observed especially in the trans-boundary areas, while the values along three major rivers are considerably small. FFMIs at each observatory are plotted on the graphs with x-axis of 1) Q_{max} (recorded maximum daily discharge) Q_m (average annual maximum daily discharge) ratio (Q_{max}/Q_m), and 2) average annual maximum daily discharge (Q_m) as shown in **Figure 2.4.14**.

According to "Geomorphologic Effects of Monsoon Floods on Indian Rives, V. S. Kale, 2002", the world average of FFMI is about 280. It is observed from the figures that 17 points exceed this world average out of 84 stations. It is also observed that the variation of FFMI by stations is large even among the points with similar scale of discharge, although the average FFMI decreases along with the increase of discharge scale.

As a whole, the variation of annual maximum discharge is rather small in this country except for northern trans-boundary areas and south-eastern hilly areas. And the FFMIs of many points are below world average even in the flash flood affected areas.

2.4.4 Hydrometeorological Observation Network in and around Bangladesh

(1) Observation Network in Bangladesh

As mentioned in **Section 3.5**, FFWC receives rainfall and water level data from 91 water level and 56 rainfall gauging stations inside Bangladesh. The majority forward the information in 'real-time' by means of wireless or mobile/fixed telephone etc. Apart from that, there are a large number of hydrometeorological stations controlled by several agencies, and a dense observation network is now established in Bangladesh. Those agencies/organizations include:

- Bangladesh Meteorological Department (BMD),
- Bangladesh Water Development Board (BWDB),
- Institute of Water Modeling (IWM),
- Bangladesh University of Engineering and Technology (BUET), etc.

Of these, BMD and BWDB are the main organizations in charge of hydrometeorological observations.

A) BMD

The general meteorological activities such as surface observation, upper-air observation or receiving of satellite images are conducted by BMD. The items of wind speed/direction, atmospheric pressure, air temperature, relative humidity and precipitation are measured every 3 hours at 35 surface observatories widely distributed across the country (see **Figure 2.4.15**), and maximum/minimum temperature and duration of bright sunshine are recorded on a daily basis. The meteorological data are transferred from each observatory to BMD Dhaka by means of wireless system, fax, tele-fax or TP, and BMD Dhaka sends that information to the Regional Center of World Meteorological Organization (WMO) in New Delhi, India. The information is used in weather forecasting for the South Asian countries based on mathematical modeling.

Meteorological radar equipment has been installed at four locations, i.e. Dhaka, Rangpur, Cox's Bazar and Khepupara (see **Figure 2.4.15**). Since the observation range of the radars has a radius of 400 km, the entire territory of Bangladesh is now covered by these observatories. Due to this radar network, the prediction of cyclone routes and investigation on the characteristics of cold air mass etc. is possible. Moreover, using cloud pictures and cloud intensity obtained from these radar sites, real-time quantitative estimation of rainfall intensity is also conducted. In Bangladesh, rainfall intensities are defined in the following categories:

- Light rainfall (1 ~ 10 mm/hour)
- Moderate rainfall (11 ~ 22 mm/hour)
- Moderately heavy rainfall (23 ~ 44 mm/hour)
- Heavy rainfall (45 ~ 88 mm/hour)
- Very heavy rainfall (89 mm/hour ~)

However, since the estimated rainfall intensities have not yet been compared to records of surface observatories, their accuracy is not clear at present. Moreover, a calibration curve, which expresses the relationship of intensity between radar echo and actual rainfall, has been applied from Japan without any modification. The calibration curve should be changed according to the characteristics of the climate of Bangladesh. Accurate observation of rainfall at the surface observatories with short interval (1 hour at longest) is necessary for derivation of the county's own calibration curve.

BMD is now planning to install a Doppler radar at Moulvi Bazar. More accurate estimation of rainfall intensity together with the observation of speed of air masses or rainfall area is available by Doppler radar. According to the BMD staff, the main purpose for the installation of Doppler radar is to better quantify the rainfall intensity and behavior of the rainfall area in the north-eastern area of Bangladesh and Meghalaya mountainous area further to the north. This is one of the major origins of flash flood. As mentioned above, however, it is impossible to measure the precise rainfall intensity even after the installation of Doppler radar unless proper calibration is made.

B) BWDB

BWDB is the national agency responsible for collection, storage, retrieval, management and development of hydrological data in Bangladesh. It maintains a network of hydrological observatories to monitor different hydrological parameters throughout the country. The network consists of:

- Surface Water (SW) Hydrology,
- Ground Water (GW) Hydrology,
- Climate, and
- River Morphology.

The hydrological observatories of BWDB are summarized in the table below based on these categories.

Summary of Hydrological Observatories

Category	Observation Item	Number of Observatory
SW	Non-tidal Surface Water Level	214
	Tidal Surface Water Level	128
	Discharge	108
	Tidal Discharge	2
	Surface Water Quality	13
	Salinity	46
GW	Ground Water Table	20
	Ground Water Quality	119
	Aquifer Test	278
Climate	Rainfall	269
	Pan Evaporation	39
River Morphology	River Cross Section	1,050
	Sediment	26

As for surface water (SW), the country is divided into 4 measurement divisions, i.e. Northern, North-Eastern, South-Western and South-Eastern as presented in **Figure 2.4.16**. The locations of water level (tidal and non-tidal) and rainfall gauging stations of BWDB are shown in **Figure 2.4.17**.

Water level is observed 5 times a day at 3-hourly intervals (from 0600 to 1800 hours) throughout a year in principle. According to BWDB staff, the observation is made even in the night time in case of abnormal flood situations. However, the record taken in the nighttime was not found in the existing BWDB database. Rainfall is observed on a daily basis. The observation of water level and rainfall is basically made using manual gauging equipment. BWDB staff manufactures wooden staff gauges and manual rainfall gauges in its own factory. It also has a laboratory with 100 m long waterway for the adjustment of current meters, and the adjustment is conducted regularly by the staff of C&I division.

According to FFWC, the precision of manually observed water level is approximately +/- 10 cm, this being the sum of the precision of the leveling during installation of the gauges and the precision of staff gauge observation. Staff gauge shifting is carried out frequently according to the rise and recession of water level at most sites. Due to bank erosion, river course shifting or sedimentation, it is very difficult to install permanent staff gauges unless there are suitable structures such as embankment, spur or bridge at the gauge sites. Although leveling surveys are conducted whenever a gauge is shifted, this operation can definitely contribute to inaccuracies in water level observations. According to the results of field reconnaissance and the inventory survey conducted during this JICA Study, there are many staff gauges where the axis leans markedly or where gauge markings are too dirty to be read.

In terms of rainfall observations, it is reported that the BWDB manual gauge tends to overestimate rainfall amounts by 5 to 7%. This is based on comparison of the automatic rainfall gauge installed just a manual gauge by BUET as part of the "Japan Bangladesh Joint Study Project on Floods (1997)".

These discrepancies in observed hydrometeorological data are critical when considering not only the precision of flood forecasting but also overall water resources management in Bangladesh.

Discharge measurement is conducted two to three times a month by velocity area method. For small rivers, a graduated rope is placed across the stream and current meter measurements are made. For big rivers, although some special equipment such as echo-sounder is utilized, the velocity area method is also employed. A 10 to 20% overestimation in the measured discharge was pointed out in FAP24 (River Survey Project; 1994) in the measurement stations on the major rivers. Responding to that, the rating (H-Q) curves have been corrected and necessary modifications in the historical discharge data have been made.

The data/record taken at each observatory is sent to BWDB Dhaka by courier or post every three months. The data gathered in Dhaka is converted to computer format and stored in the database server after checking its quality. The data can be supplied to any organizations including private sectors in both document and digital formats.

River cross sections have been surveyed by river morphology circle of BWDB. The network of BWDB's cross-section survey is illustrated in **Figure 2.4.18**, and the name of rivers surveyed are listed in **Table 2.4.3** together with the number of cross-sections, the interval of sections, frequency of the survey work and so on.

(2) Availability of Hydrometeorological Data outside Bangladesh

According to an agreement between the Governments of India and Bangladesh concluded in 1972 and subsequent meetings of Joint Rivers Commission (JRC), the hydrometeorological data of the following 20 observatories in India are transferred to Storm Warning Center of BMD and Flood Forecasting and Warning Center of BWDB, during the monsoon season defined as the period from May 15 to October 15, by means of wireless or telex, or transmitted directly to BWDB divisional offices by means of wireless (point-to-point basis data exchange).

Available Hydrometeorological Data of Indian Observatories

Basin	Station Name (Data Item)
Ganges Basin (2 locations)	Siliguri (R), Farakka (WL, Q, F)
Brahmaputra Basin (10 locations)	Domohori (R, WL, Q, F), Gajaldoba (WL), Jalpalguri (R), Coochbehar (R), NH31 (WL), Ghugumari (WL), Dhubri (R, WL, F), Tura (R), Goalpara (R, WL, F), Pandu (Q)
Meghna Basin (5 locations)	Sirchar (R, WL, Q, F), Badarpur (WL), Dharamnagar (WL), Kailashahar (WL), Khowai Town (WL)
Other (3 locations)	Amarpur (WL), Agartala (R), Sonamura (WL)

Note: R: rainfall data, WL: water level data, Q: discharge data, F: forecasted water level data

The locations of these 20 stations are shown in **Figure 2.4.19**. Out of these 20 stations, the data of following 6 water level stations are sent directly to BWDB divisional offices in 'point-to-point' data exchange.

Observatories Subject to Point-to-point Water Level Data Exchange

River Name	Stations	
	India	Bangladesh
Monu	Kailashahar	Monu Railway Bridge
Gumti	Amarpur	Tikkarchar
Kushiyara (Barak)	Badarpur	Sylhet
Teesta (Tista)	Gajaldoba	Dalia
Dharla (Jaldhaka)	NH31	Kurigram
Dudkumar (Torsa)	Ghugumari	Kurigram

In terms of the data from 6 point-to-point basis stations, the water level data of each station is sent to Bangladesh side regularly by means of wireless voice communication. However, there is a condition for the remaining 14 stations that the rainfall data is transferred only if the rainfall amount at the observatory exceeds 50 mm/day, and for water level data only if it reaches warning stage, i.e. 1 m below the danger level. Since all those water level stations are too close (within 100 km) to the border and neither discharge nor river cross-section data in India are available, the hydrometeorological information from India is not fully utilized for the flood forecasting system. More detailed discussion is made in **Chapter 3**.

2.4.5 Water-related Problems in International Rivers

Bangladesh borders India along the western, northern and major sections of its eastern boundaries, Myanmar along some sections of its eastern boundary and the Bay of Bengal in the south. More than 90 % of the surface water originates outside the country.

Fifty nine (59) international rivers, including the large scale international rivers such as the Ganges and Brahmaputra, are officially recognized in Bangladesh. The points where those rivers enter or exit from Bangladesh are shown in **Figure 2.4.20**, together with the names of those rivers.

Out of those 59 international rivers, 56 are shared with India, while remaining 3 are shared with Myanmar. Proper water management inside Bangladesh therefore cannot be realized without considering the situation of upstream countries, especially in India.

As water-related issues in the international rivers, following items can be considered:

- Exchange of flood information,
- Sharing of low water,
- Management of water quality, and
- Management of sediment transport

The exchange of water related information containing above items have not been done smoothly, because of its political sensitiveness. The political bottlenecks lying on the international river management is discussed in **Chapter 5**.

Following are the general views on the assessments carried out so far by different organizations or institutions in order to prove the water-related influences of the upstream activities on Bangladesh quantitatively.

Flood

1. The effect of river basin development activities in the upstream countries such as India or Nepal, etc. on flood magnitude in Bangladesh has not yet been recognized significantly, because the scale of human activity is still negligible compared to the scale of the GBM basin.
2. It is said that the inadequate operation of water-related structures such as dams or regulators located in India causes some harmful effect on the flood magnitude and sometimes the operation itself pulls out 'artificial' flood in Bangladesh. However, this still does not go beyond hypothesis because the information on the structural operation is not accessible from Bangladesh.

