Brahmaputra and the Meghna rivers by 19, 13, and 11 percent respectively. Deeper flood will be seen in the lowlands and depressions regions. These regions are Faridpur, Southwest of Dhaka, Rajshahi, Pabna, Comilla, Sylhet and Greater Mymensingh districts. Another research reported that an increase in precipitation over the GBM basins of about 5 percent combined with a temperature increase of around 1°C could result in small changes in peak discharge, but up to a 20 percent increase in flooded area (Mirza et al., 1998). Additional area flooded would tend to have small flood depth (flood category Fo), but would still cause additional destruction compared to current floods. Severity of extreme floods, such as the 20-year flood event, is estimated to increase marginally (The World Bank, 2000).

Various researchers have identified that there is a lack of information on susceptibility to flash-floods under climate change-induced hydrological regime, therefore making it difficult to comment on how it would affect the country (ADB, 1994; BUP-CEARS-CRU, 1994; Warrick and Ahmad, 1996, Alam et al., 1998). Similarly, no targeted research has been undertaken to understand and establish whether new area will become more prone to water-logging as a response to increased monsoon intensity under climate change regime. Despite the insufficient research initiatives on climate induced flood impact assessment exercises, it remains a stand-still case as little is known with respect to the economies of adaptation in Bangladesh.

Under this context, the current study aims at understanding the flood regime in Bangladesh, with particular focus on the monsoon flood incidences and climate change perturbations. Furthermore, the current flood risk management efforts are also elaborated from the perspective of mega flood event in Bangladesh.

**Objective and research questions**

The main objective of this study is to gain understanding of the mechanism of incidences of flood in Bangladesh, its spatial and temporal spread over different regions of Bangladesh as well as to prepare an inventory of the flood management measures in Bangladesh.

The current review has covered the following key research questions:

- What are the key features of flood in Bangladesh? What are the different types?
- What are the hydro-meteorological causes or factors behind the occurrences of flood event in Bangladesh?
- What is the extent of flood loss for different sectors?
- What is the current state of the flood management system in Bangladesh?

**Methodology and scope**

The output derived from this study is primarily based on literature review. The priority objective of this literature review was focused on exploring research gaps from the available research initiative.
However, in some cases, data collected from Bangladesh Water Board was analysed to support arguments. The task considered web-based archives of free and paid version of published literatures, which were explored with the following keywords: flood, flooding, Bangladesh, climate change, vulnerability, flood risk etc. Apart from that hard copy of book chapters have also been collected and reviewed.

The review mainly covered the monsoon flooding. Due to scantiness of available literature sources, flood types like flash flood and other coastal floods and urban flood issues were not covered in detail. Bangladesh, as a whole, was considered as the study area. However, other regional countries in the greater Ganges-the Brahmaputra-the Meghna River System, were also brought into focus for understanding the basin wide linkage.

Investigation of past floods patterns suggest that, about 26% of the country is endangered by annual flooding and another additional 42% is at risk because of floods with varied intensities (Ahmed and Mirza, 2000).

Learning from Mega Floods in Bangladesh

Basic features of flooding in Bangladesh

Flood is a recurring phenomenon in Bangladesh and typically has been within acceptable limits. Nevertheless, occasionally they became devastating. History of floods in this country is perhaps inseparable from the history of this land. In every century, the Bengal delta has witnessed nearly half a dozen floods, almost equal to the magnitude and intensity to the terminal ones in 1987, 1988 and 1998. A total of 28 major river floods occurred in the past five decades. Flat topography, heavy rainfall, geographical location, trans-boundary flows and the impact of global warming including socio-economic and flood conditions have added complications in Bangladesh’s flood situation. In the following sections, spatial and temporal distributions of flood events are briefly discussed.

Climate

There are three main seasons in Bangladesh. Pre-monsoon season that extending from March to May, with the highest temperature and evaporation rates, accompanied by thunderstorms, as well as cyclones along the coastal area. The monsoon season that is the most rainfall, cloudiness, and humidity extending from June to throughout September. Rainfall floods occur during this period. Post-monsoon season is from October to November, and it is characterized by high heat and humidity, with decreasing rainfall and increasing sunshine. The dry season, or winter, is from December through February, and it is cool, dry, and sunny.
The western part of Bangladesh is the driest, while the northeast has the highest mean annual rainfall. 85 to 90 percent of the annual total befalls during April and September, the ‘rainy’ season. However, the rainy season is longer in the northeast compared to the west. Rainfall varies from year to year, which leads to the problem of drought, excessive or untimely rainfall, and floods. Tropical storms are also variable both spatially and temporally.

Rainfall in Bangladesh exceeds evapo-transpiration rates in the monsoon season, and for the year as a whole, even in dry years. However, evapo-transpiration rates exceed rainfall in the winter and the beginning of the pre-monsoon season.

Types of floods in Bangladesh

Four main types of natural floods occur in Bangladesh (Ahmad et al., 1994; Ahmad et al., 2000): flash floods, river or monsoon floods, rainwater floods, and coastal floods induced by storm surges (as in Figure 1 below). Broad description and effect of each flood are elaborated below. This report will concentrate on the first three categories, i.e., the occurrences of inland flooding for detailed information and other coastal flood, urban flood issues were discarded in the later sub-sections.

**Flash Floods**

Flash floods usually take place in the hilly area during the pre-monsoon months of April and May. It appears within a short lasts for a few hours to a couple of days. Run-off due to exceptionally heavy rainfall rushes to the plains in the neighboring upland area with high velocity. Sometimes it happens several times a year. Nevertheless, when it happens it mauls standing crops and destroys the physical infrastructure at the foot of the northern and eastern hills of the region (Huq et al., 1996). Flash floods caused extensive damage to crops and property, particularly in the haor area. For crops, it is very vulnerable, mainly due to its timing of occurrences. Early floods (in April-May) generally causes severe damage to Boro rice in the eastern foothill regions virtually every year. Damage to property - especially road and railway embankments and bridges, and buildings alongside river channels - occurs during exceptionally high flash floods. Flood breach flood embankments along some eastern rivers, especially the Khowai, almost every year. Cultivated land and land adjoining foothill streams sometimes get buried under the sand (DoE, 2006).

*History of floods in this country is perhaps inseparable from the history of this land. In every century, the Bengal delta has witnessed nearly half a dozen floods, almost equal to the magnitude and intensity to the terminal ones in 1987, 1988 and 1998.*
Figure 1: Area in Bangladesh having susceptibility to various types of floods

Source: WARPO-Halcrow et al., 2004
Rainwater Floods
Occurrence of heavy rainfall over the floodplain areas and terrace areas in Bangladesh because rainwater floods. Runoff instigated by heavy pre-monsoon rainfall (April-May) accumulates in floodplain lowlands and in the lower parts of valleys within the Madhupur Tract. Later (June-August), local rainwater is increasingly accumulated on the land by the increasing level of water in adjoining rivers. Thus, the extent and depth of rainwater flooding vary within the rainy season and from year to year, depending on the amount and intensity of local rainfall and contemporary water levels in the major rivers that the controlled drainage from the land. Rainwater flooding is a characteristic of meander floodplains, major floodplain areas, and old piedmont and estuarine floodplains. The interior parts of tidal and young estuarine floodplains are also flooded mainly by rainwater. The severe 1987 flood in northwestern parts of Bangladesh was mainly caused by excessive rainfall occurring over the northern part of the area throughout the monsoon. It was aggravated at times by flash floods passing down the Teesta and other rivers entering Bangladesh from the northwest, and by high levels in the Jamuna and the Ganges rivers (DoE, 2006). The most severe late flood of 2004 in the southern and central parts of Bangladesh was also due to excessive rainfall (DoE, 2006).

River or Monsoon Floods
Normal river floods occur during the monsoon. River floods result from snowmelt in the peak of the Himalayas and heavy monsoon rainfall over mountain, the Tripura Hills, the upper Brahmaputra, the Assam Hills, and Ganges flood plains outside Bangladesh. They particularly affect active river floodplains. The large catchment of the GBM system receives a huge amount of rainfall in each monsoon, about nine-tenths of which flow through the major rivers in Bangladesh. These rivers sometimes cannot drain all the water coming from the combined GBM catchments. Consequently, bank spillage occurs which inundate the adjacent lands. River floods range beyond the active floodplains and damage crops in parts of the adjoining meander floodplains, mainly alongside distributaries. The timing of the flood (whether early or late) and sometimes the duration of flooding are as critical determinants of crop damage as is the absolute height reached by a particular flood. Along with the flood waters, a significant number of sediments is transported into the floodplains of Bangladesh. Sediments accumulated in different channels decrease the drainage capacity of small rivers, road and railway bridges and culverts, as well as irrigation and drainage canals.

Coastal Flooding
The southwestern coastal areas are inundated through high tidal surges. There are a large number of pockets in the southern coastal area that are deliberately made free from ‘normal tidal’ flooding. Marginal area, outside the embankments is prone to tidal inundation. Occasionally excessive rainwater accumulates inside an embankment, which does not have adequate drainage facilities; particularly the low-lying pockets of such an embankment suffer from flood caused by drainage congestion. Drainage congestion can often be caused chiefly by the differences of water level inside and outside the embankments, essentially the latter remaining at a higher stage. Occasionally flood damage can occur in the embanked area when high tides overtop the coastal embankments.

A combination of strong onshore winds accompanying the tropical cyclones along with the low barometric pressure causes the storm surges to an onrush of water with high amplitude. As a result of the coastal area hit by cyclones, up to a few good kilometers of the inland coastal area get flooded temporarily with huge amounts a seawater or brackish estuarine water. These
powerful storms are liable for maximum casualties as caused by previous cyclones (Haider et al., 1991). However, the storm surge in May 1965 was an exception. It had extended up to along the line of Meghna estuary to a greater portion of the inland to the south of the Sylhet Basin, therefore flooding the adjoining land area with non-saline river water. The cyclone of November 1970 wrought pervasive devastation with gushes of high amplitude of water in the nearby coastal area, causing a loss of more than 300,000 lives.

**Floodplains**

Floodplains in Bangladesh have great regional diversity. There are five main kinds of floodplains:

- Active river floodplains,
- Meander floodplains,
- Piedmont plains,
- Estuarine floodplains, and
- Tidal floodplains.

The youngest alluvial land along the major rivers is the active river floodplains, which includes the Active Teesta Floodplain, Active Brahmaputra-Jamuna Floodplain, and Active Ganges Floodplain. They are subject to deposition of new sediments, and erosion due to shifting river channels.

Meander floodplains include the older parts of the Teesta, Brahmaputra-Jamuna, Karatoya-Bangali, Ganges, and Surma-Kusiyara floodplains, as well as floodplains along the lower parts of rivers like Karnaphuli and Sangu. Meander flood plains resides smooth landscapes, and are crossed by a few active river channels and abandoned river channels, together with small drainage channels that only carry flow during the rainy season. Sediments in the meander floodplains are usually sandy on the higher ledges, but get silty on the lower slopes, and then become clay in the depressions. Most meander floodplain regions can be divided into older and younger flood plains. Older floodplain land does not receive deposits of new alluvium. However, the younger floodplain land receives occasional new deposits during high river floods. Meander flood plains remain stable over long periods of time, unlike active floodplains. The margins of some older floodplains, such as the Karatoya-Bangali Floodplain are subject to some riverbank erosion by the Jamuna River. Likewise, major and minor rivers, channels, and tributaries are all subject to change over time.

Piedmont plains are found at the foot of hills. Rivers are subject to flash flood deposit these sediments. The piedmont plains include the Old Himalayan Piedmont Plain. Occasional flash floods occur on this floodplain, in the valleys in the north. Rapidly permeable loamy soil predominates in the area. Other piedmont plains include the plains at the foot of the Northern and Eastern Hills. They slope outward from the neighboring hills. There is considerable sedimentation variation, nonetheless in general they grade from sands close to the hills, silt loam and clay over most of the plains, heavy clay in the basins where the piedmont plains merge in meander or tidal plains. Run-off from higher to lower parts of the plain causes the sediments to recourse when the plain is not flooded. Rivers and streams crossing the piedmont plains may break into new courses from time to time as the channels become clogged with sedimentation from flash floods. This instability creates problems for flood control.

Estuarine floodplains can be divided into two main parts, the Old Meghna Estuarine Floodplain and the Young Meghna Estuarine Floodplain. They both have a smooth, almost leveled land with little to no river channels. The differences in elevation between the ridges and adjoining depression centers are less than 2 metres, within a distance of 0.5 to 1 km. Parts of
the Old Meghna Estuarine Floodplain had man-made drainage canals dug more than hundred years ago. It is no longer flooded by tidal water and does not receive new alluvial sediments. Clay gets accumulated in the basin centers, due to run-off of water during heavy rainfall, but the clay deposits are not as extensive as they are on meander floodplains. The Young Meghna Estuarine Floodplain is still subject to tidal flooding and to erosion of the margins by shifting channels. Most of the Young Meghna Estuarine Floodplains are relatively stable, but the outer margins are subject to significant changes due to erosion and accretion as channel shift. Tidal flood plains are nearly leveled clay plains crossed with interconnected tidal rivers and creeks. A narrow strip of silt sediments and soils borders the banks of rivers and creeks. Difference of elevation between riverbanks and basin centers are about 1 meter or less, over a distance of 1 km. Under normal conditions, the tidal floodplains are submerged by silty water at high tide for at least part of the year. Embanked areas remain cut off from tidal flooding and sedimentation. These areas are subject to rainwater flooding and local redistribution of sediments through rainwater run-off from ridge to basin sites. The tidal water is saline yearlong in the southwestern area on the Ganges tidal floodplain, and fresh in the northeast. In the southern coastal region of Bangladesh, floodwater is fresh during the monsoon season and saline during the dry season. On the other hand, un-embanked area on the Chittagong Coastal Plains, are mainly saline throughout the year. Although tidal floodplains are mainly stable, the tidal rivers and creeks have occasionally changed course and old channels have silted up. Changes in sedimentation rates have also transpired in recent centuries.

The GBM delta encompasses parts of the action, meander, estuarine, and tidal floodplains described earlier. A delta is the lower part of the river floodplain where smaller channels flow out from the main channel towards the sea. The Old Meghna Estuarine Floodplain and the Middle Meghna Floodplain are stable and no longer receive significant amounts of sediments, which is why they are best regarded as moribund parts of the delta, along with the High Ganges River Floodplain. The apex of the Ganges part of the delta is near the Farakka Barrage in India while the apex of the Brahmaputra part is positioned where the old Brahmaputra channel separates from the current Jamuna channel.

