equipment for proposed 23 telemetric gauging stations are presented in **ANNEX-V**. The selected type of hydrometeorological gauge and method of data transmission from gauge to telemeter house is summarized in **Table 7.2.4**.

## 7.3 Data Transmission System

### 7.3.1 General

The adopted data transmission system for the flood forecasting and warning system should take into consideration the various components of the FFWS including observation, analysis, dissemination and response as well as the control systems. The overall communication network is shown in **Figure 7.3.1**.

(1) Basic Strategy of Transmitting Technology

Observation System

a) From Gauging Station to Regional Office
   - VHF Radio for telemeter observation system
   - Mobile communication (Digital HF Radio) for manual observation system

b) Between regional office and central office
   - Digital HF Radio for data communication with T&T public line

Dissemination System

a) From Central and Regional office to receiving office (Warning Message Dissemination)
   - Fax or E-mail using T&T public line

b) From Telemeter gauging station to objective O&M office and Upazilla office (Point to Point Direct Data Dissemination)
   - VHF Radio for telemeter dissemination system

Control System in Central and Regional Offices

- Local Area Network (LAN) with Ethernet

(2) Requirement for Data Transmission System

Succession of Existing Analysis System

Existing analysis system is developed for ease of use. All software is packaged on a platform software and is able to run even on the personal computer. This analysis system is connecting to Ethernet LAN in FFWC, on taking a convenient environment for FFWC staff to confirm and modify analysis system by any computer connecting to this LAN. FFWC staff has been trained on and developed this system. So, proposed analyzing system as central and regional control system will take succession of existing analyzing system basically.

Common Database

Common data base is planned to sit between interface equipment and MIKE11 analysis equipment. The relation among equipment will be simple and trouble will be minimized due to using common database. Furthermore, the data in the common database will be easily used by other systems. For the common database, accessibility with open and common interface is necessary.

Cope with Different Collection Interval

Analysis system should be able to cope flexibly at different collecting intervals of observed data because the collecting interval and reliability are different from telemeter gauging station and manual gauging stations. The analysis system should also be processed even if observed data from manual gauging stations can not be collected.

Regional System

Regional system should send reports both where and when they are actually needed. Regional system will be processed essentially using Regional forecasting model for more detailed analysis. For the effective use of regional system in emergency, monitoring observed data and warning report are done automatically.

Point to Point Direct Data Dissemination

For warning in flash flood areas, telemeter data (water level and rainfall data) from telemeter gauging station are sent directly to objective O&M divisional offices and Upazilla offices where such information is needed.

Improvement of Information System

a) Interagency Network

Flood forecasting and warning information should be transmitted to objective government agencies to ensure effective and quick action against flood disaster. Government has responsibility for keeping the people safe and for operation of interagency network for transmission of such information.

In line with this concept, an IT (Information Technology) policy was established in Bangladesh, BTTB is expected to take leadership to coordinate with other public utility sectors (PDB, Railway, Gas, etc). BWDB should discuss with them to make the interagency network.

b) BWDB Network

Apart from the interagency network, a BWDB own network connecting among the various sectors of BWDB should be established for effective business, quick action in emergency and full access and use of all information resources. Emergency information should be transmitted quickly between central office, divisional office, and field office and should be exchanged between suitable sections such as O&M and hydrology section.

For this proposed system, an HF wireless network with BTTB public lines is planned between regional offices and central office. Although at present it is not considered to be a high-level information network, it would be BWDB-exclusive and could be easily maintained by BWDB.

The current HF wireless network is considered most effective for BWDB at present. However, in the future when Regional systems are fully active and many types of information are to be transmitted between central office and regional office, new information technology such as microwave, which can transmit huge volumes of data quickly, will be required. If a microwave network can be confidently maintained by BWDB, the Study team proposes this type of system for its network.

(3) Basic Design Concept

Data transmitting flow is shown in **Figure 7.3.2**.

a) Data from Gauging Station
   - Observed data from telemeter gauging stations are transmitted with VHF telemeter radio line and transmitted automatically to the data base in regional office at least hourly.
   - Observed data from manual gauging stations is transmitted with mobile line or Digital HF Radio line and transmitted automatically to the common database in regional office at least once a day.
   - Regional warning report is made by regional system using observed data from telemeter gauging station

b) Data from Regional Office
   - Observed data stored in the common database in the regional office are transmitted to central with Digital HF Radio line at least once a day.
   - Model boundary data for regional systems are analyzed by supermodel in central office using transmitted observed data from regional office.

c) Data from Central Office
   - Model boundary data for regional system, analyzed by Supermodel in Central office, are transmitted to regional office with Digital HF Radio line at least once a day.

d) Model Operation at Regional Office
   - Regional system is processed by regional model using observed data and model boundary data.
   - Regional forecasting report is made by regional system using observed data and model boundary data.

e) Dissemination from Central /Regional Office
   - Regional warning and Regional forecasting reports are made by regional system and disseminated to objective agencies such as BWDB O&M divisional office, District office and Upazila office.
   - Central forecasting report is made by central system and disseminated to objective central agencies such as DMB, EOC, PMO, TV, and Newspaper.
   - Dissemination is done using e-mail and fax by T&T public line.

f) Point to Point Direct Data Dissemination

- For warning in flash flood area, telemeter data (water level and rainfall data) from telemeter gauging stations are sent directly to objective O&M divisional offices and Upazila offices where such data are needed.
- At these O&M divisional offices and Upazila offices, there is a monitor panel displaying water level and Rainfall data.

7.3.2 Data Observation System

(1) General

In **Section 4.2.3**, alternative plans for transmission of recorded data were outlined.

Of the alternative plans, it was concluded that VHF radio was optimum method to data transmission from gauging station to regional office, and HF data transmission was optimum method from regional office to central FFWC.

In this section, basic concepts for building up the data transmission system are provided. Descriptions of frequency management in Bangladesh and radio tests conducted by the Study Team are mentioned. Preliminary specifications of equipment are mentioned in **Section 7.7**.

(2) From Gauging Station to Regional Office

A combined system of telemeter and mobile network are proposed for data transmission from the gauging station to the regional office.

The proposed telemeter station network will incorporate 23 telemeter stations (see **Section 4.2.2**). Manual observations at the remaining 85 gauging stations of the existing FFWC hydrometeorological network will continue. At the manual stations, gauge readers will transmit the observed data via the mobile network.

The telemeter and manual systems are outlined below.

Telemeter System

Data from the telemeter gauging stations will be transmitted directly to the regional offices. In some cases topographic conditions and long distances would result in difficulties in direct transmission of data and repeater stations will be provided.

a. Basic Concept

***Use of BWDB's existing Frequencies:*** Existing BWDB's frequencies (149.250MHz and 166.075MHz) will be used for the VHF telemeter system.

***Location of Repeater Station:*** In principal, repeater stations are installed at the BWDB O&M offices located throughout the country. The available land is suitable for the erection of the high antenna towers and maintenance of the equipment is easily undertaken. Furthermore, staff at the O&M offices can obtain the observed data directly from the display panels. If O&M offices are not available the repeater stations will be installed at a site in the local Upazilla office.

***Antenna Height:*** At the telemeter station, the standard antenna pole is proposed as 10m in height. At the repeater station, a higher antenna height of 20 to 40m was considered due to availability of land.

***Stored Repeater System:*** To avoid deterioration in the Signal to Noise (S/N) ratio caused by long distance transmission, a stored repeater system is proposed in which transmitted data are stored and re-transmitted at every repeater station.

***Power Supply System:*** At the telemeter station, although commercial power will be unavailable, solar power with battery will be effective.

At the repeater station in the O&M office, commercial power with battery will be utilized. The battery will be used in case of disruption to commercial power.

Where the repeater station is to be installed at a site other than the O&M office, solar power with battery will be adopted, as commercial power is likely to be unavailable at some locations.

***Criteria of Signal to Noise (S/N) Ratio:*** There is no international criteria on radio circuit design for a telemeter system at 150MHz band. Therefore, based on criteria established by the Ministry of Land, Infrastructure and Transport, Japan, an S/N ratio of 34.5dB or more for one interval is proposed.

b. Result of Design

According to the above concept, telemeter system network is designed. The diagram of telemeter network in Bangladesh is shown in **Figure 7.3.3**. The diagrams of telemeter network in each region are shown as listed below:

| Region | Figure No. |
|---|---|
| Region-NE | **Figure 7.3.4** |
| Region-NC | **Figure 7.3.5** |
| Region-SE | **Figure 7.3.6** |
| Region-SW | **Figure 7.3.7** |
| Region-NW | **Figure 7.3.8** |

Antenna height and antenna type of the radio stations are listed in **Table 7.3.1**.

As the result of design, the total number of the necessary repeater stations for building up the telemeter system in Bangladesh is 28.

Manual System

Apart from those locations at which telemeter stations will be installed, all remaining gauging stations in the FFWC network will remain manually observed using a gauge reader. For the manual system, there are two options for data transmission between the gauging station and regional office. One is based on a mobile network system and the other on an HF data transmission system. A comparison of the advantages and disadvantages of each is given below.

The mobile network system has an advantage that apparatus for data transmission is small and light. In future, the network area will be widely distributed and the mobile network will be effective as a method of data transmission from the gauging station. HF data transmission is less reliable and a backup system such as BTTB public line is necessary. However, a BTTB public line is sometimes not available at gauging stations. For that reason, in principal, a mobile network system is proposed for data transmission from manual gauging stations. Only if a manual gauging station is located outside the mobile network will HF data transmission be used.

**Comparison between Mobile Network and HF Data Transmission Systems**

| | Mobile network | HF data transmission |
|---|---|---|
| Advantage | Apparatus for data transmission is small and light.<br>Mobile network is more reliable than HF data transmission. | Data transmission is conducted within BWDB's own network. |
| Disadvantage | If outside mobile network, data cannot be transmitted. | It is necessary to familiarize the gauge reader with the use of a personal computer for operation of HF data transmission.<br>HF wireless stations are not appropriate for proper installation of a personal computer. |

Basic concepts of a mobile network system are shown below and details of HF data transmission are discussed in sub-clause (3) "From Regional Office to Central FFWC".

[Mobile Network System]

In Bangladesh the mobile network is becoming increasingly more widespread and gaining in popularity, therefore being more effective. At manual gauging stations, observations will be continued by the gauge reader. In order to transmit the observed data, one mobile apparatus will be provided to the gauge reader at each station and he/she will input the data into the mobile apparatus. The gauge reader will then transmit the data to the data server at the regional office for analysis.

The basic concept to build up the mobile network effectively is summarized below.

a. Basic Concept of Mobile Data Transmission

***Easy operation:*** Some gauge readers are not familiar with the mobile apparatus. It is necessary for every gauge reader to use it easily and instantly.

***Precise data input:*** Wrong data should not be sent to the regional office. Since inputting the data is done by the gauge reader manually, it is necessary to prepare a system that will prevent the gauge reader from transmitting the wrong data.

b. Selection of Mobile Apparatus

There are two types of mobile apparatus for data transmission. One is a mobile phone and the other is a PDA (Personal Digital Assistant).

It is easier to input the data into a PDA and it has a larger display than a mobile phone. Therefore, operationally, a PDA is considered to be better. However, the mobile phone network is currently spread more widely throughout the country (and will be in the future). Therefore, the mobile phone has been selected for data transmission from the manually observed stations.

c. Necessary Function of Mobile Data Transmission

***Input data checking system:*** The mobile apparatus should have a function for the gauge reader to check the input data before transmitting.

***Sending acknowledgment system:*** After data are transmitted and input to the data server at the regional office correctly, the mobile apparatus should acknowledge receipt of data.

