Chapter – 2
SURFACE WATER RESOURCES OF BANGLADESH
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Bangladesh is a deltaic country located at the lower part of the basins of the three greatest rivers of the Ganges, the Brahmaputra and the Meghna. The floodplain of these rivers and their numerous tributaries and distributaries covers about 80% of the country. This makes the dimensions of Bengal delta simply enormous. The three rivers drain a total catchment area of about 1.72 million of which only 7% lies within Bangladesh (Fig 2-1). The remaining area lies in India, Nepal, China and Bhutan. Bangladesh can be divided into seven hydrological regions considering surface water flow processes and major rivers as boundaries. These regions are NorthWest, North Central, Northeast, SouthWest, South Central, SouthEast and Chittagong (Fig 2-2). All the regions except Chittagong are hydraulically connected through the three major rivers.

As a result of the flat topography of the floodplain, one fifth to one third of the country is annually flooded by overflowing rivers during monsoon (June-Sept) when the rainfall within the country is also very high. High tides and occasional cyclonic storm surges from the Bay of Bengal also cause floods in the coastal areas. Unlike cyclones and the associated storm surges, which take a huge toll of lives and properties, rainfall and river floods are annual phenomenon causing untold miseries to the people and damages to crops, properties and infrastructure. The total annual rainfall contributes to flow of 250,398 million cubic meters whereas flow coming from outside the border amounts to 999,124 million cubic meters carried by the rivers of Bangladesh of which 90% comes during monsoon. Bangladesh is interlaced by a network of 230 rivers and innumerable canals and water bodies. Out of these rivers 57 are transboundary (Fig 2-3).

The annual volume of flow past Baruria just below the confluence of the Brahmaputra and Ganges is 795,000 million cubic meters, which is equivalent to 5.52 meters of depth over the 14.40 million hectares of land area of Bangladesh. In contrast the average annual rainfall of the country is 2.32 meters. High water level of the major rivers slows down the flow of their tributaries resulting in backing up of water in the tributaries. The systems of the three major rivers discharges into the Bay of Bengal through a single outlet in Bangladesh which is the Lower Meghna.

Figure 2.1: Ganges, Brahmaputra and Meghna river basins

Source: BANCID Seminar on evolution of a scientific system of FF&WC 1997
Map showing the 57 Indo-Bangladesh common rivers.

Source: BWDB, MPO, 1985
Bangladesh is one of the most densely populated countries in the world having a population of about 130 million at present within a total surface area of 147,570 sq. km. The density of population is 850 per sq. km, which is one of the highest in the world. The annual growth rate of population is 1.7 per cent, has put a lot of pressure on the limited resources of the country—land and water. It has been calculated that if this trend continues then the population of Bangladesh will be about 180 million by the year 2025. The long-term water vision for Bangladesh is to attain food self-sufficiency by this year. This will ask for unhindered flow in the 57 border rivers during dry season.

**Estimating Surface and ground Water Supply**

In 1989 and 1991 National Water Plan Phases 1 and 2 assessed available water resources from rivers, catchment areas, and groundwater sources. The “water resource base available for development” was derived from a number of mathematical and simulation models (fig 2-4). The most important were the water balance model used to determine the extent of surface water, for both current use and further development.

**Surface Water Supply**

The availability of surface water was derived by the water balance model for 173 catchments, translated into 60 planning areas and then 5 regional areas (northeast, northwest, southeast, southwest, and south-central). Total water outflow was considered the potential available for developing irrigation, fisheries, and navigation, and for meeting environmental needs.

Because Bangladesh lacks gravity diversions and water storage structures the annual outflow from major rivers to the Bay of Bengal is essentially equal to the annual inflow from India. Net diversion is minimal; water balance studies show that even in the dry month of March, when diversion is maximised and base flow minimised, net diversion from the entire riverine system is only 5 percent of inflow. Stream flow accounts for only part of available surface water. The total picture, considering such factors as surface inflow, rainfall, evapotranspiration, percolation to groundwater aquifers, diversion for irrigation, infiltration, and return flow is given by a hydrologic simulation of

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5. ibid.
6. ibid.
7. The water balance planning model made use of a number of individual simulation models to estimate each component of water supply and demand. The models were aggregated in an interactive system to produce a water balance scheme. For example, the urban and rural water supply and demand model, using population and population growth projections, was related to the catchment water abstraction model for estimating intermediate water balance. This was then related to other individual models, such as the linear surface water simulation model, which led to the final water balance scheme used in the national plan.
Land Classification, Cropping and Irrigation Coverage
Analysis of BBS and SODAPS data to yield upazila crop data covering 16 crops and 21 development modes

Crop Water Requirements
Evaluated for 4 major crops
HYV aman, HYV Aus, HYV boro & wheat

Urban and Rural Water Supply Demands
Demand projections based on population growth

Existing Agricultural Water Use
Evaluated for 58 Planning areas

Catchment Water Abstraction Characteristics
Upazila data aggregated and translated to catchments

Water Balance Model
Based on 158 catchments and eight major crops

Groundwater Models
- Potential Recharge
- Usable Recharge
- Range of high medium & low values by flood phase and technology

Linear Surface Water Simulation Model
Not required in Phase II

Drought Model
Water requirements for B aus, LT aman and HYV aman

Planning Area Analysis I
Planners manual interface between the various computer models

Hydraulic Models when required:
Surface Water Simulation Model
HEC-2 Program

Resource Projection Model
Crop production and development streaming

Planning Area Analysis II
Planners identification of projects using model outputs

Investment Analysis Model

The National Water Plan

The Water Balance and Planning Models in NWP II
the water balance model. This model estimated the runoff remaining after existing uses in 1989–90 for the five regions (table 2-1). Water availability during the minimum dry period was 3,710 million cubic meters in February 1990, during the maximum wet period, 111,250 million cubic meters in August 1990.

Table 2-1. Regional Surface Water Available for Development, 1989–90 (Million cubic meters)

<table>
<thead>
<tr>
<th>Region</th>
<th>Dry months</th>
<th>Wet months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nov Dec</td>
<td>Jan Feb</td>
</tr>
<tr>
<td>NW</td>
<td>2,970 1,840</td>
<td>1,160 780</td>
</tr>
<tr>
<td>NE</td>
<td>5,090 1,710</td>
<td>710 130</td>
</tr>
<tr>
<td>SE</td>
<td>820 950</td>
<td>750 640</td>
</tr>
<tr>
<td>SW</td>
<td>1,180 580</td>
<td>270 140</td>
</tr>
<tr>
<td>Total</td>
<td>18,310 9,520</td>
<td>5,940 3,710</td>
</tr>
</tbody>
</table>

Estimating Surface and Groundwater Demand

Water is used primarily for municipal and household use, industry, irrigation, fisheries, navigation, and the environment. In 1991 the National Water Plan took into account all of these, but it did not make reliable estimates for water demand outside of agriculture and municipal uses. The major focus in the 1991 water plan was current and future crop water requirements. The needs of fisheries and the navigation sector, because they are more difficult to estimate, were estimated arbitrarily as a percentage of the total flow.

Demand from the Irrigation Sector

In 1991 the Master Planning Organization projected on the basis of anticipated irrigation projects the demand for irrigation in March 2018 to be 14,290 million cubic meters (table 2-2). This was determined by an investment analysis model whose input was estimated surface and groundwater availability from the water balance model described earlier. Thus the future demand for irrigation water was based on its projected availability.

Demand from Domestic and Industrial Users

Domestic and industrial users were given priority over all other users for allocation of scarce water supplies. Even though the National Water Plan was not detailed, considerable attention was
given to various long- and short-term strategies for meeting projected demands, for technical possibilities, and for mitigating the fall in the watertable expected as a result of recommendations to develop groundwater irrigation. The projected demand for 2018 was 170 million cubic meters (table 2-2).

**Demand from the Fisheries Sector**

Estimation of water needs for fisheries (capture as well as culture fisheries) during the monsoon and the dry season is a complex task because the water bodies involved are not static. For example, monsoon floods link inland open waters (rivers, floodplains, beels, and estuaries), creating an integrated biological production system where fish and prawn breed and multiply (annex A). The Master Planning Organization estimated combined demand from the fisheries, navigation, and environmental sectors at 9,910 million cubic meters (table 2-2).

**Demand from the Navigation Sector**

Phase 2 of the National Water Plan (MPO 1991b) attempted to allocate sufficient river discharge (or draught) to maintain waterways as classified by the Bangladesh Inland Water Transport Authority. The analysis indicated no draught problems for many such waterways. For the ones that did show significant problems, the proposed solution was to allocate 40 percent of regional river discharge for navigation and fisheries use. The plan did not, however, attempt to put together an investment scheme for the water transport system. The combined demand of this sector, fisheries, and the environment was projected at 9,910 million cubic meters for the year 2018 (table 2-2).

**Table 2-2. Projected Water Supply and Demand, March 2018**

<table>
<thead>
<tr>
<th>Water requirements</th>
<th>Water supplies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount (Million m³)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>14,290</td>
</tr>
<tr>
<td>Navigation and Fisheries</td>
<td>9,910</td>
</tr>
<tr>
<td>Domestic uses and industry</td>
<td>170</td>
</tr>
<tr>
<td>Total</td>
<td>24,370</td>
</tr>
</tbody>
</table>

11 ibid.
Demand from the Environmental Sector

Concern for the environment was expressed in the National Water Plan, although no specific environmental protection plan was developed. Some policies and actions were recommended for minimizing water pollution from municipal and industrial waste, fertilizers and pesticides, and surface water salinity, particularly in the southwest region.

Net Water Balance Estimate of 1991

As noted, the water balance differs considerably in the wet and the dry seasons. To highlight the major issues of balancing demand and supply, it is useful to look at the water balance in the critical dry month of March.

Of the 7.56 million hectares of land in Bangladesh capable of irrigation, 6.9 million hectares were projected in Phase 2 of the National Water Plan to be under irrigation by 2018 if all the short-term projects, mid-term schemes for major rivers and large barrage projects were developed. Under this condition, the total water requirement for March 2018 would be about 24,370 million cubic meters (table 2-2). The supply from all sources, including major rivers and groundwater, was expected to be 23,490 million cubic meters. Hence there was a projected shortfall of 880 million cubic meters of water. However, these projections were made on the basis of several stringent assumptions in 1991. The projections are most likely to change because of factors such as the 1997 water treaty with India and a more accurate estimate of groundwater availability.

Water Demand in the Dry Season

The principal use of water in Bangladesh is for irrigation, which has increased significantly since the mid-1970s. With only about one-third of the cultivated area in Bangladesh presently under irrigation, this trend is expected to continue. At the same time, demand for other uses of water will increase along with population, urbanization, navigation, and economic development. Industrial- and electric-power generation systems are relatively small users, but their future must be safeguarded. Due to the prolonged drought even surface water dries up. The ponds, swamps and beels are virtually without any water. The water levels of the Dakatia and Gumti rivers fall dangerously while Fakri, Ghunghur and other rivers dry up completely. The low-lift pumps and power pumps installed on the banks of these rivers for the irrigation of Boro fields generally have no water to lift.

With the drastic fall in surface water flow during the dry season, the coastal areas of Bangladesh also face three types of saltwater intrusion in streams, groundwater, and soil.