Lowflow (Draught) and Groundwater

1. Monthly average discharge of March at Hardinge bridge decreased from 2,500 m^3/sec (before 1975) to 1,000 m^3/sec (1975 and after) due to the operation of Farakka barrage commenced in 1975 at about 40 km upstream from the international border along the Ganges (Padma) river.
2. As for the effect of Gojaldoba barrage (India) located in the upstream of the Teesta river on the lowflow in Bangladesh, no quantitative assessment result has been found.
3. Since the locations and dimensions of the water-related structures both existing and proposed are not opened to the public in Bangladesh, the quantitative assessment of the structures surrounding Bangladesh is unclear.
4. The groundwater level in Bangladesh is falling down continuously because of the increase of water consumption. However, there is no quantitative evidence which shows the groundwater decline due to development of upstream basin area.

Water Quality and Sediment Transport

1. It is widely recognized that the water quality in the international rivers may have worsened, however no quantitative assessment results in relation to the human activities in the upstream area have been found.

2. Sediment discharge in the downstream area may be reduced once a river-crossing structure such as dam or barrage is constructed. And it may increase if some large scale forest development work is carried out. Since the sediment discharge measured in Bangladesh is the result of the balance of those positive and negative effects, it is almost impossible to point out the effect of a certain objectives quantitatively.

As mentioned above, it is difficult and often impossible to clarify quantitatively the influence of the development activities conducted in the upstream basin area on the water-related environment in Bangladesh. One of the main reasons may be the overwhelming difference of the scales between the GBM basin(s) and the development activities. It should also be noted that without incorporating the hydrometeorological data or information on development activities outside Bangladesh, no useful result may come up from this kind of analysis.

2.5 River and Flood Control

2.5.1 River System

Bangladesh is located at the downstream end of three major international rivers, i.e. the Ganges, Brahmaputra and Meghna Rivers, all of which originate in surrounding countries. The total catchment area of these rivers is about 1.56 million km^2.

The river system in Bangladesh, as prepared by WARPO, is shown in **Figure 2.5.1**. As it is rather complicated with braided tributaries and distributaries, a schematic is shown in **Figure 2.5.2** for easier understanding.

The Ganges River originates at the western edge of the Himalayas in India. After a run of about 1,700 km through the Plains of India and collecting water from Nepal, it enters Bangladesh at its western border and is renamed the Padma River. The catchment area of the Ganges is estimated to be 907,000 km^2.

The Brahmaputra River originates in the northern section of the Himalayas in Tibet, China and initially flows eastward, turning south and again west before entering Bangladesh on its northern boundary. The total river length is about 2,300 km flowing through China, India and Bhutan. The Brahmaputra is renamed the Jamuna River in Bangladesh. Its catchment area is estimated at about 583,000 km^2.

The Meghna River originates in Assam Region, India and flows in a westerly direction, entering Bangladesh at its north-eastern border. The rivers at the entrance to Bangladesh are the Surma and the Kushiyara. Below their confluence it is renamed the Meghna River. The Meghna is divided into two stretches, i.e. the Upper Meghna and the Lower Meghna. The catchment area of the Meghna River is estimated to be about 65,000 km^2.

Aside from the above, the Karnaphuli River located in Chittagong region in the south-eastern section of Bangladesh is also an international river originating in India.

According to BWDB, the total number of rivers in Bangladesh including tributaries and distributaries is around 290. Four rivers, the Padma, Jamuna, Meghna and the Karnaphuli, can be referred to as the major rivers in Bangladesh. (There is no clear definition for this although it is essential to eliminate misunderstanding in river management in Bangladesh when river-related laws or regulations are promulgated).

The names of rivers in some cases differ along their stretches by map and by report. In this Study, stretches of the major rivers are defined as follows:

The Jamuna: ***From the northern boundary of India and Bangladesh to its confluence with the Padma.*** The Jamuna bifurcates into the Old Brahmaputra at Gaibandha, and joins the Meghna near Nursing. It is said that this was previously the main stream of the Jamuna. The Dharla, Teesta, Atrai, Dhaleshwari and Karatoya are the main tributaries of the Jamuna within Bangladesh.

The Padma: ***From the western boundary of India and Bangladesh to the confluence with the Upper Meghna.*** Main tributary of the Padma is the Mohananda. All other small rivers originating in the north-west region of Bangladesh are tributaries of the Jamuna. Although it is said there were many distributaries on the right bank of the Padma, the only major distributary now existing is the Gorai River.

The Meghna: ***From the eastern boundary of India and Bangladesh to the river mouth at the Bay of Bengal.*** The Meghna is further divided into two rivers, i.e. the Upper Meghna (upstream from its confluence with the Padma) and the Lower Meghna (downstream from the confluence of the Padma to the river mouth). The major tributaries of the Meghna are the Surma, Kushiyara and Monu in the eastern area and Piyan-Jadrat, Dhanu, Barni-Mogra, etc. in the northern area.

The basin boundaries of each major river within Bangladesh are not clear since there are many tributaries and branches. The Jamuna bifurcates into branches flowing to the eastern area that partly join the Meghna while the Padma bifurcates into several branches discharging into the Bay of Bengal.

The flow regimes of all rivers have contributed to the formation of a vast delta facing the Bay of Bengal. Overall, it can be said that Bangladesh is situated on the Delta formed by these three rivers. The Delta is said to be the largest in the world.

There are, however, some independent rivers in Chittagong district area. A number originate in India and Myanmar. The Karnaphuli is the largest river in this region and is one of the major rivers in Bangladesh. The main tributaries of the Karnaphuli are the Kraaling, Hilda and Boalkhali.

2.5.2 Flood Characteristics

Floods are one of the most critical natural disasters in the country. Large floods were recorded in 1987, 1988 and 1998. Following the devastating flood in 1988, the Bangladesh Government instigated a flood control program with assistance of foreign aid. The Flood Action Plan (FAP) was thus formulated in 1995.

According to BWDB, the flood patterns are categorized into 4 types, namely, monsoon flood, flash flood, low land inundation (in some reports referred to as rain-fed flood) and tidal flood caused by cyclones.

(1) Monsoon Flood

Monsoon rainfall during May to October brings about flooding over much of Bangladesh. These generally continue for 3 or 4 months and flood damage has been reported almost every year.

(2) Flash Flood

BWDB defines the flash flood as occurring in rivers having rather small catchments and steep river bed slope. It brings a rapid increase in flood water levels.

According to BWDB, the rivers located in the east, north-east, north, and north-west near the border with India are referred to as flash flood rivers. All join with the major rivers and bring about considerable flood damage.

The flash flood rivers causing considerable flood damage are to be seriously considered as objective areas of the FFWS. The definition of a flash flood river is not clear, but it is distinguished by small catchment and steep slope. A further special characteristic of such rivers / floods is that they can enter vast natural low land areas, so called Haors, that have large flood retarding effects reducing impacts further downstream.

Comparatively large flash flood rivers are as enumerated below.

In the east and north-east:

Surma, Kusiyara, Manu, Titas, Gumuti: Tributaries of the Meghna

Noakhari and Feni: independent rivers

In the north and north-west:

Piyanaganj and Bsulai

Dharala, Teesta, Atrai,

Among those flash flood rivers those located in the east and north-east, specifically in Sylhet division, are associated with the most severe flood damage.

(3) Lowland Inundation

Topographically, there are lowland areas or depression areas in inland regions of the country. Those areas can be inundated by relatively small amounts of rainfall because of insufficient drainage. Such lowland areas are referred to as Haor or Beel. Haor is a local name applied in the north-eastern area, while Beel is adopted in other areas. The characteristics of Haor and Beel are almost the same. Lowland areas and/or depressions are subsequently referred to as depressions in this Report. Other than the depression, there is another water body referred to as a Baor. This is a water body formed by an old river course and confined by natural levee, thus separated from the present river course.

All such depressions are inundated year around and are used for fish culture and agriculture. They can have a huge flood control function through flood retention and retardation.

BWDB has development plans for Haors and Beels based on a Polder development concept (confining dike system). These have been partly implemented. However, it is said that there are several problems such as a) deterioration of environment, b) decrease of drainage capacity in the downstream drainage canals, c) flood discharge increase in other areas, etc. Recognizing the importance of Haor development, the Bangladesh Government established a new agency, the Bangladesh Haor Development Board (BHDB). According to BHDB, the total number of such water bodies within Bangladesh is around 411. Water bodies in Bangladesh are shown in **Figure 2.5.3**. This was prepared by WARPO.

(4) Tidal Flood due to Cyclone

The country is periodically affected by major cyclones that develop in the Bay of Bengal. A cyclone brings about extreme high tides due to its low atmospheric pressure and accompanying strong winds. Coupled with heavy rains, inland drainage is extremely difficult. The major areas affected by cyclones are along the coastal reaches of the Bay of Bengal. For disaster prevention for cyclones, lengthy coastal embankments and many cyclone shelters have been constructed.

2.5.3 River Morphological Survey

Almost all rivers in Bangladesh are affected by severe river course shifting and bank erosion. BWDB has conducted river cross-section surveys since 1964. The survey program includes a) 3 major rivers every year, b) 5 medium rivers every 2 years and c) 37 minor rivers every 3 years. In general, the major rivers have been moving severely with sand bars (Char in Bangladesh) shifting several kilometers in cross-sectional direction annually. Scouring in the riverbed reaches 20 to 30m in depth according to the surveyed cross-sections.

Typical river cross sections of the Jamuna, Ganges / Padma and Meghna are shown in **Figure 2.5.4**.

2.5.4 River Structures and Flood Control Projects in Bangladesh

(1) Flood Action Plan (FAP)

After the 1988 flood (recognized as the recorded maximum flood), the Flood Action Plan (so called FAP) was formulated through the assistance of international aid. The FAP has incorporated 11 main components and 15 supporting activities. **Table 2.5.1** lists these by Funding Source and amount of required funding.

Almost all Studies were completed and some components have either already been implemented or are in progress. The FAP involves voluminous studies and identified projects. However, it seems that the projects implemented so far are those that were on-going at the time of FAP preparation. Very few of the new projects implemented are among those identified in FAP.

(2) General Views

In view of the serious damage due to floods, the Government has been forced to mitigate flood damage by means of structural measures and non-structural measures.

Herein, the Study Team defines the flood damage by the conceptual formula:

[Disaster = Hazard × Vulnerability]

The above formula indicates that to minimize disaster is to minimize the hazard by means of structural measures (lower hazard risk) and to minimize the vulnerability against disaster by evacuation.

Those two aspects should be conducted with support of the flood forecasting and warning system and institutional support including law/regulation, organization, funding, etc. GOB has undertaken several efforts to minimize the disaster in conjunctive operation of all agencies concerned.

A) Structural measures

Structural measures so far conducted by GOB consist of construction of embankment system, bank protection works, drainage system, dredging of river bed, etc. There are no flood control dams/reservoirs in Bangladesh.

B) Non-structural measures

Non-structural measures may be defined as an evacuation system. If no people are residing in hazard areas, there would be no damage. People to be affected by flood disaster should evacuate from such areas. FAP identified the non-structural measures such as Flood Forecasting and Warning Services and Flood Proofing. The latter seems to be one of the evacuation systems for rather long term evacuation or flood coping measures getting advantages from flood while living at flood risk with harmonious living condition with flood by such a way as high level house building, transportation by boat, etc. within available resources in the areas.

(3) Supporting Measure

Supporting measures are essential to operate and effectively maintain structural and non-structural measures. The Flood Forecasting and Warning System is one of the most essential supporting measures. In view of the above, GOB has provided and established the Flood Forecasting and Warning Center (FFWC) under BWDB in addition to other supporting systems including disaster management, relief, emergency rescue services, etc.

FAP presented the recommendation on improvement of Flood Forecasting and Warning System in Bangladesh. It stated the following:

Flood Forecasting and Warning Services - Expansion

- To provide timely and localized information for flood forecasting and warning through the use of more advanced equipment such as Telemeter, etc.
- Technical development through improvement and expansion of the capabilities of FFWC aiming at area-wise expansion of the services, more precise forecast such as depth/area inundation, and improvement of dissemination with development of awareness building at the grass-root level

Improved Flood Warning

- To provide timely, readily understood, warning to villagers in flash flood-prone areas
- The initiatives to be undertaken on a pilot basis, before going on covering the entire flood-prone areas, in Sylhet area and cross-boundary flash flood rivers
- To improve warning messages corresponding to "moderate", "very", and "extremely" dangerous conditions through audio and visual warning signals every 5 km along the flood path
- To enhance appropriate protective actions by villagers in response to each level of danger signal

(4) River Structures

There are no completely consolidated data on river structures covering the entire area of the country. The Study Team collected data on River Structures currently available and compiled it in this Report.