The Teesta Floodplain is not part of the delta. Instead, it is an alluvial fan, on which present and former river channels radiate outward from the foot of the Himalayas, before joining the Brahmaputra-Jamuna and Ganges as tributary channels. The Surma-Kusiyara Floodplain can be regarded as an internal delta, formed by the rivers flowing into the Sylhet Basin and then leave the basin to form a tributary of the GBM system. Delta and alluvial fan landscapes are important to flood control because drainage is often away from the main river channels.

**Spatial extent of flood**

The Ganges, Brahmaputra, and Meghna (GBM) rivers flow through Bangladesh, most of which is within the GBM catchment area (figure 2 and table 1). Bangladesh’s coastal area face storm surge flooding and the floodplains in the southeast are subjected to seasonal flooding, outside of the GBM catchment. Out of the total area 147,570 sq km, rivers and estuaries occupy about 9,700 sq km of the country.
The cyclone of November 1970 wrought pervasive devastation with gushes of high amplitude of water (in combination with strong onshore winds accompanying the cyclone) in the nearby coastal area, causing a loss of more than 300,000 lives.

The catchment regions of the Ganges, Brahmaputra and Meghna have significant physical diversity, which makes it difficult to prepare and accurate model and predict floods. Flood prediction is made more difficult as the GBM catchment area comprises several countries. About 80 percent of Bangladesh possesses floodplain and 8 percent of the country is made up of the terrace - area, like the Madhupur and Barind Tracts. Furthermore the Northern and Eastern Hills form the remaining 12 percent.

### Table 1: Country areas in the Ganges-Brahmaputra-Meghna river basin

<table>
<thead>
<tr>
<th>Basin</th>
<th>Area (Km²)</th>
<th>% of Southeast Asia</th>
<th>Countries Included</th>
<th>Area of Country in Basin (Km²)</th>
<th>As % of Total Area of the Basin</th>
<th>As % of Total Area of the Country</th>
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</thead>
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<tr>
<td>Ganges</td>
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<td>India</td>
<td>860000</td>
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<td></td>
<td></td>
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<tr>
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<td></td>
<td></td>
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<td>Nepal</td>
<td>-</td>
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<td></td>
<td></td>
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<tr>
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</tbody>
</table>

Figure 2: Catchment area of the Ganga, Brahmaputra and Meghna rivers

(Source: Hofer and Messerli, 2006; Figure 2.1, pp: 13)
Chronology of big floods

Hofer and Messerli (2006), states that over the last 115 years (1890 to 2004) Bangladesh was affected by 12 major floods\(^1\), one per decade on average. Detail chronology of immense floods has been given in the Annex-A. They have also pointed out that the temporal occurrence of flood over the stipulated period did not follow any regularity, two phases of fairly frequent flooding (1892–1922; 1974–2004) are interrupted by a long phase (1923–1973) with only one widespread inundation. After the unspectacular period from 1920 to 1950, the frequency of major flooding seems to have increased from 1950 to 2004. However, if the years from 1890 to 1922 are also taken into consideration, then this interpretation must be replaced by another conclusion: big floods seem to occur in cycles of higher and lower frequency.

Figure 3: Major floods in Bangladesh, 1890–2007

![Major floods in Bangladesh, 1890–2007](image)

Sources: Hofer and Messerli (2006).

Flood flow hydraulics

The characteristics of peak discharge of Ganges, Brahmaputra and Meghna rivers are distinctive in terms of magnitude and timing of occurrences. Mirza (2001) showed that it is the precipitation pattern, not the size of the basin area while it is the determining factor for experiencing higher discharge in the Ganges and Brahmaputra basin area. For instance, although the basin area of the Brahmaputra River is half of that of the Ganges River, average yearly peak discharge of the previous is certainly more than the later. Mean monthly flow hydrograph (discharge and water level) for the three rivers is shown in Figure 3. Analysis of hydrograph (in Figure 3) show that the coefficient of variation (CV) of the upper discharge of the Ganges is more than that of the other two major rivers that demonstrate a slightly higher uncertainty in the precipitation pattern and also the same precipitation pattern in their basin area.

Flow in the Brahmaputra river begins rising on March due to the melt off snow in the Himalayas while the Ganges discharge begin to rise in early June (or mid of May) with the onset of monsoon. Rainfall of Monsoon occurs in the Brahmaputra and Meghna basin before than the Ganges basin according to the shape of progression of the monsoon air mass. The previous two river basins also experience high rainfall due to their orographic features (Mirza, 1997). The overflow of flood in the Brahmaputra and Meghna starts from July and lasts up to August while

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\(^1\) In 2007, Bangladesh has experienced another mega flood event
the overflows in the Ganges starts from August and lasts up to September. This phenomenon points out a real likelihood of simultaneous floods in the Ganges, the Brahmaputra and the Meghna River basins. Over the same time, distribution of timing of peak discharge of the Ganges and Brahmaputra rivers shows that simultaneous peak occurred for 4 times (1966, 1984, 1998 and in 2004) over a common 10-day time. Notably in 1998, peak discharge on all the three rivers occurred simultaneously during the first week of September where peak in the Ganges and the Brahmaputra occurred simultaneously only two days apart. As a consequence, the entire middle areas of Bangladesh near the confluence point of the two rivers suffered an unprecedented flood.

The characteristics of peak discharge of the Ganges, Brahmaputra and Meghna rivers are distinctive in terms of magnitude and timing of occurrences. Notably in 1998, peak discharge in all the three rivers occurred simultaneously during the first week of September. As a consequence, the middle areas of Bangladesh near the confluence point of the two rivers suffered an unprecedented flood.

Hydro-meteorological factors behind the floods in Bangladesh

The most devastating floods that Bangladesh faced over the last ten decades (specially, 1906, 1910, 1922, 1955, 1974, 1987, 1988, and 1998) are caused by the Monsoon. Monsoon, as defined by the International Agreed Glossary of Basic Terms Related to Disaster Management (1992) as seasonal heavy rainfall and wind, the path of which diverse from one season to another.
The monsoon system is maintained by the strong differential heating of the southern part of Indian Ocean and the northern part of the mountain ranges. After forming in the Bay of Bengal, monsoon depression moves north and northwards in the regions of Orissa, West Bengal and Bangladesh. Along the path it produces very high precipitation. Monsoon depressions will often turn into land depressions if they reach the foothills of the Himalayas. Consecutive occurrences of monsoon depression or land depressions may cause severe flooding over the regions where it moves into the downstream catchment of the rivers (Choudhury et al., 2003). The occurrence of flood is exacerbated by the moist ground conditions during the monsoon season, which are favorable for converting a significant portion of rainfall into runoff.

In the recent years, a substantial number of studies have identified the key factors that contribute to the occurrences of floods in Bangladesh. In a nutshell, most of the research concluded that the extreme precipitation in the monsoon, together with the physical settings of the river basins has caused many severe floods in the last few decades. A few literatures have dealt with the cause and consequences of floods in Bangladesh provide scarce information to draw a clear answer to the question “whether floods in Bangladesh are primarily the result of events in Bangladesh itself or strongly influenced by processes outside the country2”. For some authors the external input is the principal factor for causing floods in Bangladesh, some of the statements are given below.

“Under the existing geophysical conditions in the country the amount of runoff generated by rainfall within the country may not be sufficient to cause flooding in Bangladesh. But it is a critical factor aggravating the hydrological situation in the country.”(Ahmed, 1989: 24) “A most significant contribution to flooding is the inflow of the main rivers from India, and rainfall in Bangladesh is not necessarily an indicator of conditions elsewhere over the catchments.” (BWDB, 1991a: 48)

“Though there may not be much rainfall locally, there may be heavy rainfall in the catchment area causing flood. Of course, if there is rainfall in Bangladesh as well, flood will worsen.” (Choudhury1989: 235)

“Snowmelt and rainfall produce a large water flow from the Himalayas.”(Hossain et al. 1987: 8)

“The correlation between the mean annual rainfall in the catchment area of the Ganges and the discharge at Hardinge Bridge is not evident”. (GOB 1992a: 6–8).

On the contrary, a range of studies is focusing on heavy rainfall within Bangladesh or factors other than the GBM basin rainfall as the cause of floods in Bangladesh. There are even some statements that place more importance on rainwater than on river water for the generation of floods in Bangladesh. Evidences from literatures supporting the above-mentioned statement are listed below:

“On the monthly basis it was found that a significant correlation exists between Brahmaputra and Meghna flows and rainfall over Bangladesh.” (GOB 1992a: 6–8)

“The rapid leaching of most flood-plain topsoil confirms field observations that most river and estuarine flood-plains are not flooded by river water. They are flooded with rainwater or the risen groundwater table derived from the heavy monsoon rainfall which is ponded on the land by high monsoon season river levels.” (Hossain et al. 1987: 54)

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2 Particularly rainfall runoff processes in the greater Ganges-Brahmaputra-Meghna river basin area
However, a number of authors are of the opinions that the combination of internal and external factors is the cause of severe floods:

“One of the main causes of flood in Bangladesh is heavy intense rainfall over the vast catchment area of the rivers of Bangladesh, most of which (93%) lies outside the country. Local rainfall also sometimes causes floods in different times.” (BWDB 1975: 39)

The external contribution is not the same throughout the monsoon season. As the monsoon season in Bangladesh is longer than in north-western India, the contribution to the floods from the country is significant in the beginning and the end of the monsoon season. In the middle of the rainy season the external contribution is important. (GOB 1992a)

Except a few, literature dealing with the cause and consequences of floods in Bangladesh providing very scarce information to draw a clear answer to whether floods in Bangladesh are primarily the result of events in Bangladesh itself or strongly influenced by processes outside the country3.

In recent years, Hofer and Misserli (2006) have made an attempt to analyze flood events systematically by applying consistent and standardized methodologies and by comparing the different findings made by different authors. In the upcoming discussions, a brief summary is given from their study to understand the hydro-meteorological reasoning behind the megaflood events occurred in Bangladesh during 1987, 1988 and 1998.

In existing literature, very few information is available in order to draw a clear answer to whether floods in Bangladesh are primarily the result of events in Bangladesh itself or strongly influenced by processes outside the country

Flood of 1987

The flood of 1987 ‘was the worst over the last 40 years that hit Bangladesh, and the country experienced the most deplorable decimation of lives in barely believable digits’ (Hussain and Samad 1987). The flood started in June with a flash flood in the northeast and they reached their maximum extent in August. In September, additional severe but spatially limited flooding occurred in the Ganges area and again in certain parts in the northeast of Bangladesh. All four flood types usually encountered in Bangladesh (discussed in Section 2.2) occurred separately or in combination during the 1987 flood season. By August, flooding was widespread not only in Bangladesh but also in some of the states of India such as Bihar, West Bengal and Assam.

3 Particularly rainfall runoff processes in the greater Ganges-Brahmaputra-Meghna river basin area
During the first and major rainfall period in Bangladesh (21 July–3 August), which corresponds to the first part of the main flood time, precipitation was also high outside Bangladesh, particularly in Meghalaya, Lower Assam and the Himalayan foothills of West Bengal and Bihar. During the...
second part of the central flooding period (August), rainfall was heavier outside (in the Indian lowlands) than inside Bangladesh. The monthly flow of the Brahmaputra at Bahadurabad and of the Teesta at Kaunia was above average from July to December. Except in August and September, below-average discharge was dominant in the Ganges. In the period 12–21 August, the three big rivers recorded flows above danger levels, the Teesta reached its extraordinary peak and the floods probably reached their maximum dimension. In terms of highland–lowland interactions, the flood of 1987 reveals the following interesting situation: the external input into the Meghna system directly originated in the Meghalaya Hills. In the context of the Brahmaputra system, the external input mainly originated in the foothills and the lowlands south of the Himalayas, not in the mountains. Thus, the literature states that the combination of high rainfall within the country itself and high flows from upstream across its border is an important factor in the flooding (Ahmad, 1989; BWDB, 1975; Choudhury, 1989) and this can be fully supported in the case of this 1987 flood.

Figure 6: Water Level in the Ganges, Brahmaputra and Meghna River during 1987 Flood

Other than this, the full moon in August coincided with the maximum extent of flooding in Bangladesh. The discharge of the accumulated water masses into the Bay of Bengal might have been hampered by the spring tides and might have contributed to the extent of the flooding. As a result of the intensive and widespread rains before the main flooding period, there was only minimal potential to absorb additional water in the groundwater reservoirs when the oncoming
flood wave reached the country. As a consequence, in the confluence area of the Ganges and the Brahmaputra, the groundwater table reached the surface and further aggravated the flooding condition. The factors relevant or irrelevant for causing the flood in 1987 are summarized below:

<table>
<thead>
<tr>
<th>Factors relevant for causing 1987 Flood</th>
<th>Factor not relevant for causing 1987 Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Rainfall in Bangladesh, particularly in the north-western region</td>
<td>• The pre-monsoon period</td>
</tr>
<tr>
<td>• Input from the Meghalaya Hills</td>
<td>• Single daily rainfall events</td>
</tr>
<tr>
<td>• Flood wave from the Teesta and the Brahmaputra</td>
<td>• The influence of the Himalayas</td>
</tr>
<tr>
<td>• Synchronization of the high flow of the three main rivers from 12 to 21 August</td>
<td></td>
</tr>
<tr>
<td>• High groundwater table</td>
<td></td>
</tr>
<tr>
<td>• Coincidence with a high, even spring tide after the full moon in August</td>
<td></td>
</tr>
</tbody>
</table>

1988 Flood
The inundation of 1988 was one of the worst floods in the twentieth century. The catchment area of Meghna and the Brahmaputra, including central Bangladesh, suffered most, whereas the southern regions and significant parts of western Bangladesh were only moderately affected or were even flood free. First flood phase had already occurred from mid-April to mid-May in the eastern and north-eastern parts of the country. In June almost no flooding took place. In early July the Meghna basin experienced severe flooding and the Brahmaputra was also in flood. Before this flood had sufficiently receded, all the major rivers started rising from 10 August onwards and then simultaneously and very rapidly from 20 August, reaching their peaks between 30 August and 2 September. Accordingly, the nationwide flood in Bangladesh occurred roughly between 20 August and 5 September.

