Feasibility Study for Improvement of Flood Forecasting and Warning Services in the People's Republic of Bangladesh

Final Report

Volume II
Main Report

December 2003

Nippon Koei Co., Ltd.

Japan International Cooperation Agency

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The cost estimate is based on the price level and exchange rate of May 2003
The exchange rate is

US$1 00 = BDT58 10 = ¥116 28

PREFACE

In response to the request from the Government of People's Republic of Bangladesh, the Government of Japan decided to conduct "Feasibility Study for Improvement for Flood Forecasting and Warning Services in the People's Republic of Bangladesh" and entrusted the study to Japan International Cooperation Agency (JICA)

JICA dispatched a study team headed by Mr Hideki Sato of Nippon Koei Co , Ltd to Bangladesh three times between November 2002 and December 2003 In addition, JICA set up an Advisory Committee headed by Mr Akinori Masuda of Kyushu Regional Bureau Ministry of Land, Infrastructure and Transport, which examined the Study from specialist and technical point of view

The team held a series of discussions with the officials concerned of the Government of Bangladesh and conducted field surveys at the study area Upon returning to Japan, the team conducted further studies and prepared this final report

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Bangladesh for their close cooperation extended to the team

December 2003

Matsuoka Kazuhisa

Vice-President

Japan International Cooperation Agency

December 2003

Mr Kazuhisa Matsuoka
Vice-President
Japan International Cooperation Agency (JICA)
Tokyo, Japan

Letter of Transmittal

It is with great pleasure that we submit to you the Final Report of "Feasibility Study for Improvement of Flood Forecasting and Warning Services in the People's Republic of Bangladesh"

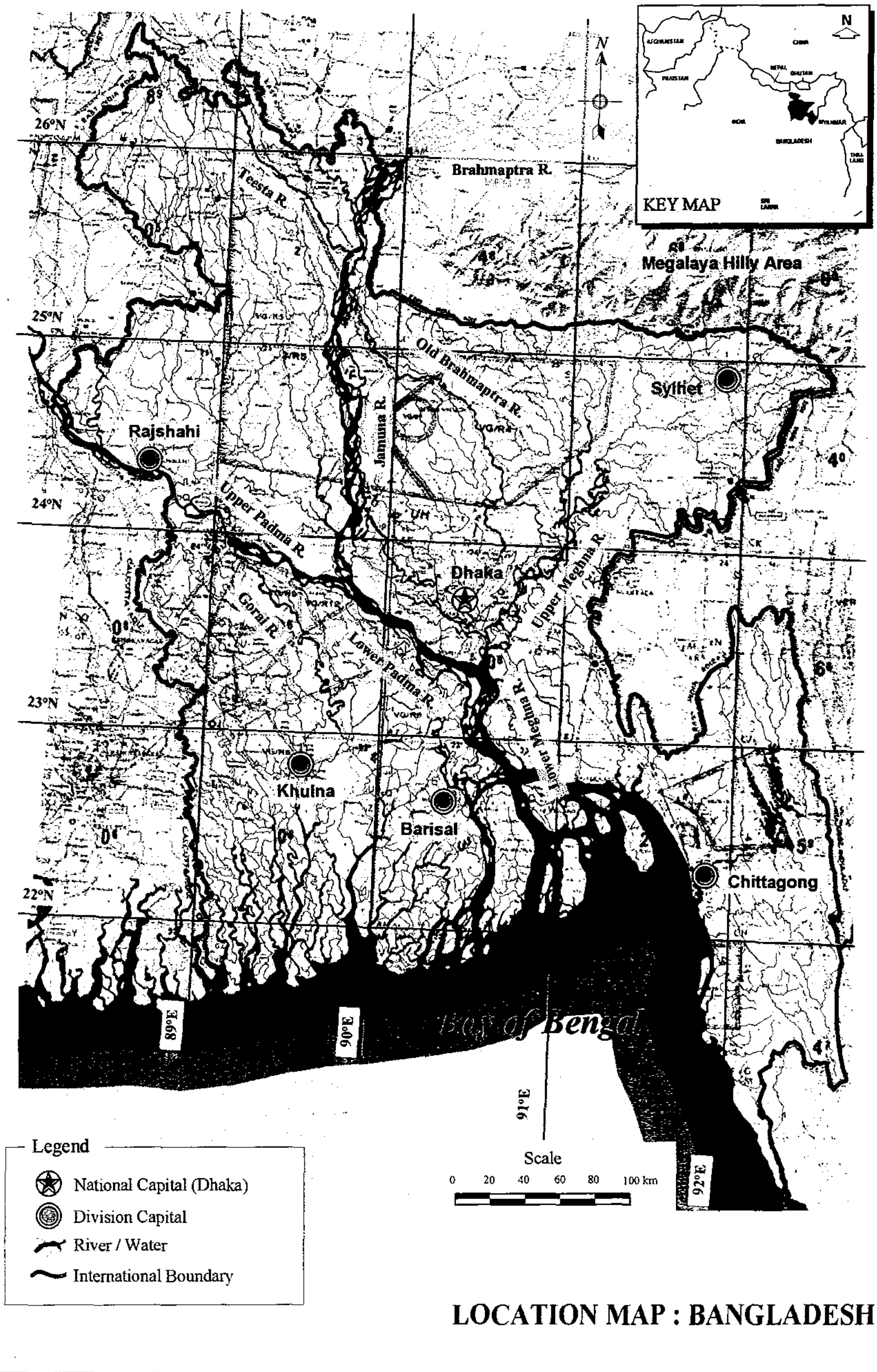
The Study has prepared the framework plan for the improvement of existing flood forecasting and warning system in Bangladesh, and conducted the feasibility study for the optimal improvement plan The Report presents the said framework plan and feasibility study results

We hope that this Report will be helpful for realization of the projects and programs proposed in this Study to mitigate the flood damage, and will contribute to the socio-economic development of Bangladesh

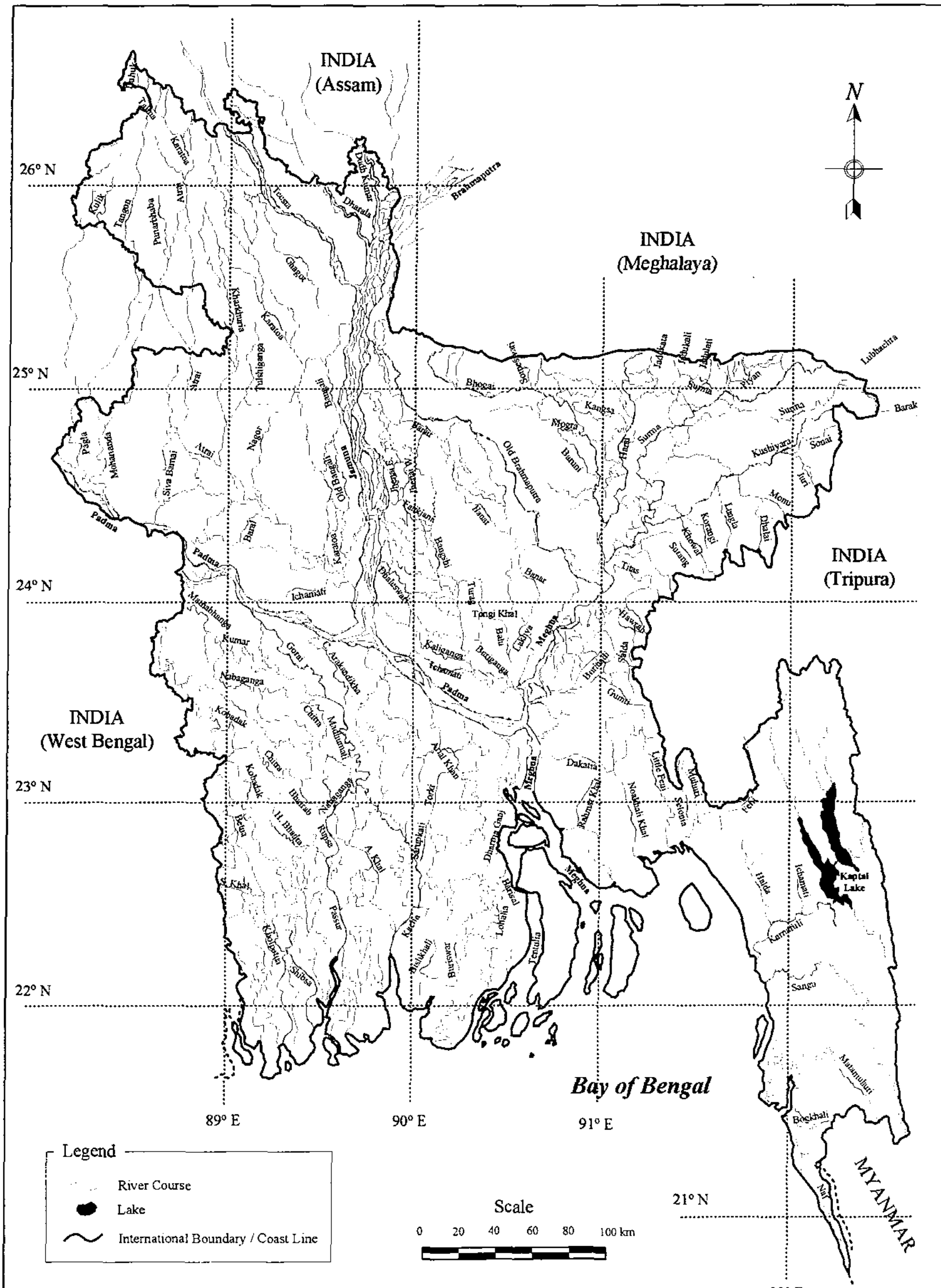
We wish to express our deep appreciation and gratitude to the personnel concerned of your Agency, JICA Bangladesh Office, the Embassy of Japan in Bangladesh, Ministry of Water Resources, Bangladesh Water Development Board and the authorities concerned of the Government of the People's Republic of Bangladesh for the courtesies and cooperation extended to us during our Study

Very truly yours,

Hideki Sato
Team Leader
for Feasibility Study for Improvement
of Flood Forecasting and Warning Services
in the People's Republic of Bangladesh