River structures may be categorized as flood control structures, water intake structures for irrigation water and domestic water, transportation facilities such as highway bridges and navigation facilities, etc. Those structures are briefly outlined below.

a) Flood control facilities

There are many existing flood control facilities such as dike embankments, bank protections, groins, etc. Specifically, the Padma, Jamuna and Meghna have lengthy dike embankments to prevent flooding. According to BWDB, the dike embankment has been designed for a design flood of 50 years recurrence probability in the major rivers (an exception is the Jamuna right embankment designed with a 100 year flood), and 10-25 years recurrence probability for other medium and minor rivers including tributaries of the major rivers.

Bank protection is designed in general as concrete block placement and brick mattress. There are some places where bank slope protection by concrete blocks has been damaged or collapsed due to riverbed and slope erosion. It seems that many rehabilitation/repair works have been undertaken to remedy these situations. This implies the necessity of the FFWS to properly operate the existing flood control structures. The cost expended for the remedy work should be clarified and compared to the original construction works, the result of which should be reflected in the design of flood control works.

b) Irrigation and domestic water intakes

There are many water intake structures. The large scale water intake structures are:

- Teesta Barrage project for irrigation in Lalmanirhat / Nilphamari
- Ganges-Kobadak irrigation project in Kushtia (so called GK Project)
- Khulna-Jessore irrigation project in Khulna and Jessore
- Meghna-Dhonagoda irrigation project in Chandpur

Basic features of those projects including some small scale projects are given in the attached **Table 2.5.2**.

Those water-related structures should have their own Flood Forecasting and Warning System for disseminating notice of water release to the downstream. However, they have no such facilities at present.

c) Polders development

Compartment development, or so called Polder development in local language, has been widely undertaken in Bangladesh in view of its likely economic solution for land use development incorporating flood control in flood prone areas. Total achievement of Polder development has reached 1.28 million ha, based on 123 Polders nationwide, more intensively in the western area of the country according to BWDB. The polder development is highly evaluated as a more economic land development. However, there would be some problems against flood. It would need flood warning since it is designed usually for a 5 year flood or less and sometimes with submergible dike.

d) Transportation facilities including highway bridges and navigation facilities

The transportation network is widely distributed and consists of roads and highways, inland navigation with ports and harbors, and airport transport n systems. Among these, water and flood-related structures are enumerated below.

<u>Bridge</u>

Existing bridges crossing the major rivers are as follows:

The Padma: Hardinge Bridge for Railway at Ishwardi, Pabna and Bheramara, Kushtia

The Jamuna: Jamuna Multi-purpose Bridge, for Highway and Railway at Kamarkhanda, Sirajganj and Bhuapur, Tangail

The Meghna: Meghna Bridge and Meghna-Gumuti Bridge, both for highway

There are other minor bridges existing and under-construction.

All existing bridges are stable at present against erosion and scouring according to the local people and the reconnaissance by the Study Team.

Ferry

Navigation is one of the important transportation means in the country. Ferry boat terminals have been operated by Road and Highway Department (RHD), Bangladesh Inland Water Transport Authority (BIWTA) and Bangladesh Inland Transport Corporation. RHD undertakes all road / highway operation and ferry operation in small rivers included 94 ferry terminals. BIWTA undertakes ferry terminal operation at 11 ports in the major rivers. BIWTC undertakes ferry operation (ship) at some 11 ports only on the major rivers.

Flood observation for ferry terminal operation has been done by the ferry operating agencies. They do not rely on flood warning by FFWC and, according to information given by those agencies, have never received flood warning from the FFWC.

Ferry terminal structures have suffered sometimes from floods, but not seriously, according to the local officials.

All facilities mentioned are therefore suffering to some degree from flood damage, specifically the river embankments.

(5) Operation of River Structures at Risk

Questionnaire and Interview Survey

The Study Team conducted Questionnaire and Interview Surveys on operation and maintenance of those river structures implemented, operated and maintained by BWDB. Questionnaire formats were distributed to 60 O&M Divisional Offices (O&M DO) of BWDB through PFFC. The major items of the Questionnaire survey were:

a) Projects completed and / or on-going under the jurisdiction of respective O&M DOs
b) Project components and Project Features & Structural details in brief
c) Implementation and O&M of river structures
d) Action undertaken by O&M DO at flood time

Results of Questionnaire / Interview Survey

Responses on this questionnaire survey were received from 22 O&M DOs only, about 37% of the total issued. The questionnaire survey was supplemented by interview survey. Although the rate of response to the questionnaire survey was rather low, the results were valuable, providing information on the existing operation and maintenance. The results are shown in **Table 2.5.3** and are summarized below. The detailed results of the questionnaire survey are presented in **ANNEX-III**.

a) Flood Warning Message

- The majority of O&M DOs said that they received warning sometimes, but not regularly

- Some O&M DOs have conducted flood forecasting by means of observation of water levels at their own gauging station under respective project
- Some O&M DOs have conducted flood warning dissemination to the government offices concerned and inhabitants nearby

b) O&M Manual

- Almost all O&M DOs have no Operation and Maintenance Manual for emergency operations (at flood time) although they have O&M Manuals for normal / annual operation and maintenance of the projects.
- They mostly have "Instructions" as a guide line for emergency operation, these being given annually by the Central Office of BWDB.

c) Necessity of FFWS

- Almost all O&M DOs have recognized the necessity of FFWS
- Some O&M DOs said that it is not necessary or better than nothing. In such case, they have conducted hydrological observations in their own gauging stations and / or received flood information from Radio / TV
- Some O&M DOs have also conducted flood forecasting for their own purposes for emergency operation

d) Anticipated benefit from FFWS

- Responding to the questionnaire survey, they replied that the rate of flood damage reduction by means of FFWS with other necessary supporting measures would be 20-90% which varies widely and is seemingly too high although the JICA Study Team has thought it would be in a range around 20% - 30%
- The figures worked out have large variation as above. However, the JICA Study Team sets a high valuation on their opinions in view of that they understand the necessity of the FFWS expecting high value of flood damage reduction rate. (Detailed assessment on the benefit of FFWS is presented in another Chapter)

e) Emergency Operation

- Some of O&M DOs submitted a flow diagram for actions to be taken at emergency case. The said flow diagram is shown in the attached **Figure 2.5.5** which was prepared by the Meghna-Dhonagoda Irrigation Project.
- The processes of such undertakings are defined below as a flow diagram. Receiving Flood Warning → Organizing Patrol Team for emergency inspection → Conducting Patrol / inspection of the river structures → Reporting to higher authority (Chief Engineer of O&M Circle, Central Office of BWDB according to its extent of possible damage when found out) → Preparation of manpower / materials and equipment →Decision making on preventive measures to be undertaken → Preventive measures taken → Reporting to higher authority→Return to the First action for further patrol

- Funding for emergency preventive measures would be settled immediately when it is urgently needed and small scale, but they have to receive the approval of the higher authority in case of big amount required. The action should be taken case by case. The patrol team consists of the members of O&M DO, Local Government Representatives, Public Representatives, etc. at the project level as required.
- It can be said that such arrangements would be almost satisfactory, except arrangement of necessary funding. However, such emergency operation seems to be different by O&M DO. Consistent operation is required.

f) O&M Cost

- Some O&M DO replied to the questionnaire on required O&M Budget
- According to their reply, the rate of annual O&M cost varies from 0.7% to 8.0%, average 4.4% of the project construction cost for normal operation and maintenance.
- Emergency O&M Cost varies depending on the situation as required.
- These figures are rather high as compared with those in other Asian countries, where annual O&M Cost would be in a range of 1.0-2.0 %. Such higher O&M Cost seems to be because of heavy damage due to recurrent flood, especially bank erosion.

g) Ledger sheet of river structures

- No O&M DOs have ledger sheets or were able to refer to their operation and maintenance
- Central Office, O&M Circle is now preparing data base of the river structures including those details of operation and maintenance activities / records.
- The ledger sheet should cover all the following
    - Project features (Project name, location, objectives, structural details, construction years, personnel responsible for planning, design and Implementation, consultant, contractor, etc.
    - Operation & Maintenance record (Years of O&M, activities of O&M, cost, financial sources, etc.)
    - Damage and repair record (Year of occurrence, extent of damage, the nature of damage, physical repairing works, cost, etc.)
    - Emergency protection works (Year of implementation, organization for emergency work, natures, cost, etc.)
    - Large scale rehabilitation works (Year of implementation, their natures, physical rehabilitation work, its cost, etc.)
    - And the like

h) Recommendation

As described above, emergency actions taken are rather good, but inconsistent among the O&M DOs. Therefore, it is recommended to take following actions urgently.

- Provide O&M DOs with Flood Warning regularly from FFWC
- Prepare O&M Manual for emergency operation on top of the operation manual of the project (for normal operation)
- Prepare ledger sheets of all the river structures including emergency operation and rehabilitation works

(6) Flood Forecasting and Warning System (FFWS)

BWDB established FFWC in 1972 and expanded it step by step as summarized below.

Year	Flood Forecasting Points	Forecasting Model
1972	10 monitoring points	Muskinghum-Cunge Flood Routing Model
1992	16 points	MIKE11 Modeling
1995/99	30 points	MIKE11 Supermodel
2000	Strengthening program with 50 forecast points	MIKE11 Supermodel

According to the previous Project Director Mr. A.N.H. Akhtar Hossain, BWDB is pointing out the needs of further development and use of flood forecasting as itemized below.

a) Improved regional level flood forecast
   - Updated digital elevation model and GIS at local levels
   - Detailed local models

b) Urban flood management
   - Dhaka City real time operation of drainage system

c) Effective dissemination & disaster management

The details on FFWS will be discussed in other sections.

2.5.5 River Structures in Indian Territory

Data on river structures in India are extremely limited as the Indian Government does not like disclosing information outside the country. The following is the information available at present.

(1) Existing River Structures for Flood Control

Flood control is one of the key issues to the Indian Government since there has been serious flood damage especially in the lower reaches of the Ganges. The Indian Government has seriously addressed flood control works and there would be many river structures for this purpose as well as water supply. However, sufficient data including hydrological information are not available.

(2) Major Structures Influential to Bangladesh

The major structures that directly influence the lower riparian areas of Bangladesh, based on the available information, are Farakka Barrage and Gajaldoba Barrage.

Farakka Barrage

Farakka Barrage is located at the Ganges River about 40 km upstream from the border of India and Bangladesh. The main characteristics of the Farakka Barrage are:

Barrage length:	2.62 km crossing the Main Ganges at Farakka
Gated barrage:	109 gates with approximately 20 m span each
Feeder canal:	38.3km long, 151 m wide & 6.1 m deep, with diversion capacity of 1,133 m^3/sec
Commissioned:	1974

The Farakka Barrage was constructed for the purposes of i) water supply to maintain navigability of the Calcutta Port in the Hoogly River and ii) salinity control in the river mouth of the Hoogly. The feeder canal is to lead water from Farakka Barrage to the Hoogly River through the Bhagirathi River. Hoogly River finally drains into the Bay of Bengal after passing Calcutta.

The Farakka Barrage is a key structure affecting water flow of the Ganges River into Bangladesh. In addition, the Barrage may also affect, to a limited extent, flooding of the lower riparian area through its gate operation. This impact is not large, however, as it seems the Barrage would be fully opened during the rainy season. However, it is conceivable that the gates could be fully or partially opened due to unexpected operation or even mis-operation. Therefore, as a minimum the Bangladesh Government should be provided with information on the actual operation of the Barrage. This warning for water release operation should have its warning system as a common practice.

Gajaldoba Barrage

Gajaldoba Barrage is located in India on the Teesta River just upstream of the existing Teesta Barrage. Features of the Gajaldoba Barrage are not known. According to the information of the Project, when the Barrage was constructed, the water in the Teesta was sufficient to meet the water supply requirements of the Teesta Irrigation Project. However, the river flow at the Teesta Barrage site is now considerably reduced. This is almost the same situation to the water shortage associated with the Farakka Barrage. The Indian Government should also provide Bangladesh with the operation record of the Gajaldoba Barrage including both water use / supply and also flood discharge. Currently Teesta Barrage is not provided with a water release warning system.