(3) From Regional Office to Central FFWC

HF Data Transmission System

BWDB currently uses HF radio for voice communication between FFWC at Dhaka and its network of wireless stations. Staff of BWDB are therefore familiar with its application. HF data transmission is also on BWDB's own network and it can more easily maintain the equipment. Based on the result of HF data transmission tests conducted in this Study, HF data transmission is considered feasible provided a backup system is available should transmission failure occur.

a. Basic Concept of HF Data Transmission System

***Use of existing BWDB's frequencies:*** At present, BWDB pays loyalty fees to BTRC for use of six frequencies (3.305MHz, 4.442MHz, 4.490MHz, 5.089MHz, 8.157MHz and 8.188MHz). In order to utilize these BWDB frequencies effectively, they should be used as much as possible.

***Preparation of Backup system:*** As seen from the results of HF data transmission testing (outlined below in sub-clause 5), data transmission from the regional office to the central FFWC was not always successful. Therefore, to improve reliability of HF data transmission, a BTTB public line should also be used as a backup.

b. Necessary Function of HF Data Transmission System

***ALE (Automatic Link Establishment):*** To reduce the load on the HF operator and save time, HF radio should, prior to data transmission, have a function to automatically select a channel of optimum frequency from the existing BWDB frequencies.

***BTTB public line for backup:*** In case of failure of data transmission by HF, data transmission should be conducted through a BTTB public line. Accordingly, HF radio equipment should have a function for automatic line changeover.

***Error Check Function:*** Error checking is necessary for precise data transmission. In addition to the data checking function installed in the modem, another error check function should be provided for the HF data transmission system to prevent transmission of garbled data.

(4) Frequency Management

The management of the frequency is essential for implementation of the telecommunication network as well as the radio communication network. A discussion and recommendations on management of frequencies in Bangladesh are presented below.

Entire Area of Bangladesh

With reference to the study of telemeter system design, the Study Team investigated the allocation of frequency at BTRC. BTRC is in charge of the management of frequency use under the Ministry of Post and Telecommunication. For the allocation of new frequencies, applications are forwarded from BTRC to NSMC (National Spectrum Management Committee) which consists of 20 members from BTTB, Ministry of Defence, PDB, Grameen Phone and so on. After internal consultation, NSMC gives the recommendation of the frequency allocation to BTRC whose staff subsequently approve its allocation. As mentioned above, the fair allocation of the frequency is made based on a mutual consent among members of NSMC. Overall, frequencies in Bangladesh are managed competently by BTRC.

According to BTRC, application for new frequencies from a governmental organization is prioritized so that BWDB may obtain a new frequency if necessary.

BWDB

BWDB's existing VHF frequency is officially allocated for transmitting telemeter data. However, this frequency has also been used at a pump station in Chandpur irrigation project, also managed by BWDB. This implies management of the frequency in BWDB is not adequate. Considering radio interference and future extension of BWDB's communication network, it is necessary to organize a division or a section that will manage not only frequencies but also the whole communication network in BWDB.

(5) Radio Test

The Study Team conducted HF data transmission tests and VHF interference radio measurements during the Second Works in Bangladesh. An outline of the objectives, contents and evaluation of these is presented below.

HF Data Transmission Test

i) Object of Test

The objective of the HF Data Transmission Test was to assess the feasibility of data transmission between the regional and central office based on the system currently operated by BWDB and also to determine the necessity of applying a new frequency. The testing was conducted between Dhaka, where the central FFWC is located, and Sylhet, the site of one of the regional offices proposed to improve the existing FFWS.

ii) Outline and Result of Test

[Outline of Test]

Text data were transmitted from one test site to another test site alternately under 16 conditions. These included various frequencies, data sizes and baud rates outlined below. (Details of the 16 conditions are described more fully in **ANNEX-VII**.)

- Frequency: 3.305MHz, 4.442MHz, 5.089MHz, 8.188MHz
- Data size: 100byte, 1kbyte
- Baud rate: 1200baud, 2400baud

The data transmission was attempted three times for each condition and was conducted in the morning, around midday and evening.

[Test Items]

Test items included:

- Checking the success or failure of data transmission
- Checking the time when data was transmitted

[Result of Test]

The results of the tests indicated:

- Data transmission at 8.188MHz frequency was better than at the other three frequencies tested (3.305MHz, 4.442MHz, 5.089MHz) regardless of time.
- Reliability of HF data transmission was variable, the average of total successful transmission at 8.188MHz being 53%.
- The success and failure of data transmission did not depend on baud rate and data size.
- Antenna input level of the receiver side at successful transmission was about 30 to 45 dBμV. Garbled data were transmitted twice at these input levels.

Test result is listed in **Table 7.3.2**. Data measured at the test site is presented in **ANNEX-VII**.

iii) Evaluation

Based on the HF data transmission test:

- Data transmission from the regional office to the central office using HF is possible. However reliability of data transmission is not particularly high.
- In order to reliably transmit data to the central office (in case of failure of data transmission by HF), a BTTB public line is necessary as a backup to the HF data transmission system.
- A system that can automatically select an optimum frequency should be installed on HF radio equipment.

VHF Radio Interference Measurement

i) Objective of Test

The objective of the VHF Radio Interference Measurement was to check the existence of radio interference at 13 telemeter stations (Amalshid, Kanaighat, Sarighat, Durgapur, Nakuagaon, Kurigram, Noonkhawa, Dalia, Panchagarh, Pankha, Comilla, Laurergarh and Bhairab Bazar) near the Indian border in order to check incoming radio interference from India.

ii) Outline and Result of Test

[Outline of Test]

The Study Team measured radio interference waves at 2 frequencies (149.250MHz and 166.075MHz) at those test sites mentioned above using a measuring receiver. Measurement of the radio interference waves at all frequencies was continued for 3 hours.

[Result of Test]

No radio interference waves were found at the above 13 stations. The results of the tests are presented in **Table 7.3.3**. Data measured at the test sites are presented in detail in **ANNEX-VII**.

iii) Evaluation

For the thirteen 13 telemeter stations at which testing was undertaken, radio circuit design using BWDB's two frequencies (149.250MHz and 166.075MHz) for the telemeter system is feasible. However, new radio stations may be installed near these sites before implementation of the project. It is therefore recommended that radio interference again be checked at the actual sites during implementation.

(6) Subject

Institutional Matter

BWDB's existing VHF is officially assigned to be used for transmitting telemeter data. However, this frequency is used at the pump station in Chandpur managed by BWDB. To avoid any impacts on the proposed telemeter system, it is necessary to organize a division or section within BWDB that manages not only the frequencies but also the whole communication network of the organisation.

Technical Matter

i) Land Acquisition for Repeater Station

BWDB has to make the necessary preparations regarding land acquisition to install VHF repeater stations in Upazillas where O&M offices are not located.

ii) Error Detecting System for HF Data Transmission

In HF data transmission tests, some garbled data were received at the receiver site. This phenomenon probably results because missed and garbled letters are beyond the existing error detection system associated with the modem of the HF radio. Therefore a more sophisticated system should be added to the HF data transmission system proposed.

## 7.4 Analysis System

### 7.4.1 General

The delineation of the country on the basis of flood type is shown on **Figure 4.1.1**. Typically, monsoonal flood areas are associated with the Padma, Jamuna and Meghna Rivers where changes in water levels during the passage of floods are relatively slow. For these areas the present MIKE11 analysis system (Supermodel) is able to forecast flood levels in the immediate future (up to 72 hours) with some accuracy. In the flash flood areas, located mainly in the north-east and north-west of the country, water level changes are more rapid and the accuracy of flood forecasts is lower. If the flash flood areas in the south-east region around Chittagong were included in the Supermodel, similar inaccuracies in flood forecasts would probably also result. In the border regions of flash flood areas, particularly in the north-east of the country, the very short time available for dissemination of warnings (see **Figure 4.1.2**) further reduces the effectiveness of the current analysis system.

Despite inaccuracies in flood forecasts the need for timely warning throughout the country was strongly conveyed by participants of the PCM workshops and in interview surveys undertaken as part of this Study.

To improve the flood forecasting system plus provide warning of flood conditions to those areas with very short lead-time the following approach is recommended:

i) Telemetry stations are to be installed at key locations in the country to obtain real-time data on water levels and rainfalls. As outlined in **Section 7.2**, 23 telemetric stations will be installed. Their locations are shown on **Figure 4.2.1**. Twenty sites are located on or near the borders of Bangladesh on major rivers flowing into the country. Most are in areas subject to flash flooding and coincide with the upstream model boundaries required for flood forecasting using the Supermodel. The remaining three stations will be located at important sites internally within the country, two on major rivers and one in Dhaka. Apart from providing continuous, real-time water level information, data from these sites will also be used for the updating procedure inherent in the flood forecasting model as described in **Section 3.5**.

ii) The analysis system will continue to be based on the Supermodel operated centrally in Dhaka. This will be supplemented with regionally-based systems installed at each of the five regional centers including:
   - North-east region at Sylhet
   - North-west region at Rangpur
   - North-central region at Dhaka (at existing central FFWC office)
   - South-west region at Barisal
   - South-east region at Chittagong.

   The regional models will cover the entire area of Bangladesh. Their respective river networks will be generally more detailed than those included in the Supermodel. Through this combined approach, output from the Supermodel will firstly define boundary conditions for the various regional models at time of forecasting (ToF) if such data are unavailable from the telemetry system or manually observed gauges. Secondly, it will define the majority of boundary conditions for flood forecasting.

iii) In the vicinity of the borders of those areas subject to flash flooding, substantial changes in water levels can occur in periods of less than 3 to 4 hours (see **Figure 2.4.8**). This is significantly less than the time required to undertake flood forecasting or preparation/dissemination of warnings from a central (or regional) office. It is therefore proposed that the real-time data from the local telemetry stations be disseminated directly to these areas.

A detailed description of the proposed analysis system is given below. In addition, an evaluation of its likely benefits in terms of improved flood forecasting is also presented.

7.4.2 Proposed Analysis System for Areas with Sufficient Time for Preparedness

Supermodel (Nationwide Model)

**Figure 4.1.2** indicates the majority of the country has time for preparedness in excess of 24 hours. In this case, available time for preparedness is defined as the duration between the flood level rising from 1 m below danger level to danger level. The time required for model operation and dissemination of warnings is less than this and sufficient time is available to issue flood warnings, assuming the dissemination process is functioning smoothly.

Flood forecasting using the Supermodel should therefore be continued by the FFWC in its current form. Following the installation of the telemetry network and introduction of digital transmission of data from the manually-observed stations there will, however, be a need to upgrade the systems installed at the FFWC. This will include the following:

- An interface for direct access to the hydrometeorological database for storage of data transmitted from both telemetry and manually operated stations.
- Development of software for the automatic checking of data once stored on the database. Procedures would include verification of data quality, methods to modify data if they were found to be inaccurate and methods to input data manually for those stations not received. These are essential as model operation requires a complete set of accurate data for all boundary stations and those internal stations used in the model updating procedure.
- An interface within the Supermodel for the automatic retrieval of data from the hydrometeorological database.

The Supermodel would be operated on a daily basis. The flood forecasts for 24 and 48 hour intervals will be used by the FFWC to issue Daily Bulletins for the following 24 and 48 hour periods (comparable to the current situation).

At present the model computations are based on a 0.5 hour time interval and flood forecasts are transferred to the database for a total of 89 locations at hourly intervals. These are overwritten when the model is rerun the following day and only forecasts corresponding to 24, 48 and 72 hour timesteps are retained. As a result no use is currently made of the short duration (hourly) forecasts. These are, however, important for the combined operation. For the proposed analysis system they must therefore be transmitted to the regional centers on a daily basis as discussed below.

In addition, observed flood hydrographs for a number of water level stations in flash flood areas show significant rises and falls occurring within the 72 hour period of forecasting. Maximum forecast flood peaks could therefore occur between the fixed 24, 48 and 72 hour periods at which results are currently disseminated. Greater use of the hourly forecasts should therefore be made by FFWC to ensure peak flood forecasts and their times of occurrence are defined in flash flood areas. Given the slow rates of rise of flood levels in the monsoonal flood areas, this problem does not arise for stations located in regions subject to this type of flooding.