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13 The Daily Star 02/04/99
Another critical issue for dry-season water management is silting in river channels. Then there are the dangers posed to fisheries and navigation. Fish are a vital source of protein for Bangladeshis, especially those in rural areas, and plans to increase fish production are dependent on an assured supply of water. A sure supply is also critical for navigational waterways, which must have a minimum depth of flow to accommodate boat and ship traffic.

Silting of River Channels

Although there are no accurate estimates of sediment discharge to the floodplain and delta of the Ganges-Brahmaputra rivers, it is obvious that Bangladesh receives an enormous sediment inflow from the upper catchments of the Ganges, Brahmaputra, and Meghna rivers. It has been estimated that about 1.67 billion tons of suspended sediment is discharged annually through the Ganges-Brahmaputra rivers in Bangladesh.\(^\text{14}\) The Bangladesh Water Development Board estimates that 1.27 billion tons per year of suspended sediment is discharged through six major rivers in Bangladesh (MPO 1986).\(^\text{15}\) Neither estimate considers bed load sediments, which may account for as much as 50 percent of the total sediment load. Forest clearing in the Himalayan watershed, in the hills of Tripura and Meghalya, and in the Chittagong Hill tracts also affects downstream erosion and sedimentation.\(^\text{16}\) Sedimentation has positive and negative effects. Benefits include new land formation, particularly in the coastal areas. Fine-grained sediments deposited on floodplains and deltas increase the fertility of the soil and compensate for subsidence. However, coarse-grained sediments (sand and gravel) deposited on agricultural land after a flood may drastically reduce the productivity of the land. Because of rapid changes in stream flow immediately after a flood, bed load and suspended sediments are heavily deposited, causing river channels to silt up. Silting also results from low stream flow, erosion of floodplain sediments after a rain, and wind-blown sediments during dry season. In coastal rivers during the dry season, sand and silt from nearby shore areas may enter the stream channel with tidal currents and start the silting process. Silting of the delta and the floodplain of the Ganges-Brahmaputra-Meghna rivers is seriously curbing surface water supply in many parts of the country and disrupting navigational routes. The Master Planning Organization (1986) noted that in the post-monsoon period, when river discharge decreases rapidly, huge sediment loads are deposited in channels and low-lying areas.\(^\text{17}\)


\(^{16}\) Ibid.

\(^{17}\) ibid
Thus, plying of riverine vessels are gradually becomes risky due to emergence of numerous shoals. At different points in the Meghna, Padma near Chandpur, Deara point of Areal Khan river, Kirtonkhola of Barisal, Ilisha, Tetulia rivers of Bhola many underwater shoal lands emerge during the dry season, hampering smooth and regular plying of marine vessels, particularly at night time.\(^\text{18}\)

With the passing of years, the routes are becoming narrower as the rivers are not dredged out when it is necessary. As a result depth of water is gradually being decreased. Big oil tankers, cargo vessels and wide body double decker passenger launches have to stay for hours together at different points on the rivers for the next high tide. In such cases, passenger launches get delayed in their journey to reach the destinations causing immense sufferings to the passengers, particularly women and children on board due to shortage of food and drinking water.

According to Bangladesh Inland Water Transport Authority (BIWTA), for smooth plying of big marine vessels it needs at least eight feet deep water along the river routes. At present it is becoming only five feet deep at Hizla Tek, Badartuni, Shoula, Patti, Haturia, near Laharhat and near Sreepur points along the river routes.\(^\text{19}\)

**Past Achievements in the Development of Surface Water Resources**

Prior to the partition of the subcontinent in 1947, there was no planned effort for irrigation and development in the areas, which now constitute Bangladesh. The irrigation projects were mostly undertaken in the upper reaches. In the Bengal Delta itself, the colonial governments mainly implemented navigational schemes to ensure the smooth flow of goods and services from the hinterland to the ports.\(^\text{20}\) The unprecedented floods in 1954 and 1955 underscored the need for reviewing the policy of benign neglect of the water sector.\(^\text{21}\)

In 1957, Krug Mission investigated the problem of water resource in the country. The report considered the development of large rivers, the interdependence of projects, and their impact on the river regime. The primary purpose of the mission was to suggest remedial measures for control of floods. It considered the proposal for a barrage on the Brahmaputra at Bahadurabad and on the Padma near Faridpur for the utilization of water for irrigation and diversion of flood flows in the monsoon season. The mission recommended embankments for flood control with

\(^{18}\) The Daily Star, Feb 26, 1999.

\(^{19}\) ibid


caution. It also pointed out the urgent need for a comprehensive and integrated planning for the country and recommended the creation of an autonomous body and preparation of a Master Plan.\textsuperscript{22} The Master Plan was prepared in 1964, to provide a long term program for the integrated development of land and water resources for a period of 20 years from 1965 to 85. It identified 51 major development projects throughout the country and 3 major barrage projects on the Ganges, Brahmaputra and Meghna.

The basic objective of the Master Plan was to achieve self-sufficiency in foodgrains for a growing population by 1975. Based on the projected population in 1985 of 106 million, with a daily per capita consumption of 500 grams, the food grain requirement in 1985 was estimated as 19.6 million tons.\textsuperscript{23}

The Master Plan gave priority to flood protection and Drainage as first stage followed by irrigation in the second phase. A total of about 2000 miles of embankments along the major rivers and their tributaries was to provide flood protection of about 8 million acres.\textsuperscript{24} Embankment along the three main rivers—the Ganga, the Brahmaputra, and the Meghna, were to be completed by 1985. In areas not requiring protection from flood, irrigation would be provided for 1.5 million acres by 1975 and 4 million acres by 1985.\textsuperscript{25}

The recommendation of the master plan. These included.

1) 0.95 Mha coastal Embankment project.
2) 0.24 Mha Brahmaputra Right Flood Embankment, the Ganges - Kobadak and Dhaka - Narayanganj Demra irrigation and a number of regional drainage improvement schemes (Old Dakatia, Little Feni river, Faridpur and Noakhali). A multi purpose storage project on the Karnaphuli River located in the Chittagong Hills was completed with an initial installed capacity of 80 mw with a project undertaken to increase that to 120 mw with a third unit.

The 1964 EPWAPDA Master Plan envisaged flood protection for 5.8 Mhw of land mainly by means of plodders.

Two types of projects were envisaged-

a) Flood embankments with pump drainage.

b) Flood embankments with tidal drainage sluice.


\textsuperscript{24} ibid

\textsuperscript{25} World Bank report on Water Resource Management in Bangladesh: Steps towards a New National Water
Irrigation within these flood-protected areas was also envisaged, but flood control was given a priority.

The World Bank reviewed the master plan in February 1966, at the request of the government. The IBRD considered the plan a useful beginning and a unique attempt to collect and bring together all the necessary data on a scale sufficient to formulate an integrated development plan of land and water resources. The mission agreed on the general principles regarding the importance of flood control, drainage and irrigation but expressed serious reservations on the suggested strategy and specific proposal of the plan.

The World Bank suggested the following strategies for water development:
1. Improved agricultural practice and inputs in 14 million acres not affected by severe flooding.
2. Small quick yielding projects (LLP, Rural work program, etc) requiring limited institutional support.
3. Institution building, data collection, and completion of the ongoing projects.
4. Planning and implementation of small pilot projects and initiating feasibility studies during the plan period (65-70).

The mission pointed out that if a "slower and step-by-step pattern of development were adopted, it would require redistribution of resources (from the water sector to agricultural inputs or research) reflecting first, a change from execution of large projects to studies and data collection, and second a marked increase in agricultural inputs and resources supported by small schemes of water development to facilitate and augment farmers' own efforts." The mission pointed out that much of the watershed and main length of the Ganges and Brahmaputra lie outside the country and as such the plan is susceptible to any action taken in the upstream by India. Without some international agreements, the execution of some Master Plan projects is impossible, particularly those dependent on the Ganges-Padma system.

Following the review of the 1964 Master Plan, IBRD reassessed its position in 1967 and proposed an action plan in 1970. Technical assistance by the Harvard center of Population Studies was provided to EPWAPDA, resulting in the 9 million IBRD report. In 1972 the World Bank undertook the Land and Water Sector Study advocating development of smaller-scale irrigation facilities. During the 1970s and 1980s small-scale irrigation spread rapidly, initially under public investment programs and later through private sector funding.

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plan, opcit.
26 ibid
27 ibid
With this Background, Bangladesh launched her First 5-Year Plan (73-78) with emphasis on minor irrigation scheme (LLP and Tubewells) to promote self-reliance and set priorities for economic recovery. After 2 years, the achievement fell far short of expectation due to the ambitious assessment of resources. No financial assistance was forthcoming for large projects. Therefore a more realistic 3-year hard core program was prepared with emphasis on LLP and Tubewells. It was during this period that low cost flood control and drainage projects attracted the attention of planners. The strategy was to increase food production through minor irrigation projects (low lift pumps) and exploitation of ground water.\(^{29}\)

Some 71\% of irrigation water are now sourced from ground water which is likely to continue to be the major source of irrigation water for dry and pre monsoon cropping. But fears are expressed about unregulated ground water exploitation or water mining being responsible for lowering of the water table. On the other hand one of the main reasons for the slow development of surface water resources is the reluctance of the donors of International rivers. Bangladesh on the other hand cannot execute such projects from her own meager resources.

**Table 2-3: Growth of irrigation area since 1982 in Bangladesh. The technology used for irrigation is those of canal, LLP, Traditional, Manual, DTW and STW.**\(^{30}\)

<table>
<thead>
<tr>
<th>Irrigation Season</th>
<th>Irrigated hectare(million ha)</th>
<th>% of Water Source Ground Water</th>
<th>% of Water Source Surface Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982-83</td>
<td>1.52</td>
<td>40.8</td>
<td>59.2</td>
</tr>
<tr>
<td>1983-84</td>
<td>1.61</td>
<td>47.2</td>
<td>52.8</td>
</tr>
<tr>
<td>1984-85</td>
<td>1.77</td>
<td>50.2</td>
<td>48.8</td>
</tr>
<tr>
<td>1985-86</td>
<td>1.74</td>
<td>52.1</td>
<td>47.9</td>
</tr>
<tr>
<td>1986-87</td>
<td>1.84</td>
<td>52.9</td>
<td>47.1</td>
</tr>
<tr>
<td>1987-88</td>
<td>2.06</td>
<td>54.0</td>
<td>46.0</td>
</tr>
<tr>
<td>1988-89</td>
<td>2.38</td>
<td>56.2</td>
<td>43.8</td>
</tr>
<tr>
<td>1989-90</td>
<td>2.58</td>
<td>55.8</td>
<td>44.2</td>
</tr>
<tr>
<td>1990-91</td>
<td>2.79</td>
<td>55.3</td>
<td>44.7</td>
</tr>
<tr>
<td>1991-92</td>
<td>2.75</td>
<td>63.0</td>
<td>37.0</td>
</tr>
<tr>
<td>1992-93</td>
<td>2.96</td>
<td>65.1</td>
<td>34.9</td>
</tr>
<tr>
<td>1993-94</td>
<td>2.94</td>
<td>64.8</td>
<td>35.2</td>
</tr>
<tr>
<td>1994-95</td>
<td>3.31</td>
<td>69.3</td>
<td>30.7</td>
</tr>
<tr>
<td>1995-96</td>
<td>3.73</td>
<td>69.1</td>
<td>30.9</td>
</tr>
<tr>
<td>1996-97</td>
<td>3.79</td>
<td>71.0</td>
<td>29.0</td>
</tr>
</tbody>
</table>