Floods were also reported outside of Bangladesh. The flood-affected area in Assam (the Brahmaputra lowland in India) was one of the largest flood affected area in the twentieth century. In the Ganges system, floods were reported in Bihar and West Bengal in June, in Nepal in July and the far western Ganges catchment in late September. Unlike the events in Assam, the timing of the floods in the Ganges system was different from that in Bangladesh.

Popelewski (1988) refers to a swing, during the summer of 1988, towards the positive phase of the Southern Oscillation, which results in heavy rains, in the monsoon area (the Southern Oscillation is an alteration in the pressure difference at sea level between the eastern and western Pacific Ocean).

The middle period of the flood was influenced heavily by local rainfall affecting the entire country: 3–12 July, 10 August–13 September (the last time mainly affecting the north-eastern and north-western parts of Bangladesh). In the initial and central period of the flood, occurrences of rainfall outside Bangladesh was also dominant. During the two main flood periods in Bangladesh (early July and the last part of August), rainfall was also exceptional in Cherrapunjee (2,697 mm between 3 and 12 July, 2,669 mm between 23 and 29 August) and in Shillong, both of which are located in the Meghalaya Hills.
Figure 7: Flood-affected area synthesized for the entire monsoon season of year 1988.

Sources: Hofer and Messerli (2006).
During the monsoon season the maximum discharge that is usually reached has been analyzed for being exceeded by the high flows. The maximum flow of the Brahmaputra was particularly outstanding, with a return period\(^4\) of 60 years. From 23 August to 6 September, the time of nationwide flooding, all three major rivers recorded flows of above the danger level. With a temporal difference of only five days, the annual discharge peaks of the Ganges and the Brahmaputra were almost synchronized. But not all the discharge characteristics can be explained by the rainfall situation in Bangladesh alone. A few of the hydrological patterns are a combined result of intensive rainfall in north-western and north-eastern Bangladesh, rainfall in the Himalayan forelands and the northern part of the Meghalaya Hills, and extensive flooding in Assam.

Figure 8: Water Level in the Ganges, Brahmaputra and Meghna River during 1988 Flood

At all stations, the recorded groundwater level was above average for most of the monsoon season. The highest groundwater level was reached during the time of nationwide flooding. There is a non-systematic connection between the phases of the moon and the discharge hydrograph of the Meghna. However, the spring tide related to the new moon on 11 September could have backed up the Meghna waters during the main flooding time.

\(^4\) A return period also known as a recurrence interval is an estimate of the interval of time between events like an earthquake, flood or river discharge flow of a certain intensity or size. It is a statistical measurement denoting the average recurrence interval over an extended period of time.
The factors that were relevant or not relevant for causing the 1988 flood, are summarized below:

<table>
<thead>
<tr>
<th>Factors relevant for causing 1988 Flood</th>
<th>Factors not relevant for causing 1988 Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Widespread above-average rainfall during August both inside and outside Bangladesh</td>
<td>• Flood triggered by the Ganges on its own</td>
</tr>
<tr>
<td>• Constant above-average rainfall in Bangladesh from June to August</td>
<td>• Single daily rainfall events</td>
</tr>
<tr>
<td>• Combination of local and external input (swing in the southern oscillation) before and during the flood</td>
<td>• The influence of the Himalayas</td>
</tr>
<tr>
<td>• Significant rainfall in northern and north-western Bangladesh, in Meghalaya and in Assam</td>
<td></td>
</tr>
<tr>
<td>• High, at times above-danger-level, flows of all three major rivers in August and September</td>
<td></td>
</tr>
<tr>
<td>• Temporal synchronization of the highest flow of the Brahmaputra and the Ganges, and of a very high flow of the Meghna</td>
<td></td>
</tr>
<tr>
<td>• High groundwater table at the onset of the first flood phase and throughout most of the monsoon period</td>
<td></td>
</tr>
<tr>
<td>• Backwater effects owing to a spring tide</td>
<td></td>
</tr>
</tbody>
</table>

1998 Flood

The floods in 1998 were the longest lasting and most devastating in 100 years. In that flood, 53 districts of the 64 districts of Bangladesh were affected by floods of differing magnitude, and about 50 per cent of the country was under water for almost 67 days, at depths of almost 3 meters. The most severe flooding occurred along the main river courses and was particularly severe in a large stretch in the whole area of confluence of the three rivers, including the capital city of Dhaka. Interestingly, most of the few flood-free zones were located in southern and south-western Bangladesh, a feature that was already in evidence in previous flood years. Flood conditions prevailed continuously from July to mid-September. The situation became critical on three particular dates: 28 July, when 30 per cent of the country was under water, 30 August, when 41 percent of the country was flooded, and 7 September, when 51 percent of the country was inundated. Moreover, the extent of flooding in Bangladesh on 7 September was probably the greatest in the twentieth century.

In July and August rainfall was significantly above average in Bangladesh, especially in the central and eastern parts of the country. The rainfall situation outside Bangladesh was difficult to spectaculate. The monsoon rain started on 5th July and stretched till 6th September. All three major rivers were flowing above danger levels for a significant number of times. Whereas the Brahmaputra and the Meghna crossed the danger level in July, the Ganges also did the same but only after mid-August. All three major rivers responded to the main rainfall periods within Bangladesh. The flood peaks on 28 July and 7 September were reached immediately after a
rainfall period. The three major rivers reached their annual peak almost simultaneously between 7 and 9 September. At one stage, on 7th September, 25 water level stations out of 46 monitoring stations flowed above danger level, which was the worst day of the country (BWDB 1998). The Ganges reached its highest ever-recorded water level. However, in terms of the duration of the above-danger-level flow and the dimension of the peak discharge, the flood of 1987 was more important.

Figure 9: Water Level in the Ganges, Brahmaputra and Meghna Rivers during 1998 Flood

At the time of simultaneous high peaks of the three major rivers between 7 and 11 September, high tides and strong monsoonal currents were observed in the Bay of Bengal. At a number of hydrological stations the water table reached the highest ever recorded levels. The La Niña situation resulted in very humid monsoon conditions that aggravated the flooding condition.

The inflow into Bangladesh from Assam through the Brahmaputra and from the Indian Gangetic Plain through the Ganges during August and early September was certainly important.

5 Wikipedia says, El Niño is a band of anomalously warm ocean water temperatures that periodically develops off the western coast of South America and can cause climatic changes across the Pacific Ocean. There is a phase of ‘El Niño–Southern Oscillation’ (ENSO), which refers to variations in the temperature of the surface of the tropical eastern Pacific Ocean (El Niño and La Niña) and in air surface pressure in the tropical western Pacific. The two variations are coupled: the warm oceanic phase, El Niño, accompanies high air surface pressure in the western Pacific, while the cold phase, La Niña, accompanies low air surface pressure in the western Pacific.[2][3]
The few news reports do not indicate that there were major flood events that came anywhere close to those in Bangladesh in terms of dimension and duration. Due to unavailability of sufficient information, it was difficult to calculate the particular contribution. Nevertheless, satellite images provide evidence of uninterrupted and fairly wide strips of flooded area along the Brahmaputra from Assam to Bangladesh as well as along the Ganges from Bihar and West Bengal to Bangladesh.

Figure 10: Flood-affected area and flood intensity, synthesized for the whole monsoon season: 1998

Sources: Hofer and Messerli (2006).
The factors that were relevant or not relevant for causing the 1998 Flood are summarized below:

<table>
<thead>
<tr>
<th>Factors relevant for causing 1998 Flood</th>
<th>Factors not relevant for causing 1998 Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>• The La Nina situation</td>
<td>• Rainfall in the pre-monsoon and early</td>
</tr>
<tr>
<td>• Constant and intensive rains, particularly within Bangladesh, during July and August</td>
<td>monsoon period;</td>
</tr>
<tr>
<td>• Simultaneous and constant above-danger-level flows of the three major rivers</td>
<td>• Input from the Himalayas</td>
</tr>
<tr>
<td>• Backwater effects resulting from the synchronization of the peak flow of the three major rivers between 7 and 9 September and from high tides</td>
<td></td>
</tr>
<tr>
<td>• The contribution of flow in the river systems, in decreasing order of quantity: Brahmaputra, Ganges, Meghna.</td>
<td></td>
</tr>
</tbody>
</table>

**2004 Flood**

The Surma, the Kushiyara and consequently the Meghna River experienced highest ever recorded water level due to excessive early monsoon rainfall in the upstream hilly regions of Meghna and Brahmaputra basins during the second and third weeks of July. At the same time, Brahmaputra basin experienced the same. The Brahmaputra at Bahadurabad point reached the peak on July 14. Ganges at Hardinge Bridge point and Meghna at Bhairab Bazar hit the peak simultaneously on 24 July. This caused widespread inundation in the Meghna and Brahmaputra floodplains.

Like most other megafloods in Bangladesh, the rainfall in the upper catchments outside Bangladesh dominated the occurrence of floods in 2004. A study initiated by BUET (Rahman et al., 2005) showed that there was the huge amount of rainfalls, more than 40% than average, in all the three basins, especially in the Meghna basin, over two and half weeks prior to the peaks in the three major rivers. It was noticed there was a time lag of 6-10 days from rainfall in the upper catchments until the corresponding peak is felt within Bangladesh. The study also showed that the durations of floods in 2004 in the Meghna Basin were considerably lower compared to those in previous major flood years. Meghna River was above the danger level for over five weeks, while the water level in the Brahmaputra was above the danger level for little over two weeks. Duration of floods in the Brahmaputra basin was also much shorter than that in 1998, but equal to that in 1988.

The effect of spring tide in the lower Meghna estuary also caused strong backwater effect that resulted in delayed recession of flood water for a longer period of time.
Figure 11: Flooded area on July 24, 2004

Sources: FFWC website
Figure 12: Water level hydrograph for the Ganges, the Brahmaputra and the Meghna river covering the monsoon season of Year 2004

<table>
<thead>
<tr>
<th>Factors relevant for causing 2004 Flood</th>
<th>Factors not relevant for causing 2004 Flood</th>
</tr>
</thead>
<tbody>
<tr>
<td>• constant and intensive rains, particularly outside Bangladesh, during July</td>
<td>• rainfall in the pre-monsoon period</td>
</tr>
<tr>
<td>• simultaneous and constant above-danger-level flows of the three major rivers</td>
<td>• input from the Himalayas</td>
</tr>
<tr>
<td>• backwater effects resulting from the synchronization of the peak flow of the three major rivers between 14 and 24 July from high tides</td>
<td>• the La Nina situation</td>
</tr>
<tr>
<td>• contribution of flow for flood in the river systems; in decreasing order of importance: Surma-Kushiyara, Brahmaputra, Ganges, Meghna.</td>
<td></td>
</tr>
</tbody>
</table>

**Extent of flooding: historical perspective**

Figure 10 covers a 53-year period (1954–2007) during which all four of the most extensive floods occurred after 1986 (1987, 1988, 1998, 2004) and it is striking that two record floods (1988 and 1998) have a return period of 100 years or more. At the same time, since 1975, low flood extents have become more frequent. In the flood ranking given in Appendix 2, the five years with the
lowest flood-affected area over the 50-year period all occurred after 1980 (1982, 1990, 1992, 1994, 2001). In addition, if the whole time series is plotted in terms of percentage of inundation coverage, it will be found that the extent of significant floods seems to have gradually decreased (see flood-affected area 1955, 1974, 1987, 1988, 1998) (Hofer and Messerli. 2006). However, if the occurrence of significant floods (more than 25% of inundation coverage) is considered over the stipulated period it would be found that the frequency of significant floods has increased in the recent years (Figure 11). One may come across differing statements in a number of literatures regarding the non-existent or even declining trends of flooding versus the assumption of increasing trends (Rahman 1989b, Hossain et al. 1987, Ahmad 1989, Brammer 1990, Agarwal and Narain 1991, Ives 1991), but it is proved from the above discussion that over the second half of the last century, overall flood inundation statistics is showing a slight declining trend and the inundation coverage by the big floods are increasing in the recent years. It has been enumerated that 1998 flood was around a 100-yr return period flood which was followed by the 1988 flood of 55-year return period flood, whereas 1974, 1987 and 2004 floods are around 10-year return period floods. So it is evident that frequencies of big floods have been increasing in recent years.

Hofer and Messerli (2006) have explored the human dimensions for interpreting and the observed tendencies discussed above. They have investigated the probable correlation of upstream land use change specifically, deforestation, and embankment construction with the occurrence of flood in Bangladesh. They found no correlation of flood with the upstream land use changes as the forest situation at least in parts of the Himalayas is improving. Although there exists some strong oppositions against the correlation between the construction of embankment and riverine flood, but Hughes et al. (1994: 21) states that it is ironical that the embankments have served to prevent normal flooding even though failed to prevent the abnormal flooding thereby lessening the benefits obtained from the normal flooding. Another reason for the increasing area affected during very big flood events could be the loss of beels (seasonal or perennial lakes) and swamps in the floodplains, which served as natural storage for excess water (Keddy et al., 2009).

**Studies found no correlation of flood with the upstream land use changes as the forest situation at least in parts of the Himalayas is improving. There exists some strong oppositions against the correlation between the construction of embankment and riverine flood. It is noted that the embankments have served to prevent normal flooding even though it failed to prevent the abnormal flooding ...**
Figure 13: Historical flood inundation statistics

Figure 14: Historical trend in flooded area for major flood events
A comparison of most devastating floods in the recent period is shown below (Table 2):

<table>
<thead>
<tr>
<th>Return Period (in years)</th>
<th>Affected Area (% of the country)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>37%</td>
</tr>
<tr>
<td>12</td>
<td>39%</td>
</tr>
<tr>
<td>13</td>
<td>40%</td>
</tr>
<tr>
<td>55</td>
<td>63%</td>
</tr>
<tr>
<td>90</td>
<td>69%</td>
</tr>
</tbody>
</table>

Spatial correlation of monsoon flood in the Ganges-Brahmaputra-Meghna (GBM) basins

Hofer and Messerli (2006) have investigated the correlation of flood history with a comparison between the data of Bangladesh with those of the Indian plains (Uttar Pradesh, Bihar, West Bengal and Assam) as in Figure 12. They stated that flood history in the lowlands of the Ganges–Brahmaputra–Meghna systems is obviously characterized by significant regional differentiation. More specifically, extreme rainfall in the upper riparian (e.g., in Assam) may have some strong influence on flood in Bangladesh. They found that no floods of similar magnitude and intensity are recorded in the entire Ganges–Brahmaputra–Meghna system in the same year and that the flood history of Uttar Pradesh and West Bengal is even negatively correlated to the flood history of Assam. The flood history of Bangladesh in the period 1954–1994 correlates well with the flood history of the Indian Brahmaputra plain (Assam) and is negatively correlated with the flood history of at least parts of the Indian Ganges Plain (Uttar Pradesh, West Bengal). They confirmed that there is no general trend towards increasing frequency and extent of floods in the lowlands of the Brahmaputra and Ganges rivers. The only tendency is an increasing inter-annual variability of the flood-affected area and an increasing range between the lowest and the highest annual figures of the extent of flooding.