<u>Regional Models</u>

To complement the Supermodel, regional flood models are to be installed at the five regional centres outlined in **Section 7.1**. Regional surface water analysis models were developed for six areas of the country as part of the "Surface Water Simulation Modelling Programme (SWSMP)" study. These included:

- The South-East Region model, developed during the First Phase of the SWSMP study. This covers the area bounded on the west by the Meghna River from the Bay of Bengal upstream to Bhairab Bazar and east to the Indian border.
- The North-East Region model, developed during the Second Phase. This covers the area in the upper reaches of the Meghna River (upstream of Bhairab Bazaar) to the northern border of the country (east of the Jamuna River).
- The North-West Region model, developed during the Second Phase. This area is

bounded by the Padama River to the south, Jamuna River to the east and the Indian border to the north and west.

- The North-Central Region model, developed during the Second Phase. This covers the area bounded by the Jamuna River to the south and west, the Meghna River to the east and the Old Brahmaputra River to the north.
- The South-West Region model, developed during the Second Phase. This covers the area to the west of the Lower Meghna River, south of the Jamuna River extending to the Bay of Bengal and the Indian border to the west.
- The Chittagong Hills Area model, developed during the Third Phase. This covers the area around Chittagong, extending to the southern border with Myanmar.

Validation for each has continued (the most recent being completed in 2002) and it is proposed that the regional flood forecasting models be based on these existing SWSMP models. All models apply the same theoretical approach as used in the Supermodel, that is hydraulic analysis based on the application of MIKE11 with catchment runoff derived using the NAM rainfall-runoff model. A summary of the proposed regional setup with associated regional models is given below and shown schematically on **Figure 7.1.1**. In this breakdown the SWMP-defined South-East model will be installed in Dhaka (North-central region) while the Chittagong Hills model will be installed in Chittagong (South-east region).

**Regions and Associated Regional Models**

| Region | Regional Centre | SWSMP Regional Model Installed at Regional Centre |
|---|---|---|
| North-east | Sylhet | North-East |
| North-west | Rangpur | North-West |
| North-central | Dhaka | North-Central, South-East |
| South-west | Barisal | South-West |
| South-east | Chittagong | Chittagong Hills |

A comparison of river networks in the Supermodel and regional models indicates the following:

i) The river network for the North-East (NE) model is only marginally more detailed than for the comparable region in the Supermodel. All rivers converge to a single downstream boundary at Bhairab Bazar on the Meghna River. This is the only link with the river system for the remainder of the country. The region can therefore be simulated independently of flood levels in other regions as water level data at Bhairab Bazar (at which a telemetry station is proposed) defines the single downstream boundary condition. Only several additional upstream boundary stations are required in the NE regional model (to those in the Supermodel). These can be defined either as constant discharges or by applying a factor to discharges of neighbouring stations, the same approach used in the current Supermodel.

ii) The river networks for the North-Central (NC) and North-West (NW) models are only marginally more detailed than the comparable regions in the Supermodel. Additional boundary conditions in the regional models are defined by stations on major rivers including the Jamuna, Padma, Teesta and Old Brahmaputra. The required water levels and discharges for these must be defined using a combination of observed data from telemetry stations plus output from the Supermodel.

iii) The regional model defining the area around Comilla is referred to as the South-East model in the SWSMP study. The majority of boundary stations for this region are defined by river levels on the Upper and Lower Meghna Rivers and tidal levels on the Bay of Bengal. The former can be obtained from the Supermodel while the latter could be derived using tidal data from observed FFWC stations (such as Daulatkhan or Noahkalia) with the appropriate phase corrections. Additional upstream boundary conditions would be based on either constant discharges or factoring of the observed discharges at nearby gauging stations.

iv) The South-East region in the present study covers the area around Chittagong and the Chittagong Hill Tracts. This region is not currently included in the Supermodel. The associated regional model in the SWSMP study is the Chittagong Hills model. Hydraulically the region is not connected with the remainder of the country. Boundary conditions can be defined using the proposed telemetry stations at Panchapukuria and Chittagong. Additional tidal data for the two southern rivers included in the regional model would be based on observed data at Chittagong with appropriate phase corrections. At the $TOF_{REG}$ it will be necessary to define the remaining upstream boundary estimates based on either constant discharges or factoring of the observed discharges for the station at Panchapukuria.

v) The river network for the South-West (SW) model is significantly more detailed than for the comparable region in the Supermodel. For the regional model there are additional model boundaries, particularly defining tidal conditions downstream on the Bay of Bengal in the Sundarban region. Upstream boundaries are defined by discharges and water levels along the Padma, Jamuna, and Upper Meghna Rivers. Like the North-East and North-Central models, these can only be defined using output from the Supermodel. A number of the downstream tidal boundaries will be defined by the proposed telemetry stations. Those additional tidal boundary conditions for locations at which data are not available would be based on these with the appropriate phase corrections.

For the Supermodel, modeling at the time of forecasting ($ToF_{SM}$) utilizes data available from the hydrometeorological network up to 0600 hours. Whenever a regional model is operated during the day, the associated time of forecasting ($ToF_{REG}$) is likely to be some hours later. For the $ToF_{REG}$ many of the external boundaries for the North-East, North-Central, North-West, South-East and South-West regional models will be defined by data from the proposed telemetry network. If such information is unavailable, output from the Supermodel will be used directly, that is external boundary conditions will be defined using hourly flood forecasts extracted from the Supermodel. As noted above, these will be transmitted from the central office in Dhaka to the regional centres.

For flood forecasting, the results of the Supermodel must be used to define all external boundary conditions for all regions apart from the south-east region (Chittagong Hills model). These will need to be estimated by the FFWC personnel as this region is not included in the current Supermodel.

The major benefit of combined operation of the Supermodel and regional model is that the latter can be operated at any time intermediate to the Supermodel. That is, it can be run more frequently whenever large increases in flood levels are monitored on the borders (particularly in flash flood regions). This combined operation of the Supermodel and regional model (termed intermediate operation) should improve flood forecasts in the region at least in the 12 to 24 hours after $ToF_{REG}$ when compared to those based on the Supermodel.

For intermediate operation, it is proposed that the same internal stations as used in the Supermodel also be adopted for the regional model in the updating process applied in the MIKE11 model. There will be a period extending from 0600 (ToF for Supermodel) to the ToF for the regional model when water level data are unavailable for relevant internal stations. During this period, hourly forecasts as derived using the Supermodel would be included in the hindcast period. This should have negligible impact on the accuracy of flood forecasting as discussed in **Section 7.4.4**.

### 7.4.3 Proposed Analysis System for Areas with Insufficient Time for Preparedness

Quantitative forecasting of future water levels or discharges with sufficient accuracy is not possible at present for the boundaries of the flash flood areas. Rainfall data in these areas and also in the upstream catchments outside Bangladesh are unavailable at short-time intervals (or indeed even at daily timesteps). However, inhabitants of those areas near the borders of the flash flood regions require information or warning messages to be issued by the government.

Even limited information defining 1) observed water levels and 2) observed rainfalls at the international borders allows people living immediately downstream to take positive action to minimize the impacts of flooding. With the proposed telemetry network located in the border areas, observed flood levels and rainfalls can be disseminated to authorities and end users directly. These data would at least provide an indication of the direction of future immediate changes in local flood levels.

It is therefore proposed that data from each local telemetry station be disseminated directly to the local authorities. The data should be linked to a rudimentary system with warnings issued based on actual flood level, rate of change in water levels over the preceding 2 to 3 hours and/or recent rainfalls if defined intensities are exceeded.

### 7.4.4 Assessment of the Improvement of Accuracy Obtained from Proposed System

(1) General

The main inaccuracies in flood forecasting are likely to result from poor estimation of forecast boundary conditions (both water level and rainfall), changing hydraulic characteristics of the river network (river channels etc), limited model calibration, and the estimation of catchment floods using rainfalls assumed to be areally and temporally uniform. Prior to finalizing the recommended analysis system, forecasting was undertaken using the Supermodel to identify the primary causes of inaccurate flood forecasting. The modelling assumed:

i) Boundary conditions for the following 72 hours were as recorded, that is no errors occurred in their estimation, with model updating undertaken using all internal boundary stations (27) as currently adopted.
ii) Boundary conditions for the following 72 hours were as recorded but the number of internal boundary stations used for model updating was limited to the three stations proposed for installation of the telemetry network.
iii) Boundary conditions for the following 72 hours were as recorded, that is no errors occurred in their estimation, but no model updating was undertaken.

The flood forecasts derived by FFWC using estimated boundary forecasts and applying the 27 internal boundary stations for model updating were also obtained from the FFWC database for those periods analyzed.

Comparison of FFWC flood forecasts with those of case i) quantified the likely level of improvement achieved with improved accuracy in boundary estimation. Any remaining errors in flood forecasts should then reflect limitations in model calibration, inaccuracies in estimation of catchment runoff (based on the limited rainfall availability and its assumption of areal and temporal uniformity for subcatchments) and adopted hydraulic characteristics of the river network. These errors could only be minimized through ongoing model calibration, continued updating of river network characteristics, and improved estimation of rainfall.

Comparison of cases i) and ii) defined the likely reduction in forecast accuracy when the number of updating stations is reduced. This is a more practical matter in terms of defining the required number of internal boundary stations required to minimize forecasting errors.

Comparison of cases i) and iii) defined the likely reduction in forecast accuracy when no model updating is applied.

Both statistical and graphical comparisons were undertaken. The statistical analyses were based on deriving the absolute errors in flood forecasts at 24, 48 and 72 hour time intervals. The graphical analysis involved comparing hourly flood forecasts at selected stations. This was particularly useful in evaluating model performance for flash flood areas. Simply applying a statistical approach using forecasts at a fixed time interval (24, 48 or 72 hours) can be misleading as errors in timing of flood forecasts are also more pronounced for stations in these regions.

(2) Statistical Comparison of the Result

A summary of the absolute errors for all forecasts stations adopted by FFWC in their current system is presented in **ANNEX-VI**. Stations are grouped according to their location in monsoonal or flash flood areas. As well as the mean absolute error (MAE) and maximum absolute error for each station for the period of analyses, the absolute errors for a range of exceedance probabilities are also listed.

A summary of the results is presented in **Table 7.4.1**. The following observations are made:

a) The average MAE's for both flash flood and monsoonal flood areas are exceeded around 30% of time. This implies errors are less than the MAE for a relatively large percentage of the period analyzed but larger errors occur periodically. This was also apparent when analyzing the results for the stations individually.
b) For stations in monsoonal flood areas, forecasting errors assuming FFWC boundary estimation are relatively low (average MAE's for all stations for 24, 48 and 72 hour forecasts are only 7, 14 and 20cm respectively). Nonetheless, there is some minor improvement in the accuracy of flood forecasts when applying 'as recorded' boundary conditions (both absolute and maximum errors). Achieving only a minor improvement reflects the relatively good accuracy of the current boundary estimates for monsoonal rivers made by FFWC. Average MAE's for the boundary stations in the monsoonal areas are only 9, 17 and 25 cm for 24, 48 and 72 hours respectively (see **Table 3.5.3**). Also as distance downstream from the boundaries to forecast stations increases, the influence of boundary conditions reduces. Overall, flood forecasts using boundary estimates applied by the FFWC are already relatively accurate for all durations for the monsoonal flood areas, particularly up to 48 hours. Improved boundary estimation will therefore reduce forecasting errors in the monsoonal flood areas but only marginally.
c) For those stations in flash flood areas, the accuracy of the 24 hour forecasts only improved marginally when applying 'as recorded' boundary conditions. This was somewhat surprising but probably also reflects the fact that errors in flood forecasts based on a fixed time interval are also indicative of timing errors in the forecast hydrograph. Although there was a definite improvement in flood forecasts for 48 and 72 hour durations, the errors for flash flood areas for all durations remained significant.
d) The limited improvement with 'as observed' boundary conditions in the flash flood areas therefore reflects limitations in model calibration, inaccuracies in current runoff estimation (catchment rainfalls are assumed to be uniform areally and temporally over the 24 hour period) and the impacts of likely changes in hydraulic characteristics for the river network. To reduce errors below those associated with the modeling using 'as observed' boundary conditions would require improved model calibration and more accurate estimation of catchment rainfalls.
e) The Supermodel currently applies a discharge updating procedure to improve forecasting (see **Section 3.5.4**). In this method, actual discharges at internal boundary points are 'adjusted' during the hindcast period (prior to time of forecasting) to ensure observed and simulated flood levels (and hence discharges) are comparable at the stations used in the updating. The adjustment procedure is then also applied for the period of forecasting. In the current Supermodel setup,

around 27 internal boundary points are defined.