The salient features of the scheme for the development of surface water resources in Bangladesh may be summarized as follows:

- Modern irrigation in Bangladesh was in the initial stages exclusively based on surface water. For example, in 70-71, surface water projects supplied water to about 96% of irrigated land in the country. This ratio has fallen to 54% in 84-85.³¹
- Major surface water irrigation projects serve only 15% of the area irrigated by surface water. Traditional means irrigate more areas than these major projects.³²
- Low lift pumps are the main source of surface water irrigation. About 56% of surface water irrigation are provided by LLP’s.³³
- All the major projects can be divided into 2 categories: gravity flow and lift irrigation by LLP’s. Large pumps are used for gravity flow irrigation in Ganges-Kobadak, Dhaka-Narayanganj-Demra, Narayanganj-Narsinghdi projects. Gravity flow irrigation is also provided in some projects without any pumps. LLP’s are used in Barisal irrigation project, Karnaphuli irrigation project and Chandpur irrigation project.³⁴
- One of the biggest surface water schemes in the country is the Teesta Barrage project, which is being executed primarily with the resources of Bangladesh.
- Bangladesh ran into difficulties in designing and operating large lift schemes such as the Ganges Kobadak Project in the SouthWest with three very large 36 cumec pumps. According to one observer the project has not been able to meet its objective as a result of a mistaken technological choice.³⁵
- Work on Pabna-Natore-Sirajganj 'Panasi' multipurpose project is progressing fast involving over Tk 100 crore. The 'Panasi', a massive development project of BADC for socio-economic development of the rural people started from January 1999, with an initial fund of Tk 40 lakh. The project will help to boost agricultural production, create employment opportunities, eradicate poverty for socio-economic development and to maintain the ecological balance in 24 thanas of the three districts.³⁶

Under the project, a total of 75 kilometres of canal will be re-excavated for irrigation network and water outlet. Some 20 cross dams and control structures will be constructed and 300 ponds

³¹ ibid
³² ibid
³³ ibid
³⁴ ibid
³⁵ Khan Hamidur Rahaman, August, 1985. opcit
will also be re-excavated. At least 250 deep tube wells will be installed and 500 irrigation canals would be constructed to improve and expand irrigation facilities. A total of 4,500 farmers will be trained up to implement the project, besides, a total of 500 metric tons of seeds will be procured and supplied to the farmers to encourage cultivation of different crops. Moreover, 100 kilometre of feeder road will be constructed, valuable timber and fruit bearing trees will be planted in the project areas. Some 24 demonstration farms will be set up to acquaint the farmers with the modern methods of cultivation. The farmers will also be imparted training on fish culture and poultry farming.

- The Government of Bangladesh has started examining the feasibility of constructing barrages across the Ganges and the Brahmaputra for harnessing surface water from the economic, technical and environmental standpoints. Priority is being given to the Ganges barrage mainly to mitigate the adverse environmental degradation that has already taken place in that region over the last few decades or so. Feasibility of alternatives to the Ganges barrage (e.g. dredging of the Gorai River) as well as of barrages over some smaller rivers are also being carried out.

- Work has already started in river training direction with the construction of "hard points" at three locations of the Brahmaputra. A master plan for taming this river has already been prepared with the assistance of Chinese experts. The Flood Action Plan (FAP) had also prepared another document for the purpose; what is now needed is a Master Plan encompassing all major and medium-sized rivers. River dredging and desiltation by manual labour is expected to become increasingly important.

- Substantial improvement in the flood warning and forecasting system and in flood disaster management can be visualized. Flood proofing is now being introduced at the pilot level in the floodplains and charlands of the Brahmaputra river and soon may be expanded over all vulnerable areas. Flood plain zoning and flood insurance are two other non-structural flood management measures that need to be considered.

- If the proposed dams and reservoirs are constructed in India and Nepal, then Bangladesh will benefit in flood moderation even though hydro-power generation will be the main objective of these interventions. Bangladesh may collaborate with India in developing the reservoir on the Sonkosh river in Bhutan for the purpose of augmenting flows at Farakka. Since the proposed Sapta Kosi High Dam at Barakhetra (in Nepal) now being negotiated between India

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and Nepal would be of significant benefit downstream, Bangladesh should be interested in its implementation and management.39

Another important project is the proposed dam and reservoir at Tipaimukh on the Barak (known as the Meghna in Bangladesh). This could mitigate the flooding in Sylhet (and adjoining Cachar areas in India) significantly. Navigation will be the other major benefit for the region, besides generation of hydro-power. Planning and design have already been completed by India, which could now be jointly reviewed by the two countries for optimizing benefits. Adverse environmental impacts if any, on Bangladesh, need to be studied before Bangladesh can agree to the project which is now reported to are ready for implementation. Similar joint projects on the Gumti, the Monu, the Khowai also need to be considered.40

Construction of Cross dams in the coastal belt for land accretion and erosion control is another major investment program that merits serious consideration. Several cross-dams built over shallow channels have been very successful and beneficial in terms of land accretion, and others have been proposed at various times. Most notable among them is Sandwip Cross dam connecting Sandwip with the mainland. Some feasibility studies have already been completed for the project, but more analysis is needed to evaluate its environmental impact.41

The fate of Chitra-Nabaganja rivers Irrigation Project covering croplands in Magura and Narail districts has become uncertain after 23 years of its beginning. The project was undertaken in 1975 at a cost of Tk three crore. Kuwaiti Government provided the financial assistance for the project, which was aimed at bringing 70 sq kilometre area of land on both the sides of the Chitra and Nabaganga rivers under irrigation for boosting crop production. The entire area was divided into 306 agricultural blocks to help enable the tillers to cultivate their land easily with the help of power pumps and other mechanical facilities. There are 234 blocks in Sadar and 17 in Lohagara thanas of Narail district, 30 in Shalikha and 25 in Mohammadpur thanas of Magura. The total land area brought under the project was over 15,000 acres.42

But this project, failed to yield any benefit for the growers despite immense possibilities. Lack of proper planning and designing have been identified as the main stumbling blocks to it reasons for the slow development of surface water resources is the reluctance

40 Ibid.
41 Bangladesh Water and Flood Management Strategy, FPCO, Dhaka, September 1995
of the donors of International rivers. Bangladesh on the other hand cannot execute such projects from her own meager resources.

- No major project for the development of navigation has been undertaken. The main emphasis in the navigation sector was on the dredging of arterial waterways. The re-excavation project to give the moribund Dhanmondi lake has taken a back seat. The ten crore taka project which began October 1998 and was expected to be completed by June 2000, would now take a longer time. This has not been caused by any unavoidable adversity but by the bureaucratic interference.\(^43\)

- No major scheme for supply of Drinking water from surface water resources has been executed. Though, "Rainwater Harvesting System" is one of the devices, NGOForum for Drinking Water Supply and Sanitation, had developed in the coastal areas to ensure round-the-year pure drinking water supply facilities. By applying this system, people can easily store rain water for using as pure drinking water. The system has proved feasible both economically and technically in the area. The NGOF started the project in early 1997 in remote villages of Satkhira and Khulna districts and so far it has installed some 34 Rainwater Harvesting Plants there. Most of the plants were installed at two thanas of Satkhira district.\(^44\)

- Majority of the surface water projects, justified in terms of increased cereal crop production, overlooked, and in some cases exacerbated the water needs of sectors such as fisheries, forestry, domestic and industrial water supply, navigation, and the environment\(^45\)

- The government-sponsored "Ashrayan" project is going on to rehabilitate 50 landless families suffering from erosion in Thengamara area of Kalkini thana.\(^46\)

NATIONAL WATER PLAN

The initiative to prepare a new National water plan for Bangladesh had its genesis in discussion held during a National symposium on River Basin Development held in Dhaka in Dec'1981.\(^47\) The ministry of Irrigation, Water Development and Flood Control prepared a project proposal with the assistance of BWDB and UNDP. In Jan'1983, the MPO was created to carry out the NWP project with technical assistance and support of UNDP and World Bank as the executing agency.

The MPO started functioning since July 1983. The 1st Interim Report was completed in 1983 Nov, which included a review of available data and a work plan. A national workshop on

\(^{43}\) The Independent, March, 1999.
\(^{45}\) Ahmed, Q.K., Ahmed Nilufer, Rasheed K.B., "Resources Environment and Development in Bangladesh (with particular reference to the GBM basin)", Academic Publisher 1994.
\(^{46}\) The Daily Star, April 1999.
National water planning program was inaugurated by the President of Bangladesh in Dec'1982. The second Interim Report was completed in July'84. This report consisted of a main report supported by 10 technical volumes summarising progress and findings from studies within various sections of MPO. The main report dealt extensively with a review of water sector issues in the 3rd Five-year plan period (85-90).

The IIIrd interim Report was completed in Jan 1985. This report was intended to provided an early opportunity to discuss the long term framework of the NWP, particularly long term issues in the supply and demand for water resources and their relation to food grain production.

A National workshop was held in March 1985 to discuss the preliminary findings of MPO. In 1986 the Master Planning Organization produced the first National Water Plan (Phase 1). This assessed the availability of water from different sources and provided some idea of future demand from different sectors. Phase 2 was completed in 1991. The National Water Plan assembled substantial information and used a range of planning models and analytical tools for recommending public sector strategies and programs. Many of the recommendations were endorsed by donors and adopted by the government. The Master Planning Organization also prepared a draft water code, which was not adopted, and made other proposals to institutionalize the process of water planning and long-term resource management. Despite these achievements, the National Water Plan fell short of being comprehensive. To recast the plan with an intersectoral and interdisciplinary approach, the Master Planning Organization was restructured as the Water Resources Planning Organization in 1991. One of its main mandates was to develop national policies and strategies for utilizing and conserving water resources. The organization, however, was disabled by structural problems, and it lacked the authority to carry out coordinated water planning on a national scale. Staffed mostly by engineers from the Bangladesh Water Development Board, it did not have the diverse professional talent required to manage the complex task of intersectoral water management. After the severe floods of 1987 and 1988 refocused attention on the need to address flooding, a number of studies were undertaken, some by the government and some with donor support. The studies underscored the dearth of information on technical, socioeconomic, and environmental factors needed for deciding between different plans for flood management. In 1989 a set of twenty-six studies and pilot projects was undertaken by various donors coordinated by the World Bank, with the aim of

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producing a flood action plan.\textsuperscript{50} The principles included safe conveyance of the large cross border flows to the Bay of Bengal by construction of embankments on both sides of the major rivers. It was further reconfirmed at a seminar held at Delft university, the Netherlands in September 1991, that the very basis of FAP is the belief that effective protection against flooding in Bangladesh is possible only by constructing a system of embankment along all the major rivers. The cost of such construction would be huge: initial estimates put the figure at 5 to 10 billion US dollars that would make the FAP the "very biggest development project in Bangladesh’s history".\textsuperscript{51}

**Water Management in the Wet Season**

Floods are a recurring phenomenon in Bangladesh. Each year about 22 percent of the country are flooded. Sixty percent of the country experiences a flood every hundred or so years (table 2.4). The intensity and timing of floods vary from place to place and year to year.