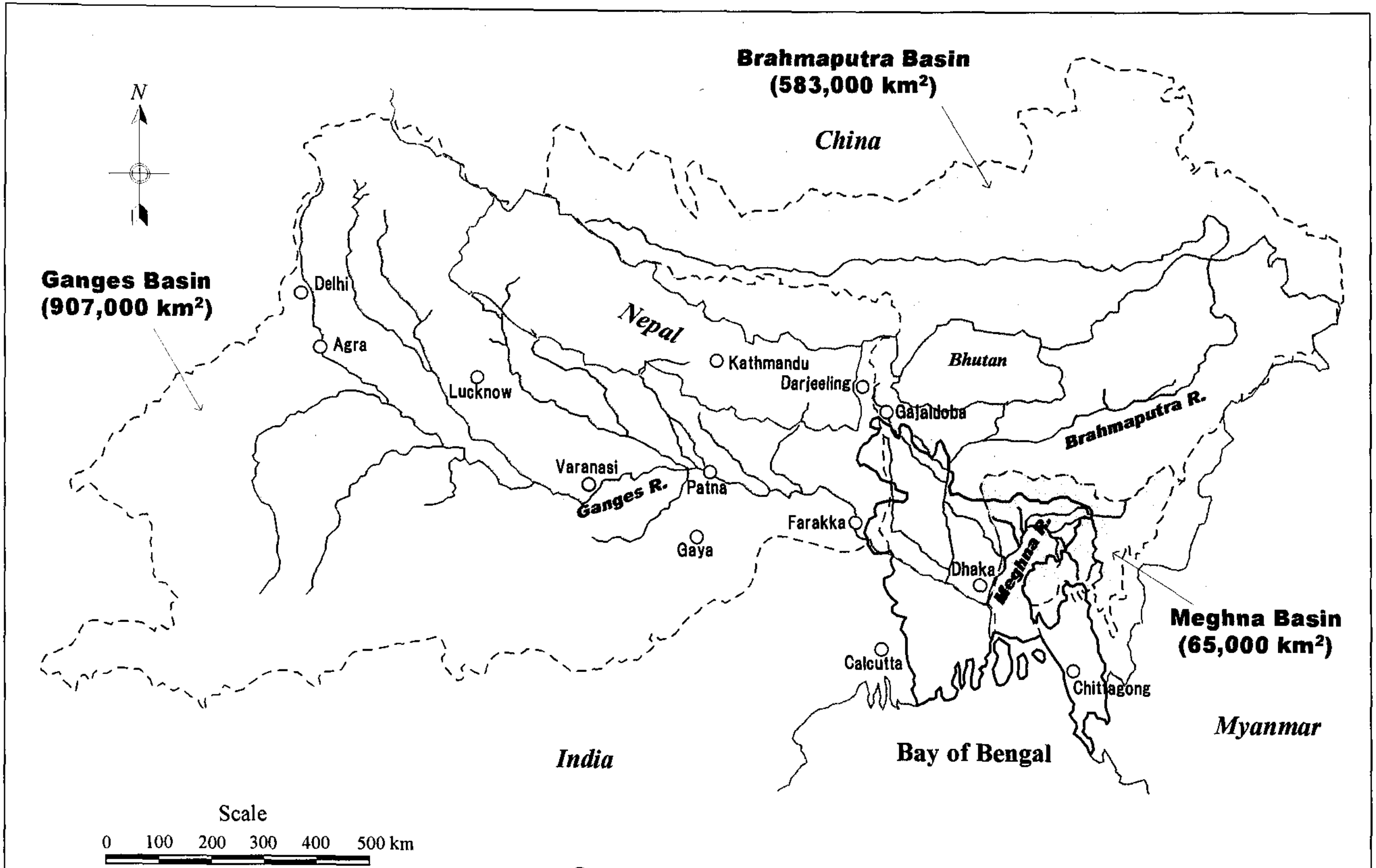


LOCATION MAP : BANGLADESH



Source : BWDB

LOCATION MAP : RIVERS OF BANGLADESH



LOCATION MAP : BANGLADESH AND INTERNATIONAL RIVERS

FEASIBILITY STUDY FOR IMPROVEMENT OF
FLOOD FORECASTING AND WARNING SERVICES IN
THE PEOPLE'S REPUBLIC OF BANGLADESH

OUTLINE OF THE STUDY

1. Present Condition

Bangladesh	Location	Northeastern part of South Asia
	Total land area	147,000 km^2
	Major international rivers	Ganges / Padma (907,000 km^2), Brahmaputra / Jamuna (583,000 km^2), and Meghna (63,000 km^2)
Socio-economy	Population	121 4 million (2001)
	GDP	2,450 billion Taka (2000/01)
	Per-capita GDP	20,182 Taka (2000/01)
Hydrometeorology	Annual rainfall	1,200 mm (west) to over 5,000 mm (northeast)
	Flood types	Monsoon Flood, Flash Flood, Tidal Surge, and Local Inundation
Flood Damage	Flood affected area (Number of deaths):	89,970 km^2 (2,379 persons) in 1988 monsoon 100,250 km^2 (918 persons) in 1998 monsoon
	Annual flood damage:	12 2 billion Taka
Telecommunication	Diffusion rate	Fixed phone 0.39 units/100 habitants Mobile phone 0.40 units/100 habitants
Institutions	Water-related agencies	i) National Water Resources Council (NWRC) ii) Ministry of Water Resources (MOWR) a) Bangladesh Water Development Board (BWDB) b) Joint Rivers Commission (JRC) c) Water Resources Planning Organization (WARPO) d) River Research Institute (RRI) e) Bangladesh Haor and Wetland Development Board (BHWDB) f) Institute of Water Modeling (IWM) g) Center for Environment and GIS (CEGIS)
	Water-related law and regulations	i) National Water Policy ii) National Water Management Plan iii) National Water Code (under preparation)
Current FFWS	Observation system.	91 manual water level gauging stations 56 manual rainfall gauging stations [Existing Telemeters] a) 14 locations (installed in 1985 and 1996) b) 5 operational (as of September 2003) c) Not effectively used in the current FFWS

Data transmission system	Voice communication by means of HF wireless (SSB)
Analysis system	Supermodel based on hydrological-hydraulic calculation software (MIKE11)
Dissemination system	Flood warning messages issued by Flood Forecasting and Warning Center (FFWC)
Response system.	Led by Disaster Management Committee (DMC) of local authorities
Ongoing projects:	i) Consolidation and Strengthening of FFWS (DANIDA) ii) Water Management Improvement Project (WB) iii) Comprehensive Disaster Management Program (UNDP), etc.

2. Approach to the Improvement of FFWS

Study Period: November 2002 – December 2003

Scope of Work

1) Formulation of Improvement Plan of FFWS
2) Feasibility Study of the Selected Optimum Scheme
3) Transfer of Technology

Basic Approach

1) Clarification of present conditions of existing FFWS and problems encountered therein
2) Formulation of improvement plans of FFWS based on the study of conceivable alternative plans
3) Selection of optimum plan
4) Feasibility study on the optimum plan

3. Framework Plan of FFWS (Feasibility Project)

Proposed Optimum Scheme (Framework Plan of FFWS)

Control System

1) Central Control System (Control Station: Dhaka)
2) Five Regional Control System
   a) NE Region (Control Station: Sylhet)
   b) NW Region (Control Station: Rangpur)
   c) SE Region (Control Station: Chittagong)
   d) SW Region (Control Station. Barisal)
   e) NC Region (Control Station: Dhaka)

Manual-Telemeter Combined Observation System

1) Water Level Gauging Stations
   a) Manual: 68 (NE: 11, NW: 17, SE: 7, SW: 12, NC: 21)
   b) Telemeter: 23 (NE: 7, NW: 5, SE. 2, SW: 5, NC. 4)

2) Rainfall Gauging Stations
   a) Manual 45 (NE 7, NW 10, SE 9, SW 10, NC 9)
   b) Telemeter 23 (NE 7, NW. 5, SE: 2, SW 5, NC 4)

Project Cost.

Investment Cost 1,148 2 million Taka

Annual O&M Cost 65.6 million Taka (excluding depreciation cost)

Economic Evaluation:

EIRR 26 4 %, NPV. 708 million Taka, B/C. 1 1 (Applied Discount Rate 12 %)

Social / Environmental Evaluation No negative effect

4. Pilot Project

Project Features

Control System

1) Central Control System (Control Station Dhaka)
2) NE (Sylhet) Regional Control System

Manual-Telemeter Combined Observation System

1) Water Level Gauging Stations
   a) Manual. 68 (NE 11, Others: 57)
   b) Telemeter: 23 (NE 7, Others: 16)
2) Rainfall Gauging Stations
   a) Manual: 45 (NE 7, Others. 38)
   b) Telemeter 23 (NE 7, Others 16)

Project Cost

Investment Cost 813 7 million Taka

Annual O&M Cost 51 2 million Taka (excluding depreciation cost)

Project Implementation

Leading Agency. BWDB

Implementation Period Jan. 2004 – Dec 2008 (including financial arrangement, design, and guidance period)

5. Priority Studies to be Conducted

Components of Priority Study

1) Formulation of O&M Plan of Improved FFWS
2) Clarification of River Management
3) Strengthening of Dissemination and Evacuation (Response) System
4) Institutional Study
5) Collection of the Information on River Management and Review of Danger Level

FEASIBILITY STUDY
FOR
IMPROVEMENT OF FLOOD FORECASTING AND WARNING SERVICES
IN
THE PEOPLE'S REPUBLIC OF BANGLADESH

FINAL REPORT

VOLUME-II : MAIN REPORT

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PART-III FEASIBILITY STUDY

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ABBREVIATIONS

ADB	Asian Development Bank
ADCP	Acoustic Doppler Current Profiler
ADG	Additional Director General
ADPC	Asian Disaster Preparedness Center
AE	Absolute Error
ARGS	Automatic Rainfall Gauging Station
ASCE	American Society of Civil Engineers
AWLGS	Automatic Water Level Gauging Station
BADC	Bangladesh Agricultural Development Agency
BBS	Bangladesh Bureau of Statistics
BIWTC	Bangladesh Inland Water Transport Corporation
BM	Bench Mark
BMD	Bangladesh Meteorological Department, Ministry of Defense
BR	Bangladesh Railway
BRAC	Bangladesh Rural Advancement Committee
BRTA	Bangladesh Rural Telecom Authority
BTRC	Bangladesh Telecommunications Regulatory Commission
BTTB	Bangladesh Telegraph and Telephone Board
BUET	Bangladesh University of Engineering and Technology
BUP	Bangladesh Unnayan Parishad (Bangladesh Development Council), NGO
BWDB	Bangladesh Water Development Board
C&I	Construction and Instrumentation Division, BWDB
CAP	Community Action Plan
CBO	Community Based Organizations
CC	Community Contract
CCC	Community Coordination Committee
CDMP	Comprehensive Disaster Management Program
CE	Chief Engineer
CEGIS	Center for Environmental and Geographic Information Services
CFAB	Climate Forecast Applications in Bangladesh
CFD	Controlled Flooding and Drainage
CIDA	Canada International Development Agency
CPI	Consumer Price Index
CPP	Cyclone Preparedness Program
CPR	Center for Policy Research, NGO in India
CSFFWS	Consolidation and Strengthening of Flood Forecasting and Warning Services
CVCF	Constant Voltage Constant Frequency
DAE	Department of Agriculture Extension
DANIDA	Danish International Development Agency
DEM	Digital Elevation Model
DFID	Department for International Development, UK
DG	Director General
DHI	Danish Hydraulic Institute
DL	Danger Level
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DMIC	Disaster Management Information Center
DOE	Department of Environment
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DRR	Directorate of Relief and Rehabilitation
ECA	Environment Conservation Act
ECR	Environment Conservation Rules
EIA	Environmental Impact Assessment