Figure 15: Extent of flood-affected area in Uttar Pradesh, Bihar, West Bengal, Assam and Bangladesh, 1954–1994
Figure 15 (continued)

Bihar

Average: 7.74%
Trend line: \( y = 0.0043x + 7.6629 \)

West Bengal

Average: 9.25%
Trend line: \( y = 0.0243x + 8.8002 \)

Assam

Average: 12.68%
Trend line: \( y = 0.0068x + 12.535 \)

Bangladesh

Average: 19.73%
Trend line: \( y = 0.3869x + 28.246 \)

Source: Hofer and Messerli, 2006
Some myths and misunderstandings

Bangladeshi people are living with flood since time immemorial, but a number of long-established myths and a couple of misunderstandings put shade on the real scientific understandings that ultimately increase the suffering of those exposed to flood hazards or delay the provision of effective mitigation measures. Brammer (2004) pointed out a number of floods related myths and misunderstandings among the people of Bangladesh. It is important to differentiate between ‘floods’ and ‘flooding’ before describing these issues. Brammer (2004) defined flooding as the normal seasonal submergence of floodplain, valley and terrace land which occurs every year and to which people’s traditional settlements and economic activities are well adapted. On the other hand, floods represent abnormal of unwanted submergence if land occurring less frequently which can damage crops and property, disrupt people’s normal living conditions, communications and economic activities, and endanger the people’s life and their livestock. According to Brammer (2004), a list of general myths and misunderstandings are summarized below:

Myth 1: Flooding from rivers
One of the myths says that overflows in rivers and their banks cause floods and flooding. As elaborated in the previous sections, most of the Bangladesh’s floodplain regions are flooded predominately by rainwater, either within Bangladesh or parts of the Ganges-the Brahmaputra-the Meghna basins, not by silty river water. This myth is further dispelled from soil sample analysis results of new alluvium or a young floodplain, old floodplain and peat soil zones of Bangladesh. Although chemical characteristics of new alluvium are neutral to moderately alkaline in reaction (pH 7.0-8.4), but most topsoil on meander floodplains and old estuarine floodplains (which together occupies half of the countries floodplain area) are strongly or very strongly acidic in nature (pH 4.5 to 5.5). Topsoil acidification in soils developed in sediments that originally were neutral or alkaline in response is a clear indicator of rainwater flooding. Furthermore, floodplains in Bangladesh have a ridge and basin landscape with loamy soils on the ridges and clay soils in the basins. However, if significant amount of alluvium were to be deposited by annual (or even occasional) floods from rivers, then relatively silty deposits would have buried the old ridge and basin soils close to the present riverbanks; further away more clayey deposits would have buried them. Another evidence is observed in the case of Peat soil that is found extensively in the interior parts of the Ganges River Floodplain. Peat soil is acidic in nature; acidic peat soils would not occur in the low-lying area if significant amount of alluvium (calcareous in nature) were being deposited from the deep annual floods.

Myth 2: Fertility of alluvium
The second myth is consequence of the first one, namely that our permanent and perennial wetlands are enriched with the addition of alluvium deposited by river floods and flooding which provides and maintains the fertility of the countries floodplain soil. A number of researchers reflected this widely held belief, Hossain et al. (1987) states “floods bring much silt in their wake which is deposited on cultivable lands and increases their fertility”;

‘The copious amounts of silt (2 billion tons per year) fertilize the flooded fields enabling Bangladeshi farmers to grow up to three rice crops per year’ states a UN publication on floods (Miller, 1997);
The fact remains that the raw alluvium of Bangladesh’s major rivers is relatively infertile in the short term. The minerals contained in river alluvium are of kinds that weather relatively slowly. Therefore, they contribute to soil fertility on a long-term basis (i.e., over tens or hundreds of years) rather than immediately in the year of their deposition. In particular, new river alluvium contains little organic matter, and it thus provides little phosphorus or nitrogen that plants could use immediately. Thus the supposed high organic matter content of new river alluvium is itself a widely believed half-truth. The fertility associated with seasonal flooding apparently comes from the flooding itself. It does not come from any sediment brought in by the floodwater. There are four sources of this fertility. Three of them are biological (algae, bacteria, and organic matter); and the other is chemical. In addition, nitrogen provided by leguminous plants benefits crops grown on seasonally-flooded soils as well as those on upland soils that are not flooded.

Belief 1: Himalayan degradation and floods in Bangladesh
The role of deforestation in the upstream area in causing floods in the downstream area of the GBM basins has triggered interesting debates (BWDB, 1987; Thompson and Warburton, 1985; Hofer, 1998; Ives and Messerli, 1989; Rogers et al., 1989). BWDB (1987) indicated that the deforestation in the upstream contributed significantly to the increased rates of sediment supply and accretion. Huda (1989) reported that due to urbanization and agricultural development in India and Nepal, the problems of flooding and sedimentation are worsening. Ahmad (1989) reported in an interview with Reuter on 9 September 1978, Tom Elhaut, who directs IFAD projects in Bangladesh, had stated that disastrous floods sweeping huge area of Bangladesh are now an uncontrollable yearly event and mostly man-made. He had further said that deforestation and soil erosion in the Himalayas had removed natural barriers to the monsoon rains. It was the environmental havoc wreaked by the destruction of Nepalese forests that did the most damage.

Conversely, most of the publications (referred hereinafter) do not report any significant recent increase in the sediment load of the larger rivers and their tributaries, or in the magnitude of annual flooding and levels of river discharge (Ives and Messerli, 1989). Thompson and Warburton (1985) questioned the linkage between massive floods in the plains and land use activities upstream in the Himalayas. However, they noted that there were some technical uncertainties encountered when analyzing the human components of erosion, flooding and shifting hydrological patterns. Hofer (1998) concluded that the land use changes in the Himalayas were not responsible for the floods far downstream in India and Bangladesh. As a consequence of the catastrophic flood in Bangladesh in 1998, there were no grounds for considering deforestation in the Himalayas as a significant cause of the flooding in the delta of the river system (Roger et al., 1989). Carson (1985) mentioned, that the problems associated with sedimentation and flooding in Bangladesh and India are the results of the geomorphic characters of their rivers. People’s efforts to encroach riverside areas and deforestation play a minor role.

Belief 2: Floods are getting worse
Rahman (1989) articulates a view widely held in Bangladesh that the country has experienced floods more often than in recent years. Every year the highest records have been broken by the following year evidently exceeding the damages associated with the floods.

Brammer (2004) argued on the basis of available hydrological data of the Brahmaputra River at Bahadurabad station that flood level and flood frequency have not increased with time. But he agreed that the damages caused by major floods are increasing apparently, mainly due to increasing infrastructure and agricultural development.
Belief 3: Embankments cause riverbeds to rise
A number of researchers (e.g., Ahmad, 1989; Adnan, 1991) have argued that bed level in the rivers confined by the embankment rises due to deposition of excess sediments that result into rising of bed level above the adjacent flood plain. Their concern is partially true in the case of river Gumti and some other rivers in the eastern region, as well as internationally in the case of Mississippi and the major Chinese rivers. But there are other counter agreements also:

- Though the banks of the river Ganges and the Brahmaputra have been embanked the most, but review of FAP 24 (1996) did not find any evidence of the rise in the bed level on the river Ganges and the Brahmaputra, after examining the information from 40 years of record.
- A China-Bangladesh joint study found that narrowing the riverbanks using training works and channel closures could lower the bed level.

Climate Change and Monsoon Flooding

Hydrologic extremes like flood and drought are an expected outcome of the global climate change due to enhanced greenhouse effect. The interactions between increases in greenhouse gases and the hydrological systems are very complex. In a nutshell the interaction between the physical process of climate change and its impact in the hydrologic regime can be viewed as follows:

- Increased temperature will result in changes in evapo-transpiration, soil moisture, and infiltration
- Increased atmospheric carbon dioxide (CO₂) may increase global mean precipitation
- Increased temperature due to warming and increase in the ocean mass (principally from land-based sources of ice like glaciers and ice caps, and the ice sheets of Greenland and Antarctica) will catalyst to rise the global sea level
- Changes in the precipitation event could affect water availability in soils, rivers and lakes with negative implication in the demand-supply equilibrium
- Increased evapo-transpiration enhances the water vapor content in the atmosphere, the greenhouse effect, and the global mean temperature may rise even higher

Under the scope of the current study, particular attention is riverine flood (or monsoon flood), which could be affected by the following climate related phenomena:

- Changed pattern in the frequency and intensity in extreme rainfall event may subsequently increase the intensity of flood
- Rise in the sea level may cause the backwater effect causing the rise in the river water level, or obstacle the upstream discharge to be drained off into the sea
- Increase in the soil moisture may increase the physical runoff or overland flow
- Possible changes in temperature, precipitation and evapo-transpiration may result in a change in soil moisture, groundwater recharge and runoff and could intensify flooding and droughts in various climatic zones.

A review of literatures shows that a number of studies have addressed the physical process
of climate change and its consecutive impact on flood regimes (Gordon et al. 1992; Whetton et al. 1993; Kattenberg et al., 1996; Arnell et al., 1996; McGuffie et al., 1999; Lal et al., 2000; Hu et al., 2000; IPCC, 2001; IPCC, 2007). Lal et al. (2000) found that there is also an increase in intra-seasonal precipitation variability and that both intra-seasonal and inter-annual increase is associated with intra-seasonal connectivity during the summer. IPCC (2001a) concluded that relatively small climatic changes could cause large water resources problem, particularly flood vulnerable area of India and Bangladesh. Flooding is largely dependent upon extreme rainfall events. Gordon et al. (1992) and Whetton et al. (1993) indicate that global warming may produce changes in the frequency of intense rainfall because of possible changes in the paths and intensity of depressions and storms; and possible increase in convective activity. Climate model experiments suggest that rainfall intensity and number of wet spells are likely to increase in greenhouse gas concentrations (McGuffie et al., 1999; IPCC, 2001a; IPCC 2007). Despite this limitation, evidence from climate models and hydrological studies suggest that flood frequencies are likely to increase with global warming, though the amount of increase is very uncertain and for a given change in climate, will vary considerably between catchments (Arnell et al., 1996) and at finer resolutions (Kattenberg et al., 1996; IPCC, 2007).

A number of hydrological models (empirical and water balance modelling carried out by Mirza and Ahmed, 2005; Tanner et al., 2007; IWFM and CEGIS, 2008; CCC, 2009) have been used to assess the impact of climate change on the riverine flooding of Bangladesh. Mirza (2002) identified that future changes in the precipitation regime have four distinct implications: change in the timing of flood due to possible changes in the seasonality, increase in the magnitude, frequency, depth, extent and duration of floods; change in the timing of peaking and change in the likelihood of synchronization of flood peaks of the major rivers, and dramatic change in the land-use patterns in Bangladesh. He also showed that a 20-yr return period flood event in the Ganges, Brahmaputra and Meghna Rivers will be changed to 13-yr, 15-yr and 5.5-yr return period floods due to a possible increase in temperature by 2°C which means the catastrophic flood\textsuperscript{6} events. For extreme level rise in temperature by 6°C, return period of the same frequency catastrophic flood event will reduce by 3.4 times, 2.3 times and 8.5 times for the Ganges, Brahmaputra and Meghna rivers, respectively.

Another study by Tanner et al (2007) reaffirms that there will be uncertain rainfall changes, ranging from large decreases to large increases, as a result of which flooding in Bangladesh will also be extremely uncertain. It is assumed that extreme peak river-discharges are likely to occur more frequently. For example, the recurrence interval for the devastating 1998 flood will reduce from roughly 50 years to 30 years in the 2020s and 15 years in the 2050s. Drainage congestion is already a growing problem in Bangladesh and is likely to be exacerbated by sea level rise. The study suggests an increase in inundated area of up to 3 per cent in 2030s, and 6 per cent in 2050s, with a probable increase in hazard frequency by 2.6 per cent per annum (Figure 13). They have also shown that the onset characteristics of flood in the Brahmaputra, the Ganges and the Meghna Rivers in future (during the period 2040-2060) is expected to be much earlier than the existing condition, which will be very detrimental for boro rice harvesting in the region.

\textsuperscript{6} Range of flooded area 50,000-57,000 sq. km and range of % inundation 34%-38.5%, as classified by Mirza (2001)
The above-mentioned results somewhat contradict the findings of the CLASIC project outputs (IWFM and CEGIS, 2008) which showed from the predictions based on climatic input from all GCMs and RCMs that mostly show decrease in the annual flow volume, wet season flow volume and dry season flow volume of the Ganges as a result of climate change. Other than the Ganges, results for the Meghna are of similar nature to that of the Brahmaputra except that results based on one RCM indicates increase. Some of the results indicate early floods in the Brahmaputra and the Meghna. Most of the results based on RCMs indicate increase in the flooded area. Besides, they have noted a substantial water deficit in future, when northwest and southwest regions are likely to be the worst affected.

Climate models and hydrological studies suggest that flood frequencies are likely to increase with global warming, though the amount of increase is very uncertain and for a given change in climate, will vary considerably between catchments and at finer resolutions.
Mega Floods—impacts and Damages

In Bangladesh, flood is a natural calamity. In most of the rural areas, people have been exposed to it almost every year in the past; they face it now, and probably will continue to cope with it in the future also. But it usually comes into the focus of mass media when the impacts are disastrous for overall economy, human fatalities and also in terms of sector specific unrecoverable losses.

As stated before, the mega flood in Bangladesh has been selected in terms of vulnerability measured by timing and magnitude of the historical major flood events. The timing of flood is generally represented by the return period or probability or recurrence of floods, and magnitude has been represented by the physical, social and economic damage caused by the mega flood. The damage statistics of big floods are shown in the following Table 3, which has been primarily used for the assessment of flood vulnerability.