**Table 2.4 Areas Affected by Flooding\textsuperscript{52}**

<table>
<thead>
<tr>
<th>Return period (year)</th>
<th>Affected areas (% of the country)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>30</td>
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<tr>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>20</td>
<td>43</td>
</tr>
<tr>
<td>50</td>
<td>52</td>
</tr>
<tr>
<td>100</td>
<td>around 60</td>
</tr>
<tr>
<td>500</td>
<td>around 70</td>
</tr>
<tr>
<td>Mean</td>
<td>22</td>
</tr>
</tbody>
</table>

**Definition of flood**

If an area goes under water and even remains so, for sometime we call it inundation. But when this inundation causes damage to property and life, disrupts communication and brings harmful effects to not only human beings but also to flora and fauna, we will call it flood.\textsuperscript{53}

**Flood Damage**

The available flood damage information is not always complete and consistent. The best available source of flood damage information at hand is the Ministry of Disaster Management and relief. The assessments by various institutions are compiled together into an overall flood damage

\textsuperscript{50} Ahmed, Q.K., Ahmed Nilufer, Rasheed K.B., "Resources Environment and Development in Bangladesh (with particular reference to the GBM basin)", Academic Publisher 1994.


\textsuperscript{52} World Bank 1989b.

assessment. **Fig 2-5** shows the flood damages in physical terms for the years from 1985 to 1995. There were considerable crop damage even in the years of moderate flood. The flood control embankment itself suffers substantial damage. Flood damage to embankments has a strong correlation with the magnitude of flood. Again the properties and infrastructure suffer substantial damage during large and medium floods. In addition to damages shown in **Fig 2-5**, there are consequential effects such as reduced employment, industrial production loss, reduced consumer demand, reduced economic activities due to disruption of daily life of people etc. When converted into monetary unit it is found that flood damage to infrastructure and property outweighs the damage to crops.\(^{54}\)

### Geographical Factors Responsible for floods

**Surrounded by mountains:** Bangladesh is on the floodway of an immense area, situated in the tropics between 20°34'N and 26°33'N latitudes and 88°0'E and 92°41'E longitudes. The country is surrounded by hills on its three sides—Rajmahal hills on the West, the Himalayas and the Meghalaya plateau on the North and Tripura Chittagong hills on the East (Figure 2-6), and by the bay of Bengal on the South. The rainfall runoff from the vast hilly area coupled with snowmelt in the Himalayas brings a huge inflow of water to Bangladesh during the wet monsoon season. From June to October large quantities of warm moist air travel from the Indian ocean North over Bangladesh and then to the Himalayan slopes as monsoon winds. Upper air turbulence and the long mountainous barjjer stretching east to west make this moist air rise and as a result cooloff and bring about enormous amounts of orographic rains which enter into the Bangladesh territory in the form of runoff.

**Lower riparian country:** Bangladesh is located at the lower part of the basins of three great rivers, the Ganges, the Brahmaputra and the Meghna. The primary cause of floods in Bangladesh is the excessive rainfall in the catchment areas of these rivers. The total annual rainfall contributes to flow of 250,398 million cubic meters whereas flow coming from outside the border amounts to 999,124 million cubic meters carried by the rivers of Bangladesh of which 90% comes during monsoon.\(^{55}\) Bangladesh is interlaced by a network of 230 rivers and innumerable canals and water bodies. Out of these rivers 57 are transboundary.

The annual volume of flow past Baruria just below the confluence of the Brahmaputra and Ganges is 795,000 million cubic meters, which is equivalent to 5.52 meters of depth over the


\(^{55}\) ICID, Seminar paper on Evolution of a Scientific System of Flood Forecasting and Warning in the
Figure 2.5 Time series plot of flood damages in physical units (reproduced from Chowdhury et al., 1997)
Figure 2-6

BENGAL BASIN

Source: BANCID, 1997
14.40 million hectares of land area of Bangladesh. In contrast the average annual rainfall of the country is 2.32 meters. High water level of the major rivers slows down the flow of their tributaries resulting in backing up of water in the tributaries. The systems of the three major rivers discharges into the Bay of Bengal through a single outlet in Bangladesh which is the Lower Meghna.

Floodplain Country: The extensive flood plain of the three rivers and their tributaries and distributaries is the main physiographic feature of the country. About 80% of the country are flood plains composed of predominantly recent alluvial deposits transported from the hills by the rivers. Hill areas in the northern and eastern part occupy about 12% and the terrace areas in the center and northwest occupy about 8%. The country is crossed by 230 rivers, most of which are either tributary or distributary of the three major rivers. The total length of the river courses is approx. 24,000 km and cover 9,770 sq. km or 7% of the country. The entire land of Bangladesh is almost low and extremely flat with the exceptions of a few hills. A generalized relief contour map is shown in Fig 2-7. The Capital City Dhaka which is about 225 km from the coast is within 8 meters above the mean sea level. Because of the flat topography, flooding spreads evenly and accumulates on the plains. The alluvial rivers have natural levees at both banks, which slope down to back swamps. There are numerous natural depressions—Hoars, Beels and Boars. The rivers causing floods assume a minimum gradient owing to the flatness of the land surface. The depressions hold much water and inundate appreciable areas along the periphery.

Types of Floods in Bangladesh

1 Natural Floods

About one-fifth to one third of the country is flooded to varying degrees each year during June through September when about two thirds of the foodgrain (mainly rice) are produced. The sources of Natural flood in different parts of the country is shown in Fig 2-8. The following Natural floods are encountered.

River flood: The main source of flooding is the bankover flow from the major rivers the Ganges, the Brahmaputra and the Meghna, and their tributaries and Distributaries during June to September. A broad strip of land adjacent to the rivers is shown in Fig 2-8. About 30% of the country is prone to river floods.

Rainfall flood: About 80% of annual rainfall in Bangladesh occurs during June to September when the river flow high stopage due to huge inflow of water from the catchment outside the country. As a result drainage is impeded. Besides high intensity and long duration rainfalls cause local flooding.

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Ganges, Brahmaputra, and Meghna River Basins, 1997, opcit

Figure: Generalised relief contours in meters

Figure: Flood Types (Reproduced from FFCO, 1995)
when the local river cannot drain quickly. Average annual rainfall for the whole country is about
2,400 mm. It ranges from a low of 1,200 mm in the Northwest to almost 6,000 mm in the Northeast
(Figure2-9).

**Flash Flood:** In the Northern and eastern hill streams, flash floods occur during the pre monsoon
months of April and May. Flash floods in the North eastern region cause damage to dry season boro
rice crop just before or at the time of harvesting and also to towns and other infrastructure.

**Tidal Flood:** The areas adjacent to estuaries and tidal rivers in the south west and south central
parts of the country get flooded twice a day due to astronomical tide from the Bay of Bengal.
During Spring tide, which occurs fortnightly, large area is flooded by tidal water. Tide is
experienced upto 225 km inland in the wet season. A considerable area in the southwest region is
below high water level of Spring tide.

**Storm surge flood:** The storm surges due to tropical cyclones in the Bay of Bengal occasionally
cause severe disaster in the coastal areas. The flood can occur during April to June and September
to November.

Approximately 12,000 sq. km of coastal land is prone to cyclonic storm surge floods. Intrusion of
storm surges in the Southwest region can be upto 55 km while in the Chittagong area it can be upto
15km. Estimated surge depths of 100-year return period are 7.8, 5.2 and 4.5 m at the entrance of the
lower Meghna estuary, at the Southwest region coast and at Chittagong coast respectively.

2 **Man Made floods**

Construction of infrastructure (mainly road) without keeping adequate provision for an impeded
drainage of rainwater is causing flood hazards during hazards during heavy rainfall. For example
this man made factor was one of the main reasons for rapid increase in flood depths and excessive
duration of flood during the devastating rainfall flood that occurred in September – October of 1995
in the North west region of Bangladesh. Reduction of flood storage area due to filling up of low
lands and depressions is also exacerbating the flooding condition. Another cause of concern is the
damage caused by sudden floods due to failure of flood control embankments. The high velocity of
flood flow due to breaching of embankment does many harms to the agricultural land by depositing
coarse sand.

**Mechanism of Floods in Major rivers and Hydrological Regions**

Bangladesh can be divided into seven hydrological regions considering surface water flow
processes and major rivers as boundaries (FPCO, 1995). These regions are Northwest, North

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57 Halcrow, S.W. & Partners Ltd and others (1993), Final Report of South West Area Water Resources
58 Choudhury, J.U., Determination of shelter height in a storm surge flood risk area of the Bangladesh
Figure 2-9

Isohyet of annual rainfall (Source: Brammer, 1996)
Central, Northeast, Southwest, South Central, Southeast, and Chittagong. All the regions except Chittagong region are hydraulically connected through the three major rivers. **Floods in major rivers:** The extensive flooding in Bangladesh each year is related principally to the three main rivers---Ganges, Brahmaputra and Meghna. The Brahmaputra river has the largest flood flow among all the rivers in Bangladesh followed by the Ganges and the Meghna. **Fig(2-10) presents the annual runoffs hydrographs of the Brahmaputra and the Ganges.** The Brahmaputra starts rising in March/April due to snow melt in the Himalayas and usually attains a peak in June remaining steady for a while. It rises again and reaches the annual peak in July/August from heavy Monsoon rainfall. The Ganges starts rising in June / July and attains the annual flood peak in late August or early September.

The important elements that determine the extent of flooding are the timing and duration of flood peaks of the Ganges and the Brahmaputra. When the peaks of the two rivers coincided in 1988, severe flooding occurred and more than half of the country was flooded.

The Surma and Kushiara reach their peaks between June and August but the Meghna at Bhairab Bazar may not reach the peak until August/ September due to storage in the numerous depressions of Sylhet and Adjoining areas and the backwater effect from the Ganges which also carries the Brahmaputra flood. This results in severe flooding in the Meghna basin. The spring tide and Monsoon wind setup in the Bay of Bengal cause strong backwater effect in the lower Meghna river which is the single drainage outlet of the Ganges, Brahmaputra and Meghna rivers. As a result drainage is slowed down causing increase in the duration of flood. About one third of the country is under the influence of tides.

**Flood in North- West region**

The NW region are bounded by Brahmaputra in the east and Ganges in the South. The rivers Teesta , Dudhkumar and Dharla cause flash floods. Inside the region flooding and drainage problems in most parts are mainly caused by the drainage patterns of the internal rivers which have catchment areas within Bangladesh and have very flat gradients of 1 to 5000. The Karatoa- Atrai- Gur- Hurasagar is the latest internal river system which passes through the chalaan beel and brings flood to the central part. The majority of these rivers drain to the Brahmaputra through a single outlet at Hurasagar which is just upstream of the Ganges Brahmaputra confluence. Outfall conditions are often constrained during monsoon by high water levels in Brahmaputra and thus inturn results in and extensive flooding throughout the lower Atrai and Lower Bangali. The severity of flooding may be exacerbated by rainfall within the region. The region experienced a devastating rainfall flood in September- October 1995.
Figure 2-10

Figure: Discharge hydrographs of Brahmaputra river at Bahadurabad and Ganges river at Hardinge Bridge in 1988

Source: BANCID, Seminar on evolution of a scientific system of FF & WC in the GBM river basin 1997
Floods in the North-Central region

The annual flooding in this region can be categorized into three types: rainfall flood due to intense rainfall inside the region, normally in June/July river floods owing to overbank spillage from the major boundary rivers, specially Brahmaputra, normally in early September, and river flood as a result of overbank spillage from the internal regional rivers. They may occur separately or in combination. During the monsoon season large volumes of excess rainwater accumulate in the depressions and low-lying areas. The predominantly high water levels in the major boundary rivers coupled with high water levels in the regional rivers conveying spills from the Brahmaputra, prevent the withdrawal of excess rainfall from the internal flood plains. As long as the commanding water levels in the boundary rivers remain high, the levels in the regional rivers also remain high and the drainage of water from the region is severely inhibited. The Meghna-Padma at the South East corner is tidal influenced causing further reduction of drainage in the region.