EOC	Emergency Operation Center
ERD	Economic Relations Division, Ministry of Finance
FAO	Food and Agriculture Organization of the United Nations
FAP	Flood Action Plan
FCDI	Flood Control, Drainage and Irrigation Project
FFMI	Flash Flood Magnitude Index
FFWC	Flood Forecasting and Warning Center, BWDB
FFWS	Flood Forecasting and Warning System (Service)
FFYP	Fifth Five Year Plan
FHC	Flood Hydrology Circle (proposed)
FPCO	Flood Plan Coordination Organization
FPP	Flood Proofing Project
GBM	Ganges-Brahmaputra-Meghna (Basins or Rivers)
GDA	Ganges Dependent Area
GDP	Gross Domestic Product
GIS	Geographical Information System
GK	Ganges Kobadak (project)
GMS	Geostational Meteorological Satellite
GNP	Gross National Product
GOB	Government of Bangladesh
GOJ	Government of Japan
GP	Grameen Phone (Mobile Phone Service Company)
GPS	Global Positioning System
GWHC	Ground Water Hydrology Circle, BWDB
GWPB	Ground Water Processing Branch, BWDB
HDI	Human Development Index
HF	High Frequency
HYV	High Yielding Variety
ICB	International Competitive Bidding
IDA	International Development Association
IEE	Initial Environmental Examination
IFCDR	Institute of Flood Control and Drainage Research, BUET, now renamed as Institute of Flood and Water Management (IFWM)
IFWM	Institute of Flood and Water Management, BUET, formerly known as IFCDR
IIDS	Institute for Integrated Development Studies, NGO in Nepal
ILA	International Law Association
IMD	India Meteorological Department
IMDMCC	Inter-Ministerial Disaster Management Co-ordination Committee
IT	Information Technology
ITCZ	Inter-tropical Convergence Zone
IWM	Institute of Water Modeling, formerly known as Surface Water Modeling Center (SWMC)
JBIC	Japan Bank for International Cooperation
JICA	Japan International Cooperation Agency
JOCV	Japan Overseas Cooperation Volunteers
JRC	Joint Rivers Commission
JRC	Japan Radio Co., Ltd.
LCG	Local Consultative Group
LDAP	Local Disaster Action Plan
LGD	Local Government Division, MOLGRDC
LGED	Local Government Engineering Department
LGI	Local Government Institutions
MAE	Mean Absolute Error
MIS	Management Information System
MODMR	Ministry of Disaster Management and Relief
MOE	Ministry of Education
MOEF	Ministry of Environment and Forest
MOLGRDC	Ministry of Local Government, Rural Development and Cooperatives

MOU, MoU	Memorandum of Understanding
MOWR	Ministry of Water Resources
MPO	Master Plan Organization
MPT	Ministry of Posts and Telecommunications
MSL	Mean Sea Level
MTBF	Mean Time between Failures
NDC	National Disaster Council
NEC	National Economic Council
NEP	National Environmental Policy
NGO	Non-governmental Organization
NOAA	National Oceanic and Atmospheric Administration, USA
NPO	Non Profit Organization
NWDA	National Water Development Agency
NWMP	National Water Management Plan
NWP	National Water Policy
NWRC	National Water Resources Council
NWRD	National Water Resources Database
O&M	Operation and Maintenance
ODA	Official Development Assistance
OS	Operating System
PC	Planning Commission, Ministry of Planning
PCM	Project Cycle Management
PDB	Power Development Board
PFFC	Processing and Flood Forecasting Circle, BWDB
PPPDU	Program, Policy, and Partnership Development Unit
PRA	Participatory Rapid Appraisal
PWD	Public Work Department or Public Works Datum (Water Level)
R&H	Roads and Highways Department
RF	Rain Fall (stations)
RMPB	River Morphology Processing Branch, BWDB
RMR	River Morphology and Research
RMRC	River Morphology and Research Circle, BWDB
RRI	River Research Institute
SAARC	South Asia Association for Regional Cooperation
SDE	Sub Divisional Engineer
SDH	Synchronous Digital Hierarchy
SE	Superintending Engineer
SM	Supermodel
SPARRSO	Space Research & Remote Sensing Organization
SW	Scope of Work
SWHC	Surface Water Hydrology Circle, BWDB
SWMC	Surface Water Modeling Center, now renamed as Institute of Water Modeling (IWM)
SWPB	Surface Water Processing Branch, BWDB
TBM	Temporally Bench Mark
TDS	Total Dissolved Solids
TOF, ToF	Time of Forecast
TOR, ToR	Terms of Reference
UNCHS	United Nations Center for Human Settlement (Habitat)
UNDP	United Nations Development Programme
UNO	Upa-Zilla Nirbahi (Executive) Officer
UPS	Uninterrupted Power Supply
USAID	United States Agency for International Development
USD	United States Dollar
UZ	Upa-Zilla
VHF	Very High Frequency
VSAT	Very Small Aperture Terminal
WARPO	Water Resources Planning Organization
WB	World Bank

WL	Water Level *(stations)*
WMA	Water Management Association
WMIP	Water Management Improvement Project
WMO	World Meteorological Organization
WSIP	*Water Sector Improvement Project*
XEN	Executive Engineer

MEASUREMENT UNITS

Area

cm^2	=	Square Centimeters
m^2	=	Square Meters
km^2	=	Square Kilometers
ha	=	Hectares (10,000 m^2)

Volume

cm^3	=	Cubic Centimeters
m^3	=	Cubic Meters
m^3/day	=	Cubic Meters per Day
m^3/h	=	Cubic Meters per Hour
m^3/min	=	Cubic Meters per Minute
m^3/sec (cumec)	=	Cubic Meters per Second
ft^3/sec (cusec)	=	Cubic Feet per Second
l or lit	=	Liter (1,000 cm^3)
lpcd	=	Liter per capita per day
MCM	=	Million Cubic Meter

Length

mm	=	Millimeters
cm	=	Centimeters
m	=	Meters
km	=	Kilometers

Weight

g	=	Grams
mg	=	Milligrams (1/1,000 g)
mg/l	=	Milligrams per liter
µg/l	=	Micrograms per liter
kg	=	Kilograms (1,000 g)
kg/cm^2	=	Kilograms per square centimeter
t	=	Metric ton (1,000 kg)

Currency

US$	=	United State Dollars
JPY	=	Japanese Yen
Tk (BDT)	=	Bangladesh Taka

Time

s	=	Seconds
min.	=	Minutes
h	=	Hours

Energy

kVA	=	Kilovolt Ampere
kW	=	Kilowatt

Others

per/km^2	=	Persons per Square Kilometer
rpm	=	Revolutions per Minute
Hz	=	Hertz
MHz	=	Megahertz
B (b)	=	Byte
KB (kb)	=	Kilobytes
dB	=	Decibel
MSL	=	Mean Sea Level
Lakh	=	One Hundred Thousand
Crore	=	Ten Million

Economy

EIRR	=	Economic Internal Rate of Return
FIRR	=	Financial Internal Rate of Return
NPV	=	Net Present Value
B/C	=	Benefit Cost Ratio

PART-I GENERAL

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

Bangladesh is located in the delta area formed by three international rivers, namely the Padma (Ganges), Jamuna (Brahmaputra) and Meghna Rivers Although the lifestyle of the people in Bangladesh is well adapted to flood phenomena, damage due to inundation, river bank erosion or breach of river structures, etc still occurs in various regions in every monsoon season In the 1988 and 1998 monsoon seasons, about 2/3 of the country was submerged and extensive damage was reported Other than the monsoonal flood, floods referred to as "flash flood", "tidal surge" and "local inundation" are also recognized and contribute to flood damage in this country

In addition to extensive and serious damage, floods in Bangladesh limit the effectiveness of land use planning, economic growth and so on To cope with this, a Flood Action Plan (FAP) was launched immediately after the occurrence of the 1988 flood with an initiative of the World Bank, and a number of projects under the auspices of FAP were implemented. FAP is now being taken over by the National Water Management Plan (NWMP), whose final version is subject to the approval of the Government of the People's Republic of Bangladesh (GOB)

In terms of flood forecasting and warning services (FFWS) in Bangladesh, a forecasting analysis system has been developed and continuously improved through the technical and financial assistance of DANIDA (Danish International Development Agency) However, since the hydrometeorological records utilized for the forecasting analysis are obtained by manual operation, transmitted through wireless voice communication, and manually input to the model, problems related to reliability, accuracy and immediacy of the input data have occurred. Furthermore, telemeter systems installed in 1985 and 1996, funded by Japanese debt relief, have not been effectively utilized in the forecasting system due to the limited number and inadequate alignment of telemetry stations. GOB nonetheless recognizes the importance of the improvement and expansion of the existing telemetry network to ensure prompt and accurate forecasting analysis

Based on the above circumstances, GOB submitted a request to the Government of Japan (GOJ) in 2001 for technical assistance to conduct "**the feasibility study for upgradation and expansion of data communication / transmission network for flood forecasting and warning services**" In response to the request, the GOJ decided to conduct the study covering not only the data communication network but also other system components such as dissemination The name of the study was subsequently modified to "**the feasibility study for improvement of flood forecasting and warning services**" (the Study) under a consensus between GOB and GOJ. The Scope of Work (S/W) and Minutes of Meeting (M/M) of the technical cooperation for the Study were agreed between the Ministry of Finance (MOF), Ministry of Water Resources (MOWR), Bangladesh Water Development Board (BWDB) and Japan International Cooperation Agency (JICA) on July 11, 2002 in Dhaka This Study has been performed in conformity with the S/W and M/M

JICA organized the Study Team with the selected consultant in order to carry out the Study The Team conducted the Study in close cooperation with the GOB through counterpart officials of BWDB JICA also established an Advisory Committee formed by staff of the Ministry of Land, Infrastructure and Transport and the Ministry of Foreign Affairs (GOJ) in order to guide the Study Team and review study findings

The GOB established a Steering Committee to support the Study Team chaired by the Secretary of the MOWR with members from various related agencies

1.2 Objectives of the Study

The objectives of the Study are as follows

1) To formulate the improvement plan of the flood forecasting and warning system in Bangladesh in order to mitigate flood damage focusing particularly on improvement of the data communication system,
2) To conduct a feasibility study of the selected optimal scheme, and
3) To perform technology transfer to Bangladesh counterpart personnel in the course of the Study

1.3 Scope of the Study

The area subject to the Study includes the whole of Bangladesh.