The analyses indicated there are only minor differences between flood forecasts using the current number of internal boundaries or with the three sites located internally within the country at which telemetry stations are proposed. This is important as real-time data are required at all external and internal boundary (updating) points for model operation. If the amount of input data can be reduced with minimal impact on model accuracy, forecasts based on modeling using only the more limited data from the telemetry network could be provided with confidence.

f) Excluding the updating procedure from the analyses resulted in negligible impact on the errors in flood forecasting (comparison of cases i) and iii), that is with and without model updating and applying the observed water levels as boundary forecasts). The errors for the stations located in the monsoonal flood areas are low in any case indicating a reasonably high accuracy in model calibration. As the greater percentage of flow comes from outside the country, the effects of possible inaccuracies in local catchment runoff estimation will be negligible. It is therefore considered unlikely that the accuracy in flood forecasts could be increased much above that currently achieved up to the 24 hour forecast. Beyond this period, improvement could be achieved with better boundary estimation as noted above.

For the flash flood areas, the updating has negligible effect. This is probably due to the large fluctuations in water levels during floods. During the hindcast period on which discharge adjustments are based for the forecast period, such variations did not generally occur and so the results of the hindcast analyses were not valid for the forecasting periods when flooding occurred.

These analyses are limited to the available data in 2003 and should be further assessed by FFWC using earlier years. Although the inclusion of updating does not appear to provide any substantial improvement in flood forecasting, it is proposed that the existing number of internal stations (27) be retained in the Supermodel.

(3) Graphical Comparison of the Result

Graphical comparisons of observed and forecast flood hydrographs are also shown for typical stations located in monsoonal and flash flood areas. The forecasts, based on cases i) and ii) above, are for 24 hour periods, plotted at 3 hourly intervals. For the approach followed by the FFWC, only 24 hour estimates are available as hourly forecasts were not retained during processing. Where applicable, the observed flood hydrograph at the boundary station immediately upstream of the stations is also included. This provides a qualitative comparison with the response of downstream forecasting stations to changes in local boundary conditions.

The two floods that occurred in early and late June, 2003 are presented. These represent the largest events that have occurred in 2003 after flood forecasting using the Supermodel was commenced by the FFWC. The following observations are made:

a) There are generally only minor differences in flood forecasts over the 24 hour period if the number of update points (internal boundaries) is set at 27 (as currently adopted by the FFWC), 3 (corresponding to the internal stations at which telemetry will be installed), or updating is not undertaken. Comparisons for a number of the stations are shown on **Figures 7.4.1**. It should be noted that the results with no updating were excluded as they were essentially the same as those computed using 3 update stations.

b) For those stations located in the flash flood areas, namely Moulvi Bazar and Jariajanjail (north-east region), the flood forecasts when based on 'as observed' boundary estimates better match the observed hydrograph. The results during the initial hydrograph rises are, however, generally poor for Moulvi Bazaar but more accurate for Jariajanjail. Remaining errors are therefore not due to incorrect boundary estimates. Improvements would probably be achieved through improved model calibration in the flash flood areas, more representative estimates of catchment rainfalls used in deriving local catchment inflow (both spatially and temporally) and inaccurate discharge rating curves adopted for the boundary stations.

c) Forecasts in the flash flood areas based on FFWC boundary estimates are poor when substantial rises in boundary water levels occur immediately after the ToF. Application of the combined approach using the Supermodel in conjunction with the relevant regional model when large changes in flood levels are observed should result in improved flood forecasts over the immediate 12 to 24 hours.

d) The NAM model is currently being applied using an average temporal pattern over the 24 hour period. It is therefore being reduced in some ways to a daily model. This is not sufficiently accurate for flash flood areas where flood levels can change significantly in periods of hours. It is essential that a 'true' hourly simulation be included in the modeling, that is the rainfalls must be based on more representative hourly rainfall patterns. These can only be provided with automatic stations (through telemetry) or use of radar images as discussed below.

### 7.4.5 Estimation of Forecast Boundary Conditions

#### (1) Utilization of Indian Hydrometeorological Data

For the monsoonal flood areas, the major inflows occur along the Jamuna and Padma Rivers. One approach to improve forecast boundary conditions on these rivers (at Noonkhawa and Pankha respectively) could be through comparison of water level data with stations upstream in India. The longer the distance upstream, the greater the possible lead time for estimation of forecast boundary conditions. At present only limited data are available to the FFWC from India (as outlined in **Section 3.3**). Water level information is, however, only forwarded from the Indian authorities for specified stations when the rivers increase to within 1 m of their respective danger levels. For the major rivers these include data from the Farakka Barrage on the Ganges River and Goalpara and Dhubri on the Brahmaputra River.

A comparison of water levels for Noonkhawa and Goalpara (some 105km upstream) is shown on **Figure 7.4.2**. The data for Noonkhawa have been lagged by 15 hours to reflect the likely travel time between the two sites and differentiated according to a rising or falling hydrograph at Goalpara. This indicates a reasonable relationship could be developed between these sites but there is still some scatter in the data. Further comparisons including separating data according to the year did not reduce the scatter appreciably. Estimation of water levels at Noonhkawa would therefore still be subject to inaccuracies even though the distance between the sites is relatively small. Comparison of the water levels for Pankha and Farraka Barrage is also shown on **Figure 7.4.2**. The distance between the stations is only around 30km. Hence the good relationship is hardly surprising. However, the comparison highlights the need to continually review the data to ensure changes in channel sections and/or datums at one or both sites included in such relationships are quickly identified.

Forecasting of 48 and 72 hour boundary water levels for both Jamuna and Padma Rivers would require comparisons to be made with stations in India a considerably greater distance upstream of the border, probably of the order of 350 km and 500 km respectively. These assume a flow velocity of around 2 m/s, not unreasonable during monsoon flooding.

Relevant stations upstream of Pankha on the Padma River include Mongyr (265km upstream) and Patna (405 km upstream). Beyond Patna the Ganges River splits into one main and several smaller tributaries. On the Brahmaputra River upstream of Noonkhawa, Tejpur (335 km upstream) and Debrugarh (580 km upstream) would be suitable. Given the scatter in the data noted between Goalpara and Noonkhawa, errors associated with the relationships between the boundary stations and those greater distances upstream are likely to increase and may well be of a similar magnitude to those based on the estimating technique currently adopted by FFWC. Nonetheless, relevant data should be obtained by the FFWC from Indian authorities and the comparisons made.

It should be noted that even if data from these stations are available and relationships can be derived, additional assumptions may be necessary as the actual travel times downstream to the boundary stations differ from the durations used in forecasting, that is 24, 48 and 72 hours.

(2) Coordination with Ongoing CFAB Project

To provide flood forecasts with longer lead time in excess of the currently adopted 72 hours, alternative approaches will be required. One promising technique is the Climate Forecasting in Bangladesh (CFAB) project, a joint approach currently being undertaken by the Georgia Institute of Technology in conjunction with the BWDB. The basic variables to be forecast are the discharges of the Jamuna and Padma Rivers at the borders with India. Three forecasting timeframes are being developed, namely short period (1 to 6 days), medium range (20-25 days) and long range (1 to 6 months). The short and medium ranges would be of use in providing forecast flood levels relevant to flood warnings with relatively long lead times.

For short period forecasting, area-averaged rainfalls produced by weather forecasting centers such as European center for Medium Range Weather Forecasts (ECMWF) and National Centre for Environmental Prediction (NOAA/NCEP) are utilized in conjunction with a linear regression technique to generate the discharge forecasts. The medium range forecasts are based on a scheme requiring data from 8 predictors defining the intraseasonal variability of the monsoon. These include precipitation over the Central equatorial Indian Ocean, sea level pressure and soil moisture over central India, intensity of the low-level Somalia Jet stream, location of the upper tropospheric easterly jet stream, the SST over equatorial Indian Ocean, upper tropospheric equatorial zonal wind and surface winds over the equatorial Indian Ocean and Arabian Sea.

The results to date appear promising and further studies are now ongoing with the aim of transferring the software to Bangladesh in the near future. These approaches, however, only derive flood forecasts for the two major rivers and so are only applicable to the longer term flood forecasting for the monsoonal flood areas (using the Supermodel). They do not derive flood forecasts at the longer timescales for the flash flood areas. The probable inaccuracies in defining boundary estimates for the flash flood areas such long periods in advance should not, however, have any significant impact on forecasting accuracy for stations in the monsoonal areas.

Prior to issuing flood warnings based on long-term forecast procedures, it would be essential to confirm their accuracy. Issuing warnings that are later found to be significantly in error could lead to a lack of confidence in future forecasts. Steps required to minimize the impacts of flooding as a result of subsequent forecasting would be less likely to be implemented.

(3) Application of the Information of BMD Radar Network

For the flash flood areas, water level stations exist upstream of several boundary stations used in the north-east section of the Supermodel. These include Silchar and Kailashahar upstream of Amalshid (Barak River) and Monu Railway Bridge (Monu River) respectively. In the north-west region, Indian stations include Gajaldoba upstream of Panchagarh (Teesta River) and Jaldhaka upstream of Kurigram (Dharala River). However, comparisons of concurrent flood hydrographs for the up- and downstream water level stations indicate travel times from all Indian stations, which are relatively close to the borders, are too short to allow any meaningful use to be made of the data even if transmitted to the FFWC in real-time.

Catchment areas associated with rivers on the boundaries of the flash flood areas range from around 500 $km^2$ up to around 10,000 $km^2$ (not large in comparison to the major rivers in the monsoonal areas) and channel slopes are relatively steep. Response times to rainfall incident on these catchments is relatively short and in many cases probably of the order of less than 12 hours. In addition, rainfall intensities can be extreme, particularly in the Meghalaya Ranges (north-east of Bangladesh) where annual rainfalls approach 10,000 mm.

Improved estimation of boundary forecasts is likely to be possible only with better definition of rainfall defining both spatial and temporal distribution. This would require cloud intensity information obtained from BMD radar or NOAA satellite data. A preliminary concept for this analysis is illustrated in **Figure 7.4.3**.

Errors in rainfall estimation based on radar can result from a number of sources including the following:

a) Errors in the radar itself due to beam blocking and anomalous beam propagation. Radars are currently installed in the north-west (Rangpur), central (Dhaka) and south-east (Chittagong) regions. BMD has, however, proposed that an additional site be established in the north-east (Sylhet). This would provide a good coverage over Bangladesh plus the adjacent small catchments in India associated with flash flood areas, minimizing such errors.
b) Errors due to bias in radar rainfall measurement. Accurate calibration of the radar coefficient (Z)-rainfall intensity (R) relationship based on observed rainfall data is required to minimize any bias in rainfall estimation. Therefore it is essential that the available rainfall data used in the calibration of the relationship provide good coverage both areally and temporally to reduce these errors. For this to be possible, rainfall data would be required from stations located in India, particularly in the Meghalaya Hills (north-east region) and Assam (north-west region).
c) Random errors caused by temporal and spatial sampling, height sampling, variations in the adopted Z-R relationship and quantifying the rainfall amounts. Again this would be important in the Meghalaya Hills were elevations are extremely variable.