Table 3: Comparative statistics of flood coverage and impact in Bangladesh

<table>
<thead>
<tr>
<th>Year</th>
<th>Asset losses (million US$)</th>
<th>Fatalities</th>
<th>Affected area ('000 sq km)</th>
<th>Houses damaged ('000s)</th>
<th>GDP current (million US$)</th>
<th>Asset losses as % GDP</th>
<th>Estimated return period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>936</td>
<td>28700</td>
<td>30</td>
<td>NA</td>
<td>12459</td>
<td>7.50%</td>
<td>9</td>
</tr>
<tr>
<td>1984</td>
<td>378</td>
<td>1200</td>
<td>30</td>
<td>NA</td>
<td>19258</td>
<td>2.00%</td>
<td>2</td>
</tr>
<tr>
<td>1987</td>
<td>1167</td>
<td>1657</td>
<td>30</td>
<td>989</td>
<td>23969</td>
<td>4.90%</td>
<td>13</td>
</tr>
<tr>
<td>1988</td>
<td>1424</td>
<td>2379</td>
<td>47</td>
<td>2880</td>
<td>26034</td>
<td>5.50%</td>
<td>55</td>
</tr>
<tr>
<td>1998</td>
<td>2128</td>
<td>918</td>
<td>31</td>
<td>2647</td>
<td>44092</td>
<td>4.80%</td>
<td>90</td>
</tr>
<tr>
<td>2004</td>
<td>1860</td>
<td>285</td>
<td>33</td>
<td>895</td>
<td>55900</td>
<td>3.30%</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Islam and Mechler (2007)

In Table 3, information on impacts in terms of asset losses were set in relation to GDP in the year of the event to calculate losses in relative terms independent of exposure and changes therein. Disaster statistics, as used in this case, list the direct economic losses in terms of impacts on physical structures such as roads, buildings and other assets. The second to last column in Table 3 show those values in terms of GDP and the last column tabulates return periods of events as estimated by Islam (2005). These direct impacts range from 2% of GDP for the 1984 flood (with a suggested return period of 2 years, i.e. a 2 year event) to 7.5% for the 1974 flood event, a 9-year event (Islam N., 2007).

The aim to reduce vulnerability remains significant in Bangladesh as it is constant as the people and societies continue to counteract with the natural hazards. The efforts at reducing the vulnerability can be readily perceived accounting the statistics. The 1998 flood event, considered the largest event so far with an estimated recurrence period of 90 years, incurred relative asset losses of 4.8% of GDP, whereas those losses were much higher in the 9 year floods of 1974. Similarly, fatalities were reduced strongly in the 1998 event (ca. 900) with a much stronger hazard intensity compared to the 1974 disaster (ca. 29,000 dead). In the year of the event the probabilities of economic asset losses as a percentage of GDP, a so-called loss-frequency curve could be
established. Adjustments need to be undertaken in order to arrive at a first-order representation of risk for the present conditions (Islam N., 2007). Moreover, during 1984 the affected area due to flood was unknown that why the Figure 14 shows the asset loss of the five floods in relation to the Table 3.

Figure 17: Comparative analysis for the selection of mega flood in Bangladesh

A bubble chart (figure 17) has been developed using 3-variables, where the timing represents size of the bubble or return period and the other two variables are related to the physical and economic vulnerability. Accounting the combination of the three vulnerability factors, the 1998 flood can therefore be perceived as the principal megaflood that the country has faced in the course of time.

**Flood loss in Bangladesh**

Historical water level and discharge data show that the peak of discharges in the Ganges, Brahmaputra and Meghna Rivers do not occur at the same time in each year. Snowmelt in the Himalayas contributes to the rise of the Brahmaputra that starts during March while at the start of June snowmelt and onset of monsoon causes the Ganges to rise. Owing to the pattern of progression of the monsoon air mass, monsoon rainfall occurs in the Brahmaputra and Meghna rivers earlier than the Ganges River. The flood peaks of the Brahmaputra occur in July and August while peak flows occur in the Ganges in August and September (Tanner et al, 2007).

The onset and withdrawal of the peak flows are shifting. Analysis of discharge measurement collected by BWDB for the last 50 years for Brahmaputra/Jamuna River river at Bahadurabad (Brahmaputra/Jamuna River) show that the peak discharge is increasing. The average timing of peaking has shifted earlier to the first week of August from middle of August but is now in the (Figure 3). On the other hand, records at the Bhairab Bazar station show that the peak discharge of Meghna is decreasing and delaying slightly as it has moved to the last week.
of September from mid July in the late 1970s (Figure 4). At the station Hardinge Bridge on the Ganges, peak discharge is increasing but peaking time is advancing about one day in a decade (Figure 5). If the present trend prevails, the chances of occurrence of coincidence of Ganges and Brahmaputra peaks will be less.

An account of damages to the economy caused by floods shows that there has been a marked rising trend of economic losses (Islam K. M., 2006). It is encouraging, however, to note that the number of reported deaths due to river floods in Bangladesh has a clear decreasing trend (Figure 15).

Figure 18 (A, B): Economic damage and death toll associated with different flood years in Bangladesh
Flood loss to agricultural sector

There exists a strong relationship between (flooding) land-type and cultivars used during monsoon (Kharif-II) season. Susceptibility to yield reduction of a particular variety is higher if the land in question has higher susceptibility of flooding. Land type F0 (highland, intermittent or flooded up to 30 cm) is not flooded (Ahmed, 2006), whereas land type F4 (lowland/ very lowland, flood depth Over 180 cm, Seasonal (>9 months) or perennial flooding (Ahmed, 2006)) is flooded for more than from mid July in the late 1970s (Figure 4). At the station Hardinge Bridge on the Ganges, peak discharge is increasing but peaking nine months of the year with a maximum flood depth of more than 1.8 meters. About 3.3 million hectares are subjected to flood depth of 30 to 90 centimeters. An area of about 0.076 million hectares has a flood depth of more than 1.8 meters, which remains under water for more than nine months in a year (Ahmed, 2006).

Depending on the terrain and topography about 6 million hectares of cultivable land are susceptible to flooding. Severe floods, which cause extensive damages to crops and some damages to property, especially roads, occur at intervals of about 7-10 years (Ahmed, 2006). Catastrophic floods, occurring at intervals of 20-50 years or more, almost totally destroy crops in adjoining floodplains, and also cause considerable damages to houses, roads and other infrastructure (Ahmed, 2006). As argued in various studies, some floods can often be adjusted in agriculture (e.g. through changes in cropping patterns) and are seldom harmful. Flooding often increases the productivity of agricultural land through increase in soil fertility. The agricultural shortfalls in the years/seasons of floods are to some extent compensated by above normal production in the years/seasons in the aftermath (Islam K. M., 2007).

From the following Table 4, it is evident that the flood damage during 1988 was the maximum; though the flood frequency of 1998 flood is almost double than that of 1988 flood. In the recent years, during the 2007 flood, although the flood was represented as a medium category flood but the devastation in the agriculture sector was huge mainly due to repeated occurrence of flood at a short interval.

<table>
<thead>
<tr>
<th>Year</th>
<th>Flood affected area (m.ha)</th>
<th>Percent of total area</th>
<th>Cropped area damaged in m.ha (Damage in million Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>5.70</td>
<td>39</td>
<td>1.21 (36,727.6)</td>
</tr>
<tr>
<td>1988</td>
<td>8.20</td>
<td>61</td>
<td>2.12 (35,462.1)</td>
</tr>
<tr>
<td>1998</td>
<td>10.02</td>
<td>68</td>
<td>1.74 (37,661.5)</td>
</tr>
<tr>
<td>2004</td>
<td>3.57</td>
<td>24</td>
<td>0.19 (6,099.5)</td>
</tr>
<tr>
<td>2007</td>
<td>4.4</td>
<td>30</td>
<td>1.12 (42,165)</td>
</tr>
</tbody>
</table>

Source: Siddiqui and Hossain (2006)

Islam (2006) has conducted an analysis of damage to wet season’s rice crops which shows that historically Bangladesh is damage-prone by 3.7 per cent of production annually (averaged over 37 years). Of this, Aus is subject to annual damage by 4.4 percent and Aman by 3.4 percent.
Islam (2006) investigated that during the disastrous flood of 1998, Aman production fell short by nearly 21 per cent below the normal trend production (Table 5). The shortfall in wet season rice crops together (Aus+Aman) was 20 per cent below the trend production. By contrast, the production of the dry season rice crop (Boro), however, was 10 per cent above the normal trend in the same year. Similar are the findings for the flood of 2004 when the shortfall in wet season rice crops together (Aus+Aman) was 6 per cent below the trend production. The production of the dry season rice crop (Boro), however, was 2 percent above the normal trend. Similarly, in all the years of flood and years in the aftermath, the Boro productions were above the normal trend (Table 5). It has been found that for both the rice crops, Aus and Aman (individually and wet season), there exists a negative correlation along with corresponding flood-affected area and a positive correlation for the Boro as the farmers put an additional effort for the dry seasonal crop (Boro).

<table>
<thead>
<tr>
<th>Flood years</th>
<th>Aus fluctuation from trend (%)</th>
<th>Aman fluctuation from trend (%)</th>
<th>Aus+Aman fluctuation from trend (%)</th>
<th>Boro fluctuation from trend (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>14.9</td>
<td>2.39</td>
<td>5.02</td>
<td>-9.1</td>
</tr>
<tr>
<td>1987</td>
<td>13.55</td>
<td>-6.26</td>
<td>-2.13</td>
<td>0.51</td>
</tr>
<tr>
<td>1988</td>
<td>11.93</td>
<td>-17.72</td>
<td>-11.52</td>
<td>16.13</td>
</tr>
<tr>
<td>1989</td>
<td>0.73</td>
<td>8.68</td>
<td>5.86</td>
<td>15.11</td>
</tr>
<tr>
<td>1997</td>
<td>-1.45</td>
<td>-7.94</td>
<td>-7.29</td>
<td>-9.5</td>
</tr>
<tr>
<td>1999</td>
<td>-2.71</td>
<td>3.85</td>
<td>2.88</td>
<td>7.74</td>
</tr>
<tr>
<td>2003</td>
<td>17.1</td>
<td>8.96</td>
<td>11.48</td>
<td>-3.18</td>
</tr>
<tr>
<td>2004</td>
<td>-0.93</td>
<td>-8.6</td>
<td>-6.05</td>
<td>2.19</td>
</tr>
</tbody>
</table>

Note: N=24 (1981-2004), Trends for the years of flood are highlighted.

**Flood loss to non-agricultural sectors**

Islam (2006), referring to the rapid flood appraisal report of ADB and UNDP for 1998 flood, states that the non-agricultural sectors together (e.g., infrastructure and commercial sectors), including the non-crop sector suffered enormous losses, constituting 51 per cent of the total loss with the agricultural sector (crop plus non-crop) suffering 49 percent of the total loss. The loss situation of the 2004 flood is yet more significant as the non-agricultural sectors suffered loss accounted for as high as 74 percent of the total loss while the remaining 26 percent is attributed to the losses suffered in the agriculture (crop plus non-crop) sector.
Flood impact in the water management infrastructure

The impacts of the 1988, 1998 and 2004 flood are shown in the Table 6. The table shows that the damage to embankments during the 1998 flood was maximum of 2990 km, whereas irrigation and drainage canals and other structures have been destroyed mostly by 752 km and 1465 during 2004 and 1988 flood respectively. The economic cost for repairing water management infrastructures of Bangladesh Water Development Board (BWDB) was huge, for example during 2004 flood, repair and maintenance cost has been estimated as Tk. 7,803 million.

Table 6: Damage to water management infrastructure due to mega flood events in Bangladesh

<table>
<thead>
<tr>
<th>Type</th>
<th>1988</th>
<th>1998</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment (km)</td>
<td>1,990</td>
<td>2,990</td>
<td>2,964</td>
</tr>
<tr>
<td>Irrigation/drainage canals (km)</td>
<td>283</td>
<td>373</td>
<td>752</td>
</tr>
<tr>
<td>Structures (nos.)</td>
<td>1,465</td>
<td>1,031</td>
<td>1,041</td>
</tr>
<tr>
<td>Protection works (km)</td>
<td>265</td>
<td>187</td>
<td>129</td>
</tr>
</tbody>
</table>

Source: Siddiqui and Hossain (2006)

Impact of flood in the transportation sector

Railway

The Bangladesh Railway was hard hit by the devastating floods of 1987, 1988, 1998, 2004 and 2007. Damage figures available up to 2004 are given in the Table 7. It has been found that the length of the damaged track was the highest (i.e. 1053 km) during 1998 and a total of 167 bridges and culverts have been damaged during 1987 flood.

Table 7: Damage to transportation sector due to mega flood events in Bangladesh

<table>
<thead>
<tr>
<th>Flood year</th>
<th>Length of damaged track (km)</th>
<th>No. of bridges and culverts</th>
<th>Cost of rehabilitation (million Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>650</td>
<td>167</td>
<td>790.53</td>
</tr>
<tr>
<td>1988</td>
<td>1053</td>
<td>74</td>
<td>1244.51</td>
</tr>
<tr>
<td>1998</td>
<td>349</td>
<td>86</td>
<td>1020.02</td>
</tr>
<tr>
<td>2004</td>
<td>415</td>
<td>128</td>
<td>1270.00</td>
</tr>
</tbody>
</table>

Source: Siddiqui and Hossain (2006)

Roads and Highways

During 1987 flood, a total of 8500 km of national road, regional and feeder roads were submerged for 7 to 54 days from 23rd July to 24th September. In 1988, 3700 km of national, regional and feeder roads were submerged for two periods: from 27th June to 15th August for 50 days and from 20th August to 3rd October for 44 days. During 1998 and 2004 flood the inundation duration was 70 days and 28 days respectively within the month of July to September.
### Table 8: Damage to roads and highways due to mega flood events in Bangladesh

<table>
<thead>
<tr>
<th>Flood year</th>
<th>Length of road submerged (km)</th>
<th>No. of embankment damaged</th>
<th>Length of pavement damaged (km)</th>
<th>Number of bridge and culvert damaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>1987</td>
<td>8500</td>
<td>2800</td>
<td>1500</td>
<td>225</td>
</tr>
<tr>
<td>1988</td>
<td>3770</td>
<td>3800</td>
<td>1800</td>
<td>600</td>
</tr>
<tr>
<td>1998</td>
<td>9622</td>
<td>4329</td>
<td>4244</td>
<td>1204</td>
</tr>
<tr>
<td>2004</td>
<td>6728</td>
<td>NA</td>
<td>2780</td>
<td>265</td>
</tr>
</tbody>
</table>

Source: Siddiqui and Hossain (2006)

**Impact of flood on health sector**

The chart presented below shows the trend of diarrhea cases and deaths by year from 1985 to 2006, where it is evident that over the period of 1985 to 1998 no of human fatalities caused by diarrhea is maximum and in the later period it has been increasing. The chart below shows the percentage of 4 major diseases. Diarrhea reached above 70% among all diseases in the floods of 2004, and in the remaining floods it reached an average of 35%.