Floods in the North-East Region

About 60% of total runoff in the NE region is produced mostly in the form of flash floods, outside Bangladesh by the three Indian catchment- the Meghalaya, the Barak and the Tripura River catchment. The remaining 40% runoff is generated locally owing to rainfall occurring inside Bangladesh. The annual flooding pattern is easily distinguished into two types- the flash floods and the River floods. Flash Floods occur in April- May in the piedmont rivers on the Southern and Northwest boundaries of the region as a result of intense rainfall over short duration when the water levels in the rivers and beel are relatively low. This rapidly rising flood spills overbank and eventually flows into the main low-land flood plains and also in the flood basins through khals. Rapid rise in river stage and consequent flow cause intense damage. As the water levels of the internal rivers are relatively low, the flood stage in the piedmont rivers recede very quickly after the cessation of rainfall. The slowly rising river floods occur in the monsoon season when the rivers flow very high causing overbank spills, which is aggravated greatly by the backing up of water by the Meghna river resulting in deep flooding throughout the Sylhet depression and extending into the Hoar areas of the Surma Kushiara flood plains.

Floods in South-West Region

The South-West region is a part of the Ganges Delta. The region is relatively free from the fluvial flooding except in the northern part of the region which may experience slowly rising river flood through over bank spills from the Ganges and its distributaries. The principal flooding mechanism is the tidal flooding by which the coastal region is flooded twice a day during spring tides. The coastal zone comprises the extensive flat deltaic land which is crossed by large estuaries from the
Bay of Bengal. The average tidal range varies from approx. 3.0 m on the coast to 0.5 m at 275-km inland. The rivers in the delta receive less upland fresh water flow and consequently suffer from saline ingestion.

**Floods in South- Central Region**

Like the South West region, this region is also vulnerable to tidal flooding. The Northern part of this region suffers from the overbank spills from Padma and Lower Meghna. Moreover this region is also vulnerable to periodic cyclonic storm surge flooding from the Bay of Bengal. As a result of the extreme flatness of the Delta, storm surge can propagate as much as 60km inland. The entire coastal region is crisscrossed with extensive interconnected network of rivers and estuaries. Unlike the Southwest region, this region does not suffer from severe saline ingestion due to fresh water flow from the lower Meghna.

**Floods in South –East Region**

Almost the entire SE region is low lying and flat. The Northern part of the region is dissected by a large number of rivers which bring flash flood from the Tippera hills above the Indian border to the Meghna. Again the region experiences flooding due to drainage congestion due to high water level in the lower Meghna. The coastal areas contain number of islands and are subject to storm surge flooding from tropical cyclones mainly in April /May and October/November.

**Floods in the Chittagong Region**

This region is different from the rest of the country having generally elevated relief and being independent in terms of hydrological response from the three major rivers. About 65 % of the area is covered with forests. All the areas have their catchment areas mostly within Bangladesh and drain directly to the Bay of Bengal. The rivers all have comparatively steeper slopes and cause flash floods. The coastal area are quite vulnerable to cyclonic storm surge flooding.

**The Frequency and Extent of Flood Damage**

Though the people in Bangladesh have lived with flooding for a long time, the problem has become acute with the floodplains more heavily populated and the extent of flood damage increasing over the years. Structures built on floodplains, including roads and towns, obstruct floodwater recession and drainage. It is estimated that flood damage to roads and highways alone runs to several million dollars each year. The loss of crops and property also exacts a high price.

Normally floods begin with flash floods in the hilly areas during the pre-monsoon months of April and May. The monsoon generally arrives in June. The Meghna and the Brahmaputra rivers tend to reach their peak during July and August; the Ganges River usually reaches its peak in August .The average annual depth of flooding and the areas mostly vulnerable to flooding are illustrated in Fig 2-11, and 2-12
Figure 2-11

The average annual depth of flooding
Figure 2-12

Areas normally flooded by small rivers
Areas normally flooded by Brahmaputra, Ganges — Meghna spills and small rivers
Areas vulnerable to flooding caused by storm surge from the Bay of Bengal
Areas normally free from flooding

The Bangladesh flood areas
During September, Severe flooding occurs if the peaks of the Ganges and the Brahmaputra coincide.

There are five land categories affected by flood (table 2-5). Land type F0 is not flooded, whereas land type F4 is flooded for more than nine months of the year with a maximum flood depth of more than 1.8 meters. The distribution of land types (table 2-6) shows that floods affect about 6 million hectares of cultivable land. Of this, about 3.3 million hectares has flood depth of 30 to 90 centimetres. About 0.076 million hectares has a flood depth of more than 1.8 meters and remains under water for more than nine months of the year. Each year about 2.6 million hectares, or 18 percent of the country, is flooded. During severe floods nearly 36 percent of the country may be affected. The unprecedented flood of this century (both in terms of depth and duration, especially the latter) has caused heavy damage to both the paddy seedlings and planted area of Aman in the country. According to a rapid appraisal report (recently carried out by the BIDS-IFPRI team), the total loss of aman crop (taking into considerations both total and partially damaged area as well as the recovery/replanting possibilities after the recession of flood water and additional yield in unaffected regions) is tentatively estimated to be between 2.1 to 2.7 million tons. If we take the average of this range (2.4 million tons) then this means a shortfall of 22 per cent from last years aman production (which itself was adversely affected due to lack of rainfall during the grain-filling stage) and 32 per cent from the target production of aman for the current year (9.50 million tons). Given the damage of aus crop estimated to be 3 lakh ton (the target production being 1.9 million tons), the total rice production (assuming a boro harvest of 7.8 million tons) is estimated to be 16.6 million tons - a shortfall of 13 per cent from last year's to production (18.70 million tons) and of 16 per cent from the target production (19.20 million tons) for 1998-99. The total food grain production, with a target wheat production of 1.8 million tons, thus is estimated to be 18.40 million tons - a shortfall of 2.1 million tons from the last year's production (20.51 million tons), and of 2.6 million tons from this year's target production level (21.00 million tons). Such a crop damage is estimated to be around 7 per cent of GDP. Of course, the shortfall would be lower if the production of either boro or wheat exceed their respective target levels.

\[59\]
Table 2-5. Land Types Based on Flood Depth

<table>
<thead>
<tr>
<th>Land type</th>
<th>Description</th>
<th>Flood depth</th>
<th>Nature of flooding</th>
</tr>
</thead>
<tbody>
<tr>
<td>F0</td>
<td>Highland</td>
<td>Not flooded</td>
<td>Intermittent or flooded up to 30 cm</td>
</tr>
<tr>
<td>F1</td>
<td>Medium</td>
<td>30 to 90 cm highland</td>
<td>Seasonal</td>
</tr>
<tr>
<td>F2</td>
<td>Medium</td>
<td>90 to 180 cm lowland</td>
<td>Seasonal</td>
</tr>
<tr>
<td>F3</td>
<td>Lowland</td>
<td>Over 180 cm</td>
<td>Seasonal (&lt; 9 months) or perennial</td>
</tr>
<tr>
<td>F4</td>
<td>Lowland/ very lowland</td>
<td>Over 180 cm</td>
<td>Seasonal (&gt; 9 months) or perennial</td>
</tr>
</tbody>
</table>

Table 2-6 Distribution of Land Type by Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Cultivable area (Millions of hectares)</th>
<th>F0</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northwest</td>
<td>2.451</td>
<td>1.307</td>
<td>0.797</td>
<td>0.194</td>
<td>0.153</td>
<td>—</td>
</tr>
<tr>
<td>(100)</td>
<td>(53)</td>
<td>(33)</td>
<td>(8)</td>
<td>(6)</td>
<td></td>
<td></td>
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<tr>
<td>North central</td>
<td>0.909</td>
<td>0.308</td>
<td>0.267</td>
<td>0.168</td>
<td>0.160</td>
<td>0.006</td>
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<td>(100)</td>
<td>(34)</td>
<td>(29)</td>
<td>(19)</td>
<td>(18)</td>
<td>(0)</td>
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</tr>
<tr>
<td>Northeast</td>
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<td>0.481</td>
<td>0.301</td>
<td>0.361</td>
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<td>0.013</td>
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<tr>
<td>(100)</td>
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<td>(18)</td>
<td>(22)</td>
<td>(30)</td>
<td>(1)</td>
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<tr>
<td>Southwest</td>
<td>1.666</td>
<td>0.545</td>
<td>0.713</td>
<td>0.281</td>
<td>0.120</td>
<td>0.007</td>
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<td>(100)</td>
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<td>(43)</td>
<td>(17)</td>
<td>(7)</td>
<td>(0)</td>
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<td>Southeast</td>
<td>1.313</td>
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<td>0.474</td>
<td>0.300</td>
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<td>(100)</td>
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<td>(36)</td>
<td>(23)</td>
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<td>South central</td>
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<td>(100)</td>
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<td>(58)</td>
<td>(13)</td>
<td>(3)</td>
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<tr>
<td>Active floodplain</td>
<td>0.533</td>
<td>0.253</td>
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<td>0.126</td>
<td>0.017</td>
<td></td>
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<tr>
<td>(100)</td>
<td>(47)</td>
<td>(26)</td>
<td>(24)</td>
<td>(3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9.562</td>
<td>3.514</td>
<td>3.288</td>
<td>1.558</td>
<td>1.124</td>
<td>0.076</td>
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<td>(100)</td>
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<td>(12)</td>
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<td></td>
</tr>
</tbody>
</table>

Note: Figures in parentheses indicate percentage of cultivable area in the region.  

60 Ibid. 
61 World Bank report on Water Resource Management in Bangladesh: Steps towards a New National Water plan, opcit..
Riverbank Erosion

Erosion and flood may not be concurrent but the two phenomena are caught in a vicious cycle. Erosion leads to heavy siltation on river bed, a fact that is chiefly responsible for the annual inundation of land by the turgid rivers during monsoon.62

Most of the rivers of Bangladesh flow through unconsolidated sediments of the Ganges-Brahmaputra-Meghna floodplain and delta. The sediments are susceptible to erosion by river current and wave action. River erosion includes channel shifting, the creation of new channels during floods, bank slumping due to undercutting, and local scouring from the turbulence caused by obstruction. The Teesta, Brahmaputra, Ganges, Meghna, and Surma-Kushiyra rivers all flow within well-defined meander belts on extensive floodplain where erosion is heavy. Erosion is rapid on the outer circumference of the meanders, while deposition occurs on the inside loop. Sudden changes are common during floods and cause rapid bank erosion. In lower deltaic areas, river erosion is accompanied by erosion from tidal currents and storm surges from the sea.