The approach would initially require calibration of radar information for the catchments, particularly in the flash flood areas, using observed storm events. If this produces realistic results, more accurate rainfall intensity information (both in terms of spatial distribution and also temporal pattern) could be defined from radar or satellite data. It is likely that rainfall forecasts could be made only for the next 24 to 48 hours. Even within this period, errors could be large as forecasting storm trajectory is extremely difficult and rainfall variability in flash flood areas is extremely high.

The main output of this analysis would not, however, be the accurate estimation of rainfall depths but water level or discharge at the model boundaries. This would provide both an indication of both the magnitude of flood discharges and also timing, both essential to define boundary forecasts. In this context, further analyses based on rainfall-flood routing would be required, including calibration of a distributed rainfall-runoff model for the various catchments.

The key point for the execution of this analysis is to obtain numerical data of radar or satellite images. The support of BMD staff is essential, since the result can also highlight the effectiveness of BMD's existing radar network. This could add weight to the establishment of a doppler radar at Moulvi Bazar as currently proposed by BMD.

### 7.4.6 Comments on Proposed Analysis System

With the proposed data transmission network, both telemetry data and data from manually observed stations will be transmitted to the closest regional centers. The interfaces at the regional centers will allow the information to be transferred directly to the regional databases. Establishing regional flood models will ensure simulations can be undertaken as required even if transmission of data between the central and regional offices is disrupted. The implementation of regional models operating at the regional centers should also allow earlier dissemination of flood warnings and quicker local verification of model performance through comparison with observed water levels.

The availability of water level data from stations on the major rivers in India will allow the development of relationships to define boundary forecasts for Noonkhawa and Pankha. As a minimum, this will provide a more consistent approach than that currently followed by FFWC. Current practice relies on experience of the FFWC staff operating the model. This could prove problematic in future years when staff changes occur. Relationships developed would have to be continually updated to ensure changes in conditions at the various water level stations used were incorporated.

The application of the model using 'observed' boundary forecasts has indicated further calibration of the model, particularly in the flash flood areas, is essential to minimize forecasting errors. A major calibration of the Supermodel was undertaken in 2003 by DHI. The revised model setup is likely to be implemented in 2004. FFWC should use this model prior the next wet season to assess its accuracy in forecasting in the flash flood areas based on data recorded in 2002 and 2003. In addition to the calibrations, the discharge rating curves used in defining discharges at the boundary stations should be confirmed.

Flood forecasting beyond 72 hours is currently not undertaken. The workshops and interviews indicated warnings of 4-5 days would be required to allow early harvesting of crops prior to inundation due to future flooding. For this to be implemented, the use of short and medium-term weather forecasting techniques such as that currently being developed as part of the Climate Forecast Applications in Bangladesh (CFAB) project underway in conjunction with BWDB should be investigated. If the CFAB project proves successful, discharge estimates for short (5 day) and medium term (20-25 day) timeframes could be provided for the Jamuna and Padma Rivers. Boundary forecasts for the flash flood areas would also be required for the Supermodel to be applied. These would need to be estimated (they are not computed using the CFAB method) and could be significantly in error. However, as noted in the analyses using the Supermodel, inaccuracies in the flash flood areas have negligible impact on forecast accuracy for the monsoonal flood areas.

For the monsoonal flood areas, the rates of water level rise are sufficiently slow for flood forecasting to be undertaken on a daily basis using the Supermodel. The proposed telemetry network will therefore be of primary benefit for flood forecasting and warning in the flash flood areas. Substantial increases in river levels, which have been observed to be in excess of 2 to 3m over a 3 hour period, can occur at any time. The FFWC must therefore be prepared to apply the regional models immediately such changes in boundary conditions are observed or risk the possibility of not providing flood warnings with sufficient lead time. It is therefore necessary that the regional centers remain operational on a generally continuous basis throughout the period in which flash flooding occurs.

## 7.5 Dissemination System

### 7.5.1 Basic Strategy

(1) Objective of FFWS

As explained in **Section 3.6**, the flood warning dissemination system is not working properly. It is clear that without a functioning dissemination system, the overall FFWS may not provide any benefits. **The objective of the FFWS is ultimately to disseminate flood warning to the end beneficiaries**, so that they can take necessary actions accordingly.

The FFWS is not only aimed at calculating the possible flood. The most important action is to disseminate warnings to the people, surely, accurately, in a timely and official manner under the responsibility of the government. Hydrological and meteorological conditions may change from time to time. Therefore flood forecasting and warning should be disseminated in a timely manner to reflect the real situation of weather and flood conditions.

Flood warning may be divided into 1) ***forecasting***, 2) ***warning***, and 3) ***evacuation order*** according to the situation. The ***warning*** may be divided further such as, for example, Signal No.1, No.2, No.3, etc. This would depend on the severity of the possible flood. For instance, Signal No.1 may indicate to people the possibility of flooding, Signal No.2 may indicate the need to close schools, and so on and Signal No.3 to provide advice to the public to prepare for evacuation. Such information can be issued with more surety by the regional office than the central office. The former generally has greater knowledge of existing conditions in the area regarding levels of flooding, preparations of the local public regarding flood awareness and so on.

(2) Regional Disaster Management

Disaster management is commonly undertaken by concerned agencies in most countries at a local rather than central level. As noted above, flood warnings should generally be issued by the regional office due to its greater knowledge of local conditions, that is the 'real situation'.

FFWS is one of the most important and essential supporting measures for the regional disaster management. Central Office can and should take actions to assist / support emergency countermeasures including financial arrangements, supply of emergency goods, etc.

(3) O&M Divisional Office's Initiatives for FFWS

Operation and Maintenance Divisional Offices (O&M DO) have undertaken:

a) Emergency countermeasures to prevent flood damages at river structures,
b) Flood forecasting and warning services based on their own hydrological observations at the river structures (often driven by necessity as warnings from the FFWC are not received), and
c) Flood warning message dissemination to the local population.

Thus, O&M DOs are familiar with flood forecasting and warning activities. Most importantly, O&M DOs need FFWS for the operation and maintenance of their river structures but sometimes must reply on local people for information on flood conditions. These actions can therefore also be taken at local level by the O&M DOs surely, accurately, timely and officially as they have many branch offices distributed over the country. Therefore, FFWC (and specifically the proposed FHC) should coordinate with O&M DO.

(4) Request to UNDP and DMB

As explained in **Section 3.6**, responsibility for the warning dissemination system lies with BWDB, DMB and Local Government Institution. According to the BWDB Act, 2000, BWDB is only responsible for warning preparation. This is to be provided to various central government agencies and district administration. DMB is responsible for pre-disaster preparedness. According to the Standing Orders on Disaster, 1999, warning dissemination to the grass root level is a responsibility of District, Upazilla and Union Disaster Management Committee. There is no provision for warning dissemination to the various river structures.

Because of this legal status, the present Study has divided the proposed Project into components, part of which is to be executed by BWDB and the rest to be given serious consideration for uptake by DMB and Local Authorities. As mentioned in **Section 3.8.1**, UNDP will soon implement a Comprehensive Disaster Management Project (CDMP). It is therefore strongly requested that UNDP and DMB take up part of the warning dissemination component in this project.

(5) Point to Point Dissemination

During the field investigation by the Study Team, it was found through discussion that in some border areas lead time is very short between flood warning and occurrence of the event. In such cases, the Upazilla administration attempts to obtain water level data from nearby gauging stations. Based on that information, they also attempt to disseminate warnings and arrange response systems. It was strongly suggested by the local community during these discussions that if they could obtain water level data sooner, actions could be implemented to provide warnings, mitigate flood damage and so on even before the warnings from FFWC are received.

In addition to the warning information provided after application of the hydraulic model (as part of the FFWC procedure), it is therefore proposed that real time water level data be transmitted directly to Upazilla administrations in those areas where lead time is as low as 4 hours or less. This system, referred to as point-to-point dissemination, will be implemented using a special terminal located in the offices of the local administration. This would indicate current water levels and could also be programmed to set off alarms if water levels reached predefined targets.

### 7.5.2 Required Components

(1) Inhabitants

Required components related to flood warning dissemination for the inhabitants are as follows:

- After preparation of the flood bulletin, the Flood Hydrology Circle (FHC) will provide the information to all district administrations, all BWDB O&M zonal offices and all relevant central government agencies. For speedy dissemination, use of email, internet website and auto-dial fax should be implemented.
- Area specific warning with inundation maps should be prepared by FHC.
- Until there is a proper area specific warning, gauges should be fixed at village level and correlate these with the nearest danger level. This must be done by the Union DMC in close collaboration with local people.
- Danger levels should be reviewed periodically by BWDB.
- New topographic maps should be prepared by BWDB.
- Lead time should be increased by FHC. This lead time can be different based on the flood type. In flush flood area, at least 4 hours are required for evacuation. In other flood areas, at least 4 days are required from agricultural and other damage reduction viewpoints.
- Local BWDB staff who is a member of District DMC should help interpreting the warning message considering the local context.
- District DMC will send the interpreted and area specific warning to Upazilla by phone, fax, email or police wireless.
- Upazilla DMC will provide this information to union by phone or mobile. If there is no telephone connection in some union or if such union is not covered by mobile network, SSB wireless set is to be provided to those unions. Operation cost of mobile or wireless should be arranged by participatory basis.
- NGOs should be involved in the Union DMC.
- Union DMC will take responsibility to inform all people by means of dram beating, flag hoisting, red light signaling, using mosque loud-speakers and personal communication.
- BWDB staff, who is a member of the District DMC will monitor the dissemination process in the lower tiers and assist District DMC to ensure the dissemination.

- Feedback system should be introduced. For example, once the Union DMC receives information, they should confirm that to the Upazilla DMC.
- Flood Preparedness Program (FPP) should be introduced similar to CPP. This can be initiated under DMB through UNDP's CDMP.
- Volunteers should be trained under FPP for warning dissemination.
- In some border area, actual water level in the nearby river will be informed to Upazilla administration for point to point dissemination. A terminal will be paced by BWDB at the Upazilla administration that will provide information of present water level as recorded by the telemetric station. There are 32 Upazillas to be provided with such terminal in the project. The names are, Tetulia, Panchagarh Sadar, Boda, Debiganj, Dimla, Jaldhaka, Kishoreganj, Khansama, Patgram, and Hatibandha in northwest; Jhinaigati, Nalitabari, Durgapur, Kalmakanda, Tahirpur, Jamalganj, Bisambharpur, Sunamganj sadar, Doarabazar, Chhatak, Goainghat, Jaintipur, Kanaighat, Zakiganj, Beani Bazar, and Kamalganj in northeast; Brahmanpara, Burichang, and Comilla Sadar in Comilla area and Fatikchhari, Rauzan and Hathazari in Chittagong area (**Figure 7.5.1**)
- BWDB will do periodic maintenance for the terminals placed at the Upazillas.

(2) River Structures

Required components related to flood warning dissemination for the river structures are as follows:

- After preparation of the flood bulletin, the Flood Hydrology Circle (FHC) will provide this information to all BWDB OM zonal offices and central offices of all relevant agencies operating various river structures. These would include Roads and Highways (RHD), Bangladesh Inland Water Transport Authority (BIWTA), Bangladesh Inland Water Transport Corporation (BIWTC), Bangladesh Agricultural Development Corporation (BADC), etc. For speedy dissemination, use of email, internet website and auto-dial fax should be implemented.
- For major facilities such as ports, bridges, major highways and major ferry terminals, flood warnings will be given directly by FHC to the field operation offices.
- FHC should prepare specific warnings for major structures including national highways, ports, ferry terminals, barrages, bridges and major embankments.
- BWDB O&M zonal offices will convey the warning to all divisional offices and directly to the major structures themselves.
- BWDB O&M divisional offices will inform all field operation offices of the warning.
- Flood warnings received by relevant agencies will be passed on to their respective field operation offices.

### 7.5.3 Implementation Demarcation

As explained in **Section 7.5.1**, a major part of the flood warning dissemination system is not within BWDB's mandate. Required components described in **Section 7.5.2** clearly state the responsible authority. Of these, the items for which BWDB should be responsible will be included in the present Project. For the other items, it is strongly recommended that they be included in the CDMP study being undertaken by the UNDP. After that project they should be implemented by DMB and local government institutions.