(3) Future Water Resources Development Projects in India

India suffers serious flooding in the monsoon period and shortage of water in the dry season. The Indian Government is therefore contemplating many water resource developments including flood control. The most significant projects among them that could seriously impact on Bangladesh are presented below.

River-Linking Projects within Indian Territory

There are many proposed river-linking projects in the Indian Territory. The implementation programs of those projects are not known yet. However, when those projects are realized, the river water in the downstream reaches would be reduced accordingly. The Ganges Water Treaty was agreed and duly signed in 1996 with the condition that available water at Farakka Barrage shall be diverted 50% each to India and Bangladesh when the water at Farakka is 70,000 cusec or less. This implies there is no guarantee to divert certain definite amounts of water to Bangladesh in the future when such River-Linking Projects are realized.

Brahmaputra-Ganges Link Project

This is a massive river-linking project to connect the Brahmaputra and Ganges Rivers. The scheme is not finally agreed among the riparian countries but will comprise the following:

i)	Location:	Assam
ii)	Canal Dimensions:	334 m long, 800 m wide, 9 m deep
iii)	Excavation Volume:	2.5 billion m^3
iv)	Canal Capacity:	2,833 m^3/sec
v)	Land Area for Canal:	270 km^2
vi)	Major River Crossing:	14 numbers

The basic scheme of this project is to construct a linking canal passing through Bangladesh territory.

Bangladesh has protested about this project owing to conceivable disadvantages related to decreased flows in the Jamuna River downstream of the proposed intake, resulting deterioration of the river environment and other water-related problems.

Barak River Linking Project

According to newspaper reports, there is also an Indian river-linking project in the Barak River, located in the Eastern Territory of India. The Surma and Kushiyara Rivers, the Bangladesh rivers located downstream of the Barak River, would be seriously affected by this river-linking project. The details of this scheme are not known yet.

2.6 Flood Damage

2.6.1 Historical Performance of Flood Damage

Flooding is a regular phenomenon in Bangladesh with a portion of Bangladesh normally being flooded every year. According to the results of statistical analysis on flood affected areas conducted in this Study (refer to **Section 2.4**), about 20% of the country is inundated with a 2 year recurrence interval. Historical records indicate five major floods occurred in the 19th century (1842, 1858, 1871, 1885, and 1892). Nineteen floods affecting an area of more than 30,000 km^2 (20% of total land area) have occurred after 1954 as shown in **Table 2.6.1**. The highest death toll was 2,379 people in 1988, followed by 1,987 people in 1974 and 1,657 people in 1987. The largest amounts of damage were roughly estimated as 160,000 million Taka in 1998 followed by 100,000 million Taka in 1988.

2.6.2 Component of Flood Damage

The flood damage diversifies according to the type of flood and the type of objects to be damaged.

(1) Type of Flood

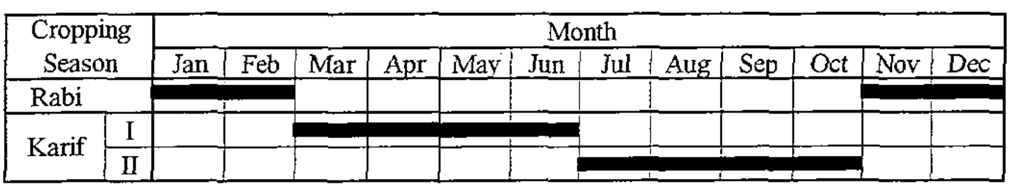
Firstly, flood damage is quite different according to the type of flood such as i) monsoon flood, ii) flash flood, iii) lowland inundation and iv) tidal surge accompanying a cyclone. The water level during a monsoon flood increases gradually and if people have sufficient time to evacuate then, in general, the damage is minimized. But with flash floods or tidal surges, their timing and magnitude are difficult to accurately forecast and there is insufficient time to evacuate. Then the associated damage is usually huge. But the actual floods often occur as a result of a mixture of these different types.

(2) Type of Assets

The flood damage differs according to the type of assets as follows.

a) Agriculture

Damages to agricultural products is closely related to the cropping pattern and flood depth. Cropping year is divided into two distinct cropping seasons, namely, "Kharif" and "Rabi" seasons. Based on crop adaptability and crop culture, the Kharif season has been further divided into "Kharif-I" and "Kharif-II" as shown in the following chart:



Kharif-I season is from March to June. Drought and pre-monsoon floods often act as constraints. Aus rice and Jute are grown during this season while mixed aus-amon and Deep Water Rice (B. Amon) seeds are sown for crop establishment before the advent of floods.

Kharif-II season is during July to October. Most of the rainfall is received during this season which is characterized by high rainfall, low evaporation, low solar radiation, high temperature, high humidity and maximum flood levels. Among rice, T. Amon is grown during this season while B. Amon, sown in kharif-I, matures towards season end. Floods often create problems during the early part of the season while rainfall ceases towards the end of the season when crops grown on higher elevation suffer drought stress.

On the other hand, Rabi season is during November to February. Rabi is a short, dry season which is characterized by scanty or no rainfall, low temperature, and clear skies. The agricultural environment during this season is very favorable for high yields per unit area. The number of crops during the Rabi season is large compared to the number grown during Kharif season, although the cultivated area of this season is rather small. Boro rice, wheat, potato, oilseeds, pulses, spices, tobacco, vegetables etc. are the crops grown during this season.

The choice of crops to be grown in an area is determined to a large degree by flooding characteristics. The depth, timing, duration and rate of rise and fall of water levels are important factors influencing when and what crops can be grown. Since depth of flooding is a key factor in crop selection, four different land classes based on flood depth are used in water resources development projects as presented in **Table 2.6.2**. Each land class is associated with a specific land use in terms of main crop rotation (see **Figure 2.6.1**). These land classes with associated depth of flooding and crops suitable during Kharif-I and Kharif-II are shown in **Table 2.6.2**.

Judging from the relationship among crops, land class and flood depth, flooding does not always result in crop damage, and there is a phenomenon that the floods and crops have been co-existing. Therefore it should be noted that floods do not only result in damage but can also benefit crops and farmers.

b) Fishery

Damage to fishery product results from the raised water levels in the fish pond. The owners of fish ponds cover them with nets to avoid the fish flowing away from ponds. But they cannot be protected against sudden and large scale floods such as flash floods or tidal surges. The fishery products are affected by loss, death and diseases by various causes and so on.

c) Livestock

Livestock such as cattle, poultry and goats are also one of the important resources of people's daily lives in rural areas. Livestock can move by themselves and can evacuate led by their owners only when there is enough time to evacuate. But they cannot escape when rises is water levels are sudden such as during flash floods, which do not give them enough time. Livestock can be affected by loss, death by drowning, diseases of various types.

d) Buildings

Structural damage differs according to the type of building, materials used in construction and whether the area to be built is urban/rural or riverside. According to the field reconnaissance carried out by the Study Team, farmer's houses in rural areas are generally built either on infilled ground (heights more than 3m above general ground level) or supported by bamboo or concrete poles high enough to avoid their inundation. These farmers' houses are assumed to be mostly protected from the normal scale flood. But houses near riverside are flooded almost every year with slight damage because their floors are very low. An example of flood damages of building by type and materials is shown in **Table 2.6.3**.

On the other hand, the movable assets of buildings differ also by type of building such as 1) household effects in residential house, 2) seeds, machines and tools for cultivation in farmer's house, 3) machines, raw materials, products in factory, and 4) documents, desks and chairs, inventory, telephone and OA equipment including computer in commercial building. These assets are very important elements whose loss can be avoided by evacuation from flood supported by flood warning.

According to the field reconnaissance by the Study Team, residents do not always evacuate with their household effects during low levels of inundation. Platforms are prepared on which their household effects are placed in case of the normal flood. They leave these in their houses and the head of households guard to ensure their security. But in case of flash flood or tidal surge, they cannot afford to remain at their houses with the property.

e) Infrastructure

Damage to infrastructure is primarily with regard to river infrastructure and transportation. The river infrastructure is composed of embankments, structures (sluice/bridge/culvert), irrigation canals, protection works and others. The transport infrastructure is categorized into roads, railways, bridges and ferry ports. Furthermore, river bank erosion by flood has seriously impacted on the environment of the riverside areas.

(3) Damage to Human Life

To save human life is the first priority for protection from flooding. The FFWS plays a very important role as one of the non-structural measures, especially in the situation of insufficient infrastructure to mitigate flood damage. The causes of death by flooding are not only directly through drowning but also indirectly through snake bites, electric shock, being hit by heavy or sharp materials, and diseases due to deteriorating sanitation of the environment caused by water pollution, destruction of sewerage facilities and decomposing foods. Injuries during floods are also generated by various causes.

(4) Other Damages

Flood damage is not limited to those cases mentioned above. There are many kinds of other intangible damage including increased fuel use by traffic congestion, loss of business opportunities, reduction of industrial output, closure of schools, hospitals and other public facilities and so on.

2.6.3 Actual Flood Damages

(1) Records of Flood Damages

Flood damage is recorded by various agencies for their own purposes, but at present there is no regularly published information on the various sources of damage or comprehensive documents where such information has been collated. The major agencies to manage the flood damage records are FFWC under BWDB, DMB and DRR (Directorate of Relief and Rehabilitation) under MDMR, EMB, Disaster Forum Bangladesh and newspapers. Disaster Forum Bangladesh is a forum of 60 national and international NGOs, government and donor agencies, academics and practitioners involved in the field of disaster management in Bangladesh. This forum commenced publication of an annual report in 1997 named "Bangladesh Disaster Report".

This report is comprehensive and includes records and comments of most disasters that now occur in Bangladesh.

The records of flood damage in FFWC are reported in the 'Annual Flood Report', published annually after the end of the monsoon season. Its contents are limited to damage to infrastructure managed by BWDB such as embankment, structure (sluice/bridge/culvert), irrigation canal and so on. DRR has records which include damage to infrastructure such as roads, bridges and dams, human life, homesteads, crops, livestock, fisheries and so on. These records are sent by the district office of DRR that collects them from local administrative offices of Upazilla.

The most comprehensive record of flood damage collected by the Study Team was the "Report on Bangladesh Flood 1998 (Chronology, Damages and Response)". This was a special report compiled by Management Information & Monitoring (MIM) Division of DMB in December 1998. It is recommended that this kind of report/record is officially prepared and published on a regular basis.

(2) Flood Damage

Delineation of flood prone areas based on long term flood information has been conducted and published by the Soil Research Development Institute. In this map, entire Bangladesh is divided into 6 systems, i.e. Teesta, Brahmaputra (Jamuna), Meghna, Ganges (Padma), Karnaphuli and Coastal Tidal Systems. Flood prone areas by type of flood are shown in **Figure 2.6.2** and summarized below:

- High frequency of river flood: Almost all area of riverside of the Teesta, the Ganges, the Jamuna and the Meghna
- High frequency of flash flood: Near the Indian border of the Meghna and the south western area of the Karnaphuli in Chittagong Division
- Severe tidal flood: Coastal tidal area

As already mentioned above, since there are no regularly published records of flood damages, it is very difficult to analyze in detail the flood damages. **Table 2.6.4** shows flood damages that occurred in 1998. According to this record, total number of affected people was more than 30 million. The most affected numbers were located in Dhaka District of Dhaka Division (3,038,867 persons, 35% of population) followed by Sirajganj District of Rajshahi Division (2,000,859 persons, 74% of population) and Narayanganj of Dhaka Division (1,512,797 persons, 71% of population). The total number of deaths was recorded as 918 people. Dhaka District was most affected (125 persons) followed by Shariyatpur District of Dhaka Division (64 persons) and Brahmanbaria District of Chittagong Division (52 persons).

Total damaged crop area due to 1998 flood was around 1.9 million ha. The most crop damages were recorded in Comilla District of Chittagong Division (108,719 ha), followed by Barisal District of Barisal Division (84,282 ha), Nawabganj District of Rajshahi Division (83,693 ha), Brahmanbaria District of Chittagong Division (59,595 ha) and Natore District of Rajshahi Division (56,851 ha).

The damage for crops by ton and by Taka are shown in **Table 2.6.5** and the damages for livestock are shown in **Table 2.6.6**.