The flood forecasting and warning system is considered to consist of five (5) sub-systems in view of its operational process These are outlined below.

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

To improve the existing flood forecasting and warning system, the following works were conducted.

1) Detailed investigations in order to clarify the present condition of the existing FFWS and problems being encountered therein,
2) Formulation of improvement plans of FFWS after detailed study of conceivable alternative solutions from which an optimal plan was selected, and
3) Feasibility study on the selected optimal plan.

1.4 Study Schedule and Activities

1 4 1 Study Schedule

In order to achieve the objectives mentioned above, the overall work schedule of the Study was divided into two phases as shown in **Figure 1.4.1** and as summarized below

(1) First Period of the Study (November 2002 – March 2003)

Phase 1 Basic Study

a) Collection and review of existing data and information
b) Field reconnaissance
c) Detailed field investigation by sub-contract
   i) Inventory survey on meteorological and hydrological observation system
   ii) Survey on evacuation condition and awareness of flood victims
   iii) Inventory survey on electric communication system
d) Analysis on present FFWS and extraction of problems
e) Flood damage analysis
f) Formulation of alternative improvement plan of FFWS

(2) Second Period of the Study (May 2003 – November 2003)

Phase 2 Feasibility Study

a) Comparative study of alternative improvement plans and selection of optimal scheme
b) Technology Transfer Seminar/Workshops (1) and (2)
c) Supplemental data collection and field reconnaissance
d) Study of appropriate international river management
e) Preliminary design of facilities
f) Implementation planning and cost estimate
g) Project evaluation

1 4.2 Activities

(1) Explanation and Discussion of Inception Report

Upon submission of the Inception Report to BWDB on November 17, 2002, the contents of the report were explained by the Study Team to the counterpart staff of BWDB on November 20, 2002 The Steering Committee meeting was held on November 23 and 24, 2002 The study approaches and methods proposed in the Inception Report were accepted in principle by the Committee.

(2) Collection and Analysis of Data/Information and Field Survey

Data/information relevant to the Study were collected from the national government agencies and local government authorities. Field reconnaissance was also conducted in the study area to acquire necessary information on natural and social conditions

(3) Field Investigations

Field investigations conducted for the basic study included a) inventory survey on meteorological and hydrological observation systems, b) survey on evacuation condition and awareness of flood victims, and c) inventory survey on electric communication system All field investigations were completed during the phase 1 study period

(4) Analysis of Current Flood Forecasting and Warning Services

Based on the data/information collected and the results of field investigations, the current flood forecasting and warning services were analyzed The analysis was conducted for each sub-component, that is, 1) observation system, 2) data transmission system, 3) analysis system, 4) warning dissemination system, and 5) response system In addition to these 5 sub-components, the institutional aspects supporting the current FFWS were also analyzed

(5) Flood Damage Analysis

Analysis to quantify flood damage was conducted Based on the available information of damage from previous floods and the results of field investigations, items such as 1) flood affected area, 2) number of affected people, and 3) damaged properties were integrated Flood damage in monetary terms was estimated according to the recurrence period of flood events and annual average flood damage was calculated

(6) Extraction of Problems Encountered by Current FFWS

The problems associated with the current FFWS were extracted for each sub-component. These also included institutional aspects. In addition, PCM (Project Cycle Management) workshops were conducted at five (5) different locations in January 2003, and the problems to be overcome to meet the requirements raised by the end users were defined.

(7) Formulation of Alternative Improvement Plans

Alternative plans for improvement of each FFWS sub-component and institutional aspects were firstly proposed. From these, six (6) combined alternative improvement plans were formulated

(8) Preparation, Explanation and Discussion of Progress Report (1)

The Progress Report (1) was prepared and submitted on March 5, 2003 Prior to submission of the report, a discussion on its contents was held with BWDB counterpart staff on March 1, 2003 The Steering Committee meeting was held on March 5, 2003, and Progress Report (1) was accepted in principle by the Committee.

(9) Comparative Study of Alternative Plans and Selection of Optimum Plan

The six alternative improvement plans were studied and analyzed in detail leading to the selection of one optimum improvement plan

(10) Preparation of Interim Report

The Interim Report was prepared in the middle of June 2003 as originally scheduled

This presented all results of the investigation and study conducted during the phase-1 Basic Study stage

(11) Explanation and Discussion of Interim Report

The Interim Report was submitted on June 21, 2003 The contents of the report were explained and discussed with the counterparts on June 22, 2003 The Steering Committee meeting was held on June 25, 2003, and the contents of the report were accepted in principle by the Committee

(12) First Technology Transfer Seminar/Workshop

The first Technology Transfer Seminar/Workshop was held in Dhaka on June 25 and 26, 2003 Four (4) presentations were made by the Japanese Consultants and Advisory Committee and two (2) presentations were made by Bangladesh counterparts

(13) Additional Data Collection and Field Survey

Additional data/information necessary for the feasibility study (phase-2) stage were collected and further field surveys including 1) reconnaissance for the determination of exact location of telemeter facilities/equipment and 2) radio propagation tests were undertaken.

(14) Study on International River Management

The effective river management in Bangladesh cannot be realized without proper cooperation among the countries related to the three international rivers, i.e the Ganges/Padma, Brahmaputra/Jamuna and Meghna Rivers The current status of the water-related issues on the international rivers was analyzed and recommendations for proper international river management were raised

(15) Feasibility Design

Feasibility design was conducted for the selected optimum improvement plan The design includes the hydrometeorological observation method/system at the proposed telemetric gauging sites, data transmission method/system, analysis system and dissemination system

(16) Construction Plan and Project Cost Estimation

A construction plan was formulated for the proposed project and project cost was estimated

(17) Project Evaluation

The evaluation of the proposed project was conducted taking into consideration the economic, social and environmental aspects. The economic efficiency of the project was confirmed, while no negative social and environmental impact would arise as a result of the project

(18) Preparation of Implementation Program

The implementation schedule and institutional arrangement were formulated and discussed with the counterpart agency

(19) Preparation, Explanation and Discussion of Progress Report (2)

Progress Report (2) was prepared and submitted on September 8, 2003 The discussion on the contents of the report was made with BWDB counterpart staff on September 9, 2003 Although the Steering Committee meeting was held on September 14, 2003, no conclusions resulted from the meeting

(20) Preparation of Draft Final Report

The Draft Final Report including all aspects mentioned above was prepared and submitted on October 21, 2003

(21) Explanation and Discussion of Draft Final Report

The contents of the Draft Final Report were explained to the Bangladesh side in detail through the Joint Meeting and Steering Committee Meeting held on October 23 and 26, 2003, respectively Detailed discussions on the proposed project were made between Japanese and Bangladesh sides.

(22) Second Technology Transfer Seminar/Workshop

The second Technology Transfer Seminar/Workshop was held in Dhaka on October 29 and 30, 2003 Three (3) presentations were made by the Japanese Consultants and Advisory Committee and two (2) presentations were made by Bangladesh counterparts

(23) Preparation of Final Report

Based on the Draft Final Report, the Final Report was prepared in December 2003 taking the comments and/or suggestions raised by the Bangladesh side into consideration

1.5 Staffing

JICA organized the Study Team and Advisory Committee for the Study

The Study Team totally comprised nine (9) members, consisting of a team leader and seven (7) experts and an administrative coordinator as shown in **Figure 1.5.1** and enumerated below

JICA Study Team

Designation/Work Assignment	Name
(1) Team Leader / River and Flood Control Expert	Hideki SATO
(2) Deputy Team Leader / Telecommunication System Expert	Masato OKUDA
(3) Flood Forecasting and Warning System Expert	Gregory R HOOKEY
(4) Radio Transmission Expert	Masahiro SAKAGAMI
(5) Hydrologist	Kensuke SAKAI
(6) Economist / Financial Analyst	Kiminari TACHIYAMA
(7) Institutional Expert	A K M Nurul ISLAM
(8) Expert of International Coordination	Naoko ANZAI
(9) Administrative Coordinator	Hiroto NAKAGAWA / Tadahiro FUKUDA

The Advisory Committee was formed to provide technical guidance and advice to the JICA Study Team during the period of the Study. Members of the Advisory Committee included

a) Chairman of the First Year Works
   Mr. Shigetsugu YAMAMOTO
   Kyushu Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan
b) Chairman of the Second Year Works
   Mr Akinori MASUDA
   Kyushu Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan
c) Member
   Mr Yasunobu MAEDA
   Kinki Regional Development Bureau, Ministry of Land, Infrastructure and Transport, Japan

1.6 *Transfer of Technology*

The Study Team made considerable efforts to ensure transfer of technology on investigation/planning methods and skills as well as the basic data/information required for the planning During the Works in Bangladesh, two methods were applied for technology transfer. These included on-the-job training and Joint Meetings between the counterparts and Study Team In addition to these routine activities, the technology transfer seminars/workshops were held at the beginning of the Second Works in Bangladesh (June 25 and 26), and at the end of the Third Works in Bangladesh (October 29 and 30) Brief descriptions of those activities and the evaluation of those activities are presented below

1.6.1 On-the-Job Training

Efforts were made to provide on-the-job training to each counterpart through day-to-day works Each team member attempted not only to undertake their investigation responsibilities but also to provide the counterpart with guidance as to the purpose and procedures of the investigation.