![Figure 19: Comparative analysis of diseases for the selected mega floods in Bangladesh](Source: WHO, 2007)

**Impact of flood on other infrastructure**

The Table 9 below elaborates the comparative severity and impact of the three major floods in Bangladesh for other infrastructures like rural roads, bridge and culverts, growth centers and Ghat or Jetty in the rural area. In terms of damage and rehabilitation cost, impact of 1998 flood was disastrous which required a total rehabilitation cost of Tk. 8250 Million for repairing the above-mentioned infrastructures.
### Table 9: Damage to other social infrastructure due to mega flood events in Bangladesh

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Damage during different floods (total rehabilitation cost in million Tk.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1988</td>
</tr>
<tr>
<td>Rural Road</td>
<td>3015 (1782.00)</td>
</tr>
<tr>
<td>Bridges/Culvert</td>
<td>16240 (1530.00)</td>
</tr>
<tr>
<td>GC/Market</td>
<td>155 (216.00)</td>
</tr>
<tr>
<td>Ghat/Jetty</td>
<td>42 (27.00)</td>
</tr>
</tbody>
</table>

Source: Siddiqui and Hossain (2006)

The growth in population and urbanization is gradually outstripping the carrying capacity of local ecosystems. With vast populations and properties, Dhaka city, for example, is expanding down into the low-lying area on the periphery in most unplanned ways, which has posed enormous environmental threats. Urban flooding has recently emerged as alarming events, which is created by drastic reduction of the low-lying area and thereby destruction of natural drainage system resulting from rapid urbanization and infrastructure development. Drainage congestion continued in the DND (Dhaka-Narayanganj-Demra) area for more than a month, even with a short duration flood such as the 2007 event. This is a burning example of water logging due to drainage congestion that occurred as a result of not adequately considering the natural inflow and outflow of water during the planning and implementation stages. Poor operations and maintenances of the structure also have contributed to the disaster. Urban flood losses are thus becoming more and more important in Bangladesh. Controlled flooding is obviously not an appropriate strategy in urban area, as often as the case in agriculture. Protection of urban and commercial centers thus demands a high priority.

## Evaluation of Flood Management Measures

### Flood control efforts in Bangladesh

Historically, water and flood management policies have been dominated by structural measures, as is evident from massive investments particularly in the agricultural projects in Bangladesh. Prior to the disastrous floods of 1954 and 1955, there was very little flood control activity in this region. After this, the United Nations Commission, prepared the first and the most important document on water development of Bangladesh in 1957. The report reveals that the combination of high rainfall within the country itself and high flows from upstream across its border popularly known as Krug Mission, named after its Team Leader.

Following the recommendations of the Krug Mission, the Water and Power Development Authority (WAPDA) was established in 1959 and assigned the task of developing water resources in Bangladesh. As a consequence, WAPDA took the task of construction of massive large-scale flood embankments. Although the Krug Mission report had also recommended for increasing the capacity of river flow and improving drainage capacity, but at that time it was neglected. Meanwhile, a number of experts (John R. Hardin, 1960; Thijsse, 1964) suggested measures for...
tackling flood problem focusing mainly on structural measures. Hardin (1960) proposed channel improvement together with improvement and confinement of flood flow by embankments and drainage improvements. It also focused on practical problems of constructing flood regulation measures in Bangladesh, as it is located in a flat terrain. Prof. Thijssse (1964) also suggested the construction of embankments along with channel improvement as a means of reducing the flood flow. In addition to this, he put particular emphasis on scientific studies of the rivers, and suggested that before taking any actions with regard to a river channel it should be imperative to evaluate the effects that it would produce.

Since 1965 the World Bank became associated with the water and agriculture development program of Bangladesh. The bank have recommended a shift in the strategy from large scale engineering projects to small scale FCD schemes: low lift pump (LLP), shallow tube well (STW), deep tube well (DTW) and improved cropping practices were encouraged for achieving self-sufficiency in food. This shift in policy, relying mostly on small-scale projects, continued until again Bangladesh was devastated successively in 1987 and 1988. Before this, the Master Plan Organization (MPO) that was established in 1983 with an aim to prepare national water resources planning submitted its first phase of final report in 1986. But the MPO was not specifically mandated to deal with disastrous floods other than the structural measures like FCD and FCD/I related works.

Work began soon after the 1988 flood, on the Flood Policy Study and the Flood Preparedness Study. It was carried out by a team of local and expatriate professionals along with assistance from the UNDP, which was completed in the early 1989. Simultaneously, three other studies were also carried out: Report on Survey of Flood Control Planning in Bangladesh, sponsored by the Japanese Government, Pre-feasibility Study of the Flood Control in Bangladesh funded by the French Government and the Eastern Waters Study sponsored by USAID. (Banglapedia, 2013)

The Government of Bangladesh in the meanwhile had requested the World Bank (WB) to coordinate efforts at mitigation of flood problems in Bangladesh and at the same time the international community also stressed the need for a coordinated action in the G7 Summit held in Paris in July 1987. Accordingly, the WB coordinated the preparation of a flood action plan, reviewed the findings from various studies and finalized a Flood Action Plan (FAP) in November 1989. The FAP comprised of 26 components as an initial stage in the development of a long term comprehensive system of flood control and drainage works in Bangladesh. Although implementation of the plan has not progressed as expected due to various delays and confusions, a review of the plan remained valid up to 2001 till the development of National Water Policy (NWPo, 1999) and National Water Management Plan (WARPO, 2004). FAP outputs were mainly criticized for its scant attention to the wider economic, environmental and social consequences of large engineering projects. Another drawback was evident that the inherent weakness of the compartmentalization concept, which have lead to a new term human-made ecological disasters (Ali et al. 1998), such as inlets and outlets are silting up and fields becoming clogged. Furthermore, the limitation of the FAP study was that it had only considered the river flood in the Policy Plan; flash flood and rainwater flood were mostly ignored.

WARPO (2004) is a major breakthrough from the traditional bias towards structural mitigation of flood. It focuses on establishing equilibrium from the demand-supply perspective. It strongly emphasized on the integrated management perspectives where the planned activity programs were presented under eight sub-sectoral clusters: institutional development, enabling
environment, main rivers, towns and rural area, major cities, disaster management, agriculture and water management. Although in the NWMP it was proposed for a periodic review of the implementation of the 84 activity program, but till to date no such review has been made and it has been suffering from the same sluggishness as the outcome from FAP and several other studies faced during implementation. Recent occurrence of 2007 flood has once again reminded Bangladesh about the importance of non-structural measures, especially in the case of emergency management.

A brief list of structural and non-structural measures implemented in Bangladesh is given below:

<table>
<thead>
<tr>
<th>Structural Measures</th>
<th>Non – Structural Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal Polders</td>
<td>Flood zoning</td>
</tr>
<tr>
<td>Embankments or Flood walls</td>
<td>Flood proofing</td>
</tr>
<tr>
<td>Regulators</td>
<td>Flood fighting</td>
</tr>
<tr>
<td>Sluices</td>
<td>Flood insurance</td>
</tr>
<tr>
<td>River closures</td>
<td>Flood evacuation and shelter management</td>
</tr>
<tr>
<td>Submersible Embankments</td>
<td>Flood related rules and regulations</td>
</tr>
<tr>
<td>Channel Improvement</td>
<td>Changes in cropping pattern</td>
</tr>
</tbody>
</table>

**Flood management measures**

The factors such as failure of structural measures providing full security, added flood losses due to false sense of security, insufficient maintenance plus increased concern for related recently changed past issues of the environment, along with emphasis towards non-structural measures have been advocated in many studies.

"**FAP outputs were mainly criticized for its scant attention to the wider economic, environmental and social consequences of large engineering projects. Another drawback was evident that the inherent weakness of the compartmentalization concept, which have lead to a new term human-made ecological disaster. WARPO (2004) is a major breakthrough from the traditional bias towards structural mitigation of flood. It focuses on establishing equilibrium from the demand-supply perspective. It strongly emphasized on the integrated management perspective**"
Structural measures

Coverage
The common structural measures are embankment, polder, dwarf embankment, dam, barrage, regulator, sluice, cannal improvement and river closure. Structural adaptation for providing the current flood protection coverage is shown in Figure 20. In Bangladesh BWDB (and in recent years LGED) is the key actor for planning, implementation and monitoring of the structural adaptation measures.

Till 2006, BWDB completed a total of 684 small, medium and large scale water sector development projects, of which a total of 473 small, medium and large-scale projects include FCD and FCD/I projects. These projects provided flood control and drainage facility to a 5.89 million ha of land. As a part of this, a total of 9,943 km of embankment, 13,949 floods control/regulating structures, 5,111 kms of drainage canals have been constructed (BWDB, 2006). Region-wise distribution of 473 major FCD and FCDI projects is shown in Table 10.

<table>
<thead>
<tr>
<th>Region</th>
<th>No. of projects</th>
<th>Gross area (mha)</th>
<th>Range in ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>North-West</td>
<td>104</td>
<td>3.16</td>
<td>150-526316</td>
</tr>
<tr>
<td>North-East</td>
<td>69</td>
<td>0.64</td>
<td>355-81000</td>
</tr>
<tr>
<td>South-East</td>
<td>47</td>
<td>0.68</td>
<td>200-150000</td>
</tr>
<tr>
<td>South-West</td>
<td>73</td>
<td>1.79</td>
<td>200-384396</td>
</tr>
<tr>
<td>South-Central</td>
<td>22</td>
<td>0.58</td>
<td>720-154084</td>
</tr>
<tr>
<td>Total</td>
<td>473</td>
<td>8.79</td>
<td>150-526316</td>
</tr>
</tbody>
</table>

Source: Water Development Board, 2006
Evaluation of effectiveness of structural adaptation

**Overall Impact of Flood Control Projects**

**Impact of Flood Control Project in inland area**

Every year normal flood inundated one fifth of the total area of Bangladesh (147,570sq km). In 1988, three fourth area of the country were flooded severely, even the Dhaka city, the capital of Bangladesh, flooded quite extensively (70% of the total area). The Government then undertook and completed an emergency project of constructing approximately 30 km of the earthen embankment, 37 km of floodwall, 7 sluices and one pumping station. A study by Khondaker and Chowdhury (1992) revealed that the majority of the people are benefited from flood hazard through siltation in the agricultural land though it has created severe drainage congestion, water logging at several location.

There are about 50 beels in the north-west region whose surface area varies from 10 hectare to 607 hectare while the depth varies from 0.3m to 3.0m. Since 1970, a large number of polders by peripheral embankments have been constructed in the region to protect rice from monsoon flooding. In general, effect on crop production have, in general, been positive due to increased facility, but the same study report (Development and Climate Change Study on Bangladesh by OECD, 2003) found that the FCD projects across the board have had a major adverse effect on capture fisheries, due to reduction in the area of permanent water bodies and blockage of fish migratory routes.

In the northeast region there are about 47 haors of 8,000 sq.km area (Ali, 1990). Many of these haors are provided with partial flood control projects. Constructing submersible embankments around the area against pre monsoon flooding provides protection of winter crops.

**Poldering impact on the south-west (coastal) region**

The land of coastal area in southwest region is very flat and comprises numerous low-lying beels. As the entire coastal area of the land lies below the high tide level, it was subjected to periodic flooding with saline water. The polders were given gravity drainage outlets to drain excess water of local rainfall into the surrounding tidal river. Initially, the projects have helped in increased crop production but now are beset with many environmental problems. The combined effects of this poldering development have resulted in progressive silting up of the tidal rivers and creeks, drainage congestion in the poldered area, stoppage of land formation, and increased level of water and soil salinity (Shahjahan and Hossain, 1991).

The most severely affected among the poldered area is Beel Dakatia. It is reported that all the outfall of the polders are silted up and surrounding river beds are now 0.6m to 1.2m higher than the average ground level within the polder (ADB, 1986). Resulting resultant drainage congestion due to impedance of gravity flow has created a deep-water ponding within the polder. Decade-long water logging has resulted in destruction of croplands, trees and other vegetation covers, inundation of homesteads, change in composition of soil and water in such a way that it is retarding fisheries and other aquatic life forms (Adnan, 1991).

**Evaluation of the Effectiveness of Structural Adaptation**

The performance of the Flood Control Drainage (FCD) projects, and Flood Control Drainage and Irrigation projects so far, indicate that water conservation and irrigation scheme have the potential of being more successful in terms of agricultural production than purely FCD projects.
Embankments are the most popular type of structural measures used for protecting the agricultural lands, small towns and major cities that are designed to combat floods of 1 in 10 year, 1 in 25 year and 1 in 50 year return periods. But from the experience of 1998, 2004 and 2007 floods, which have occurred after the Flood Action Plan (FAP) era, it has been revealed that existing embankments are inadequate in adapting to the mega floods.

An earthen embankment is not a permanent solution for flood protection; it may fail due to, breaching and/or erosion of the river bank. It is very difficult to prevent breaching due to complex geo-morphological and socio-economic factors in Bangladesh. Damage due to embankment failure is very high due to increased economic activities after the project and high flow velocity. The issue of man-made hazard should be given due attention during planning studies (Chowdhury, 1991).

River erosion is an added problem that continually threatens the very existence of the embankments. The deltaic plain constituting Bangladesh is young and periodically undergoes changes since 1936. Table 11 (Huda and Chowdhury, 1989) reveals the extent of bank erosion of various rivers prior to the flood of 1987, where they showed that the problem is worst in the Brahmaputra Right Embankment project where breaching occurred nine times repeatedly since 1968.