A map showing flood affected crop area in September 1998 was published by the Soil Resource Development Institute (SRDI). From this map, it can be observed that the area alongside upstream reaches of the Teesta, the Jamuna, the Padma and downstream reaches of the Padma are extremely affected. It is noticeable that the crops in areas of the Karnapuhli system were damaged early by prolonged rain and flood but replanted in September. Comparing with the flood status map in 1998 issued by FFWC, the area with a "Severe" degree of flood impact mostly coincided with areas on the upstream Padma and Jamuna and downstream reaches of the Padma. It did not coincide with the middle reaches of the Padma which was only very slightly affected. The flood status of the Atrai river is normal to moderate with very slightly flood affected area for crops.

The damage of 1998 flood in monetary value has been estimated by several past researches. However, all those research results do not include damage to human life, damage due to injury, damage to homesteads etc. Since there are no standards for the estimation of economic damages to humans or homesteads in Bangladesh, the basic concept of the standards to evaluate the damage to human lives published by the Ministry of Land, Infrastructure and Transport (Japan) was taking into considering the social and economic conditions of Bangladesh.

2.6.4 Estimation of Annual Average Flood Damage

(1) Categories of Flood Damage

Flood damage can be classified as tangible or intangible. In this study, the tangible damage was quantified as much as possible and is categorized on the basis of the characteristics of damaged assets and human lives affected by flood as follows:

Categories of the Flood Damages

1. Damages to Assets	
(1) Building	(a) Structure
	(b) Indoor Movables
(2) Agricultural Products	(a) Crops
	(b) Livestock
	(c) Fishery
(3) Infrastructure	(a) River Infrastructure
	(b) Road
	(c) Telecommunication
2. Human Lives	
(1) Injuries	
(2) Death	
3. Other Damages	

(2) Detailed Flood Damage Data

A methodology for comprehensive estimation of flood damage has not yet been established in Bangladesh. But the "Report on Bangladesh Flood 1998 (Chronology Damages and Response)" compiled by Management Information & Monitoring (MIM) Div., Disaster Management Bureau includes most damage that occurred in 1998. The information from that study formed the basis for the estimation of damage in this project.

According to that report, there are some types of damage that are not yet evaluated in monetary terms, such as damage to buildings, infrastructure and human lives. In such cases the Study Team evaluated these using assumptions based as much as possible on the "Residents-Household Survey", a component of the "Survey on Evacuation and Awareness of Flood Victims" conducted by the JICA Study Team in February 2003.

<u>Damages to Assets</u>

- The damages for buildings are estimated on the basis of unit value of buildings, damage rate by inundation depth, the number of partially and fully damaged houses by district. The two levels of damage rates are set up by the characteristics of flood damages. The one is for the damages by flash flood and the other is for the damages for normal flood in monsoon season. The damages by the flash flood is assumed to be higher than the flood damages in the monsoon season. Then, the higher damage rate was set up for the damages in the flash flood area. The damage rate by inundation depth are shown in **Table 2.6.7**.
- The damages for live stock are estimated on the basis of the average damages per head for the kinds of livestock such as (cattle, goat and poultry), the number of livestock by district which were affected and died.
- The damages for human lives are estimated by assumption of expenditure of medical cares for injuries and the average income to be earned by victims after their death for died persons by district.

- The damages for crops, fishery and infrastructure except roads by district for BWDB Project (Rehabilitation Cost and Emergency Requirement) and telecommunication are based on the "Report on Bangladesh Flood 1998".
- The damages for roads is based on the 1998 Flood Damage Assessment, Final Report. Nov. 1998. Govt. Peoples Republic of Bangladesh, Local Govt. & Engineering Dept.

Damages to Human Lives

- The injuries were estimated on the basis of the number of injuries by district and by referring to the "Report on Bangladesh Flood 1998", the average damages per house by referring to the "Residents-Household Survey".
- The damages of death is difficult to estimate in general because the human lives have no market prices in the economy. In this study, the income which the person might be expected to earn in his life after death is assumed to be the damages of his death. Then the damages of death were estimated on the basis of (i) the number of death by district by referring to the "Report on Bangladesh Flood 1998", (ii) the average income by referring to the "Residents-Household Survey", (iii) the average age and (iv) the average year to work by the statistical yearbook of Bangladesh.

Other Damages

- The flood damages are not limited to the tangible damages mentioned above. There are many kinds of intangible damages. The other intangible damages are estimated by setting up the rate to total damages for assets as 20%.

As a result, the estimated damages of 1998 flood by the Study Team were 155,735 million Taka at the current prices of 2002.

The detailed assumptions by category are shown in **Table 2.6.8** and the flood damages by category are shown in **Table 2.6.9**.

(3) Average Annual Flood Damage

The flood damage was then estimated for 2, 5, 10, 25, 50 and 100 year return periods. In this Study, the return period associated with the 1998 flood damage was assumed to be 50 years.

The major considerations in estimating flood damage by return period are as follows:

- Vulnerability for flood hazard is considered as same level as current situation.
- The people of Bangladesh are accustomed to protect their properties in their long life experiences to minimize the damage. They do not always consider the flood to bring the damage to them as the negative benefits but rather they are assumed to have utilized the positive effects of flood such as natural water supply by flood for irrigation, new soil flew from upstream to fertile their farm lands, fishing in the flooded field or river and so on.
- The crops are planted in the proper season to minimize the flood damages by

taking account of the characteristics of crops.

- There is very slight flood damage in the flood of short term return period such as 2- and 5-year. Then it was assumed that only the indoor movables and crops would be damaged but other damages of category could not be damaged in flood prone area of 2-year of return period. The flood damage for the return period of 2-year was estimated as 6,040 million Taka.
- The flood damage in catastrophic conditions like the flood happened in 1998 as 50 years of return period tends to be drastically increased.
- The flood damage for the infrastructure in the short return period is negligibly smaller than that of longer return period.
- The flood damage is related to the years of return period and the flood prone area by return period

By taking account of those considerations mentioned above, and adopting the flood damages of 2 year return period as 6,040 million Taka and 50 year return period as 155,735 million Taka, the flood damage by return period was estimated by the following formula.

$$D_T = \alpha \times D_{50} \times \left\{ (A_T / A_{50}) \times (T/50)^{\beta} \right\}$$

Where,

T:	Return Period of Flood Event (Year)
D_T:	Flood Damages in the Return Period of T Year (Million Taka)
A_T:	Flood Affected Area in the Return Period of T Year (Million Taka)
α, β:	Adjustment Factor for Natural Conditions and Life Style of the People in Bangladesh

The formula for which the values of D_{50}, A_{50}, α and β are substituted is as follows.

$$D_T = 1.98611 \times 155{,}735 \times \left\{ (A_T / 100{,}250) \times (T/50)^{0.84789} \right\}$$

The result of calculation of the flood damages by return period by adopting this formula is shown in the following table.

Estimated Probable Flood Damages

Year of Return Period	2	5	10	25	50	100
Flood Affected Area (km^2)	30,000	39,900	49,100	89,500	100,250	103,700
Flood Damages (Million Taka)	6,040	13,136	23,644	51,424	155,735	166,603

On the basis of the estimated probable flood damage as shown in the following table, the average annual flood damage is estimated as 12,160.9 million Taka.

Average Annual Flood Damage

(Unit: Million Taka in 2002 Prices)

Return Period (Years)	Probability of Occurrence	Flood Damages	Average Damages	Probable Damages	Average Annual Damages
1	----------	0			
	(1/1)-(1/2)		3,020.0	1,510.0	1,510.0
2	----------	6,040.1			
	(1/2)-(1/5)		9,588.2	2,876.5	4,386.5
5	----------	13,136.4			
	(1/5)-(1/10)		18,390.5	1,839.1	6,225.5
10	----------	23,644.7			
	(1/10)-(1/25)		37,534.4	2,252.1	8,477.6
25	----------	51,424.1			
	(1/25)-(1/50)		103,579.8	2,071.6	10,549.2
50	----------	155,735.4			
	(1/50)-(1/100)		161,169.3	1,611.7	12,160.9
100	----------	166,603.3			

2.7 Telecommunications

2.7.1 General

Telecommunication methods are generally divided into wired communication incorporating fixed telephone networks, wireless communication network incorporating mobile phone networks, and satellite communication networks. In this section, Basic Data on the density of the Telecommunication Infrastructure (fixed telephone, mobile phone, Television, Internet Host) are given followed by a description of the existing telecommunication network.

2.7.2 Current Telecommunication Network

(1) Basic Data of Telecommunication Infrastructure

The density of the telecommunication infrastructure in Bangladesh as compared to neighboring countries (India, Pakistan, Nepal) is shown below based on the International Telecommunications Union (ITU) statistics for 1998 and 2001.

This indicates the density of telecommunication infrastructure in Bangladesh is very poor even when compared to neighboring countries.

Fixed Telephone Density

Fixed Telephone Density (units/100 habitants)

Country	1998	2001
Average of Asia & Oceania	7.92	11.23
India	2.20	3.38
Pakistan	1.89	2.35
Nepal	0.89	1.26
Bangladesh	0.3	0.39

Increasing rate of fixed telephone density is not as high as mobile phone density in Bangladesh.

Mobile Phone Density

Mobile Phone Density (units/100 habitants)

Country	1998	2001
Average of Asia & Oceania	3.25	9.92
India	0.12	0.56
Pakistan	0.14	0.55
Nepal	-	0.07
Bangladesh	0.06	0.40

There has been a very significant increase in the mobile phone density in Bangladesh.

Television Density

Television Density (units/100 habitants)

Country	1998	2000
Average of Asia & Oceania	19.14	21.7
India	7.1	7.8
Pakistan	8.6	13.1
Nepal	0.4	0.7
Bangladesh	0.7	1.5

The television density increased by approximately twice in Bangladesh, but still remains very low.

Internet

Internet Host Number and Density

Country	1998		2001	
	(Number)	(Density)	(Number)	(Density)
Average of Asia & Oceania	-	8.3	13,364	9.5
India	13,253	0.13	82,979	0.8
Pakistan	3,096	0.21	11,319	0.8
Nepal	153	0.07	1,513	0.6
Bangladesh	-	-	3	0.0002

Internet host number in Bangladesh was only three in 2001. This is extremely low when compared with neighboring countries.

(2) The Telecommunication Network

1) Wired Communication Network

In Bangladesh, the nationwide telephone network is for the most part administered by a governmental agency, the Bangladesh Telegraph and Telephone Board (BTTB), with segments of the network operated by a number of private entities such as the Bangladesh Rural Telecom Authority (BRTA).

BTTB network

Over the last several years, the network operated by the BTTB has been upgraded to high speed digital technology. For instance, optic fiber and microwave technologies have been introduced for the trunk lines and a telecommunications network with a maximum transmission capacity of 155 Mbps has been constructed, utilizing the world's most advanced Synchronous Digital Hierarchy (SDH) technology. The coverage area of digital exchange subscribers is also increasing year by year in the larger cities.

Nationwide, the number of subscribers has been increasing. However, in rural areas, people do not appear to be drawn into subscribing to telephones and thus the upgrading of telecommunications equipment in these rural regions has not taken place as rapidly. There seems to be several reasons for the more limited expansion of telephone networks in the rural regions. The first and foremost is the initially high expense for subscribing to a new telephone line in Bangladesh (20,300 Taka, in 2002). Furthermore, it appears that the time between applying for a telephone service and its actual usability is too long. Despite the fact that the trunk line capacity has been enhanced, the service level to end users has not been improved.

BRTA network

BRTA mainly provides local telephone services in rural areas. It has grown steadily by offering immediate initiation of service at a relatively low fee. At present, the BRTA operates its own dedicated network with direct connections between its local service areas and Dhaka.

2) *Wireless Communication Networks*

In Bangladesh, GRAMEEN is the only nation-wide cellular telephone service provider and City Cell, AKTEL and SHEBA provide services only to major cities and urban areas. The cellular telephone service network has grown substantially in recent years due to the lower cost of installation in comparison to landlines.

GRAMEEN mobile phone

At GRAMEEN, the number of new subscribers has increased from 3,085 in 2000 to 9,222 in 2001. Moreover, GRAMEEN's service network is constructed along the Bangladesh Railway lines and extends coverage to rural areas. Thus it has a nationwide network equipped with optic fiber and microwave networks. The company's strategy has been to expand its business to not only urban but also rural areas. GRAMEEN is entering into a number of new businesses including internet provision and governmental projects and the company's policy is to involve itself in more public projects. Additionally, GRAMEEN, being a private entity, is well aware of the imperative of offering good services to its customers. It is therefore quite possible to be utilized as a relay line for the FFWS telecommunication system.