However, the counterpart assignment of GOB was not sufficient for the desired level of on-the-job training and opinion exchanges during the Works in Bangladesh

1 6 2 Joint Meeting

Joint Meetings with the counterparts and the Study Team were held in Dhaka during the Work Stages in Bangladesh The dates and main subjects of the Meetings are as follows

First Joint Meeting held on December 4, 2002

a) Introduction of the Study Team members and counterparts of BWDB,
b) Explanation of the Inception Report and work schedule by the Study Team,
c) Explanation of the detailed field investigations by the Study Team,
d) Explanation of basic strategy of the study on the telecommunication system by the Study Team, and
e) Explanation of the Organization of GOB by counterparts

Second Joint Meeting held on January 11, 2003

a) Explanation of the Study progress by the Study Team,
b) Explanation of the PCM Workshop held on January 2, 2003 in Sylhet by the Study Team,
c) Explanation of the River Management Strategy in Bangladesh by counterparts,
d) Explanation of hydrometric system in Bangladesh by counterparts, and
e) Explanation of river morphological survey system in Bangladesh by counterparts

Third Joint Meeting held on February 1 and 2, 2003

a) Discussion on the basic concept of the selection of automatic gauge sites, and
b) Presentation on suitable location of telemeter stations in view of flood analysis model by counterparts

Fourth Joint Meeting held on March 1, 2003

a) Explanation of the draft of Progress Report (1) by the Study Team, and
b) Discussions on the contents of Progress Report (1)

Fifth Joint Meeting held on March 11, 2003

a) Report of the discussion results of the Steering Committee Meeting held on March 5, 2003 by the Study Team, and
b) Confirmation of undertakings of the counterparts during the absence of the Study Team from Dhaka

Sixth Joint Meeting held on June 22, 2003

a) Explanation of the Interim Report by the Study Team, and
b) Discussions on the contents of the Interim Report

Seventh Joint Meeting held on July 3, 2003

a) Confirmation of the result of the Steering Committee meeting held on June 25, 2003,
b) Explanation of the outline of proposed institutional arrangement by the Study Team, and
c) Confirmation of the possibility of a field visit to India by the Study Team and counterpart members

Eighth Joint Meeting held on August 14, 2003

a) Brief reporting of the progress of the Study by the Study Team, and
b) Discussion on the necessary arrangement for the implementation of the proposed project

Ninth Joint Meeting held on September 9, 2003

a) Explanation of Progress Report (2) by the Study Team, and
b) Discussions on the contents of Progress Report (2)

Tenth Joint Meeting held on September 15, 2003

a) Confirmation of the result of the Steering Committee meeting held on September 14, 2003, and
b) Detailed discussions on the contents of Progress Report (2).

Eleventh Joint Meeting held on October 23, 2003

a) Explanation of the Draft Final Report by the Study Team, and
b) Discussions on the contents of the Draft Final Report

Twelfth Joint Meeting held on November 1, 2003

a) Reconfirmation and Detailed Explanation of the proposed project, and
b) Confirmation of the actions to be taken by BWDB and the Study Team

1 6.3 Technology Transfer Seminar/Workshop

(1) First Technology Transfer Seminar/Workshop

The first Technology Transfer Seminar/Workshop was held on June 25 and 26, 2003. The number of participants was approximately 60 on the first day and 30 on the second day The following presentations were made by Bangladeshi and Japanese personnel·

Day 1 (June 25, 2003)

Morning Session

a) Opening Session

b) Explanation of the Interim Report by the JICA Study Team

Afternoon Session

c) Basic Strategy of Strengthening FFWS in Bangladesh by BWDB
d) Flood Control and FFWS in Japan by the JICA Advisory Committee

Day 2 (June 26, 2003)

Morning Session

e) Telecommunication System for FFWS in Japan by the JICA Advisory Committee
f) River Management in the International Rivers by the JICA Study Team
g) Estimation of Rainfall Amount by Radar Raingauge by the JICA Study Team

Afternoon Session

h) Basic Strategy of Strengthening Disaster Management in Bangladesh by the Disaster Management Bureau (DMB)
i) Summary and Conclusion by the JICA Study Team
j) Closing Session

(2) Second Technology Transfer Seminar/Workshop

The second Technology Transfer Seminar/Workshop was held on October 29 and 30, 2003 The number of participants was approximately 60 on the first day and 30 on the second day The following presentations were made by Bangladeshi and Japanese personnel

Day 1 (October 29, 2003)

Morning Session

a) Opening Session

Afternoon Session

b) Explanation of the Draft Final Report by the JICA Study Team
c) River Management in Bangladesh by BWDB
d) River Management in Japan by the JICA Advisory Committee

Day 2 (October 30, 2003)

Morning Session

e) Regional Disaster Management in Japan by the JICA Study Team

Afternoon Session

f) Disaster Management in Bangladesh by BDPC
g) Summary and Conclusion by the JICA Study Team
h) Closing Session

1 6 4 Evaluation of Technology Transfer

The technology transfer was one of the main objectives of the Study as mentioned above Although effective transfer of technology through on-the-job training was not realized due to the manpower deficit of BWDB, a few counterparts showed their keen interest in the planning and design technique applied in the Study. Those competent counterparts gave sincere and valuable suggestions for the planning and design works conducted by the Study Team, based on their own experiences

On the other hand, counterparts obtained valuable knowledge through their exposure to this Study As mentioned before, though it was not possible on the part of BWDB to provide one-to-one full time counterparts, one full time counterpart was provided at the later stage He attended various discussions, participated in the questionnaire survey and feasibility design. Through this, he obtained important planning techniques that can be applied for other projects

A number of part time counterparts were provided by BWDB for the entire period of the Study The counterparts for telecommunication not only participated in the field investigation and analysis but also carried out radio communication tests The counterpart for economic analysis received valuable on-the-job training on socio-economic analysis, flood damage assessment, project cost estimation and project evaluation The counterparts for analysis received vital exposure to understand the inherent limitation of the model

Based on this, it can be inferred that extensive technology transfer has taken place through this Study However, this could have been much more effective if full time one to one counterparts had been provided by BWDB

Two BWDB counterpart personnel visited Japan to participate in the counterpart training provided by JICA during the period from September 23 to October 11, 2003 This training course gave broad-based knowledge on flood forecasting and warning, river management, and telecommunication to them Specifically, they understood the importance of the regional disaster management through the training in Japan

1.7 Final Report

The Final Report presents all findings of the field investigations and results of the Study including the Basic Study (Framework Plan) and Feasibility Study undertaken by the Study Team and BWDB counterparts

The Final Report consists of four (4) volumes; Volume-I Executive Summary, Volume-II Main Report, Volume-III Supporting Report, and Volume-IV Data Book

CHAPTER 2 PRESENT CONDITION

2.1 Geography

Bangladesh lies in the northeastern part of South Asia between latitudes 20°34' and 26°38' north and longitudes 88°01' and 92°41' east The country is bounded by India to the west, north and northeast, by Myanmar (Burma) to the southeast, and the Bay of Bengal to the south (see **Location Map: Bangladesh**). The area of the country is around 147,000 km^2

Bangladesh occupies a unique geographic location spanning a stretch of land between the great Himalayan mountain chain to the north and the ocean to the south It is virtually the only drainage outlet for a vast river basin complex made up of the Ganges, Brahmaputra and Meghna Rivers and their tributaries

Three broad physiographic regions are discernible within the country including flood plains (representing 80% of the land area), terraces (8%) and hills (12%). Each of these regions exhibits its own geo-morphological characteristics, which are further divided into 9 sub-divisions according to the physiographic map published by Geological Survey of Bangladesh (1990)

The country is crisscrossed by a network of rivers including the Padma, Jamuna, Meghna, Teesta, Surma and Kharnaphuli Rivers and their tributaries Together these number about 230 and have a total length of around 24,000 km (see **Location Map: Rivers of Bangladesh**). River slopes in Bangladesh are extremely low due to ongoing deposition of sediment by these rivers during the monsoon season. This results in flooding being a regular occurrence almost every year.

The land surface is primarily covered by alluvial and deltaic deposits.

2.2 Socio-Economy

2.2 1 Administration

Bangladesh is governed by a Parliamentary form of Government The Government of Bangladesh is headed by the President However, the executive power lies with the Prime Minister, who is assisted by a council of Ministers of 38 ministries.

The country is divided into 6 administrative Divisions, i e Dhaka, Chittagong, Khulna, Rajshahi, Sylhet and Barisal Each division is divided into Districts (Zilla) as shown in **Figure 2.2.1** At present there are 64 Districts Each District is further divided into sub-districts (Upazilla) Currently there are 507 Upazilla, of which 36 are in Metropolitan cities In urban areas, the Upazilla is called Thana

For each urban area, there are municipalities and for bigger urban areas, there are city corporations. Each municipality and city corporation is divided into wards This is the lowest tier of administration in the urban area

For rural areas, each sub-district (Thana) is divided into Unions while each Union is further divided into Villages

2 2 2 Socio-Economic Indicators

(1) Population

The population of Bangladesh as of 2001 was 121 4 million with an average annual growth rate of 1 49 %. The overall population density was 826 person/km^2 In terms of Divisions, Dhaka Division has the highest population accounting for 31 4% of the overall number It also has the highest density of 1,243 person/km^2 With regard to District, Dhaka District has the highest density with 5,858 person/km^2 From the viewpoint of disaster management, Dhaka district therefore has the highest potential for flood damage

The population density map by District as of 2001 is presented in **Figure 2.2.2**

(2) GDP

The gross domestic product (GDP) in 2000/01 was about 2,450 billion Taka with an average annual growth rate between 1991/92 and 2000/01 of 8 9% The per capita GDP was 20,182 Taka in 2000/01 with an average annual growth rate between 1991/92 and 2000/01 of 7 1%. The most rapid growth was associated with the industrial sector (10.6% per annum) followed by services (9.2%). In the agricultural sector, fishing showed the highest growth rate at 14 5%.

The service sector accounted for the largest share of GDP (49 2%) in 2000/01, having shown a slight increase in percentage terms since 1991/92 Over this same period the agricultural sector decreased marginally to 24.9% while the industrial sector increased to 25 9%

The gross domestic product (GDP) at constant 1995/96 prices shows that even when excluding the influence of inflation Bangladesh is still experiencing substantial economic growth. The equivalent GDP at current prices was estimated to have increased to 2,178 billion Taka in 2001/02. Over the ten year period from 1991/92 this represented an average annual growth rate of 4 9% The equivalent per capita GDP grew to 17,675 Taka in the same period at an average annual growth rate of 3 4%. The most rapid growth was associated with the industrial sector (7 2% per annum) The highest growth sub-sector was construction with an annual rate of 8.5%.