Another type is dwarf embankment, which is provided for the protection of pre-monsoon boro crops, allows to be overtopped during the monsoon. This type of embankments are constructed in the flash flood zone of north-central and northeastern part of the country, which are the appropriate and eco-friendly examples of living with flood rather than to control it. Although, there exists some strong opposition against the correlation between the construction of embankment and riverine flood, Hughes et al. (1994: 21) stated: *ironically, embankments serve to prevent ‘normal floods’ whilst failing to prevent ‘abnormal floods*, thus reducing the beneficial functions of normal flooding. Besides, embankment, different kinds of river structures, e.g., regulators, sluices, dams and barrages were constructed as a part of flood mitigation.

<table>
<thead>
<tr>
<th>River</th>
<th>No. of location of bank erosion</th>
<th>Length of erosion (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brahmaputra</td>
<td>38</td>
<td>160</td>
</tr>
<tr>
<td>Ganges-Padma</td>
<td>30</td>
<td>94</td>
</tr>
<tr>
<td>Meghna</td>
<td>6</td>
<td>13</td>
</tr>
<tr>
<td>Teesta</td>
<td>8</td>
<td>35</td>
</tr>
<tr>
<td>Minor rivers</td>
<td>18</td>
<td>31</td>
</tr>
<tr>
<td>Flashy &amp; Others</td>
<td>165</td>
<td>78</td>
</tr>
<tr>
<td>Tidal rivers</td>
<td>18</td>
<td>83</td>
</tr>
</tbody>
</table>

In the coastal zone, for protecting the land from storm surge and salinity, ring-embankment or polders have been constructed for 1 in 25 year storm surge and 1 in 10/15 year tidal flood protection. But during the devastating cyclone of 1985, 1991 and 2007, this protection has been found very inadequate.
The residual impact of embankment on environment is deteriorating day-by-day, causing huge drainage congestion inside the embanked area destroying the natural wetlands and perennial water bodies. Embankments are preventing normal seasonal movements of fish and consequently affect capture fisheries, and this can worsen when drainage results in reclamation of beels. Whereas flood control can reduce groundwater recharge, embankments can worsen floods outside the embankment and hence increase the impact on the people and land use in the unprotected area. There are always losers and winners when embankments are built and their complex social impacts must be thoroughly considered. Public cuts on the embankments are sometimes made either to reduce water levels or to admit needed water where levels differ on opposite sides.

Therefore, in the long run, structural measures for flood control, as a sustainable solution for adapting to flood may be self-defeating. Viability of flood management projects need to be assessed on risk based consideration rather than conventional benefit-cost consideration. Proper floodplain land use regulation should be adopted to reduce flood damages. Actually, the approach to flood loss reduction thus needs to be based on multi-disciplinary perspectives (e.g. engineering, behavioral and socio-economic), rather than only engineering ones. This concept actually triggers the need for adaptation through non-structural measures.

Non-structural measures: response process and warning

Evolution of organized disaster preparedness in Bangladesh

Organized disaster preparedness in Bangladesh can be said to have started with the formation of the Cyclone Preparedness Program (CPP). After the devastating cyclone of 1970 when half a million lives were lost, the League of Red Cross, now the International Federation was requested by the UN General Assembly to undertake a leading role in pre-disaster planning for the country. The Cyclone Preparedness Program (CPP) of Bangladesh Red Crescent Society (BDRCS) came into being in 1972. In June 1973, the Government of Bangladesh approved CPP and undertook the financial responsibility for some of the recurring expenses and setup a joint program management mechanism by creation of a Policy Committee and an Implementation Board.

The Ministry of Relief and Rehabilitation was created in 1972 with a view to providing relief and rehabilitation to the disaster affected people in the country. This ministry was vested with the responsibilities of formulation of policy and plan, and implementation of relief and rehabilitation activities. In the year 1982, Ministry of Relief and Rehabilitation was transformed into a division under the Ministry of Food; later in 1988, it was again made the Ministry of Relief.

On the 29th of April 1991, the southeastern part of the country was hit by a devastating cyclone killed an estimated 150,000 people and caused extreme damage to property (Banglapedia, 2006). Soon after, a short-term project was started called the Assistance to Ministry of Relief in Coordination of Cyclone Rehabilitation. During the implementation of the project, the Project Steering Committee (PSC) in one of its meetings on 28 January 1993 endorsed the concept of the specialist disaster management unit as one of the outcomes of the project. In compliance with this endorsement, the Government of Bangladesh (GoB) had established the Disaster Management Bureau (DMB) in April 1993 to act as a successor to the Disaster Coordination and Monitoring Unit (DMB, 2010).
In 1994, this ministry was renamed as the Ministry of Relief and Rehabilitation and in 2004, it was merged with the Ministry of Food and to date is called the Ministry of Food and Disaster Management. Ministry of Food and Disaster Management has been divided into two divisions namely: Food Division and Disaster Management and Relief Division considering the extent of damages and losses in recent years. The latter is consisted of the Disaster Management Bureau (DMB) and the Directorate of Relief and Rehabilitation (DRR) (DMB, 2010).

Regulatory instruments for disaster preparedness and response

The Standing Orders on Disaster (SOD) was the first, and until recently, the sole guiding principle for disaster management related activities in Bangladesh. The SOD is a comprehensive document which details out the roles and responsibilities of different government agencies and the humanitarian organizations concerning disaster management at all levels. The first SOD was formulated in the year 1997 in Bangla and was modified and translated into English in 1999. The revision of the first SOD was felt necessary with a view to making it more comprehensive and also to make it up-to-date in line with various national, regional and international issues and agenda (for instance, the 2004 and 2007 floods and 2007 cyclone Sidr in Bangladesh; the SAARC Framework of Action 2006-15 for comprehensive disaster management and emergency preparedness; World Conference on Disaster Reduction 2005 in Kobe, Japan).

Besides detailing out the roles and responsibilities of all government line agencies, another major task that has been carried out in the SOD is the formation of two sets of committees at national and local levels for coordination of disaster preparedness and emergency response activities. Of the 13 national level bodies, the apex is called the National Disaster Management Council (NDMC) with the Prime Minister in the chair. At the local level, there are five-tier committees starting from City Corporation and District through Upazilla (sub-district) and Pourashava (municipality) to Union. While the responsibilities of all of these committees are focused on comprehensive disaster risk management with an emphasis on risk reduction, there is another group of committees for Disaster Response Coordination to ensure enhanced response at these levels.

The Disaster Management Act, once enacted, will be the legal basis for disaster risk and emergency management in Bangladesh. The Disaster Management Act, as outlined in the draft, duly addresses the need for strengthening early warning system and also the operations for effective response and rescue activities (DMB, 2010).

The National Disaster Management Council (NDMC) for the period 2010-2015 has approved Disaster Management Act to keep the provision for National Disaster Management. The National Disaster Management Plan puts the Disaster Management and Relief Division as principal for disaster risk reduction and emergency management planning in Bangladesh. Thereby, implying the incorporation of hazard specific plans and the local level plans, down to the lowest administrative unit, for this case the Union Council.
### Figure 21: Policy and Coordination mechanism as outlined in the SOD (adapted from DMB, 2010)

<table>
<thead>
<tr>
<th>Regulatory Framework</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>National Mechanism for Policy Guidance and Coordination</td>
<td></td>
</tr>
<tr>
<td>National Disaster Management Council (NDMC)</td>
<td></td>
</tr>
<tr>
<td>Inter-Ministerial Disaster Management Coordination Committee (IMDMCC)</td>
<td></td>
</tr>
<tr>
<td>National Disaster Management Advisory Committee</td>
<td></td>
</tr>
<tr>
<td>Earthquake Preparedness and Awareness Committee (EPAC)</td>
<td></td>
</tr>
<tr>
<td>National Platform for Disaster Risk Reduction (NPDRR)</td>
<td></td>
</tr>
<tr>
<td>National Disaster Response Coordination Group (NDRCG)</td>
<td></td>
</tr>
<tr>
<td>Cyclone Preparedness Programme (CPP) Policy Committee</td>
<td></td>
</tr>
<tr>
<td>CPP Implementing Board</td>
<td></td>
</tr>
<tr>
<td>Committee for Speedy Dissemination and Determination of Strategy of Special Weather Bulletin</td>
<td></td>
</tr>
<tr>
<td>Committee for Focal Points Operational Coordination Group</td>
<td></td>
</tr>
<tr>
<td>Coordination Committee of NGOs Relating to Disaster Management</td>
<td></td>
</tr>
<tr>
<td>Disaster Management Training and Public Awareness Task Force (DMPTPATF)</td>
<td></td>
</tr>
<tr>
<td>Supporting Role of Ministry of Food and Disaster Management</td>
<td></td>
</tr>
</tbody>
</table>

### LOCAL LEVEL POLICY AND COORDINATION

<table>
<thead>
<tr>
<th>LOCAL LEVEL POLICY AND COORDINATION</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>City Cooperation Disaster Management Committee (CCDMC)</td>
<td></td>
</tr>
<tr>
<td>District Disaster Management Committee (DDMC)</td>
<td></td>
</tr>
<tr>
<td>Upazila Disaster Management Committee (UzDMC)</td>
<td></td>
</tr>
<tr>
<td>Pourashava Disaster Management Committee</td>
<td></td>
</tr>
<tr>
<td>Union Disaster Management Committee</td>
<td></td>
</tr>
<tr>
<td>Local Disaster Response Coordination Group (LDRCG)</td>
<td></td>
</tr>
<tr>
<td>City Corporation Disaster Response Coordination Group (CCDRCG)</td>
<td></td>
</tr>
<tr>
<td>District Disaster Response Coordination Group (DDRCG)</td>
<td></td>
</tr>
<tr>
<td>Upazila Disaster Response Coordination Group (UDRCG)</td>
<td></td>
</tr>
<tr>
<td>Pourashava Disaster Response Coordination Group (PDRCG)</td>
<td></td>
</tr>
<tr>
<td>Meeting and Responsibility LDRCG</td>
<td></td>
</tr>
<tr>
<td>Local Level Multi-Agency Disaster Incident Management System</td>
<td></td>
</tr>
</tbody>
</table>
Apart from the government domain, there is the Disaster Emergency Response (DER) Group to complement the government’s coordination role in emergency response. DER is a key national forum that brings together government, NGOs, donors and UN agencies to improve effectiveness and efficiency of emergency response. It is one of the sub-groups of the Bangladesh Local Consultative Group. The main objective of the DER group is to enhance the operational systems to ensure an effective preparedness and a more coordinated response from the humanitarian community (LCG Bangladesh, 2011). The Ministry of Food and Disaster Management of the Government of Bangladesh is the DER Chair while the United Nations World Food Program (WFP) serves as the DER secretariat. The Standard Operating Procedures (SOPs) of the United Nations Country Team (UNCT) in Bangladesh is considered as the guiding principle for the activities of the DER group.

The preparedness and response mechanism

Preparedness

The institutional setups and the regulatory instruments discussed in the previous sections outline a part (strategy, policy, institutional structure) of the preparedness activities; the other part, according to the ISDR definition of ‘preparedness’, includes forecasting and warning issues.

Bangladesh Meteorological Department (BMD) is responsible for providing forecasts and issuing warnings for severe weather phenomena such as tropical cyclones, tornadoes, nor’westers, heavy rainfall, etc. Within BMD, there is a Storm Warning Center (SWC) that dedicatedly works on storm and cyclone issues. For floods, the responsibilities are vested with the Flood Forecasting and Warning Center (FFWC) under Bangladesh Water Development Board (BWDB). The Disaster Management Information Centre (DMIC) at the DMB keeps abreast of developments of any threats through collaboration with these two warning issuing agencies. It is then the responsibility of the Bureau to ensure receipt of warning signals for imminent disasters by all concerned officials, agencies and mass communication media. Currently, flood forecast is provided by the Flood Forecasting and Warning Center (FFWC) of BWDB for 50 stations and flood monitoring is conducted for another 30 stations where forecasting is provided for lead time of 24 and 48 hours at a confidence level of 90-95% (Siddiqui and Hossain, 2006).

Figure 22: Flood Forecasting and Warning process at FFWC (adapted from FFWC)

Response

The post disaster activities start with a rough estimation of loss and damage. This is done with the filling up of the SOS Form (DMB, 2010). The SOS form is a statement of the approximate loss and damage and emergency requirement. This is carried out at the Upazila level within one hour of the occurrence of flood. It includes information on affected area and people and checks the
nature of intervention required in that particular area. The collected information is sent through the Upazila executive officer to the district headquarters and then to the Emergency Operation Centre (EOC) at the Disaster Management Bureau (DMB). A detailed account of loss and damage at Upazila level is prepared using the Form D (DMB, 2010). It compares the baseline status of population, infrastructure and services in a particular Upazila with the post-disaster situation to draw a comprehensive picture of the impact of the disaster event.

The Disaster Emergency Response (DER) Group in Bangladesh has devised other tools for the assessment of loss and damage in disaster. The Rapid Initial Report (RIR) gives a brief account on the state of the affected population, their assets and infrastructures to identify the level of intervention required in an area. The RIR is suggested to follow for collecting Union or Upazila level damage and loss information and is required to be carried out within 12-48 hours after the occurrence of a disaster. The other tool that DER Group has devised is called the Rapid Emergency Needs Assessment (RENA). The RENA is targeted to identify how badly an area has been impacted by a disaster event and their coping capacity. It helps to determine the need for response and identifies the methods of timely and effective delivery (LCG Bangladesh, 2010). The RENA carried out at the Upazila level to build blocks for the district level, is a very comprehensive tool that collects gender and age segregated population information. Besides, it has a provision to identify extremely vulnerable groups based on gender, age, health condition, ethnicity and other social parameters. Furthermore, the need for external assistance on immediate, short-term, medium-term and long-term basis can be identified with regard to life and livelihoods services.

Figure 23: Disaster Emergency Response (DER) Group information flow chart

(Source: LCG Bangladesh, 2011)
Evaluation of non-structural adaptation measures

Early warning has enormous damage-reducing effects. However, formal warning systems in Bangladesh sometimes do not perform satisfactorily. The warnings in Bangladesh need to be understandable and effective. A supposedly false warning can have adverse effects on future warnings. This was the case in a study area- Bahubal- case study of flash flood (GBV Bangladesh, 2013)- where a considerable number of people did not pay heed to the warning message because few days earlier a warning message on an impending flash flood was issued which did not actually occur. In another study area (Khatunganj - tidal flood), very few people believed the warning while some could not understand the language of the warning signals issued (ibid).