Their mobile network provides not only voice communication but also data communication. Thus, this network is applicable for digital data communication of the FFWS.

3) Satellite Communication Networks

VSAT System

The VSAT system is a global trunk-line satellite network consisting of a large antenna and a number of ground stations distributed throughout the nation. The hub-station is responsible for managing and controlling the entire network. In Bangladesh, the system is operated exclusively by a multi-faceted corporation, SQUARE. The system's hub station is located in Dhaka, and with a number of corporate network users as a basis, SQUARE manages a robust O&M system. SQUARE can possibly act as a relay line provider.

INMALSAT System

This satellite communications network has been developed and is being operated to facilitate ocean communications. Due to its relative ease of installation and operation, the system is widely utilized for stationary communications as well as mobile communications facilities. In Bangladesh, BTTB acts as a window for handling subscription applications and payments. The drawback of this system is that the station equipment owner is responsible for maintaining equipment. It is therefore difficult to ensure maintenance of the facilities of this System.

4) Other Telecommunication Situation

Optical Fiber of PDB

The Power Development Board (PDB) owns and operates an optic-fiber network, though it is only a small part of the whole network. This partial optic-fiber network has been installed on both 230 KV and 123 KV powerlines, connecting the sections from Dhaka to Chittagong and Bhairab Bazar. However, it is said that these lines are not being operated currently.

At present, there is a plan to construct a nationwide load dispatching system. The plan is to utilize both OPGW (Optical Fiber Composite Overhead Ground Wire) and microwave as basic components of the network, and it should be completed in two years. However, the feasibility of leasing the network cannot be determined and it is not considered possible to use Optical Fiber of PDB at present.

Interagency network

Governmental agencies should be directly connected for smooth exchange of important information, quick decisions, and cooperation of agencies. Bangladesh governmental activity is independent within each agency and there is insufficient communication and cooperation between them. Thus, there is some duplication of networks. Interagency networks connecting disaster related agencies such as BWDB, DMB, BMD, IWM, SPARRSO, CPP, CEGIS, etc. are necessary to ensure effective and cooperative governmental services through communication. Particularly during flood or cyclone emergencies, cooperation among MDMR (Ministry of Disaster

Management and Relief), MOWR (Ministry of Water Resources), and other relevant Ministries by means of an interagency network is essential.

Power Supply

In operating communications facilities, it is indispensable that the power supply be reliable. PDB runs reasonably extensive power supply lines as long as there are trunk roads. However, their power supply lines are not reliable with power blackouts at least once a day, some lasting as long as 30 minutes.

2.7.3 Future Development Plans

Figure 2.7.1 shows the past trend of fixed telephone and mobile phone growth in Bangladesh to the 2001 financial year.

(1) Fixed Telephone

According to the BTTB annual report, the growth of telephone exchange capacity in Bangladesh in the last five years was on average only 50,000 lines per year. The pending demand for telephones has been increasing at a faster rate than telephone expansion. For this reason, BTTB has implemented programs including:

- Install new digital telephone exchanges both for expansion of exchange capacity and to replace some of the old manual/analog exchanges.
- Install and expand of Trunk Automatic Exchanges at different locations of Bangladesh to meet the additional need of inter city traffic.
- Replace Analog transmission links by digital links

Telephone lines had increased to around 800,000 in 2001.

(2) Mobile Phone

The average growth rate of mobile phone subscribers in Bangladesh over the last three years was about 100 percent. The potential growth of the telecom sector in Bangladesh is bright, due to the country's large population and relatively small number of phones.

According to the International Telecommunications Union (ITU) statistics for 2001, Bangladesh had only 0.39 fixed telephones and 0.40 mobile phones per 100 inhabitants. There are virtually no telephones in the rural areas where more than 80 per cent of people live.

Mobile phone networks can be installed much more rapidly than fixed networks. According to the GRAMEEN annual report, to address this the Village Phone Program was begun in 1997 in the rural area. The program is a unique effort to provide telecommunications facilities in rural areas while providing the Village Phone operators, mostly rural poor women, a good income-generating opportunity. The program yields positive social and economic impacts. For this reason, mobile phone subscribers in rural areas will increase more.

Also the wide availability of second-generation mobile systems gives developing countries the opportunity to make a technological and commercial jump. Similarly, it is expected that Bangladesh will also experience a significant development of mobile phone services in the near future.

(3) Information Technology

Bangladesh intends to use Information Technology (IT) as the key driving element for socio-economic development. For this purpose an IT Policy was established. In the IT Policy, some infrastructure developments were presented as follows:

- The private sector will be allowed to create a Broadband Telecommunication Backbone within the country as well as a High Speed International Network.
- BTTB will develop a national access platform for more efficient Internet use.
- Internet exchange will be set up for national inter-connectivity among Internet Service Providers.
- All analog telephone exchange will be converted to digital.

For these developments BTTB is expected to take the leadership to coordinate with other public utility sectors (PDB, Gas, Railway, etc).

2.8 Institutions

2.8.1 Overall Government Organization

(1) National Government

Bangladesh is governed by a Parliamentary form of Government. The Government of Bangladesh is headed by the President. However, the executive power lies with the Prime Minister. The Prime Minister is assisted by a council of Ministers. There are 38 ministries. Flood forecasting comes under the jurisdiction of Ministry of Water Resources (MOWR). The present organizational structure of GOB is illustrated in **Figure 2.8.1**.

(2) Local Government

Various levels of local government are being established in accordance with 'State Policy and Recommendations' of the Local Government Commission. All local government institutions come under the administrative responsibility of the Local Government Division (LGD) of the Ministry of Local Government, Rural Development and Cooperatives (MLGRD).

The country is divided into six administrative Divisions, namely, Dhaka, Chittagong, Khulna, Rajshahi, Sylhet and Barisal. Each Division is headed by a Divisional Commissioner. Each Division is divided into some Districts (Zilla). The administration of each District is headed by a Deputy Commissioner. At present, there are 64 Districts. Each District is further divided into some Upazilla (sub-Districts). Currently, there are 507 Upazilla, of which 36 are in Metropolitan cities. In urban areas, the Upazilla is called Thana.

In the rural area, each Upazilla is headed by an Upazilla Nirbahi Officer (UNO) and divided into some Unions. Unions are the lowest tier of administration in rural areas and headed by an elected Union Chairman. There are 4484 unions in the country. Each Union is composed of some villages. The total number of villages is 87,319.

For urban area, there are municipalities and for bigger urban areas, there are city corporations. There are 6 city corporations and 223 municipalities. Municipalities are headed by an elected chairman and city corporations are headed by an elected mayor. Each municipality or city corporation is divided into some wards. This is the lowest tier of administration in the urban area and is headed by an elected ward commissioner.

Some of the local government functions in urban and rural areas are entrusted to bodies elected by the people. Such bodies are Municipalities and City Corporations in the urban areas and Union Parishads (councils) in rural areas. There are also proposals for elected District Council and Upazilla Council at the District and Upazilla levels respectively.

2.8.2 *Outline of Water-related Agencies*

(1) National Water Resources Council (NWRC)

National Water Resources Council is the highest national body on all water policy issues, including coordinating all aspects of water management, resolution of inter-agency conflicts, and adaptation of common standards for the water sector. The NWRC has an executive committee that issues directives to water management institutions. The council is headed by the Prime Minister and the executive committee is headed by the Minister of Water Resources. The Council is coordinating over 40 agencies and at least 13 different ministries involved directly or indirectly in the water sector.

(2) Ministry of Water Resources (MOWR)

Ministry of Water Resources is the apex body regarding the water resources sector of the country. The Minister is the head of the ministry and appointed by the Prime Minister. The Secretary is the administrative head of the ministry. There are a number of implementing agencies under the ministry. One of the principal mandates of the ministry is to provide administrative control, overall strategic planning, budgetary provision, expenditure control, establishment management and monitoring of the line agencies. The Ministry also works on policy formulation. All projects and procurements planned by the line agencies must be approved by the Ministry. The Ministry also has the authority to approve funds for goods and services procurement from 10 million to 100 million taka. It may be noted that procurement less than 10 million taka can be approved by the line agency and over 100 million taka must be approved by the National Economic Council (NEC). The line agencies of MOWR are presented in **Figure 2.8.1** and their mandate are briefly outlined below.

Bangladesh Water Development Board (BWDB): This is the biggest agency of the

MOWR. It has the total authority of planning, implementation and operation of medium and large scale water resource projects of flood control, irrigation, river training, dredging, drainage and hydrology. The Flood Forecasting and Warning Center (FFWC) belongs to this board. More details about BWDB are compiled in the following section.

Joint Rivers Commission (JRC): This is responsible for dealings with India and other co-riparian countries through similar organizations in those countries. The JRC is mainly responsible for monitoring the existing water sharing treaty and entering into new water sharing treaties, if required. The JRC is also responsible to deal with co-riparian countries for information acquisition. The JRC Bangladesh and the JRC India meet 4 times per year on a routine basis. Each country provides 3 members to the JRC. There are task specific committees within JRC, for example, Technical standing committee, Joint committee of experts on water sharing, and Joint committee to implement Ganges water treaty.

Water Resources Planning Organization (WARPO): This is responsible for water sector planning at national level and acts as the secretariat of the executive committee of the NWRC. It is also responsible for establishing and maintaining the National Water Resources Database (NWRD), a management information system and for acting as a clearing-house to maintain coordination within the sector.

River Research Institute (RRI): Situated in Faridpur, this Institute carries out basic and applied research on rivers. This includes river training, hydraulic physical modeling, morphological analysis, estuary hydraulics, coastal hydraulics, and geotechnical investigation. There is a routine relationship between RRI and BWDB. Subsoil samples collected by the Groundwater Circle of BWDB and sediment samples collected by Morphology Circle of BWDB are sent to RRI for analysis. Also, BWDB requests RRI to carry out specific research.

Bangladesh Haor and Wetland Development Board (BHWDB): This was created by a cabinet order to preserve and develop Haor (bowl-shaped natural depression, common in the Northeast) and other wetlands. Its mandate includes project planning, and monitoring to keep the ecological and environmental balance of the wetlands.

Institute of Water Modeling (IWM): This is an autonomous trust formed by the Government to provide services in water modeling for improved and integrated water resources management. The Board of Trustees is the governing body of IWM and gives policy guidelines to the management. Sixteen trustees have been drawn from different ministries, departments and organizations of Bangladesh and abroad. The Secretary of MOWR is the Chairperson of the Trust. The daily management is the responsibility of the Executive Director. Years of close liaison with various international institutions like the Danish Hydraulic Institute (DHI) gives the IWM a high degree of competence in the fields of computational hydraulics. IWM has developed many models in the fields of river flow, flood, irrigation, drainage, morphology, sediment transport, etc. IWM also carries out applied research and conducts training programs. There is a close relation between IWM and FFWC. At present, IWM is working within the DANIDA project for model updating and providing training to the FFWC staff on model operation. The DANIDA project proposes that IWM will update the model of FFWC on a regular basis.

Center for Environment and GIS (CEGIS): This is an autonomous organization for integrated environmental analysis using GIS, remote sensing, and the information database. The organization has been set up under the aegis of MOWR supported by the Government of Netherlands. The services include consulting, research, spatial analysis, database management, and training for various sectors like water resources, agriculture, fisheries, and environment. There is a close relation between BWDB and CEGIS on the GIS-based water resources information database.

2.8.3 Water-related Law and Regulations

(1) National Water Policy

The National Water Policy is the umbrella policy for the water sector. The National Water Policy was prepared by the MOWR and enacted in 1999, with the intension of guiding both public and private actions for ensuring optimal development and management of water.

According to this policy, ownership rests with the State and the users are accorded with certain rights. The policy provides provision to regulate water use in areas of scarcity, to protect downstream users and to confer secure, defensible and enforceable water rights on private and community bodies. The Policy also mentions the priority ranking for the water rights. In general, the priority for allocating water during critical periods in the water shortage zones will be in the following order: domestic and municipal uses, non-consumptive uses (like navigation, fisheries, and wild-life), sustenance of the river regime, and other uses (like irrigation, industry, environment, salinity management, and recreation). Regarding the institutional setup, the Policy states that there should be separation of policy, planning, and regulatory functions from implementation and operational functions.