In 2001/02 the service sector contributed the largest share of GDP at constant 1995/96 prices (48 9%), having increased slightly since 1991/92. The agricultural sector was 24 6% (a slight decrease since 1991/92) while the industrial sector increased to 26 5%

In terms of the fluctuation of annual growth rate, peak growth was recorded in 1999/2000 (6 1%) but this decreased in the following two years from 2000/01 to 2001/02 It is likely the flood in 1998/99 that caused catastrophic damage in Bangladesh also resulted in a slowdown in economic growth from 5.3% in 1997/98 to

5 0% in 1998/99

(3) Other Indicators

a Labor Force

The total labor force in 1999/2000 was approximately 60 3 million, some 58 1 million being employed and 2 2 million unemployed The unemployment ratio of 3 6% has increased from 1 3% in 1985/86 It is noticeable that the ratio of female employment grew from 10 2% in 1985/86 to 37 7% in 1999/2000 The main sources of employment are the agricultural sector including forestry and fishery (62.4%), industry (10 2%) and services (27 4%) The agricultural sector is dominant despite the low contribution to GDP (25 3%) indicating its low labor productivity.

b Poverty Level

It has been said that economic development and poverty alleviation are synonymous in the context of Bangladesh and hence, poverty alleviation is the core issue of development policy Through available data from various sources, poverty is still deep-rooted and all pervasive The latest Household Expenditure Survey revealed that in 1995 47 1% of rural households were below the poverty line (daily calorie intake of less than 2,122 kcal) and 24.6 % of households were below the hardcore poverty line (daily calorie intake of less than 1,805 kcal). Analysis of data indicates improvement of the poverty situation occurs at a slow pace.

c Foreign Trade

Total exports in 1999/2000 were 247 billion Taka, having increased at an average annual growth rate of 17.0% between 1985/86 and 1999/2000 Total imports were 342 billion Taka, representing an average annual growth rate for the same period of 12.9%. Despite the higher growth rate of exports, the deficit in 1999/2000 was 125 billion Taka, this having increased year by year

The major exports include textiles and textile articles, followed by live animals and animal products The major imports are also textiles and textile articles, followed by machinery and mechanical appliances, electrical equipment, sound recorders and spare parts

d. Inflation

The general consumer price index (CPI) for the country, an indicator for inflation, increased from 154 4 to 239 1 from 1990/91 to 2000/01, an average inflation rate of 5.0%. The CPI of food increased from 154 3 to 241 4, a growth rate of 5.1% per annum, and that of non-food increased from 154.7 to 237 2, a growth rate of 4.9 % per annum From 1998/99 to 1999/2000 the CPI actually reduced This reflected the reaction to the relatively higher rate of inflation in 1998/99 of 8 9% following the devastating damage to agricultural production due to the extreme flooding

2 2 3 Financial Conditions

(1) Overview

According to the consolidated receipts and expenditure of the Government, total revenue in 2001/02 was 423 billion Taka while expenditure was 356 billion Taka. The average annual growth rates for the preceding seven years were 9.0% and 7 9% respectively. The balance in revenue and expenditure represented a surplus of 67 billion Taka

The total revenue is broken down into revenue receipt and development receipt revenue In 2001/02, revenue receipt represented 64% of total revenue and development receipt 36% The total expenditure is broken down into revenue expenditure (62%) and development expenditure (38%). As the balance between the revenue receipt and total expenditure represented a deficit of 84 billion Taka, ordinary annual revenue could not recover the total expenditure

(2) Development Expenditure of the Government by Sector

The development expenditure in 2001/02 was 136 billion Taka. The average annual growth rate for the period between 1994/95 and 2001/02 was 11.1% The most rapid growth occurred in education and training (43 4%). The larger proportion of expenditure was in transport (19.7%), followed by power and natural resources (15.0%) and education and training (14 1%) The percentage allocated to flood control and water resources decreased significantly from 15 0% in 1992/93 to 5 4% in 2001/02. In particular, the expenditure for flood control and water resources shows the decrease with the average annual growth rate of -3.1%

The financing required for development expenditure in 2000/01 was 175 billion Taka This grew by an average annual rate of 13% for the period between 1990/91 and 2000/01 On the other hand, the total resources in 2000/01 were 152 billion Taka Since 1998/99, the shortfall has increased and was around 23 billion Taka in 2000/01.

The resources are broken down into domestic resources and foreign assistance From 1991/92 to 2000/01 the share provided through domestic resources increased from 30% to 38%, while from foreign assistance it decreased from 70% to 62% In 2000/01, the financial revenue surplus component of domestic resources accounted for 30% of the total resources while the project assistance component of foreign assistance accounted for 52%

(3) Commitment and Disbursement of Foreign Economic Assistance

The commitment of foreign economic assistance (comprising grants and loans) decreased slightly from 1,916 million US$ in 1991/92 to 2,052 million US$ in 2000/01 The percentage of grants decreased from 59 6% to 45 7% while loans increased from 40.4% to 54.3%. Food and commodity aid are assumed to be closely related to alleviating damage following disasters As a component of grants, these totaled 411 million US$ in 1991/92 and 467 million US$ in 2000/01, reflecting assistance for flood damage during these periods Project aid represents the major component in both in grants (50 2%) and loans (100 0%) in 2000/01

The disbursement of foreign economic assistance reduced slightly from 1,611 million US$ in 1991/92 to 1,369 million US$ in 2000/01 The percentages associated with grants and loans are similar to those of the commitments Food aid and commodity aid also reflect requirements to alleviate flood damage such as 433 million US$ in 1991/92 and 196 million US$ in 2000/01. Project aid also represents the major component both in grants (41 9%) and loans (95 5%) in 2000/01

Comparing donors providing foreign economic assistance, during the period from 1991/92 to 2000/01 Japan was one of the larger contributors in addition to ADB, IDA, USA and UK The commitments from Japan ranged from 156 million US$ (5 9% of all commitments that year) to 591 million US$ (36 6%) Japan also contributed a significant component of the disbursements, ranging from 9 5% to 24.9% of annual totals

2 2 4 Socio-Economic Framework

(1) National Economic Development Plan

Review of the Past Development Plan

Bangladesh has made efforts to lift the economy out of its abject poverty The country has followed the course of planned development since 1973 In a medium term framework, the First Five Year Plan was launched in June 1973. This was followed by a Two Year Plan (1978-1980) due to a background of world-wide inflation and uncertainties In 1980, the five year plan framework was reinstated with three five year plans implemented in succession There was no development plan during 1995-1997 following the expiry of the Fourth Plan (1990-1995).

The last development plan was the Fifth Five Year Plan (1997-2002) It aimed at placing Bangladesh on a path of self-sustaining growth to improve socio-economic conditions for the people Acceleration of GDP growth would allow the economy to break out of the continuing poverty syndrome While there has been substantial improvement, the Plan recognizes the need for massive investment, with the private sector playing the major role to achieve rapid growth and efficiency.

The Fifth Five Year Plan expired in 2002 and no long-term national development plan is effective at present

National Strategy for Economic Growth, Poverty Alleviation and Social Development

After the Fifth Five Year Plan, "A National Strategy for Economic Growth, Poverty Reduction and Social Development" was published in January 2003 by the Economic Relations Division of Ministry of Finance The outline of this report is described in the **Supporting Report**

(2) Population Projection

Total Population

The total population of Bangladesh was evaluated by the Study Team using the results of projections conducted by BBS based on the 1991 census. In that census the projection was conducted on the basis of three scenarios, i e low, medium and high

According to the results based on the medium growth scenario, the population will increase from 123 million in 2001 to 144 million in 2010 (annual growth rate of 1.8 %), and to 163 million in 2020 (annual growth rate of 1.2 %)

Regional Population

According to the results of population projection by Division, the most rapid growth is expected in Barisal Division where growth rates of 1 8 % per annum during the period from 2001 to 2010 and 1.3 % per annum from 2010 to 2020 are estimated. This is followed by Dhaka Division with 1 8 % and 1 2% growth rates respectively

(3) GDP Projection

There has been no long-term development plan in Bangladesh. The GDP projection, required as one component of the socio-economic framework, was determined by the Study Team based on the following approach

i) Setting up of three growth scenarios (low, medium and high)
ii) Projection of Total GDP (All Sectors i.e Industrial, Service and Agricultural)
iii) Projection of GDP by Sector Origin (Sector and Sub-Sector)

According to the medium growth scenario, the total GDP will increase from 2,091 billion Taka in 2000 to 6,102 billion Taka in 2020 at a 5.5% average annual growth rate The most rapidly growing sector is expected to be the industrial sector where its share of GDP will increase from 26 3% to 29.7%. The dominant share will be occupied by the service sector, accounting for almost 50% of GDP in 2020. The agricultural sector shows the lowest growth rate and its share will decrease from 25 3% in 2000 to 20 9% in 2020. This share structure would remain consistent for all growth scenarios

The per capita GDP at constant prices of 1995/96 will increase from 17,228 Taka in 2000 to 31,401 Taka in 2020, an annual average growth rate of 3 0% This represents an increase of around 80 % (around two times) over this twenty year period

2.3 Major Natural Disasters

2 3.1 Cyclones

Tropical cyclones are frequent in the Bay of Bengal. Immediately pre- and post-monsoon periods are the seasons when cyclones and depressions form in the Bay of Bengal In the last 50 years, cyclonic storms have been responsible for the largest number of deaths and immediate devastation. These cyclones hit the coastal area of

Bangladesh Cyclones are formed in the Bay of Bengal at the rate of 1 3 per year They generally generate speeds of 150 - 225 km/hr or more and surges which are 5 - 14 m above the normal astronomical tide levels

2 3 2 Floods

Bangladesh has always experienced some degree of flooding Apart from a few small hills in the northwest and southeast, the country is essentially flat with very little of the country more than 20m above sea level. In a normal monsoon, one third of its 9 million hectares of cultivated land is flooded. Flooding is a fact of life to the people of Bangladesh and they demonstrate great resilience and skill in coping with it. Monsoon flooding, which normally affects about one third of cultivated land, is regarded by farmers as beneficial They have developed agricultural practices to make use of the floodwater for rice and jute as well as for fisheries. It is when flooding increases beyond the normal level that problems arise

2.3 3 Droughts

Bangladesh experiences drought conditions periodically Records indicate Bangladesh has suffered in the recent past from drought conditions leading to disastrous crop failure. In 1979, Bangladesh experienced a year of major drought which was estimated by many to be the worst in its recent history. Crop failure by drought also represents a significant strain on the socio-economic structure of the country

2 3 4 Earthquakes

Bangladesh is a part of the Bengal basin, one of the most seismically active zones in the world. Lying as it does at the confluence of the India, Burma and Eurasia plates, the land is extremely prone to earthquakes and in the past has experienced some of the largest recorded events.

However, due to a relatively long period free of major seismic activity greater attention has been paid to other disasters such as cyclones, floods etc. This has led to both neglect and denial of earthquakes as the most destructive of all natural disasters.