Below are some limitations of the present flood bulletin:

- Information most users indicated they needed not included in the bulletin;
- Specific identification or title on the issuance not provided
- Distinction between flood warning and daily river forecasts;

A concise format for dissemination by public radio or TV transmission is not available. Existing flood forecast and warning programs require six basic elements in order to provide accurate, timely, and useful and user-friendly hydrologic warnings and forecasts. The six elements are:

- Trained hydrologist and hydrologic technicians
- Hydrologic forecast model
- Data collection network
- Dissemination system
- Training: government and public
- Regional, area and local preparedness plans

It is important to note that any weaknesses of the above components will seriously compromise the success of the forecast and warning operation. In Bangladesh the present organizational structure is designed to be more reactive than proactive, especially at the Ministerial level of governments.

Reducing vulnerability or resilience-building through warnings, emergency preparedness and responses can be regarded as a major non-structural approach of flood loss mitigation. Experience shows that lack of emergency preparedness (which needs to exist at local levels), including infrastructural adversities (e.g. power failure and disruptions to roads and communication networks) contribute significantly to the vulnerability during floods (Islam 2006).

Experience shows that lack of emergency preparedness (which needs to exist at local levels), including infrastructural adversities (e.g. power failure and disruptions to roads and communication networks) contribute significantly to the vulnerability during floods (Islam 2006)
Summary of Learning

- Historical occurrence of floods in Bangladesh correlates well with the flood history of the Indian Brahmaputra plain (Assam).
- Four of the most extensive floods in the period 1954–2004 occurred after 1986 (1987, 1988, 1998, 2004) and two record floods (1988 and 1998) have a return period of 100 years or more. 1998 flood was around a 100-year return period flood which was followed by the 1988 flood of 55-year return period flood, whereas 1974, 1987 and 2004 floods are around 10-year return period floods.
- 1998 flood can be treated as the main Mega Flood Bangladesh has ever experienced. Some of the notable impacts on different sectors were:
  - Aman production fell short by nearly 21 per cent below the normal production trend and the shortfall in wet season rice crops together (Aus+Aman) was 20 per cent below the production trend
  - Damage to embankments were maximum 2990 km
  - Inundation of major roads and highways were for maximum 70 days
  - Total cost for rehabilitation of other social infrastructure was around Tk. 8250 Million
- Recurrence interval for the devastating 1998 flood will reduce from roughly 50 years to 30 years in the 2020s and 15 years in the 2050s due to change in climate.
- Existing embankments are inadequate in adapting with the mega floods but on the other hand, the residual impact of embankment on environment is deteriorating day-by-day, causing huge drainage congestion inside the embanked area, destroying the natural wetlands and perennial water bodies.
- Flood forecasting is provided with a lead-time of 24 and 48 hours at a confidence level of 90-95%. However, formal warning systems in Bangladesh sometimes do not perform satisfactorily. The warnings in Bangladesh need to be understandable and effective.
**Recommendations**

**Regional cooperation**

It was elaborated in section 2.8 that mega flood events as well as yearly recurrent flooding events not necessarily evolve from local hydrological phenomena; rather it is often dominated by hydrological characteristics in the upstream basins. It is also to be noted that upstream hydrology is somewhat perturbed due to anthropogenic responses, i.e., construction of dams and reservoirs, upstream water diversion and withdrawal, etc. Therefore, a joint research can be initiated by incorporating all the country parties to explore the specific modalities for this approach.

**Flood zoning and risk mapping**

A number of GO and NGO research initiatives have been undertaken to develop a geo-spatial portrayal of flood hazard all over the country, including the effect of climate change. Risk analysis and monitoring is required prior planning for any intervention. Integrated risk analysis is required, i.e., not only mapping the hazard but also incorporating location specific vulnerability information of biophysical and infrastructural components need to be developed.

**Rationalization and adequate maintenance of existing fcd projects**

To prevent failure of flood protection measures such as embankments or infrastructure, investigation is required on how to make the existing infrastructure for drainage, such as sluices, drainage channels, etc. functional. In this case, specific recommendations made by national and international case studies (the case of rivers Gumti, Mississippi and the rivers of China) can be consulted to check the economic and technical feasibility of the proposed interventions.

**Flood management modeling**

Flood management modeling should be completed and integrated with development projects. Existing flood management models should be recast incorporating existing infrastructure and land use classes.

**Erosion prediction and monitoring**

To protect the existing flood management infrastructure, analysis is needed regarding how to best use available modeling and GIS technology, to implement erosion projections and monitoring in a way that is consistent nationwide.

**Drainage improvement**

As elaborated in earlier sections, there exist a number of perceptions and beliefs about the negative impacts of embankments in terms of raised bed level in the confined rivers. Thus, investigation needs to be done regarding how to improve natural drainage systems in such a way as to bring back original conveyance capacity of the rivers. Furthermore, investigation needs to be done on dredging the off-take of rivers and if this will beneficially impact the flood distribution in wider area.

**Integrated floodplain management**

Investigation is required regarding what the local people of the floodplains want, and how to integrate the water management principles with development practices in the best way.
Urban flood management
Further study is required regarding drainage congestion in urban area, if it is an increasing phenomenon, and why. There also needs to be investigation done to see how to free up drainage routes or otherwise decrease water logging. In addition, the proper way to construct water infrastructure considering urban development in the future will also need to be investigated.

Improvement of lead-time for flood forecast
The lead-time that is suitable for the flood preparation activities determined and depends on the investigation. Correspondingly, it also depends on how lead times can be increased and if so then can they be augmented by the climate forecasts.

Flood proofing and shelters
Investigation is required to see if full flood protection would be economically viable in the lowland area of Bangladesh, and what the impacts of forgoing protection measures may be, socially and ecologically. Further options for flood mitigation should be investigated, including building clustered habitats with amenities.

Flood response
Gaps in the flood response system are needed to be identified. This can be done by observing the current system and analyzing how well it works and how efficient it is, and considering methods to improve the system, and then investigating how those changes would affect flood response systems, as well as how to actually implement such changes.

Possible changes include developing and updating the Standing Orders for Disaster Management, developing and implementing an ICT based flood response system, including a nation-wide network of flood information database, increasing awareness raising efforts, and training and capacity building among workers, volunteers, and NGO staff.

Methods for flood damage assessment
At the present, there are no methods or tools available in the country to get reliable data on flood damage. In order to develop such tools or methods, study should be done on how to most accurately and reliably collect and report such data.

Coordination
The current system of flood management should be analyzed for gaps in transparency and coordination and should be identified in order to facilitate better coordination in the future.

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APPENDIX A:
Chronology of Mega Flood

1781  Serious flood, which was more pronounced in the western part of Sylhet district. The cattle suffered much from the loss of fodder.

1786  Floods in the Meghna wrought havoc to the crops and immense destruction of the villages on the banks. It was followed by a famine, which caused great loss of life at Bakerganj. At Tippera the embankment along the Gumti gave way. At Sylhet the parganas were entirely under water, the greater part of the cattle drowned and those surviving were kept on bamboo rafts.

1794  The Gumti embankment burst again, causing much damage around Tippera.

1822  Bakerganj division and Patuakhali subdivision were seriously affected, 39,940 people died and 19,000 cattle perished and properties worth more than 130 million taka were destroyed. Barisal, Bhola and Manpura were severely affected.

1825  Destructive floods occurred at Bakerganj and adjoining regions. There were no important embankments or other protective works against inundation in the district.

1838  Heavy rainfall caused extensive inundation at Rajshahi and a number of other districts. The cattle suffered much from loss of fodder and the people were greatly inconvenienced when driven to seek shelter on high places and when the water subsided cholera broke out in an epidemic form.

1853  Annual inundation was more pronounced than usual in the west of Sylhet district, partly the result of very heavy local rainfall and partly caused by the overflow of the Meghna.

1864  Serious inundation when the embankment was breached and the water of the Ganges flooded the greater part of Rajshahi town. There was much suffering among the people who took shelter with their cattle on the embankment.

1865  Extensive inundation caused by the annual rising of the Ganges flooded Rajshahi district. Excessive rainfall seriously affected Rajshahi town.

1867  Destructive flood also affected Bakerganj. Crop was partially destroyed. But no general distress resulted.

1871  Extensive inundation in Rajshahi and a few other districts. Crops, cattle and valuable properties were damaged. This was the highest flood on record in the district. Cholera broke out in an epidemic form.

1876  Barisal and Patuakhali were severely affected. Meghna overflowed by about 6.71m from the sea level. Galachipa and Bauphal were damaged seriously. A total of about 215,000 people died. Cholera broke out immediately after flood.

1879  Flooding of the Teesta when the change in the course of the Brahmaputra began.

1885  Serious floods occurred due to the bursting of an embankment along the Bhagirathi, affected area of Satkhira subdivision of Khulna district.
1890 Serious flood at SATKHIRA caused enormous damage to cattle and people.

1900 Due to the bursting of an embankment along the Bhagirathi, Satkhira was affected.

1902 At Sylhet the general level of the river went so high that there was terrible flood. Crops and valuable properties were damaged.

1904 The crops in some parts of COX'S BAZAR subdivision and KUTUBDIA island were damaged due to an abnormally high tide. This flood was exceptional in severity in MYMENSINGH. The distress caused on this occasion is probably the nearest parallel to that which resulted from the flooding of the Teesta in 1879, when the change in the course of Brahmaputra began.

1954 On August 2, Dhaka district went under water. On August 1 flood peak of the JAMUNA river at Sirajganj was 14.22m and on August 30 flood peak of the Ganges river at HARDINGE BRIDGE was 14.91m.

1955 More than 30% of Dhaka district was flooded. The flood level of the BURIGANGES exceeded the highest level of 1954.

1962 The flood occurred twice, once in July and again in August and September. Many people were affected and crops and valuable properties were damaged.

1966 One of the most serious floods that ever visited Dhaka occurred on 8 June 1966. The flood level was almost the highest in the history of Sylhet district too. A storm on the morning of 12 June 1966 made the situation grave. About 25% of houses were badly damaged, 39 people died and 10,000 cattle were lost, and about 1,200,000 people were affected. On September 15 Dhaka city became stagnant due to continuous rainfall for 52 hours, which resulted in pools of water 1.83m deep for about 12 hours.

1968 Severe flood in Sylhet district and about 700,000 people were badly affected.

1969 Chittagong district fell in the grip of flood caused by heavy rainfall. Crops and valuable property were damaged

1974 In Mymensingh about 10,360 sq km area was flooded. People and cattle were severely affected and more than 100,000 houses were destroyed.

1987 Catastrophic flood occurred in July-August. Affected 57,300 sq km (about 40% of the total area of the country) and estimated to be a once in 30-70 year event. Excessive rainfall both inside and outside of the country was the main cause of the flood. The seriously affected regions were on the western side of the Brahmaputra, the area below the confluence of the Ganges and the Brahmaputra, considerable area north of Khulna and finally some area adjacent to the Meghalaya hills.

1988 Catastrophic flood occurred in August-September. Inundated about 82,000 sq km (about 60% of the area) and its return period are estimated to be 50-100 years. Rainfall together with synchronization of very high flows of all the three major rivers of the country in only three days aggravated the flood. Dhaka, the capital of Bangladesh, was severely affected. The flood lasted 15 to 20 days.

1989 Flooded Sylhet, SIRAJGANJ and MAULVI BAZAR and 600,000 people were trapped by water.
1993  Severe rains all over the country, thousands of hectares of crops went under water. Twenty-eight districts were flooded.

1998  Over two-thirds of the total area of the country was flooded. It compares with the catastrophic flood of 1988 so far as the extent of flooding is concerned. A combination of heavy rainfall within and outside the country, synchronization of peak flows of the major rivers and a very strong backwater effect coalesced into a mix that resulted in the worst flood in recorded history. The flood lasted for more than two months.

2000  Five southwestern districts of Bangladesh bordering India were devastated by flood rendering nearly 3 million people homeless. The flood was caused due to the outcome of the failure of small river dykes in West Bengal that were overtopped by excessive water collected through heavy downpour.
## Appendix B:

### Flood-affected Area in Bangladesh, 1954–2004

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<th>As % of total area of country</th>
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Sources: BWDB (1991a, 1998a, n.d.[a]).

Notes: n.a. ¼ no information available; figures in bold represent the first five and the last five ranks.
Appendix C: Methodology of Flood Forecasting Carried out by FFWC

FUNCTIONS:

A. Data collection
   - Voice data (HF Wireless network, 67 stations)
   - Mobile telephone (3 stations)
   - Telemetry System (14 stations)
   - Satellite Imagery (GMS, NOAA-12 & NOAA-14)
   - On-line data from Bangladesh Meteorological Department, including satellite and rainfall radar data

B. Satellite Imagery:
   - Reception of NOAA-12 and NOAA-14 images via direct acquisition facilities
   - Monitoring of cloud & depression movements, precipitation estimation from cloud temperature analysis
   - Cyclone monitoring

C. Real Time Data Management
   - GIS based map display showing water level and rainfall status (Flood Watch)
   - Data entry & processing
   - Automatic data exchange to and from forecasting model
   - Display of forecast water levels and discharges
   - Automatic generation of flood forecast bulletins
   - Generation of flood status at local administrative unit (thana) level
   - Automatic statistics generation

D. Flood Forecast Model
   Basis: One dimensional fully hydrodynamic model (MIKE 11 HD) is incorporating all major rivers and floodplains. This is linked to a lumped conceptual rainfall-runoff model (MIKE 11 RR) which generates inflows from catchments within the country.

DISSEMINATION

A. Media
   - Internet
   - Email
   - Fax, Telephone & Wireless
   - Radio & Television

El Nino and La Nina

The El Nino/ La Nina phenomena are the main sources of year-to-year variability in weather and climate for many areas of the world. El Nino and La Nina tend to alternate in an irregular cycle, which is often referred to as the ENSO cycle. The transition between El Niño and La Niña tends to be more rapid than the transition from La Niña to El Nino. El Nino episodes tend to: Develop during the Northern Hemisphere spring season. Occur every 3-5 years, usually last for 9-12 months. In contrast, La Nina may last 1-3 years; however, there is considerable event-to-event variability in the timing, intensity and evolution of both El Nino and La Nina. Periods when neither El Nino nor La Nina is present are referred to as ENSO-neutral (National Weather Service, 2006).
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