The Policy covers the following items:

National Water Policy (Chap. 4)

- River Basin Management (Sec. 4.1)
- Planning and Management of Water Resources (Sec. 4.2)
- Water Rights and Allocation (Sec. 4.3)
- Public and Private Involvement (Sec. 4.4)
- Public Water Investment (Sec. 4.5)
- Water Supply and Sanitation (Sec. 4.6)
- Water and Agriculture (Sec. 4.7)
- Water and Industry (Sec. 4.8)
- Water, Fisheries and Wildlife (Sec. 4.9)

- Water and Navigation (Sec. 4.10)
- Water for Hydropower and Recreation (Sec. 4.11)
- Water for the Environment (Sec. 4.12)
- Water for Preservation of Haors, Baors, and Beels (Sec. 4.13)
- Economic and Financial Management (Sec. 4.14)
- Research and Information Management (Sec. 4.15)
- Stakeholder Participation (Sec. 4.16)

Institutional Policy (Chap. 5)

Legislative Framework (Chap. 6)

(2) National Water Management Plan (NWMP)

The National Water Management Plan was prepared by WARPO and the draft final was completed in December 2001, and is available at WARPO's website (www.warpo.org). The Plan in now under active consideration by the National Water Council for approval. The Plan was prepared with the intention of operationalising the directives given by the National Water Policy. The Plan is a framework plan within which line agencies and other organizations are expected to plan and implement their own activities in a coordinated manner. It is proposed that NWMP will be reviewed and updated every five years. The Plan is presented in three phases: in the short-term (2000-2005) it is considered as a firm plan of ongoing and new activities; in the medium term (2006-2010) it is an indicative plan, and in the long term (2011-2025) a perspective plan.

The planned activity programs have been presented in the following eight sub-sectoral clusters:

- Institutional Development
- Enabling Environment
- Main Rivers
- Towns and Rural Areas
- Major Cities
- Disaster Management
- Agricultural and Water Management
- Environment and Aquatic Resources

Each cluster comprises a number of individual programs. A total of 84 programs are proposed with an investment cost of around 1 trillion taka.

Though there are broad guidelines on flood forecasting, there is no specific framework or project outlined on flood forecasting in the NWMP.

(3) National Water Code

It is now under preparation to align with the Policy requirement. It will review and consolidate the laws governing ownership, development, appropriation, utilization, conservation, and protection of water resources. WARPO is now preparing a draft.

However, it is not known exactly when this will be enacted. In this law, among other things, there should clear demarcation about the protected land requirement on both sides of the river.

(4) Other Relevant Policies

A wide range of policies for various sectors have a bearing on the water sector. These include:

- The Irrigation Act (1876)
- Embankment and Drainage Act (1952)
- Inland Water Transport Authority Ordinance (1958)
- Bangladesh Water and Power Development Boards Ordinance (1972)
- Irrigation Water Rate Ordinance (1983)
- Groundwater Management Ordinance (1985)
- Land Management Manual (1990)
- Water Resources Planning Act (1992)
- National Environment Policy (1992)
- National Forestry Policy (1994)
- Environmental Conservation Act (1995)
- National Energy Policy (1996)
- Water Supply and Sewerage Authority Act (1996)
- Environmental Conservation rules, including Water Quality Standards (1997)
- National Fisheries Policy (1998)
- National Policy for Safe Water and Sanitation (1998)
- National Agricultural Policy (1999)
- Industrial Policy (1999)
- Environmental Court Act (1999)
- Water Development Board Act (2000)

It may be noted that there is no land use policy or regulation. There are, however, land use plan for the large cities only.

2.8.4 Bangladesh Water Development Board (BWDB)

(1) *Institutional Setup*

Originally established in 1959 as the Water Wing of the East Pakistan Water and Power Development Authority, the organization was restructured in 1972 as BWDB and its mandate is set to water resources development. It planned and executed 625 projects till June 30, 2002 throughout the country including flood control, dredging, drainage, irrigation, town protection, coastal protection, erosion control, and land reclamation (Annual Report, 2001-2002, BWDB). Major achievements of BWDB are as follows:

- Total projects completed are 625 till June 30, 2002
- Agricultural land of 5.38 million hectares made free from flood and drainage congestion

- Irrigation facilities provided for 1.6 million hectares of land
- Total length of embankments constructed is 9,401 km, out of which 4,255 km are in coastal areas
- Total donor assistance is 2.5 billion US$ between 1972 and 1995

Bangladesh Water Development Board Act, 2000 redefines the power and functions of the BWDB.

Power and responsibility

- Control surface water flows and underground aquifers
- Develop standards and guidelines for O&M
- Procure plant, equipment and ancillary material
- Procure advisory and consultancy services
- Levy and collect service charges for O&M and cost recovery
- Undertake the execution of any water related project

Functions

- Construction of dams, barrages, reservoirs, embankments, regulators, etc. for river development, flood control, drainage, irrigation and drought prevention
- Dredging, re-excavation, and desilting of water channels
- Soil preservation, land reclamation and estuary control
- River training and river bank protection
- Construction and maintenance of coastal embankment
- Prevention of salinity intrusion and desertification
- Rainwater harvesting
- Flood and drought forecasting and warning
- Hydrological survey and investigation
- Forestry and fishery development
- Basic and applied research
- Development of water users' and other stakeholders' associations.

The National Water Policy of 1999 made the following stipulations about the mandate and structure of BWDB (Annual Report, BWDB, 2000-2001):

- Emphasizing the separation of policy functions from those of operation and management
- Confining BWDB's planning function to sub-regional and local levels only (WARPO will be the exclusive agency for macro level water resources planning)
- Making BWDB responsible for execution of projects above 1000 ha, leaving the development of small-scale projects to local bodies
- Proposing management transfer of small and medium scale projects to beneficiaries
- Emphasizing the involvement of stakeholders at all stages of the project cycle.

(2) Manpower

Until recently there was a staff of around 18,000 in BWDB. A re-organization was ordered in 1998, where the total staff strength was set at 8,860. Total staff strength is being reduced through progressive retirement by natural attrition and it is now 9,706 (June 30, 2002). It was 10,069 on June 30, 2001. It is expected that by 2006, the re-organization process will be completed. The staff composition as per re-organization is shown below. It is to be noted that support staff number is about 3 times the number of professional staff.

Target Staff Composition of BWDB

Class	*Type*	*Number*
I	Management and senior professionals	1,016
II	Junior professionals	820
III	Technicians, craftsmen, clerks, accountants, drivers, etc.	4,125
IV	Craftsmen, gauge readers, support staff, etc.	2,899
Total		**8,860**

(3) Organizational Structure

BWDB is an autonomous body under the MOWR. Under recent reforms, policy functions now vested in a Governing Council and the Board's activities are now confined to executive and operational functions only.

There is a 13 member Governing Council of BWDB, headed by the Minister of Water Resources. The main function of this Council is to give advice on the board's policy, planning, and operation. The other members of the Council are secretaries of four ministries, namely, water resources, finance, local government, and environment; Director Generals of BWDB, and WARPO; Government nominated two water specialists, one NGO representative, one chartered accountant, and two beneficiary representatives.

The Director General (DG) is the Chief Executing Officer of BWDB. There are five wings headed by Additional Director Generals (ADG), in charge of namely, administration, finance, planning, O&M-1, and O&M-2. Under the ADG (Planning), there are Chief Planning, Chief Engineer Design and Chief Engineer Hydrology. Flood forecasting comes under Chief Engineer Hydrology.

The organizational structure of BWDB focusing flood forecasting and warning services is given in **Figures 2.8.2** and **2.8.3**.

It may be mentioned that planning is done by the office under Chief Planning, design is done by the office of Chief Engineer Design under ADG (O&M-2), and all field offices are under ADG (O&M-1 and 2). For the field operation, there are 7 zones each headed by a Chief Engineer. Each zone is divided into some circles headed by a Superintending Engineer. There are in total 20 field circles. Each circle is further divided into some divisions headed by Executive Engineer. Each division is then divided into some sub-divisions headed by Sub-Divisional Engineer (SDE).

There are 4 circles under the Chief Engineer Hydrology, each headed by Director / Superintending Engineer (SE). These are Surface water hydrology circle, Groundwater hydrology circle, River morphology & research circle, and Processing and Flood forecasting circle (PFFC). There are seven branches within PFFC. Flood Forecasting and Warning Center (FFWC) is one of the branches of PFFC. FFWC is headed by an Executive Engineer (XEN). Total staff of hydrology is around 1,000 of which 260 belong to PFFC.

Field data for surface water, ground water and river morphology are collected by the respective circles and all data are sent to PFFC. Data is processed and stored by 3 respective branches of PFFC. Real time data required for flood forecasting is transmitted by C&I division to FFWC. C&I division is also responsible to operate all automatic gauging stations including telemeter stations. With a total strength of 170, C&I division is the single electro-mechanical unit of entire Hydrology.

(4) Institutional Strength of BWDB

With a long history of water resources management, BWDB has developed significant institutional strength over years, such as,

- Staffed with experienced and skilled manpower
- Country wide network
- Ample experience of project planning, design, implementation and operation
- Computerized accounting system
- Contains specialized units like flood forecasting, hydrology, dredging and others

(5) Human Resources Development of BWDB

BWDB is an engineering based organization. Officers are firstly recruited at the level of Assistant Engineer and are provided with basic training at the Central Training Academy of BWDB. Afterwards, demand-based short specialized training is provided.

Hydrology, particularly flood hydrology, is a specialized subject. It is essential to provide routine and specific training to staff working in this field. However, at present, there is no provision for continuing education and advanced training.

BWDB practices periodic rotation of duties for its staff. Hydrology service, as part of BWDB, also comes under this rule. It often occurs that a staff member who has never been exposed to hydrology service is transferred to Hydrology at a managerial post. This can create some problems.

A number of important steps were taken for the staff development of BWDB. These include:

- Establishment of Staff Development Section in 1993
- Establishment of Personnel Management Information System (MIS) (1993 - ongoing)

- Reduction of total staff of BWDB from 18,000 to 8,860 (expected to be completed by 2006)
- Re-organization of BWDB (1995-1998)
- Creation of Annual Performance Report of staff (1993 – on-going)
- Twining Mission under the Netherlands fund (on-going)
- Recruitment plan
- Training Management

In the BWDB system, officials are not entitled to an overtime allowance. However, there is a special allowance for officers working in design, planning and research related work. However, no such incentives are given to the staff of the FFWC, though in the emergency flood period they must work extra hours.

(6) Budget Allocation

The budget of BWDB is divided into revenue and development. The revenue budget includes establishment (salary, office maintenance), non-development (repair, O&M) and loan repayment. The development budget is for implementation of new projects. The budgets of BWDB for the last few years are as follows:

Budget Allocation for BWDB

Unit: Million Taka

Year	Revenue Budget	Development Budget			**Grand Total**
		GOB	Donor	*Total*	
1995-96	2,677.6	2,528.1	3,774.2	*6,302.3*	**8,979.9**
1996-97	2,619.9	3,319.7	5,262.7	*8,582.4*	**11,202.3**
1997-98	2,188.4	3,498.0	5,442.5	*8,940.5*	**11,128.9**
1998-99	2,408.1	4,041.8	6,750.9	*10,792.7*	**13,200.8**
1999-00	2,944.5	5,331.4	5,391.5	*10,722.9*	**13,667.4**
2000-01	3,133.4	5,520.1	4,357.5	*9,877.6*	**13,011.0**
2001-02	2,886.0	5,338.7	2,524.3	*7,863*	**10,749.0**

Source: Annual Reports, 2000-2001, and 2001-2002, BWDB

In 2000-2001, development allocation was for 87 on-going projects of which 81 were investment projects and 6 were technical assistance projects. In 2001-2002, the development program consists of 98 projects, of which 92 were investment project and 6 were technical assistance project.

It should be noted that the development budget of BWDB for 2001-02 was reduced considerably compared to that for 1998-99.

Yearly revenue budget allocation for PFFC for the last 4 years is given below.