Nonetheless, in establishing building codes for the country in 1993, Bangladesh was divided into three earthquake prone areas (1) First zone is the high-risk earthquake prone and consists of Kurigram, Rangpur, Bogra, Greater Mymensing, Greater Sylhet and Brahmanbaria, (2) Second zone includes medium-risk earthquake prone areas like Dinajpur, Rajshahi and Dhaka regions, Greater Chittagong, Comilla and the northern part of Noakhali, (3) Third zone which is the least earthquake prone area and includes Khulna and Barisal divisions and southern parts of Noakhali

2 3 5 River Bank Erosion

According to BWDB, annual average sediment loads entering Bangladesh are around 770 million tons The sediment flow is not uniform through the year and this can modify the load-carrying capacity of rivers. When that occurs, high velocity currents can lead to riverbank erosion. The condition of the channels also influences the degree of erosion While those rivers that remain more active can be less susceptible to erosion, slow-flowing rivers with larger deposits of sediment can be quickly eroded due to any sudden discharge during monsoon or severe local storms

The result of satellite image analysis shows that around 87,000 hectares are lost to erosion annually Most of this was previously used for agriculture About one million Bangladeshis are affected by river erosion though other disasters including cyclones and floods get far greater publicity because of their dramatic nature

2 3.6 Tornadoes

Tornadoes cause localized devastation and demand an immediate response They occur suddenly and the death and injury rate can be huge In the last decade, two tornadoes are remembered for their ferocity On April 26, 1989, a tornado hit parts of Manikganj district focusing on an area of around 50 km^2 Damage to crop and livestock was almost total and 800 people were killed

2.4 Hydrometeorology

2 4 1 Climate

Bangladesh is located in a sub-tropical monsoon zone and has four main seasons, namely winter (from November to February), pre-monsoon or summer (from March to May), monsoon (from June to September) and post-monsoon (from October to November) Annual average temperatures range from 19 to 29 °C Temperature varies from 21 to 34 °C during April to September and from 9 to 29 °C during November to January

Annual average rainfall varies from 1,200 mm in the west to over 5,000 mm in the north-east. Long periods of steady rainfall persisting over several days are common during the monsoon, but sometimes, local high intensity rainfall of short duration also occurs.

Figure 2.4.1 shows the isohyetal map of Bangladesh together with monthly average rainfall hyetographs at 6 locations, i e. Dhaka, Rangpur, Rajshahi, Khulna, Sylhet and Chittagong. Average annual rainfall at Sylhet exceeds 4,000 mm with high rainfalls being concentrated in the north-eastern area. Seventy three percent of rainfall over Bangladesh occurs between June and September

2 4 2 Hydrometeorological Conditions in Bangladesh

According to BWDB, total drainage area of the major international rivers is 1,555,000 km^2 (Padma 907,000 km^2, Jamuna: 583,000 km^2, Meghna 65,000 km^2) Only 7 to 8 % of the total drainage area is in Bangladesh, while 62% is in India, 18% in China, 8% in Nepal and 4% in Bhutan It is widely recognized that more than 90% of discharge in Bangladesh originates outside the country (see **Location Map:**

Bangladesh and International Rivers).

Monthly average runoff hydrographs at three locations (Hardinge Bridge on the Upper Padma, Bahadurabad on Jamuna, Bhairab Bazar on Meghna) are shown in **Figure 2.4.1** Peak discharges in the Jamuna River occur in July, in the Upper Padma River in August to September and in the Meghna River in July to August

Cyclones occur in the Bay of Bengal and affect Bangladesh on average 2 to 3 times annually However, since cyclones normally occur in the period of April to May and October to November, simultaneous occurrence of cyclones and river flooding is not generally observed

2 4 3 Flood Characteristics in Bangladesh

Four types of floods are generally considered in Bangladesh, namely, 1) Normal Flood (Monsoon Flood), 2) Flash Flood, 3) Tidal Surge, and 4) Local Inundation (Rainfed Flood) Of these, since local inundation is caused by poor drainage due to high water levels of major rivers, it can be considered as a part of the monsoon flood **Figure 2.4.2** shows the affected areas for the remaining three types of floods For the FFWS, monitoring/forecasting are the main targets and the following discussions focus on the impacts of monsoon and flash flooding

(1) Monsoon Flood

Three catastrophic floods were reported in the last two decades, i e. 1987, 1988 and 1998 The flood affected areas of the1988 and 1998 floods are illustrated in **Figure 2.4.3** Maximum flood water levels and numbers of days above danger level at 43 selected gauging stations for both the 1988 and 1998 floods are listed in **Table 2.4.1** together with recorded maximum water level at each station In the 1998 flood, according to the survey result of BWDB more than 100,000 km^2 (68%) of the Bangladesh territory was inundated and its duration was also extremely long.

Hydrographs of water level and discharge of the 1998 flood at Hardinge Bridge, Bahadurabad and Bhairab Bazar are presented in **Figure 2.4.4** The time scale of water level fluctuations is quite large and the slope of the hydrographs is low.

Simple correlations of water level record 1) between Pankha and Hardinge bridge on the Upper Padma, and 2) between Noonkhawa and Sirajganj on Jamuna are plotted on **Figure 2.4.5**. Although there are some inconsistencies between years, the plots show good correlation of water levels along the major rivers.

Data on flood affected area are estimated and compiled every year by BWDB and are available from 1954. The maximum flood affected area, recorded in the 1998 monsoon season, exceeded 100,000 km^2 which is around 68% of the total land area of Bangladesh Probability analysis on recorded flood affected areas was conducted with 42 samples from 1954 to 2001. Estimated flood affected areas as a percentage of total land area of the country are summarized by recurrence year in the table below.

Result of Probability Analysis on Flood Affected Area

Return Period (years)	2	5	10	25	50	100
Flood Affected Area (km^2)	30,000	39,900	49,100	89,500	97,400	103,700
Percentage of Total Area	20 4 %	27 1 %	33 4 %	60 9 %	66 3 %	70.5 %

Note Total land area of Bangladesh is 147,000 km^2

(2) Flash Flood

Flash flood is characterized by a steep rise and rapid recession of water level, often causing damage to crops and property due to inundation and high river flow velocities. According to the information obtained from BWDB, the minimum duration of flash flood is several hours The cause of flash floods is heavy rainfall concentrated in short periods. Particularly in the north-eastern area of Bangladesh, which is subject to heavy and highly intense rainfall and has very steep catchment slopes in the upstream hilly area in India, damage due to flash floods is reported almost every year

Water level and discharge hydrographs of 3 locations, i e 1) Monu railway bridge on the Monu river, 2) Sarighat on the Sarigoain river, and 3) Panchagarh on the Koratoa river, are presented in **Figure 2.4.6**

Compared to the characteristics of monsoon floods, the time scale or duration of a flood event is much smaller in the flash flood areas

(3) Quantitative Analysis of Flash Flood Characteristics Based on the Water Level Record

To assess the speed of water level rising, water level increase rate (WLIR) was calculated based on the records at BWDB stations WLIR was defined as follows

$$\Delta WL_t^T = \frac{(WL_{t+T} - WL_t)\times 100}{T} \times 24$$

where,

T · Sampling interval (hour)

t Time (hour)

ΔWL_t^T Water level increase rate at time "t" for T-hours sampling interval (cm/day)

WL_t : Water level at time of "t" (m PWD)

WL_{t+T} Water level at time of "t+T" (m PWD)

In the above equation, the actual water level increase is extrapolated for the daily basis, and this extrapolated value is referred to as WLIR

The maximum WLIR's for 3-hour observation interval are shown in **Figure 2.4.7** together with the maximum actual water level increase for 3 hours. North-eastern, north-western and south-eastern areas of the country have high WLIR's Some parts of the south-western tidal area also show high WLIR's The WLIR's are considerably smaller in the apparent monsoon flood area along the large scale international rivers

2.4.4 Hydrometeorological Observation Network in and around Bangladesh

(1) Observation Network in Bangladesh

BMD and BWDB are the main organizations in charge of hydrometeorological observations

A) BMD

The general meteorological activities such as surface observation, upper-air observation or receiving of satellite images are conducted by BMD Wind speed/direction, atmospheric pressure, air temperature, relative humidity and precipitation are measured every 3 hours at 35 surface observatories widely distributed across the country, and maximum/minimum temperature and duration of bright sunshine are recorded on a daily basis

Meteorological radar equipment has been installed at four locations, i e Dhaka, Rangpur, Cox's Bazar and Khepupara The entire territory of Bangladesh is now covered by these observatories Owing to this radar network, the prediction of cyclone routes and investigation on the characteristics of cold air mass etc are possible Moreover, using cloud pictures and cloud intensity obtained from these radar sites, real-time quantitative estimation of rainfall intensity is also conducted

However, the estimated rainfall intensities have not yet been compared to records of surface observatories, and their accuracy is not clear at present. In addition, the calibration curve expressing the relationship of intensity between radar echo and actual rainfall has been applied directly from Japan without any modification This curve should be changed according to the climatic characteristics of Bangladesh. This will require accurate observation of rainfall at the surface observatories at short interval (1 hour at longest).

B) BWDB

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

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

For surface water (SW), the country is divided into 4 measurement divisions, i e Northern, North-Eastern, South-Western and South-Eastern as presented in **Figure 2.4.8** The locations of water level (tidal and non-tidal) and rainfall gauging stations of BWDB are shown in **Figure 2.4.9**

Water level is observed 5 times daily at 3-hourly intervals (from 0600 to 1800 hours) throughout the year in principle According to BWDB staff, the observation is made even at night in case of abnormal flood situations However, no records of nightly observations were found in the existing BWDB database Rainfall is recorded on a daily basis The observation of water level and rainfall is basically made using manual gauging equipment

Discharge measurements are conducted two to three times a month by velocity area method For small rivers, a graduated rope is placed across the stream and current meter measurements are made. For big rivers, although some special equipment such as echo-sounder is utilized, the velocity area method is also employed.

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

(2) Availability of Hydrometeorological Data outside Bangladesh

According to an agreement between the Governments of India and Bangladesh concluded in 1972 and subsequent meetings of Joint Rivers Commission (JRC), hydrometeorological data from 20 observatories in India are transferred to Bangladesh during the monsoon season, defined as the period from May 15 to October 15 Transmission occurs to the Storm Warning Center of BMD and Flood Forecasting and Warning Center of BWDB by means of wireless or telex or directly to BWDB divisional offices by means of wireless (point-to-point basis data exchange) The location of the stations is shown in **Figure 2.4.10**

In terms of the data from the point-to-point basis stations, water level data are forwarded regularly by means of wireless voice communication However, for the remaining 14 stations rainfall data are transferred only if they exceed 50 mm/day, and for water level data only if they reach warning stage, i e 1 m below the danger level Since all water level stations are close to the border (within 100 km) and neither discharge nor river cross-section data in India are available, the hydrometeorological information from India is not fully utilized for the flood forecasting system More detailed discussion on this point is made in **Chapter 3**

2 4 5 Water-related Problems in International Rivers

Fifty nine (59) international rivers, including the large scale international rivers such as the Ganges and Brahmaputra, are officially recognized in Bangladesh The points where those rivers enter or exit from Bangladesh are shown in **Figure 2.4.11**, together with the names of those rivers.

The exchange of water-related information has not occurred smoothly because of its political sensitivity The political bottlenecks associated with international river management are discussed in **Chapter 5**.