## 7.6 Response System

### 7.6.1 Basic Strategy

As explained in **Section 3.7**, the response system is not functioning properly. It is obvious that without an adequate response system, the overall FFWS may not provide the required benefit. Of the various aspects of the response system shown in **Section 3.7.1**, the most important is evacuation to minimize the loss of human life. However, as also discussed in **Section 3.7**, responsibility for this sub-sector lies with the Local Government Institutions. According to the Standing Orders on Disaster, 1999, evacuation is a responsibility of District, Upazilla and Union Disaster Management Committees.

At present, there are only 95 flood shelters, of which 58 were donated by an NGO and 37 were constructed by different district administrations. The list is presented in **Table 7.6.1**. However, it is noted that people often take shelter in any available high rise structures such as schools and offices. As this is not done in an organized manner and proper facilities are generally unavailable in these shelters, people are often uncertain about moving to them during flooding. Therefore, flood shelters should be designated and if required, new ones constructed.

It is noted that there is no provision for a response system for the operation of various river structures. This should be initiated.

Because of the present legal status, the present Study divided the proposed Project into two parts. One was the response system for river structures. This is to be executed by BWDB. The other is the evacuation system that is recommended to be implemented by local government institutions. Detailed study of the latter should be included in the CDMP study being undertaken by UNDP.

### 7.6.2 Required Components

(1) Public

Required components related to response system for the inhabitants are as follows:

- DMB should prepare evacuation manual so that a formal evacuation system can be established.
- DMB should provide campaign for awareness building. Local NGOs should be involved in this process.
- Proposed FPP should carry out flood drills for improved evacuation.
- Upazilla DMC should fix flood shelter. These may include designated flood shelter,

cyclone shelter, schools, colleges, high-rise buildings, roads, embankments, etc. Specific area demarcation should be made for each shelter.

- New flood shelters should be prepared by DMB. These can be used for school in normal time.
- Upazilla DMC should also fix shelter for livestock.
- Upazilla DMC should monitor evacuation process.
- Upazilla DMC should prepare list of required facilities for each shelter to ensure proper living condition. Before the start of the flood season, necessary arrangements should be made. There should be prior planning for drinking water and sanitation facilities.
- Actual responsibility of evacuation should lie on Union DMC.
- Volunteers should be trained under the proposed FPP, who would assist in the evacuation process.
- Union DMC should earmark transportation for evacuation. Since Union Councils do not always own enough vehicles and boats, they should prepare an inventory of possible transport those can be obtained from various agencies at Upazilla and even District level.
- Upazilla DMC should arrange security for evacuated houses. Assistance should be obtained from Police, Ansars, Village Defense Police (VDP) and volunteers.
- DMB should prepare response management guideline for agriculture and fisheries.
- District DMC should issue response measures for agriculture and fisheries taking into consideration of the flood warning, working closely with relevant agencies like the Directorate of Agricultural Extension (DAE) and Fisheries Department.
- Union DMC will inform the people regarding the measures related to agriculture and fisheries. Also they will monitor the response undertaken.

(2) River Structures

River structures of the country are managed by various organizations such as BWDB (embankments, barrages, etc.), RHD (bridges, highways, etc.), BIWTA (large ferry terminals), BIWTC (large ferries), Bangladesh Railway (rail line, bridges, etc.), BADC (small scale irrigation) and so on.

Required components related to a response system for river structures are as follows:

- Response management guidelines (emergency operational procedures) should be prepared by all concerned agencies.
- The O&M office of each agency should issue response directives for the individual river structures based on the flood warning.
- Field operation offices should undertake proper response measures as stipulated in the guidelines.
- The O&M office of each agency should monitor actions taken by the field offices.

### 7.6.3 Implementation Demarcation

As explained in **Section 7.6.1**, the evacuation-related response system is not within

BWDB's mandate. Response systems for BWDB's river structures are, however, its responsibility. Required components described in **Section 7.6.2** clearly state the responsible authority. Of these, the items for which BWDB should be responsible will be included in the present Project.

For the evacuation-related response system, it is strongly recommended that this be included in the CDMP study being undertaken by UNDP. The findings should be implemented by DMB and local government institutions. For river structures of other agencies, DMB and BWDB should cooperate to implement the response system.

## 7.7 Overall Component

Based on the feasibility design outlined in **Sections 7.1** to **7.6**, the overall components of the proposed project are described below. Features of the proposed project are shown in **Figure 7.7.1**. The preliminary specifications of equipment are summarized based on requirements for (1) Central office (Dhaka), (2) Regional office, (3) Repeater station, (4) Telemeter station, (5) Manual gauging station and (6) Point-to-point dissemination. Block diagrams based on each are shown in **Figures 7.7.2** to **7.7.7.**

### 7.7.1 Central Office (Dhaka)

(1) Function

a. Analysis function
   - The central office receives regional observed and forecast data. Analyzing the regional observed and forecast data by MIKE11, a central bulletin, hazard map and observation map should be produced.

b. Monitoring function
   - The observed forecast data should be monitored on the monitoring computer.

c. Database function
   - The observed and forecast data should be stored in the database server.

d. Dissemination function
   - The bulletin should be disseminated to ministries and TV/radio stations via E-mail or fax and open to the public via the FFWC Internet website.

e. Input/output interface function
   - Communications with the regional offices should be conducted through digital HF or T&T lines. T&T is used if a digital HF link is not established. Interfaces with digital HF and T&T should be provided.

f. Regional function
   - The function of the regional offices, described in Section 7.7.2, should be provided for the analysis of the Dhaka region.

(2) Equipment Specification

<u>Central Part</u>

a. Regional I/F

| | | |
|---|---|---|
| HF antenna | : | With antenna tuner |
| HF transceiver | : | Automatic link establishment |
| T & T Modem | : | For backup line |

| | | |
|---|---|---|
| | I/F equipment | : Computer (24hour running)<br>Hard disk<br>Display<br>Ethernet I/F<br>T&T modem I/F (RS-232C)<br>Transceiver I/F (RS-232C)<br>(Software)<br>Automatic line change<br>Database access |
| b. | Database Sever (central)<br>Database server | : Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database index (water level, rainfall)<br>Data collection interval (10min. max.)<br>Data storage period (5years)<br>Accessibility (open database access) |
| c. | Super Model Analysis System<br>Analysis server | : Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Arc-View platform (existing)<br>MIKE11 (existing)<br>MIKE11 data base (existing)<br>MIKE Flood Watch (existing) for making bulletin and web contents<br>Database access |
| d. | Printer | : Color laser printer<br>Ethernet I/F |
| e. | Monitor Computer | : Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database access |

| | | | |
|---|---|---|---|
| f. | T&T interface | : | Ethernet I/F<br>T&T I/F<br>E-mail and fax sending function |
| g. | Power Equipment | : | UPS |

Regional Part

| | | | |
|---|---|---|---|
| a. | Telemeter I/F | | |
| | VHF antenna | : | 3 element collinear type |
| | Telemeter supervisory equipment | : | Transmitter and receiver (150MHz band) |
| | | : | Ethernet I/F |
| b. | Manual I/F | | |
| | HF antenna | : | With antenna tuner |
| | HF transceiver | : | Automatic link establishment |
| | Mobile modem | : | For data receiving from mobile phone |
| | I/F equipment | : | Computer (24hour operation)<br>Hard disk<br>Display<br>Ethernet I/F<br>Mobile modem I/F (RS-232C)<br>Transceiver I/F (RS-232C)<br>(Software)<br>Automatic data input function |
| c. | Database Server (regional) | | |
| | Database server | : | Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database index (water level, rainfall)<br>Data collecting interval (10min. max.)<br>Data storage period (5years)<br>Accessibility (open database access) |
| d. | Regional Analysis System | | |
| | Analysis server | : | Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display |

| | | | |
|---|---|---|---|
| | | | Ethernet I/F<br>(Software)<br>Arc-View platform (existing)<br>MIKE11 (existing)<br>MIKE11 data base (existing)<br>MIKE Flood Watch (existing) for making bulletin and web contents<br>Database access |
| e. | Printer | : | Color laser printer<br>Ethernet I/F |
| f. | Monitor Computer | : | Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database access |
| g. | T&T interface | : | Ethernet I/F<br>T&T I/F<br>E-mail and fax sending function |
| h. | Power Equipment | : | UPS |

### 7.7.2 Regional Office

(1) Function

a. Analysis function
   - The regional offices receive observed data from each gauging station. Analysing observed data by regional MIKE11, a regional report should be made.

b. Monitoring function
   - The observed and forecast data should be monitored on the monitor computer.

c. Database function
   - The observed and forecast data should be stored in the database server.

d. Dissemination function
   - Regional warning and forecasting messages should be disseminated to O&M divisional offices and district offices via E-mail or fax.

e. Input/output interface function
   - Communications with the central office should be conducted through digital HF or T&T. T&T is used as a backup in case a digital HF link is not established. Interfaces with digital HF and T&T should be provided.
   - Observed data at each gauging station should be transmitted to the regional offices via VHF telemeter, mobile phone or digital HF. Interfaces with VHF telemeter and mobile phone and digital HF should be provided.

(2) Equipment Specification

a. Telemeter I/F

| | |
|---|---|
| VHF antenna | : 3 element collinear type |
| Telemeter supervisory equipment | : Transmitter and receiver (150MHz band) |
| | : Ethernet I/F |

b. Manual I/F

| | |
|---|---|
| HF antenna | : With antenna tuner |
| HF transceiver | : Automatic link establishment |
| Mobile modem | : For data receiving from mobile phone |
| I/F equipment | : Computer (24hour operation)<br>Hard disk<br>Display<br>Ethernet I/F<br>Mobile modem I/F (RS-232C)<br>Transceiver I/F (RS-232C)<br>(Software)<br>Automatic data input function |

c. Central I/F

| | |
|---|---|
| HF antenna | : With antenna tuner |
| HF transceiver | : Automatic link establishment |
| T & T Modem | : Backup line |
| I/F equipment | : Computer (24hour operation)<br>Hard disk<br>Display<br>Ethernet I/F<br>T&T modem I/F (RS-232C)<br>Transceiver I/F (RS-232C)<br>(Software)<br>Automatic line change<br>Database access |

d. Database Server (regional)

| | |
|---|---|
| Database server | : Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database index (water level, rainfall)<br>Data collecting interval (10min. max.)<br>Data storage period (5years)<br>Accessibility (open database access) |

| | | | |
|---|---|---|---|
| e. | Regional Analysis System<br>Analysis server | : | Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Arc-View platform (existing)<br>MIKE11 (existing)<br>MIKE11 data base (existing)<br>MIKE Flood Watch (existing) for making bulletin and web contents<br>Database access |
| f. | Printer | : | Color laser printer<br>Ethernet I/F |
| g. | Monitor | : | Computer (24hour operation)<br>Storage device (CD, MO)<br>Hard disk<br>Display<br>Ethernet I/F<br>(Software)<br>Database access |
| h. | T&T interface | : | Ethernet I/F<br>T&T I/F<br>E-mail and fax sending function |
| i. | Power Equipment | : | UPS |

### 7.7.3 Repeater Station

<u>Repeater Station in O&M Office</u>

(1) Function

a. Repeater function
- At repeater stations, received data should be stored and retransmitted to a regional office or next repeater station in order to avoid attenuation of signal level of radio.

b. Monitoring function
- Observed data should be monitored at O&M offices.

(2) Equipment Specification

| | | | |
|---|---|---|---|
| a. | Repeater equipment | : | Transmitter and receiver<br>Stored repeater system |
| b. | Antenna | : | 3element collinear type |
| c. | Monitoring equipment | : | With monitoring panel |

| | | | |
|---|---|---|---|
| d. | Power equipment | : | Isolation transformer, DC power supply unit |
| e. | Antenna tower | : | Approx: 20-40m height |

Repeater Station in Upzilla without O&M Office (not Upazilla office)

(1) Function

a. Repeater function
- At repeater stations, received data should be stored and retransmitted to a regional office or next repeater station in order to avoid attenuation of signal level of radio.

b. Monitoring function
- Observed data should be monitored at Upazilla office.