Breakdown of the Budget Allocation for PFFC

Unit: Lakh Taka

Year		Circle[1)]	C&I	FFWC	SWPB	RMPB	GWPB	Total
1999-2000	Revenue[2)]	35.4	150.0	19.6	15.0	NA	16.6	NA
	Non-Dev	4.5	49.8	6.0	6.0	2.0	7.0	75.3
	Total	*39.9*	*199.8*	*25.6*	*21.0*	*NA*	*23.6*	*NA*
2000-2001	Revenue	40.4	147.0	29.3	27.8	8.3	23.9	276.7
	Non-Dev	71.0	72.6	7.0	6.8	4.0	8.0	169.4
	Total	*111.4*	*219.6*	*36.3*	*34.6*	*12.3*	*31.9*	*446.1*
2001-2002	Revenue	34.0	162.0	29.1	31.8	8.1	22.5	287.5
	Non-Dev	36.0	88.3	6.0	5.5	4.0	7.0	146.8
	Total	*70.0*	*250.3*	*35.1*	*37.3*	*12.1*	*29.5*	*434.3*
2002-2003	Revenue	33.4	170.0	NA	31.1	8.0	18.3	NA
	Non-Dev	13.5	79.8	6.5	5.5	4.0	7.0	116.3
	Total	*46.9*	*249.8*	*NA*	*36.6*	*12.0*	*25.3*	*NA*

Source: PFFC

Notes: 1) The budgets for 'Index and Publication Branch' and 'Management and Services Branch' are included in that of circle.
2) Revenue budget of PFFC is equivalent to establishment (salary, office maintenance) budget.

The non-development revenue budgets of the 4 circles under the Hydrology service in 2000-2001 and in 2001-2002 are as follows:

Non-development Budgets of Four Circles under the Hydrology Sercice

Unit: lakh Taka

Circle	2000-2001	2001-2002
PFFC	170.68*	146.87
SWHC	137.35	108.25
GWHC	52.00	57.3
RMRC	52.00	54.25

Note*: The figure of PFFC's non-development revenue budget for 2000-01 is different from that shown in the table 'Breakdown of the Budget Allocation for PFFC' above. This is minor or round error according to PFFC staff.

In the present budget allocation procedure of BWDB, the operation budget is prepared at division level and approved at circle level during April/May for the following financial year (July – June) for submission to the budget committee of BWDB. In June, the committee meets and allocates budget to circle level through the respective Chief Engineer.

(7) Water Use Levy

There is a provision to collect part of the O&M cost from the beneficiaries. Water rates were imposed in 8 projects at the rate of 10% of the gross incremental benefit of irrigation which was later reduced to 3%. However, the rate of collection was so poor that the amount collected was not even sufficient to cover the cost of staff salary of the Revenue Directorate. BWDB has identified 18 projects capable of paying water charges. However, so far water rates have been assessed on only 8 projects (Source: Annual Report, BWDB, 2000-2001).

Reasons for poor performance in cost recovery are:

- Amount collected as water rate must be transferred to the treasury, thus it cannot be used for O&M purpose. The beneficiaries thus do not feel encouraged to pay as they do not see any direct use of their contribution.
- One of the reasons is poor quality of service. People will only pay when they get the right quantity of water at the right time. Due to poor maintenance, most of the irrigation projects require rehabilitation.
- Collection mechanism is not working properly.

2.8.5 Flood Forecasting and Warning Center (FFWC)

This center was established within BWDB in 1972. The principal functions of this center are;

- data collection from field stations,
- data collection from other relevant agencies like BMD and SPARRSO,
- flood forecast model operation,
- flood warning issue, and
- operating 'Flood Information Center' during flood period (from May to October 15).

After initial support of UNDP between 1981 and 1986 and support with the equipment and facilities between 1989 and 1992, the FFWC was established in a systematic way during the FAP 10 project – Expansion of Flood Forecasting & Warning Services financed by DANIDA between 1995 and 1999. At present another DANIDA financed project is implemented for the period 2000-2004.

FFWC is headed by an Executive Engineer. There are in total 9 engineers working in the center, of which 6 are working under the DANIDA project.

During the wet season, FFWC issues Daily Flood Bulletin, Special flood bulletins, Monthly flood bulletins, Annual flood bulletins and Flood mapping.During the dry period, FFWC issues a weekly Low Water Monitoring Report.

FFWC sends their bulletins to the Prime Minister's office, various government departments, media, district administrations (partially), and BWDB divisional offices (partially). Mode of information dissemination is fax, telephone, email and recently through website (www.ffwc.net).

CHAPTER 3 CURRENT FLOOD FORECASTING AND WARNING SERVICES

3.1 History of FFWS Development in Bangladesh

The flood forecasting and warning services in Bangladesh commenced in 1972 when the Flood Forecasting and Warning Center (FFWC) was established under BWDB. The center has now operated for in excess of 30 years.

Initially, ten real-time flood monitoring stations were established and flood forecasts were based on gauge-to-gauge correlation analysis and the Muskingum-Cunge flood routing model. During the period between 1989 and 1994, a hydrological and hydraulic approach was applied under the FAP10 project 'Expansion of Flood Forecasting and Warning Services' financed by DANIDA. In this project, the MIKE11 modeling technique (refer to **Section 3.5**) was applied and 16 water level forecasting points were established for its operation. During the period between 1995 and 1999, another DANIDA project was conducted. Achievements included;

1) development of MIKE11 supermodel with GIS,
2) expansion of water level forecast points from 16 to 30,
3) arrangement of flood warning manual, and
4) staff training for the operation of the flood forecasting model.

In 2000, a further DANIDA-funded project 'Consolidation and Strengthening of Flood Forecasting and Warning Services (CSFFWSP) Phase-II' was launched. The planned main outputs are;

1) expansion of flood forecast to all flood prone areas in Bangladesh (forecasting points to be increased to 50),
2) improvement of accuracy and lead time of the forecasting model,
3) improvement of dissemination,
4) technology transfer, and
5) making suggestions for establishment of sustainable institutions.

This DANIDA project is scheduled to be completed in the middle of 2005.

At the same time, current FFWS in Bangladesh is associated with Environment Monitoring Information Network (EMIN), Community Based Flood Information System (CFIS), and Climate Forecast Application in Bangladesh (CFAB) study projects.

3.2 Overall FFWS in Bangladesh

3.2.1 General

As a result of abovementioned projects, Bangladesh now has in place a FFWS comprising:

- An observation network of real-time water level and rainfall stations extending over much of the country coupled with a data transmission network for the transfer of this information to FFWC in Dhaka.

- A hydraulic flood model (MIKE11) coupled with rainfall-runoff and flood forecasting modules for the evaluation of flood levels (developed by Danish Hydraulic Institute; DHI), referred to as the Supermodel, is now installed at the FFWC and is operated through the flood season (from 1 May to 15 October).
- Flood Warning Bulletins issued daily during the flood season and dissemination of flood warnings by the FFWC to the relevant authorities. These bulletins incorporate both real-time flood level information based directly on the water level observation network, results from the flood forecasting analyses for the prediction of future flood levels, and details on observed rainfalls.
- Flood evacuation plans aimed at minimizing both damage and loss of life through direct utilization of this information.
- Monthly and annual flood reports are regularly published and distributed.

In this JICA Study, FFWS is considered to be comprised of five major components, namely;

1) Observation System,
2) Data Transmission System,
3) Analysis System,
4) Dissemination System, and
5) Response System

Among these components, BWDB and FFWC are responsible only for observation, data transmission, analysis and a part of the dissemination systems. These are outlined in **Figure 3.2.1**. Other parts of the dissemination system and overall response system are, in principle, controlled by line-agencies of the Ministry of Disaster Management and Relief (MDMR) and local government authorities.

In this Chapter, present conditions of the existing system, problems encountered in its operation and conceivable solutions to address these issues are outlined and explained for each of the major components. For ease of understanding, the current status of the FFWS and problems encountered are summarized in **Table 3.2.1**.

In addition, organizational and institutional matters related to the existing FFWS are also described.

3.2.2 Existing Telemetric Network

(1) Current Status

In 1985 and 1996 the Government of Bangladesh established a telemetric system using Japanese debt relief funding. It comprised 14 automatic hydrometeorological observatories, 5 repeater stations and 1 control office in Dhaka. Although the purpose of its installation was to improve the service and performance of flood forecasting and warning services, the basis of the installation plan is unclear as documents describing the planning or design basis are not available.

As discussed below, a large part of the system is no longer operational due both to natural causes (erosion, sedimentation etc.) and limitations of the existing telecommunication system. In September 2003 only 5 out of the original 14 telemetric gauging stations were continuously transmitting data to the control office of the FFWC. The status of the existing telemeter system is tabulated below:

Status of Existing Telemeter System as of September 2003

No	Location	Year of Installation	Present Condition	Notes
1	Tongi / Dk	1996	Under repair	
2	Mirpur / Dk	1996	Working	
3	Rekabibazar /Dk	1996	Working	
4	Mill Barak / Dk	1996	Being shifted Operational in Sep.,2003	Will complete soon
5	Nayarhat / Dk	1996	Working	
6	Narayanganj /Dk	1996	Working	
7	Jatrapur	1996	Not working	WL gauge pipe destroyed
8	Pankha	1996	Not working	River course shifted
9	Sherpur	1985	Not working	Partially repaired in 1996
10	Shayestaganj	1996	Not working	Equip. shifted to Dhalai
11	Dhalai	1985	Under Repair Operational in Sep.	Equip. shifted from Shayestaganj
12	Monu	1996	Partially working Operational in Sep., 2003	Transmission problem, under investigation
13	Kamalganj	1985	Not working.	Partially repaired in 1996, under repair
14	Zakiganj	1996	Not working	No repeater connection

According to PFFC, the number of functional telemetric gauging stations will increase to 9 in the near future. Servicing will include use of functioning parts of those stations in a state of total disrepair and spare parts stored in PFFC. However, considering that the equipment was initially installed in either 1985 or 1996, it is now largely outdated and it is unlikely that many of these stations would be integrated into the existing FFWS.

(2) Cause of Inadequate Situation of Existing Telemeter System

As the cause of dysfunction of a number of telemeter equipment, BWDB listed up many items as discussed in the following sections. Based on the opinions of BWDB and the results of the inspections and reconnaissance conducted by the Study Team, the cause of this inadequate situation of existing telemeter system can be summarized as follows:

- Since the existing system has its own database format, which is not compatible with existing flood forecasting analysis system, manual input of the telemetric data into the analysis system is necessary.
- Due to frequent disconnection of BTTB's lease lines, the stability (sureness) of data acquisition is considerably insufficient.
- As a result, the data transferred through two different systems (manual and telemeter) should be input by single method (manual input) if the existing telemetric data is to be incorporated in the existing analysis system.

- It is much easier to apply a single system from the viewpoint of data management and daily operation.
- The motivation of the proper maintenance of the existing telemeter system is therefore not developed.

The Study Team considers that the above cycle causes the improper situation of current telemeter system.

(3) Utility Value of Existing Telemeter Equipment

Taking the above into consideration, incorporation of the existing telemetric equipment or facilities into FFWS improvement plans is not assumed. Detailed assessments of the causes of failure of the existing telemeter system are nonetheless discussed in the following sections in relation to proposals for the effective planning of an improved FFWS.

It is recommended that those existing telemetric facilities/equipment are used continuously not for the purpose of real-time data collection but for the purpose of verification of the quality of manually observed data to be collected for the FFWS purposes.

It is also recommended that the parts available from the equipment which is out of order are kept by BWDB as spare for the repair of remaining ones.

(4) Necessary Measures for Effective Use of Newly Installed System

A system with function of automatic data input is proposed in this Study taking the current analysis system into account (refer to succeeding Chapters). Considering the situation described above, following measures should be undertaken by BWDB in order to secure the effectiveness of the system to be proposed in this Study:

i) Provision of Incentive/Motivation for Repair and Maintenance

The necessity and importance of the observation system should be understood by all of the staff concerning FFWS. Accurate and timely flood forecasting information cannot be provided without acquisition of accurate and timely hydrometeorological information. The staff should understand this and sufficient manpower and budget should be allocated for the operation and maintenance activities.

ii) Training of Technical Staff

Advanced knowledge may be necessary for making proper repair and maintenance of sophisticated mechanical equipment. Other than the technology transfer to be provided by manufacturer etc., the technology exchange within BWDB is also important. The leaders of the C&I division, which is in charge of repair and maintenance of mechanical equipment, should understand basic knowledge of those equipment and transfer the know-how to their colleagues