The braided Brahmaputra-Jamuna, in addition to completely changing course after 1762 (MPO 1986), has steadily migrated westward, eroding the old floodplain and creating new sections of floodplain on its east bank. The Ganges, with larger areas of resistant clay on its older floodplain, is more stable than the Brahmaputra.63

The Bangladesh Water Development Board has estimated that about 1,200 kilometres of riverbank is actively eroding and more than 500 kilometers face severe problems related to erosion. Recent satellite-image studies of the Ganges-Brahmaputra-Middle Meghna rivers between 1982 and 1992 show that 106,300 hectares was lost to erosion, while only 19,300 hectares was accreted. The net area of 87,000 hectares lost, most of it agricultural land, is equivalent to an annual erosion rate of 8,700 hectares. Erosion of border riverbanks is serious because it can cause the loss of land to neighbouring countries.64

In last four years, Erosion by rivers has rendered about 23,800 families homeless and also devoured some 12,185 acres of agricultural lands in four thanas of the district. During this period, 45 villages of 10 unions in Shibchar thana went under water due to erosion by rivers Padma and Arial Khan.

62 Ibid.
64 The Daily Star, January 24 1999.
Besides, the erosion by rivers Arial Khan and Kumar has partially affected 18 villages of nine unions in Sadar thana of the district. At least 5,000 families were hit as some 500 acres of lands were grabbed by erosion.

Meanwhile, 13 villages of five unions in Kalkini thana were partially washed away by the erosion of rivers Arial Khan and Palodi. The erosion ate up some 485 acres of lands, leaving 2,000 families homeless.

In Rajoir thana, nine villages of four unions were partially affected by erosion. Rivers Arial Khan and Kumar devoured about 200 acres of lands of 1200 families. The Gorai river also eroded a portion of Jayanabad village of Kumarkhali thana where 260 families have become homeless.

The Irrigation Department of the then Pakistan constructed two earthen armoured groyens to protect Kumarkhali town from erosion. But due to wrong site selection, the groyens did not work properly and institutions like MN High School, Kumarkhali Degree College and poura bazar were eroded by the river Gorai.

As a precautionary measure 12 miles long Raita Mohiskundi Flood Protection Embankment was constructed in 1972, but the river Padma flowing eight miles away from the present course in 1972 has engulfed a large portion of this 12 miles long Embankment and has also affected the main canal of Ganges Kobadak(G-K) Project, seven miles away from Kushtia town. 65

It is an irony of sorts that though demographic pressure and urbanisation have over the years seen a widespread poaching of our rivers and waterways, erosion as a constant source of land loss has remained untouched, untackled. Even at a time when yearly courtship with the extremes of waterlessness and excess of water makes it imperative for us to delve in the sciences of river control, erosion as a part of it is strangely neglected.

Population Displacement

It can be seen that human beings living in the frequently devastated floodplain and riverbank erosion-prone areas manifest stark realities of life. While living in floodplain allows easy access to fertile land, excess flooding routinely destroys crops and damages property. But most devastating effect takes place from loss of land due to river encroachment since land is the main, if not only, source of living for the people who live in erosion-prone areas. Once that is gone the motion of impoverishment and marginalisation sets in. Thousands of people in the erosion-affected areas are forced to give up farming after losing their agricultural lands and homesteads. 66

This problem is manifestly present in the large river and coastal belt of the deltaic area that comprises Bangladesh. Population displacement due to riverbank erosion is endemic in many parts of the country. Although some households do move to safer areas and build safer settlements, many merely relocate within the same area that has either been already affected or bear known vulnerable characteristics.\textsuperscript{67}

Many families rendered homeless by the erosion of river Kumar have taken shelter in the ideal village of Hridoynandi of Tekerhat in Rajoir thana. But most of these people are suffering from various skin diseases due to arsenic-contaminated water. Of them, the condition of 11 people was said to be critical.

About 15,600 landless families of Shibchar thana, affected by erosion, have taken shelter on the Bhanga-Maowa road and on high grounds in the area for the last three years.\textsuperscript{68}

\textbf{The Floods of 1987}

The main 1987 flood was the result of heavy rainfall from July to September over northwest Bangladesh and that part of West Bengal (India) immediately to the north. It caused severe flooding in many minor rivers in the northwest, aggravated by the highest flood peak ever recorded on the Ganges and exceptionally high floods on the Teesta. Flooding caused breaches in the Brahmaputra's right embankment.

\textbf{Historic Efforts at Flood Management}

Since the floods of 1954 and 1955 flood control and drainage projects have played an important role in water resource management in Bangladesh. In fact, they account for about half of the funds spent on water development since 1962. In 1972, a full fledged Flood Forecasting and Warning Centre was established under BWDB with the objective of issuing warnings to aid national preparedness for floods and mitigate flood impacts. Since 1972, FF\& WC has gone through various transformation, both organisationally and technical, to meet the demands of time and to upgrade its technology. For a clearer perspective, past efforts at flood control in Bangladesh are divided into two periods: initiatives taken until the big floods of 1987–1988, some of which are continuing, and initiatives since 1988.

\textbf{Efforts Preceding the Big Floods of 1987–88}

Most flood control and drainage projects prior to 1988 were implemented for a number of reasons, including protection from main river floods and flash floods in the east, saline intrusion in the lower deltaic area, and the need to improve drainage. These projects included polders/embankments for prevention and movement of floodwater inland and for draining runoffs from rainfall. In some cases,

\begin{footnote}
\textsuperscript{67} Muhammad Z. Mamun, Associate Prof, IBA, Dhaka, "The Damaging Impacts of Densification", The Daily Star, January 7\textsuperscript{th} 1999.
\end{footnote}
pumping was reversed for irrigation. Projects divided into three categories—major, medium, and small—were implemented in the early phase (World Bank 1989a). Major undertakings include the coastal embankment (949,000 hectares), Manu River (22,500 hectares), Teesta embankment (39,000 hectares), the Ganges-Kobadak (141,000 hectares), Brahmaputra right bank (226,000 hectares), Chandpur irrigation (54,000 hectares), and Chalan Beel (53,000 hectares) projects. They involved extensive embankment and water control structures, and in the case of the Meghna-Dhonagoda, Manu, Muhuri, and Ganges-Kobadak projects, gravity irrigation covers about 185,000 hectares in addition to flood protection. In Bhola, Chandpur, and Karnafuli low-lift pump irrigation was made available along with flood control for 140,000 hectares of moderately to deeply flooded area.

Medium-scale projects, such as the Satla-Bgda, Chenchuri Beel, and Barnal-Salimpur-Kolabasukhali, were implemented as World Bank–financed drainage and flood control projects. These typically involved flood control and drainage with limited irrigation development.

Small-scale efforts included early implementation projects (funded by the Netherlands and Sweden), the small-scale irrigation project (Asian Development Bank), and the small-scale drainage and flood control project (World Bank and Canada). Started mainly as low-cost flood control and drainage projects in shallow areas, these were designed for quick implementation. They benefited areas ranging from 1,000 to 10,000 hectares.

The 1988 Floods: Occurrence, Magnitude and Frequency
In the year 1988, a devastating flood which was the worst in recorded history occurred in Bangladesh. The 1988 floods were generated by intensive rainfall that extended over North, and NorthEast Bangladesh. The 1988 floods were generated by intensive rainfall that extended over North and NorthEast Bangladesh, India, Nepal and Bhutan, the most intense local concentrations being in Assam, Meghalaya, Bhutan, and Arunachal Pradesh. The flood peak of Brahmaputra was the highest ever recorded. The flood peak of Ganges was also high, but most significantly the two peaks unusually coincided, with devastating effects on the Padma downstream of the Brahmaputra/Ganges confluence. Very large overbank areas along the Brahmaputra, Ganges and Padma were usually flooded to an unprecedented extent, and Dhaka was seriously affected. Adding to the flood congestion at Lower Meghna were an exceptionally high flood on the Meghna.

Out of 34 water level stations monitored, the highest recorded flood levels had exceeded at 10 stations. The entire flood plain of the Ganges Brahmaputra and Meghna river systems of the country including Dhaka, Naryanganj and Tongi was inundated. Fig 2-13, Fig 2-14, Fig 2-15.

70 ibid
Area flooded for over one month in September 1988.

Figure 2-14, 1988 Flood Hydrograph

Source: BANCID 1997
1988 Hydrographs of major rivers compared

Source: BANCID, Seminar on evolution of scientific system, 1997
Figure 2-16

Flood forecasting and warning system in Bangladesh

Rainfall
Real Time Data
River stage

Telemetry Data Box
Wireless Comm.

FFMC Radio Tower
Data Entry & Processing

FFWC Satellite dish

Indian Data
WMO
JRC WARPO

BMD
Weather Forecasting
Synoptic Charts

Boundary Estimation
Rainfall Water Jul

24, 48, 72 Hr Forecast
Water level
Flood Extent Maps
Thanha Inundation Maps

GIS Data Layers
Table 2-7, gives an idea of the duration of flooding in 1988. For the Brahmaputra the flood peak flow at Bahadurabad was estimated to be 98,600 cumec and its peak level of 20.62m PWD was 0.3m higher than the previously recorded maximum level of 1958. The estimated Ganges flood peak at Hardinge Bridge was 72,300 cumec which is not less than the 1987 highest recorded flood. As a consequence of the high floods on both the Brahmaputra and the Ganges and the close synchronisation of their peaks, the Padma flood peak of 132,000 cumec at Baruria was also the highest on record, though for a rather short period of 21 data years since 1966. The Meghna flood at Bhairab Bazar was estimated to be 19800 cumec, which is also the highest on record in a relatively short data period (20 years). The frequency distribution of floods indicate that the severe 1988 flood peak at Bahadurabad was probably in the order of a 100 year event. Similarly the Hardinge Bridge and Baruria flood peaks had return periods in the order of 30 years and 50 years respectively and the Meghna flood peak was a 40-50 year event.

**Efforts after 1988: The Flood Action Plan**

The severity of the floods of 1987 and 1988 led the government of Bangladesh to look for a long-term plan that would provide a comprehensive and permanent solution to the recurrent problem of flooding. Several major studies were undertaken in 1989. Notable among them were studies sponsored by the French, Japanese, and United States team and a United Nations Development Programme (UNDP)-supported flood policy study. Bangladesh, India, Bhutan, Nepal, and China also carried out four joint studies. These led to the formulation of the Flood Action Plan in 1989. A set of eleven guiding principles was developed under the UNDP study for future Flood Action Plan studies. The guiding principles emphasised differentiation between inundation and flooding; recognition of different levels of flood protection for urban and rural areas; introduction of the concept of controlled flooding and compartmentalisation; integration of structural and non-structural options for flood mitigation; inclusion of river training and bank-protection works as part of flood

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plans; incorporation of environmental considerations in engineering and planning, and participatory approaches in planning and project management. The Flood Action Plan was set up to be reviewed every two years. An outline of activities for the first five years was drawn up in a meeting of donors held in London in December 1989.

Five regional studies were also carried out under the Flood Action Plan. Specific interventions were analysed, and the most beneficial implementation sequence was determined. Each study proposed a regional water plan consisting of both structural and non-structural elements. The structural elements are based on the concepts of controlled flooding and drainage, either partial or full. Many of the structural elements were recommended for further study. A number of short-, medium, and long-term projects came out of the regional studies.

**Overview of Flood Action Plan Studies**

*Northwest region (FAP 2).* There are two types of flooding in the region: breaches in major river embankments and the backwater effect of major rivers during the monsoon. This study had the following planning objectives for the region: to create a stable flooding regime; to establish a sustainable pattern of development, balancing requirements of agriculture, fisheries, navigation, groundwater, and the environment; and to safeguard lives and property as much as possible during major floods. The study proposed structural measures, including embankments and drainage channels, along with non-structural measures such as flood proofing, improving warning systems, and providing secure stores of grain for emergency relief.