General views on the assessments carried out to date by different organizations or institutions in order to quantitatively evaluate the water-related impacts of upstream activities on Bangladesh follow

Flood

1 The effect of river basin development activities in the upstream countries such as India or Nepal, etc on flood magnitude in Bangladesh has not yet been recognized significantly, because the scale of human activity is still negligible compared to the scale of the GBM basin.

2 It is said that inadequate operation of water-related structures such as dams or regulators located in India causes some harmful effects on the flood magnitude and their operation sometimes results in 'artificial' floods in Bangladesh However, this still does not go beyond hypothesis because the information on the structural operation is not accessible from Bangladesh

Low Flow (Drought) and Groundwater

1 Monthly average discharge in March at Hardinge bridge decreased from 2,500 m^3/sec (before 1975) to 1,000 m^3/sec (1975 and after). This was due to the Farakka barrage located on the Ganges (Padma) River about 40 km upstream of the international border that commenced operations in 1975.

2 Regarding Gojaldoba barrage located in the upstream reaches of the Teesta river in India, no quantitative assessment on the impacts on low flows in Bangladesh has been found.

3 Since the locations and dimensions of the existing and proposed water-related structures in India are not available to the public in Bangladesh, no quantitative assessment of their impacts on rivers flowing into Bangladesh is possible.

4 The groundwater level in Bangladesh is falling continuously because of the increase of water consumption However, there is no quantitative evidence that shows the groundwater decline due to development of upstream basin areas.

Water Quality and Sediment Transport

1 It is widely recognized that the water quality in the international rivers may have worsened, however no quantitative assessments of the impacts in relation to human activities in upstream basin areas have been found.

2 Sediment discharge in the downstream area may be reduced once a river-crossing structure such as a dam or barrage is constructed It may also increase if developments such as large scale deforestation are carried out. Since the sediment discharge measured in Bangladesh is the result of the balance of those positive and negative effects, it is almost impossible to define the effects of specific developments quantitatively

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

2.5 River and Flood Control

2.5.1 River System

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

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

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

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

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

2.5.2 Flood Characteristics

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

(1) Monsoon Flood

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

(2) Flash Flood

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

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

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

(3) Lowland Inundation

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

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

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

(4) Tidal Flood due to Cyclone

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

2.5 3 River Morphological Survey

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

2.5 4 River Structures and Flood Control Projects in Bangladesh

(1) Flood Action Plan (FAP)

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

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

(2) General Views

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

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

[Disaster = Hazard × Vulnerability]

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

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

A) Structural measures

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

B) Non-structural measures

Non-structural measures may be defined as an evacuation system If no people are residing in hazard areas, there would be no damage People to be affected by flood disaster should evacuate from such areas FAP identified non-structural measures such as Flood Forecasting and Warning Services and Flood Proofing. The latter seems to be one of the systems for rather long term evacuation or flood coping measures. It is based on measures such as constructing buildings at higher elevation, transportation by boat, etc to reduce the risks of flooding

(3) Supporting Measures

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

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

Flood Forecasting and Warning Services - Expansion

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

Improved Flood Warning

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

(4) River Structures

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

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

a) Flood control facilities

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

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

b) Irrigation and domestic water intakes

There are many water intake structures The large scale water intake structures include

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

Basic features of those projects plus others of a smaller scale are given in **Table 2.5.2**

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

c) Polder development

Compartment development, or so called Polder development, has been widely undertaken in Bangladesh in view of its likely economic benefits for land use development incorporating flood control in flood prone areas Polder development has now reached 1 28 million ha, based on 123 Polders nationwide Development is more intensive in the western area of the country according to BWDB Polder development is highly regarded as a means of more economic land development However, there would be some problems against flood It would need flood warning since it is designed usually for a 5 year RI flood or less and sometimes with submergible dikes

d) Transportation facilities including highway bridges and navigation facilities

The transportation network is widely distributed and consists of roads and highways, inland navigation with ports and harbors, and airport transport systems

(5) Operation of River Structures at Risk

Questionnaire and Interview Survey

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

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

Results of Questionnaire / Interview Survey

The results are shown in **Table 2.5.3** The detailed results of the questionnaire survey are presented in **ANNEX-III**.

Recommendation

According to the results of the survey, emergency actions taken are generally good, but are inconsistent among the O&M DOs Therefore, it is recommended that the following actions be implemented urgently

- Provide O&M DOs with Flood Warning regularly from FFWC
- Prepare O&M Manuals for emergency operation in addition to the operation manual of the project for normal operation
- Prepare ledger sheets of all river structures including emergency operation and rehabilitation works

2 5 5 River Structures in Indian Territory

(1) Existing River Structures for Flood Control

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

(2) Major Structures Influencing Bangladesh

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

Farakka Barrage

The Farakka Barrage is located at the Ganges River about 40 km upstream from the border and was constructed for the purposes of i) water supply to maintain navigability of the Calcutta Port in the Hoogly River and ii) salinity control in the river mouth of the Hoogly The feeder canal is to lead water from Farakka Barrage to the Hoogly River through the Bhagirathi River Hoogly River finally drains into the Bay of Bengal after passing Calcutta

Gajaldoba Barrage

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

(3) Future Water Resources Development Projects in India

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

River-Linking Projects within Indian Territory

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

Brahmaputra-Ganges Link Project

This is a massive river-linking project to connect the Brahmaputra and Ganges Rivers The scheme is not finally agreed among the riparian countries

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

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

Barak River Linking Project

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

2.6 Flood Damage

2 6.1 Historical Flood Damage

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

2 6.2 Components of Flood Damage

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

(1) Type of Flood

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

(2) Type of Assets

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

a) Agriculture

Damage to agricultural products is closely related to the cropping pattern and flood depth The choice of crops to be grown in an area is determined to a large degree by flooding characteristics The depth, timing, duration and rate of rise and fall of water levels are important factors influencing when and what crops can be grown

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

b) Fishery

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

c) Livestock

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

d) Buildings

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

On the other hand, the movable assets of buildings also differ by type of building such as 1) household effects in residential properties, 2) seeds, machines and tools for cultivation in farmer's houses, 3) machines, raw materials, products in factories, and 4) documents, desks and chairs, inventory, telephone and OA equipment including computers in commercial buildings These assets are very important elements and their losses can be avoided by evacuation through the use of flood warning systems

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

e) Infrastructure

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

(3) Damage to Human Life

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

(4) Other Damage

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

2 6.3 Actual Flood Damage

(1) Records of Flood Damage

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

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

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

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

(2) Flood Damage

Delineation of flood prone areas based on long term flood information has been conducted and published by the Soil Research Development Institute In this map, the entire area of Bangladesh is divided into 6 systems, i.e Teesta, Brahmaputra (Jamuna), Meghna, Ganges (Padma), Karnaphuli and Coastal Tidal Systems Flood prone areas by type of flood are shown in **Figure 2.6.1**

According to the available record, the total number of people affected in the 1998 flood was more than 30 million The most affected were located in Dhaka District of Dhaka Division (3,038,867 persons, 35% of district population) The total number of deaths was recorded as 918 people Dhaka District was most affected (125 persons)

Total damaged crop area due to the 1998 flood was around 1 9 million ha. The largest area of crop damage was recorded in Comilla District of Chittagong Division (108,719 ha)

The damage in monetary value of the 1998 flood has been estimated in several studies. However, all results excluded damage to human life, homestead, due to injury, etc Since there are no standards for the estimation of economic damage to humans or homesteads in Bangladesh, the basic concept of the standards to evaluate damage to human lives published by the Ministry of Land, Infrastructure and Transport (Japan) was applied taking into considering the social and economic conditions of Bangladesh

2 6 4 Estimation of Annual Average Flood Damage

(1) Categories of Flood Damage

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

(2) Detailed Flood Damage Data

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

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

Based on the analyses, damage due to the 1998 flood was estimated by the Study Team to be 155,735 million Taka at current 2002 prices

The detailed process for the estimation is described in the **Supporting Report**

(3) Average Annual Flood Damage

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

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

- Vulnerability for flood hazard is considered as same level as current situation
- The people of Bangladesh have extensive experience of flooding and are accustomed to protecting their properties and minimizing damage They do not always consider floods will causes damage and a negative benefit Positive effects may also result such as natural water supply for irrigation, new soil deposited from upstream to fertilise their farm lands, fishing in the flooded fields or river, and so on.
- Crops are planted in the proper season to minimize flood damage by taking account of the characteristics of crops
- There is very minor flood damage for low return period floods such as 2- and 5-years In the case of the 2-year return period, it was assumed that only the indoor movable property and crops would be damaged in the flood-prone areas The flood damage for the 2-year return period flood was estimated as 6,040 million Taka.
- Flood damage in catastrophic conditions such as occurred in 1998 (50 year return period) tends to increase dramatically
- Flood damage to infrastructure in the low return period floods is substantially smaller than that associated with longer return periods
- Flood damage can be related to the year of the return period and the flood prone

area by return period

By taking into consideration the above, and adopting the flood damage for the 2- and 50-year return periods as 6,040 million Taka and 155,735 million Taka respectively, the flood damage by return period was estimated as shown in the table below

Estimated Probable Flood Damage

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

On the basis of the estimated probable flood damage, the average annual flood damage is estimated as 12,160 9 million Taka

2.7 Telecommunications

2 7 1 General

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

2 7 2 Current Telecommunication Network

(1) Basic Data of Telecommunication Infrastructure

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

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

<u>Fixed Telephone Density</u>

Fixed telephone density in 2001 was 0.39 units/100 habitants Increasing rate of fixed telephone density is not as high as mobile phone density in Bangladesh

<u>Mobile Phone Density</u>

Mobile phone density in 2001 was 0 40 units/100 habitants There has been a very significant increase in the mobile phone density in Bangladesh

<u>Television Density</u>

Television density in 2000 was 1 5 units/100 habitants The television density increased by approximately twice in Bangladesh, but still remains very low

<u>Internet</u>

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

(2) Telecommunication Network

1) Wired Communication Network

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

BTTB network

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

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

BRTA network

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

2) Wireless Communication Networks

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

GRAMEEN mobile phone

At GRAMEEN, the number of new subscribers has increased from 3,085 in 2000 to 9,222 in 2001 Moreover, GRAMEEN's service network is constructed along the

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

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

3) Satellite Communication Networks

VSAT System

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

INMALSAT System

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

2.7.3 Future Development Plans

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

(1) Fixed Telephone

According to the BTTB annual report, the growth of telephone exchange capacity in Bangladesh in the last five years was on average only 50,000 lines per year. The pending demand for telephones has been increasing at a faster rate than telephone expansion. For this reason, BTTB has implemented programs, and telephone lines had increased to around 800,000 in 2001.

(2) Mobile Phone

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

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

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

(3) Information Technology

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

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

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

2.8 Institutions

2 8 1 Overall Government Organization

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