(2) Equipment Specification

| | | | |
|---|---|---|---|
| a. | Repeater equipment | : | Transmitter and receiver<br>Stored repeater system |
| b. | Antenna | : | 3element collinear type |
| c. | Power equipment | : | Solar cells panel, Power distribution board, Battery |
| d. | Antenna tower | : | Approx: 20-40m height |

7.7.4 Telemeter Station

(1) Function

a. Gauging function
- Water level or rainfall level should be observed and sent to telemeter equipment.

b. Telemeter function
- Observed data should be transmitted to the regional office by VHF radio.

(2) Equipment Specification

| | | | |
|---|---|---|---|
| a. | Telemeter equipment | : | Transmitter and receiver |
| b. | Antenna | : | Yagi antenna or 3element collinear typr |
| c. | Raingauge | : | Raingauge, coder, data recorder |
| d. | Water level gauge | | |
| | (Sensing pole type) | : | Data recorder, sensing pole, transmitter, receiver, |
| | (Sonar type) | : | Data recorder, sonar type water level gauge, temperature sensor, connection board, coder |
| | *(Either sensing pole type or sonar type is applied.)* | | |
| e. | Power equipment | : | Solar cells panel, Power distribution board, Battery |
| f. | Antenna tower | : | Approx: 20-40m height |

### 7.7.5 Manual Gauging Station

Manual Gauging Station (by HF)

(1) Function

a. Data transmission function
- Observed data input by a gauge reader should be transmitted to the regional office through digital HF.

(2) Equipment Specification

| | | |
|---|---|---|
| a. | HF terminal I/F | : Computer |
| b. | HF transceiver | : Automatic link establishment |
| c. | HF antenna | : with antenna tuner |
| d. | Power equipment | : Isolation transformer DC power supply unit |

Manual Gauging Station (by mobile)

(1) Function

a. Data transmission function
- Input data checking system. (Mobile apparatus should have a function to check the input data with the gauge reader before its transmission.)
- Sending acknowledgement system. (After data are transmitted and input to the data server at the divisional office correctly, the mobile apparatus should acknowledge receipt of data to the gauge reader.)

(2) Equipment Specification

| | | |
|---|---|---|
| a. | Mobile phone | : Commonly used mobile phone (Grameen etc.) |

### 7.7.6 Point to Point Direct Dissemination (O&M office, Upazilla)

(1) Function

a. Monitoring function
- Point-to-point dissemination will be conducted at O&M and Upazilla offices to provide warning to the O&M offices and Upazilla officers. Telemeter data (water level and rainfall data) should be directly received at those locations where such data are needed.
- Telemeter data should be monitored through a monitoring panel in the O&M and Upazilla offices.

(2) Equipment Specification

| | | |
|---|---|---|
| a. | Monitoring equipment | : Receiver, monitoring panel |
| b. | Antenna | : Yagi antenna |
| c. | Power equipment | : DC Power supply unit, Isolation Transformer |
| d. | Antenna tower | : Approx: 20-40m height |

# CHAPTER 8 INSTITUTIONAL ARRANGEMENT

## 8.1 General

In **Section 3.8**, present institutional matters were discussed in detail and associated problems identified. Among these, two major concerns were identified as centralized, top-down administration and segregation of job responsibility. For better coordination, efficient functioning, cost reduction and proper management, establishment of regional offices of BWDB is considered the most appropriate. In this setup, the regional offices of BWDB will be responsible for all activities like planning, design, implementation, operation and maintenance, and hydrology including flood and low flow forecasting. Logistical facilities can be better utilized and field level coordination among various sections ensured. The benefits obtained from this system include:

- it is possible to execute works in a more coordinated manner,
- it will make maximum utilization of manpower and equipment,
- it is possible to take into account the local condition in all activities,
- it will reduce administrative procedure,
- Hydrology and O&M can assist each other as and when required, and
- it is possible to prepare localized flood warnings and assist in warning dissemination.

**Figure 8.1.1** shows the divisions and sub-divisions of BWDB. It is apparent the number of O&M divisions and sub-divisions are rather large compared to those of Hydrology. Merging these will give better efficiency and optimum use of manpower and resources.

However, it appeared from the discussion with BWDB officials, counterparts, and Steering Committee meetings that it would be rather difficult to implement this without detailed in-depth study. It may be mentioned here that the present centralized system was introduced in the late 1980s. BWDB suggested that another change may not be possible now. It would also be subject to GOB's policy decisions and major change has a direct influence on budget allocation and operational modality.

Though the Study Team is not selecting the regional offices of BWDB as part of the present Project, it is believed that this is the best option and recommends BWDB undertake a detailed Study to assess the feasibility of regional offices.

Under the above circumstances, the Study Team proposes the regional system of Hydrology as described in **Sections 4.4.2** and **4.4.4**. In addition to data collection, compilation and relevant maintenance, these offices can also provide regional flood warning. Working from central office, it is not always possible to fully comprehend and interact with the local context. Moreover, divisions and sub-divisions of Hydrology at field levels are under different circles of Hydrology. As a result, there are duplications of work. Divisions and sub-divisions of Hydrology are shown in **Figure 8.1.1**. It can be seen that there are two sub-divisions each at Dhaka, Comilla, Faridpur, Pabna, Jessore, Dinajpur and Mymensingh.

Comparative merits of the centralized and decentralized administration of Hydrology service in respect of the FFWS service are given in **Table 3.8.2**. This clearly highlights the relative advantages of the regional system over the central system.

This concept of regional offices is also proposed in line with the understanding of BWDB (**Section 6.3**), World Bank (WSIP project, **Section 3.8.1**) and other development partners.

## 8.2 Organizational Setup

### 8.2.1 Basic Strategy

The Study Team proposes regional offices of Hydrology as the basis of the organizational setup along with some major changes in the central office.

### 8.2.2 Reorganization of Central Hydrology

Even in the regional setup, reorganization of the central Hydrology is required to avoid duplication of responsibility, streamlining job functions and better coordination.

The proposed organization is given in **Figure 8.2.1**. The salient features are as follows:

- In this proposal, the present mandate of PFFC is divided based on similar work features.
- It is proposed to create Flood Hydrology Circle (FHC) instead of PFFC as shown in **Figure 8.2.1**.
- The other three circles remain unchanged from the current setup.
- A newly proposed Processing Division will be placed directly under the Hydrology service and will include three of the branches now under the PFFC, namely Processing Branch, Index and Publication Branch and Management and Services Branch (see **Figure 3.2.1**). Because of its strategic location, it will be easy for this division to coordinate with the other three data collection circles.
- There will be three divisions under FHC.
- The present FFWC will become the Forecasting division with a mandate for flood forecasting, model updating, model validation and low flow forecasting.
- A new division will be created named Data Collection Division by transferring some personnel from the Surface Water Hydrology circle.
- Since C&I division is the single electro-mechanical division of Hydrology, it should function independently of PFFC.
- Part of the present C&I will become Data Transmission division and will be placed under FHC.
- Part of the C&I division will become Instrumentation division placed directly under Hydrology Service, and will be responsible for maintaining electro-mechanical equipment of the three data collection circles.
- Mandate of the Flood Hydrology Circle (FHC) will be:

- Collection of all observation data
- Transmission of data to regional office
- Operation of the Supermodel
- Issuing of flood forecasts with regard to local context
- Become a member of the national disaster management committee
- Monitor the warning dissemination process
- Help in the evacuation and other response management
- Undertake dry season monitoring

8.2.3 The Regional Setup

In this setup, there will be a number of regional offices of Hydrology. Each regional office will have all functions of Hydrology headed by a Superintending Engineer. To a certain extent these offices will run independently. Head office will supervise, monitor and provide assistance. There will be four divisions in each regional office, namely Surface water hydrology division, Ground water hydrology division, Flood hydrology division and River morphology division. The mandate of the regional office will be similar to the central office.

There are many approaches to dividing the regions, including river basin, flood type, administrative division, logistic facilities availability, existing hydrology divisions, etc. Considering all these factors along with technical, hydrological, financial, and organizational issues, and maximum utilization of present facilities, it is proposed to create five regions of Hydrology. These are Northwest (NW), North Central (NC), Northeast (NE), Southwest (SW) and Southeast (SE). The proposed regional boundaries can be seen schematically on **Figure 7.3.3**.

The following steps are considered in the regional selection process.

1. Regional boundaries were principally defined along the three major rivers (Padma, Jamuna and Meghna). Since water level fluctuations in those rivers is rather small (day-to-day), it is suitable to set river points in those major rivers as 'boundary points'. From this viewpoint, three regions were extracted, that is NW, SW and the eastern part (group of NE, NC, and SE).
2. Since the eastern part was still rather large, it was further divided according to the basin division line. Three regions were defined for the eastern part, that is NE, NC and SE.

It may be noted that these regions are almost similar to those defined for the setup of the "Regional Models" under FAP 25 and Surface Water Simulation Modelling Programme (SWMC, 1996).

Regional office location should consider availability of various logistical facilities and activities for river management. Based on these, the regional offices are proposed to be established in Dhaka, Chittagong, Barisal, Rangpur and Sylhet.

## 8.3 Regulation on New Set-up

Any major change of BWDB can be only done by MOWR in consultation with Ministry of Establishment and Ministry of Finance. The proposals that must be implemented immediately are re-organization of Hydrology central office and establishment of Sylhet Regional Hydrology Office. After necessary consultation, MOWR should issue an order to implement these.

MOWR should act promptly to commence an institutional reform study and recommendations coming from it should also be implemented urgently. The mandate of such a re-organization should also be clearly stated.

## 8.4 Manpower Requirement for Improved FFWS

The Study Team proposes the regional operation system with some major change in the central structure. There will be five regional offices of Hydrology. Each regional office will carry out all work of Hydrology including data collection, processing, maintenance of equipment, operation of the regional model, localized flood warning, informing local authorities of the warning, and assisting in warning dissemination and response.

Manpower requirements are one of the major items of the feasibility design from the institutional aspect.

### 8.4.1 Manpower Requirement for Improved FFWS

The staffing of the present FFWS is shown in **Table 8.4.1** while manpower requirements for the proposed FFWS system are given in **Table 4.5.2**. Work items were identified initially from the two broad classifications, namely operation task and maintenance task.

The present strength is 294 and with this the optimum service should be delivered properly. However, required manpower for optimum service is 231. To determine the manpower requirement, jobs were identified both for operational task and maintenance task. Class-wise position was then determined for the regional offices and central offices. For the telemeter stations, one staff member is allotted for a number of stations for periodic rating and regular inspection. For the manual stations, one gauge reader is assigned, who will work from 09:00 to 18:00. And for telemeter stations, one gauge reader for each region is assigned to calibrate the telemeter observation system.

It is also proposed that for important manual observation stations there will be continuous data collection, even during the night through the flood season. For this purpose, extra gauge readers will be appointed by out-sourcing.

One Superintending Engineer (SE) will head the Flood Hydrology Circle. There will be three Executive Engineers (XEN) for the three divisions at central office.

Each regional office will be headed by one XEN. In this set up, there are 45 managerial level staff, 51 technical staff, 47 support staff and 90 gauge readers.

The gauge readers of FFWS (under Data Collection Division) require skills differing to those of the gauge readers of the Surface water hydrology circle. While the responsibilities of gauge readers of the SWHC are taking the observations, entering the data in a ledger and periodically mailing it to the central or regional offices, the manual gauge readers of the FHC require more technical skills. After taking the observations, the gauge readers will need knowledge of the operation of the special data input mobile devices proposed for real-time data transmission.

8.4.2 Manpower Requirement for Improved Hydrology

The Study Team proposes the regional operation system of Hydrology. Reorganization of central hydrology and set up of each regional office will be required for this purpose.