*North central region (FAP 3).* Flooding and drainage in this region is influenced by the three major rivers that form its boundary. Drainage outflow is impeded when water levels are high in the boundary rivers. The study proposed that sufficient flooding be permitted to prevent damage to fisheries and navigation, but also that the benefits of reduced flood damage to agriculture, infrastructure, housing, and industry be taken into account. Options considered in the study include both structural and non-structural measures.

*Southwest region (FAP 4).* The Flood Action Plan identified the following as major issues for this region: an acute shortage of surface water in the dry season; flooding from the Padma and the lower Meghna; protection of scarce groundwater resources; deterioration of the Sunderbans due to changes in the water regime; salinity intrusion and associated environmental degradation; and changes in river morphology. Recommendations of the study include augmentation of surface-water sources,

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73 Ibid.

relief from drainage congestion, flood control on the Ganges-Padma bank, and non-structural measures, including minor irrigation, water supply, and cyclone protection.

Southeast region (FAP 5). Major development issues identified for this region are flood control, drainage, and irrigation. The region also must cope with cyclones, salinity intrusion, and land erosion. The Flood Action Plan suggested both structural and non-structural approaches to water management problems.

Northeast region (FAP 6). The Flood Action Plan identified the main issues in this region as being year-round water management, flash floods, sedimentation, rapid shifting of river courses, and depletion of water bodies. The plan proposed different categories of projects, non-structural remedial and structural initiatives independent of any other structural initiatives being developed externally. The Flood Action Plan undertook several other pilot projects and supporting studies, including the compartmentalization pilot project (FAP 20). Using existing village roads and bridges, this project divides a protected area into compartments to facilitate uniform water management over an area. In controlled flooding and drainage, flooding is allowed to a depth that won’t cause damage to crops, infrastructure, or urban land but does benefit fisheries. Excess rain water is drained with proper management.

Other projects and studies, include the river training and active flood plain management pilot project (FAP 21/22), flood proofing pilot project (FAP 23), river survey programme (FAP 24), operation and maintenance study (FAP 13), geographic information system (FAP 19), flood modelling and management (FAP 25), and institutional development program (FAP 26).

Flood Forecasting and Warning System in Bangladesh.

After the devastating flood of 1988, the Government of Bangladesh took initiative to modernize the operation of FF&WC, by adopting the state of the art technology and integrating it into the forecast and warning dissemination process. The present flood Forecasting and Warning system in operation is composed of 5 main element (Figure 2-16), which are:

1. Real time rainfall and water level data collection.
2. Meteorological forecasting.
3. Flood forecasting
4. Flood Warning dissemination.

Floods of 1998

In 1998, after 10 years, Bangladesh was overtaken by a flood that has shattered the 100-year record of the Ganges flood. Almost equal to the 1988 flood in the Brahmaputra and Meghna, and...
The cause of this flood of 1998 is also the heavy rainfall in upper catchments of the Ganges and the Brahmaputra. But the most damaging feature of 1998 flood is its duration of more than two months, which surpassed all previous records. Rainfall within the country aggravated the flood situation. Drainage of flood water through the lower Meghna which is the single outlet for Ganges-Brahmaputra-Meghna river system, was delayed considerably by the spring tide and the monsoon wind setup in the Bay of Bengal.

About 47 districts out of 64 had been affected and 'the most hard hit areas were the central area of Bangladesh including the capital city of Dhaka. The flood dike protecting the capital city was seriously endangered and a continuous flood fighting for days had saved the protected part of the city. But many of the sub-urban areas and the less vulnerable posh areas and the diplomatic enclave, Gulshan was flooded to knee deep water.'

Table 2-8 Estimation of Flood Level and Comparison with 1987 and 1998 Flood Levels (Updated on 19/09/98)

<table>
<thead>
<tr>
<th>Flood ID</th>
<th>Station ID</th>
<th>Danger Level (m)</th>
<th>Peak level(m)</th>
<th>Days above MDA</th>
<th>MDA DL</th>
<th>SUM_MDA DL</th>
<th>River_Name</th>
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<td>14.57</td>
<td>28</td>
<td>9.29</td>
<td>Brahmaputra</td>
<td></td>
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<tr>
<td></td>
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<td>Ganges-Jamuna</td>
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<td>6.91</td>
<td>58</td>
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<td>Meghna</td>
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<tr>
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<td>Dhaka</td>
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<td>6.64</td>
<td>17</td>
<td>6.29</td>
<td>Buriganga</td>
<td></td>
</tr>
<tr>
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<td>Bahadurabad</td>
<td>19.50</td>
<td>20.62</td>
<td>15</td>
<td>7.32</td>
<td>Brahmaputra</td>
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<td>51</td>
<td>23.01</td>
<td>Buriganga</td>
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75 ibid
76 The Daily Star, August 1998.
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<tr>
<th>Flood_ID</th>
<th>Station</th>
<th>Danger Level (m)</th>
<th>Peak level (m)</th>
<th>Days above DL</th>
<th>MDA_DL</th>
<th>Date updated</th>
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<td>Dhaka</td>
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<td>7.58</td>
<td>23</td>
<td>21.64</td>
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<td>1998 Flood</td>
<td>Dhaka</td>
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<td>7.24</td>
<td>51</td>
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<td>9/12/98</td>
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<td>17</td>
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<td>1931 Flood</td>
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<td>10.54</td>
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<td>6.61</td>
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<td>9.26</td>
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Table 2-9 of flood distress level and comparison with 1987 and 1988 flood (Updated by 16/09/98)
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<th>Year</th>
<th>Flood Level</th>
<th>Days Above DL</th>
<th>MDA_DL</th>
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<td>17</td>
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<td>1991 Flood</td>
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<tr>
<td>1974 Flood</td>
<td>6.00</td>
<td>6.61</td>
<td>24</td>
</tr>
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</table>

Note: Days above DL = Days above danger level; MDA_DL = Meter days above danger level

Efforts after 1998: The Dhaka Protection Dam

In September 1998, the Prime Minister had made a promise to round off the Dhaka Protection Dam by extending it to cover 50-km of the city's eastern rim between Tongi and Demra and putting both road and rail tracks on the thing as well.  
This is universally held as having saved all of the dry parts of Dhaka west of the Airport Road. Most of Dhaka city went under water because of the absence of a similar and continuing dam on the eastern rim. Now the dam will be reality and the danger gone, if the promise is kept in time. The completion of the Bangabandhu Jamuna Bridge in record time and with minimal cost overrun, makes us confident that Dhaka can be saved during the next cyclical cataclysm.

Shortcomings of the Flood Action Plan Studies

A number of papers and reports by local experts and social groups have questioned some of the Flood Action Plan analyses of water management. Major criticism has to do with technical solutions proposed by the flood action plan, co-ordination of different components of the Flood Action Plan, and procedures for disseminating information from the studies.

The most popular method suggested for flood mitigation in Bangladesh is the construction of embankments or levees. The main attraction of embankments is that they are cheap and easy to build. The embankments often provide reasonable protection against flood. However, embankments are mixed blessings. They tend to produce a number of undesirable side effects.

First, the confining of flood flows within embankments lead to a rise of flood levels in the channel. This exposes downstream areas and the strip between the channel and embankment to higher floods. Second, the river channels have to transport more sediments compared to pre-embankments situation. In most cases this leads to a rise of the river bed. The continuous aggravation of river beds undermines the effectiveness of embankments. Third, embanking may produce an increased meandering or shifting of the river channels because of increased flood velocities in embanked channels. This contributes to frequent erosion of embankments. Thus, embankments have to be continuously retired. Fourth, if adequate measures are not planned in advance embankments may lead to the problem of interior drainage. In some embanked areas there is an acute shortage of water in the beginning of the dry season. There are reports of

Unauthorized cutting of embankments by farmers - for interfering with traditional methods of cultivation. Fifth, embankments obstruct the flow of silts into fields. In some areas of Bangladesh there are also reports of moisture deficiency and hardening of the soil. Sixth, embankments may adversely affect the production of fish and dislocate the traditional navigational routes. Seventh, the change in natural hydrology in certain areas may also create health hazards to the human as well as the livestock population. And finally, the embankment fosters increased flood-plain occupancy. When a flood of greater magnitude than the design flood occurs much greater damage is done than if no embankment had been constructed at all. Embankments and polders require regular inspection and continuous maintenance. During floods they become particularly vulnerable and flood fighting or continuous patrol is needed to maintain their effectiveness.

Embankments are often supplemented by channel improvement. In some cases channel improvement may cause bank erosion. Finally, the maintenance of improved channels in silty rivers is very costly.

In most Flood Action Plan studies and projects, the role of sediment and subsiding land was either completely ignored or marginally considered, although they play an important role in preserving the delicate balance of a floodplain and delta. The studies initially focused on flood mitigation, they later shifted to integrated water management. The resulting management plan did not properly account for the role of groundwater, and thus full water potential was not determined.

Water and environmental management were not integrated in Flood Action Plan studies. No acceptable method emerged to determine the water requirement for maintaining ecosystems during the wet and dry seasons. The Flood Action Plan addressed environmental concerns mainly by preparing a manual and guideline and recommending environmental impact assessments for most environmental concerns.

Figure 2-17

RIVER DEVELOPMENT PROPOSALS

OLD PROPOSALS (1978 and 1983) NEW PROPOSALS (since 1983)

India: Brahmaputra-Ganges Link Canal

Bangladesh: Reservoirs in Nepal:
A Chisapani
B Kaligandaki (1)
C Kaligandaki (2)
D Pancheswar
E Sapt Kosi
F Seti
G Trisulganga

Farakka Barrage
Jangipur Barrage
Feeder Canal

Ganges and Bahadurabad Barrages and Internal Link Canal

The location of Farakka barrage. Source: Crow and Lundquist (1990)
Most Flood Action Plan studies and projects excluded stakeholders from discussion of planning options. Local constituents were not fully consulted, and the process tended to be confrontational. In some cases of conflict, nongovernmental organizations represented the interests of the public.

The components of the Flood Action Plan were not sufficiently synchronized. All supporting studies should have been considered together with the pilot project before regional studies were undertaken. The Flood Action Plan Studies did not cover the Chittagong region. It, in fact, delineated subregional units for the purpose of project planning. In spite of their shortcomings, the Flood Action Plan studies and projects were useful. They stressed the importance, when dealing with floods, of accounting for the complete hydrological cycle and of developing an integrated management plan that covers not only flooding but also drainage, irrigation, navigation, the environment, and socio-economic factors.

PROBLEMS AND PROSPECTS OF SURFACE WATER DEVELOPMENT

A visible regional problem arises when neighbouring countries share a common water body and often lengthy and acrimonious negotiations among nations have brought the realisation that the development and utilisation of international river basins can only be pursued through co-operative endeavours among co-riparians.

A contributory factor to preventing an appropriate sharing of transboundary rivers is the lack of any definitive international law or enforceable global convention on the issue. Nevertheless some progress by jurists and legal bodies towards that end has been achieved recently. In 1966 the International Law Association adopted the Helsinki Rules on the uses of International Rivers. As a statement of the customary international law, the principles formulated by that body are now included in the Helsinki Convention on the use of Transboundary Water Courses, signed in 1992. This convention unambiguously imposes an obligation on the upper riparian of using waters in such a manner as not to cause any transboundary impact on the lower riparian.