The staffing of present Hydrology is shown in **Table 8.4.2**. Preliminary manpower requirements for improved Hydrology are given in **Table 8.4.3**. The work items were identified initially from the two broad classifications. However, for a more accurate assessment, an institutional reform study is necessary.

Central office will be headed by a Chief Engineer. There will be four Superintending Engineers (SE) for the four circles, that is FHC, Ground Water Hydrology Circle, Surface Water Hydrology Circle and River Morphology & Research Circle at central office and two Executive Engineers (XEN) for the two divisions, namely Instrumentation Division and Processing Division. As most of the activities are to be carried out in the field, there will be only one XEN each under the three data collection circles, namely SW, GW and RM for central office administration and coordination purposes. However, since the central FHC has to operate the Supermodel for flood forecasting and prepare nationwide forecasting, there will be three XENs for the three divisions.

One Superintending Engineer (SE) will head the Regional Hydrology office. There will be four Executive Engineers (XEN) for the four divisions, namely Regional FH, Ground Water Hydrology, Surface Water Hydrology and River Morphology and Research Divisions at each regional office. In the Regional FH, there will be three SDEs for the three sub-divisions collecting, transmitting and preparing the regional forecasts. Sub-divisions for the other three data collection divisions were estimated based on the work volume.

The required manpower for FHC was estimated in detail as outlined above but for other circles was evaluated to maintain staff numbers at comparable levels. Exact staffing should be determined through an Institutional Review Study.

# CHAPTER 9 COST ESTIMATE

## 9.1 Basic Conditions

(1) Estimation of Project Cost

In previous Chapters of the Report, a detailed description of the proposed feasibility design for improvement of the existing FFWS has been presented. Based on the proposal, costs estimates have been derived outlining both associated Investment Cost and Annual Operation and Maintenance Cost. These are described in the following sections including a summary of the various price and exchange rates also used in the analyses.

(2) Price Rate

Equipment price rates were based on price levels in Japan as at July 2003.

The price rates of all works in Bangladesh were based on the "Standard Schedule of Rates Manual", published by BWDB in July 2002.

(3) Exchange Rate

The exchange rate used in deriving project costs was determined using the rate for May 2003, that is Taka 1.0 = JPY 2.00.

(4) Currency

The project costs are divided into foreign and local currencies. As the monetary unit for each currency, the Bangladesh Taka is employed.

(5) Price Increase Rate

Price increase rate was not considered in this cost estimate.

## 9.2 Investment Cost

### 9.2.1 Conditions of Estimation of Investment Cost

(1) Scope of Estimation

The scope for cost estimation covered the four sub-systems: 1) Observation system, 2) Data transmission system, 3) Forecasting analysis system, and 4) Warning dissemination system. The scope is shown **Figure7.7.1**.

(2) Components

Investment costs were divided into direct installation costs and indirect costs. The direct installation costs were mainly estimated based on quantities and current price rates of equipment. The indirect costs were divided into administration, engineering, training and contingency components each based on a nominated percentage of the total direct installation costs (both foreign and local). The respective components are described in more detail below:

a) Direct Installation Cost

- Equipment
- Civil works
- Installation
- Maintenance tools
- Spare parts
- Ocean and inland transportation
- Office equipment

b) Indirect Installation Cost

- Administration
- Engineering
- Training
- Contingency
- Price Escalation

The following components were estimated in local currency:

- All civil works (including design and materials)
- Domestic labor cost for installation of automatic water level gauging stations
- Materials for installation of automatic water level gauging stations
- Administration cost
- Engineering assumed to be around 10% of the foreign cost
- Training assumed to be around 10% of the foreign cost
- Contingency assumed to be around 10% of the foreign cost

(3) Direct Installation Cost

Direct installation cost consisted of labor, materials, contractor's profit, tools, temporary structures and other components required for the execution of the works.

a) Equipment

- Observatory equipment: water level gauging and rainfall gauging systems for each station
- Data transmission equipment: antenna systems, radio equipment, interface systems and mobile equipment for each facility
- Analysis systems: computer software, hardware and monitoring systems both in Central and Regional offices
- Warning systems: interface computers in each divisional O&M office, FFWC Website
- Power supply for each facility

b) Civil Works

- New building construction including control rooms in Regional Offices, repeater stations in Upazillas and station houses at each telemeter gauging station
- Antenna tower construction: required at each facility
- Others included new road construction or similar at each facility

c) Installation

- Labor costs and material costs to fit and fix all equipment plus testing for material properties and machine performances.

d) Maintenance Tools

- All tools for maintenance of all equipment
- Maintenance tool costs were estimated by referring to existing FFWC and other similar facilities.

e) Spare Parts

- All spare parts for equipment
- Spare parts costs were estimated as 20% of all equipment costs

f) Ocean and Inland Transportation

- All transportation costs from supply country to demand place
- Ocean transportation costs were estimated as 9% of all equipment costs in foreign currency
- Inland transportation costs were estimated as 1% of all equipment costs in local currency

g) Office Equipment

- All office accessories: personal computers, printers, telephones, faxes and so on at each new control center
- Office equipment costs were estimated by referring to existing FFWC and other similar facilities

(4) Administration Cost

Government administrative costs were estimated as 1% of total direct installation costs expressed in local currency.

(5) Engineering

Foreign and local engineering costs for detailed engineering and procurement assistance were estimated as 14% and 1% respectively of total direct installation costs.

(6) Training

Foreign and local staff training costs were estimated as 0.9% and 0.1% respectively of total equipment and installation costs.

(7) Contingency

Foreign contingency costs were estimated as 14% of total civil works plus 4.5% of total equipment costs including installation. Local contingency costs were 1% of total civil works plus 0.5% of total equipment costs including installation.

(8) Price Escalation

Price escalations were calculated under the assumption that equipment would be installed at the end of 2005. The total of the direct installation costs both of foreign and local currency portions was subject to the price escalation. The applied price escalation rates both for foreign and local portions are shown below:

- Foreign currency portion: 0.25 %/year
- Local currency portion: 4.3 %/year

9.2.2 Investment Cost

The investment costs are estimated at 1,148.2 million Taka as shown in the table below. The foreign currency component is approximately 942.2 million Taka and the local component 206.0 million Taka. The detailed information is presented in **Tables 9.2.1, 9.2.2** and **9.2.3**.

**Investment Cost**

(Unit: Million Taka)

| Item | Currency Portion | | Total |
|---|---|---|---|
| | Foreign | Local | |
| A Direct Installation Cost | | | |
| A-1 Equipment | 494.6 | 0.0 | 494.6 |
| A-2 Civil works | 0.0 | 144.0 | 144.0 |
| A-3 Installation | 93.8 | 0.6 | 94.4 |
| A-4 Maintenance tool | 25.0 | 0.0 | 25.0 |
| A-5 Spare parts | 98.9 | 0.0 | 98.9 |
| A-6 Ocean and inland transportation | 44.5 | 4.9 | 49.5 |
| A-7 Office Equipment | 0.0 | 18.4 | 18.4 |
| Sub Total | 756.8 | 167.9 | 924.8 |
| B Administration Cost | 0.0 | 9.2 | 9.2 |
| C Engineering | 129.5 | 9.2 | 138.7 |
| D Training | 5.3 | 0.6 | 5.9 |
| E Contingency | 46.7 | 4.4 | 51.1 |
| F Price Escalation | 3.8 | 14.7 | 18.5 |
| **Total** | **942.2** | **206.0** | **1,148.2** |

## 9.3 Annual Operation and Maintenance Cost

9.3.1 General

As mention in previous sections, the existing telemeter system does not function well. One of the main reasons is that the budget allocated to operation and maintenance is insufficient. To make the FFWS more effective, a greater allocation to operation and maintenance should be allowed. Therefore in this section, in addition to estimation of project O&M cost, actual O&M cost and required O&M cost for effective management of the existing FFWS are calculated as a reference. The cases considered are indicated below:

1) Actual O&M cost (for existing FFWS)

Actual O&M cost for the existing FFWS was estimated by the Study Team based on the result of discussions with BWDB staff. These revealed that the repair and maintenance budget is insufficient to ensure the FFWS functions effectively.

2) Required O&M cost (for existing FFWS)

Repair and maintenance costs for equipment, depreciation cost and other O&M costs required for effective functioning of the FFWS were estimated by the Study Team.

3) Project O&M cost (for proposed FFWS)

This is outlined in the following section.

### 9.3.2 Conditions for Evaluation of Operation and Maintenance Cost

(1) Scope of Estimation

The scope of the proposed project covers the FFWS. Therefore, sections associated with the FFWS in the existing Hydrology service were only selected for the purpose of cost estimation.

(2) Components

The operation and maintenance costs include staff personnel, operating and management and depreciation costs.

(3) Staffing

The number of staff for the existing FFWS and required number for proper operation and maintenance of the improved FFWS are presented in **Tables 8.4.1** and **4.5.2** respectively.

(4) Operation and Maintenance Cost

The operation and maintenance costs are classified into the following components:

**Components of O&M Cost**

| Item | Details |
|---|---|
| a) Transportation cost | - business trip costs |
| b) Communication cost | - BTTB, mobile, courier, post, etc. |
| c) Vehicle operation cost | - driver's wages, fuel and oil, repairs |
| d) Boat operation cost | - driver's wages, fuel and oil, repairs |
| e) Repair and maintenance cost | - for telemeter equipment (0.5% of total telemeter equipment costs)<br>- for computer equipment (10% of total computer equipment costs)<br>- for civil construction (2% of total civil works and 5% existing gauging stations) |
| f) Light, fuel and water cost | (5% of total office staff costs) |
| g) Consumables | (3% of total office staff costs) |
| h) Advertising | (2% of total office staff costs) |
| i) Social costs | (2% of total office staff costs) |
| j) Social welfare | (1% of total office staff costs) |
| k) House and land rental | - for public space: not necessary<br>- for rental space: necessary (Dhaka Region) |
| l) Training cost | - for each official staff member |
| m) Insurance | (1% of total of "a) ~l)") |
| n) Sundry | (5% of total of "a) ~ l)") |

(5) Depreciation Cost

For replacement of the system, depreciation cost should be considered and budgeted for by the Bangladesh government. However, depreciation is usually not included in annual O&M costs for most infrastructure projects in Bangladesh.

In the case of estimation of required O&M cost for the existing FFWS and project O&M cost, depreciation costs have been included in O&M cost. Depreciation cost was estimated assuming a 5 year replacement (20% annual rate of depreciation) for hardware and mobiles, 10 year replacement (10% annual rate of depreciation) for other equipment, and 30 year replacement (3.3% annual rate of depreciation) for civil construction items.

9.3.3 Annual Operation and Maintenance Cost

The O&M cost for the project is estimated at around 202.4 million Taka, required O&M cost for existing FFWS is 70.6 million Taka and actual O&M cost is 34.1 million Taka. These are summarized below. Excluding depreciation cost, the project O&M cost is 65.6 million Taka, an increase of 21.5 million Taka annually over the required O&M cost. As shown in the results, the repair and maintenance cost will be higher to operate and maintain the existing FFWS and improve its effectiveness. In terms of staffing cost, project O&M cost is 1.4 million Taka lower than actual O&M cost reflecting the reduction in staff numbers. A detailed breakdown of the estimation of annual O&M cost is presented in **Tables 9.2.4** to **9.2.8**.

**Comparison of Annual O&M Costs**

(Unit: Million Taka/year)

| Items | Actual O&M cost (for existing FFWS) | Required O&M cost (for existing FFWS) | Project O&M Cost (for proposed FFWS) |
|---|---|---|---|
| Staff | 24.4 | 24.4 | 23.0 |
| Repair, Maintenance | 1.7 | 10.5 | 27.1 |
| Other O&Ms | 8.0 | 9.4 | 15.5 |
| *Subtotal* | *34.1* | *44.3* | *65.6* |
| Depreciation | 0.0 | 26.3 | 136.8 |
| **Total** | **34.1** | **70.6** | **202.4** |