Bangladesh As A Lower Riparian

Unresolved issues reflecting the upstream downstream syndrome in International river disputes were vividly portrayed in the Ganges basin. With regard to the left bank tributaries of the Ganges, Nepal is the upper riparian in all of them except for a small stretch of the Mahakali river where India is upstream. On the other-hand India is the upper riparian in all the three river systems of Bangladesh—the Ganges, the Brahmaputra and the Meghna. Bangladesh being the lower riparian offers an outlet

for the combined volume of the three river systems in the flood season while before the absence of a permanent water sharing accord with India, remained disadvantaged in the lean season.

Negotiations had been going on between the Ganges waters prior to 1971, but without any reduction of the problem. In 1972 the two countries had constituted a Joint Rivers Commission with the objective of getting maximum benefits from the common river systems. The barrage at Farakka some 16 km upstream of Bangladesh border was completed in 1975 to direct water from the Ganges into Bhagirathi an upstream branch of the Hoogly for flushing out the silt, easing navigation, proving more water to the city and also some for irrigation. In addition it would carry a new rail link over the Ganges to Northern West Bengal and on to Assam. From Bangladesh’s view point, the diversion of water in the dry season has a number of deleterious effects. Those most commonly cited are a loss of water for irrigation and urban use. In the mouths of the Ganges the reduced flows also allows saline bores to penetrate much further upstream than hitherto, again reducing irrigation potential, and also possibly harming ground water. From 1971 to 1977 the barrage was built and implemented without any international agreement.

In Nov 1977, The Ganges Water agreement was signed for a period of 5 years with an agreed schedule of sharing for a period of five months (Jan-May). The agreement guaranteed to give Bangladesh 80% of her share in case of exceptionally low availability of the Ganges Water at Farakka. India’s augmentation proposal was a canal crossing NorthWest Bangladesh to bring Brahmaputra water to the Ganges in India. Bangladesh however was totally opposed to such link canal.\(^3\) Fig 2-17.

A MOU was signed in 1982 for a period of 2 years. The schedule was more or less the same but the guarantee clause was replaced by a formula for burden sharing in case of exceptionally low flows.

The 1982 MOU came to an end with the Dry season of 1984. Thereafter there was a spell without any formal agreement.

In 1985, the Prime Ministers of both the countries met at Nassau, Bahamas and discussed among other things, the Ganges Water Question. In persuance of this, talks took place between delegations of the two countries at New Delhi in November 1985 and a MOU was signed on 22\(^{nd}\) November 1985. This MOU provided for withdrawals at Farakka in the ensuing three dry seasons, more or less on the same lines as envisaged in the 1982 MOU, with minor changes in some figures.

In 1988, India complaining of a lack of co-operation from Bangladesh on augmentation declined to renew the water sharing agreement. Bangladesh complained that since 1988, the amount of water coming across the border at the low point of the year has declined, to as little as 9,500 cusecs in March 1993. Which would be about a third of the guaranteed minimum stipulated between 1977 and 1982.

The Bangladesh government insistently raised the damaging effects of lost dry season surface water especially on the south-western part of the country. Those effects included general increased dryness in that part of the country that impedes dry season cultivation, aggravates the difficulties of the Ganges- Kobadak irrigation project and threatens the water supply for Khulna, as well as causing as increased inflow of salty ocean water into the delta because of reduced outflows of fresh river water\textsuperscript{84}.

Prime Minister Zia raised this matters with Indian P.M. Rao in 1993 and was promised discussion of ameliorative steps, but these apparently had not materialised Begum Zia made a plea to world opinion about it - the centre piece of her speech to the 48th United Nations general Assembly in the fall of 1993\textsuperscript{85}. In frequent statements by representatives of the Bangladeshi government, the subject was cast as an Indian abuse, of the human right of the affected population and of the environment. This grievance became a perennial item in the Dhaka press.

The South West Regional FAB study (FAB 4)\textsuperscript{86}, gave considerable stress to the increasing dryness and salinity in that area, high lighting the gradual silting up of the off take of the Gorai river, a principal distributary of the Ganges and the most important single carrier of surface water to the South West region, which includes the famous Sunderban delta forest. The Gorai currently takes no water from the Ganges during the dry season and it is feared that if this persists the gorai may be cut off in the wet season as well, which would greatly reduce the flow of surface water to south west Bangladesh. The very volumes of silt carried by the Ganges rule out keeping the Gorai open through dredging. The solution discussed in FAB 4 is to raise the level of the Ganges\textsuperscript{87}. Means barrage between the Gorai off take and the junction with the Brahmaputra, which would send water down to the Gorai course. Such river works would cost billion of dollar, displacce tens of thousands of people, and for this international funding would require a firm understanding with India on how much water

\begin{itemize}
  \item \textsuperscript{85} Bangladesh POT - 1993.
  \item \textsuperscript{86} UN Report on FAB - 1993.
  \item \textsuperscript{87} James Boyce - Birth of a Megaproject, The political Economy of Flood Control inBangladesh, Journal of Social Studies, (52) April 1991.
\end{itemize}
Till Nov. 1996 the impasse with India on surface water had changed little in its essentials. No major concessions by India nor changes in Bangladesh attitude were in view.

In 1996, India and Bangladesh, entered into an accord regarding the sharing of the Ganges Water.
The Indo- Bangla Water Sharing Agreement of 1996 According to it, India is likely to give Bangladesh a minimum of 35,000 cusecs, or 50 percent of the water available at Farakka, if the Ganges' total flow is less than 70,000 cusecs during the dry season. This was felt to increase the availability of surface water in the dry season and create a new water balance.88

Main Features of the 1996 Indo-Bangladesh Treaty on Sharing the Ganges' Water

- The treaty is for thirty years and covers the period from January 1 to May 31 each year.
- India is to make every effort to maintain inflows to Farakka at or above the forty-year average.
- Bangladesh is to receive a guaranteed minimum of 35,000 cusecs of water, as long as availability at Farakka does not fall below 70,000 cusecs.
- Not more than 200 cusecs is to be drawn off by India downstream of Farraka.
- India is to release not less than 90 percent of Bangladesh's entitlement at all times.

Table 2-10: Mean discharge (in cusecs) of the Ganges River at Hardinge Bridge for the non-Agreement (1989-1992)* period and Quantum agreed upon in the Water Sharing Treaty for the dry season.

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<tr>
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<tbody>
<tr>
<td>January</td>
<td>47,416</td>
<td>58,427</td>
<td>23</td>
</tr>
<tr>
<td>February</td>
<td>25,789</td>
<td>42,756</td>
<td>65</td>
</tr>
<tr>
<td>March</td>
<td>18,980</td>
<td>33,229</td>
<td>75</td>
</tr>
<tr>
<td>April</td>
<td>23,250</td>
<td>32,544</td>
<td>40</td>
</tr>
<tr>
<td>May</td>
<td>37,502</td>
<td>36,401</td>
<td>-3</td>
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</tbody>
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As seen from Table 2-10, the largest gain is expected for March followed by February. In the critical month of April, the availability of water in the Ganges River in Bangladesh is expected to increase by about 40 per cent. These values are the monthly average, therefore, changes in a given 10-day period may vary from the values shown in column 3 of the Table. Note that the Ganges Water Sharing Treaty is based on the average flow of a 10-day period in a given month of the dry season. For this purpose, the whole dry season (January-May) has been divided into 15 10-day cycles.

Bangladesh and India on April 1999, reviewed the sharing arrangement of the Ganges water under the historic accord of 1996 at a ministerial level meeting of the Joint Rivers Commission.
(JRC). Bangladesh's Minister for Water Resources and Irrigation, Abdur Razzaq, and the Indian Minister of State for Water Resources, Sompal led their respective sides in the talks held at the Sram Shakti Bhaban here.

It was found that Bangladesh received 35,376 cusec water at Hardinge Bridge Point during April 1-10, 1999, against the 35,000 cusec specified as Bangladesh's share in the Ganges Water sharing treaty. As per the treaty, Bangladesh's share of the Ganges flows on 10-day basis, received at Hardinge Bridge Point during the period 1st January to 10 April 1999 has shown a trend of increased quantity. Bangladesh received 41,600 cusec of water against the share of 35,000 during March 1-10, 35,683 cusec against 35,000 cusec during March 11-20 and 33,892 cusec against 29,688 during March 21-31.\(^89\)

The two sides, also discussed the sharing of waters of eight other common rivers, including the Teesta. India has agreed to supply the data of flood forecasting immediately after they receive those over phone or fax. Presently, Bangladesh has the capacity to give only 24 hours flood forecast. Barrage across Brahmaputra is also a possibility that merits looking into.\(^90\)

The south western region of Bangladesh which is solely dependent on the Ganges water for its sustenance had been facing major environmental hazards since the operation of the Farraka Barrage in the upstream of the river, but fortunately the environmental hazards are in the process of elimination after the Ganges Treaty of 1996 through guaranteed flows and restoration of the Gorai. Initial concern focussed on the division of the available dry season flow at Farraka. But now that this problem has got resolved, a number of other issues have grown in significance. First there is the possibility of augmenting the Dry season flow by upstream storage dams. Next there are many other shared rivers which should also be the subject of agreement. Hence there should be a regional rather than an individual river approach. Next whereas there is high demand for Ganges Water, but not enough of it there is little demand for Brahmaputra water which flows unused to the sea, during the wet season.

In the early 1990's India and Bangladesh suggested conflicting solutions. Bangladesh wanted many storage dams in the Ganges, the biggest on the Nepalese order to augment the low season flow. It would also allow a new navigation canal to link the new port of Mongla with Nepal, through crossing a neck of Indian land. At various stages Bangladesh attempted to initiate tri-lateral talks with all the three countries, although India resisted, insisting that it would be a vehicle through which the downstream upstream issues could be discussed.\(^91\)

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\(^88\) The Daily Star, Dec 1996.
\(^89\) The Daily Star, 9th April 1999.
\(^90\) ibid
\(^91\) Crow and Lindquist, Development of the River Ganga and Brahmaputra: The Difficulty of Negotiating a
The Indian proposal was to augment the flow at Farakka by diverting flow from the Brahmaputra. This would involve a canal half a mile wide right across the Bangladesh territory, with significant control points in Indian hands.

The current situation is that Bangladesh seems to be developing a new line, something akin to the original Indian proposal but with different political variations. The Engineering basis is for a Brahmaputra Ganges link canal but wholly within Bangladesh territory. But Bangladesh does not want to commit itself to such a solution without an agreement on the actual figures for sharing of waters in the Brahmaputra. This is extremely difficult to achieve, because there is major disagreement between the two sides over what are the correct figures for the Brahmaputra’s discharge.

Again the floods have a very limited impact on the progress of the negotiations, because the only major works upstream that could mitigate them would be the colossal storage dams which would have to be trilaterally managed by India, Bangladesh and Nepal. Recently Bangladesh has began to realise that dams might be too big, too costly, too far off in the future, and too unreliable in terms of operational performance (much of the rainfall that causes flooding would occur downstream of the storage sites anyway). Some agreements have been reached between India and Bangladesh about levees on smaller rivers which cross the borders.

Moreover the enormous sediment load carried by the major rivers adds to drainage congestion. Bangladesh has undertaken a number of pilot studies that may lead to an intricate programme of drainage and channel improvement, embankments and polderization conceptualized by an international consortium as an autonomous solution within the country’s own borders. How far this will be feasible and sufficient by itself remains to be seen. Regional co-operation offers a possibly more secure and cost effective solution to the problem of flood and drought and is not a supplementary option to be foregone lightly.