Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Flood Plan Coordination Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

APPENDIX

INITIAL ENVIRONMENTAL EVALUATION NORTHEAST REGIONAL WATER MANAGEMENT PLAN

FINAL REPORT
January 1995

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services
Institute For Development Education and Action
Nature Conservation Movement

Canadian International Development Agency

COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is constructed to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is a remnant of the past lowland forest that used to cover much of the region. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal from the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Flood Plan Coordination Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

APPENDIX

INITIAL ENVIRONMENTAL EVALUATION NORTHEAST REGIONAL WATER MANAGEMENT PLAN

FINAL REPORT
January 1995

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

Engineering and Planning Consultants Ltd.
Bangladesh Engineering and Technological Services
Institute For Development Education and Action
Nature Conservation Movement

Canadian International Development Agency

Acronyms and Abbreviations

b	broadcast
BBS	Bangladesh Bureau of Statistics
BCAS	Bangladesh Centre for Advanced Studies
BFRSS	Bangladesh Fisheries Resource System Survey
BGD	Bangladesh
BWDB	Bangladesh Water Development Board
CIDA	Canadian International Development Agency
EIA	environmental impact assessment
DPHE	Department of Public Health Engineering
EMP	environment management plan
FAO	Food and Agriculture Organization
FAP	Flood Action Plan
FCD	flood control drainage
FEAVDEP	Flood- and Erosion-Affected Village Development Project
FPCO	Flood Plan Coordination Organization
FW	future-with-Plan
FWO	future-without-plan
GEF	Global Environment Facility
HYV	high-yielding variety
ICOLD	International Commission on Large Dams
IDEA	Institute for Development Education and Action
IEC	important environmental component
IEE	initial environmental evaluation
ISPAN	Irrigation Support Project Asia-Near East
MCA	multi-criteria analysis
MOEF	Ministry of Environment and Forests
MPO	Master Plan Organization (renamed WARPO)
NACOM	Nature Conservation Movement
NAM	Rainfall-runoff model (Danish acronym)
NEMREC	Northeast Region Environment Management, Research, and Education Centre
NEMREP	Northeast Region Environment Management, Research, and Education Project
NERP	Northeast Regional Water Management Project
NFMP	New Fisheries Management Policy
NGO	Non-governmental organization
pd	person-day
PWD	Public Works Department
RRA	rapid rural appraisal
SLI/NHC	Shawinigan-Lavalin/Northwest Hydraulic Consultants
SRP	Systems Rehabilitation Project
SWMC	Surface Water Modelling Centre
t	transplanted
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WARPO	Water Resources Planning Organization (formerly MPO)

Glossary of Terms

ENGLISH TERMS

Biophysical Those aspects or components of the environment which are physical, chemical, or biological; includes air, soil, water, wild and domestic plants and animals.

Compensation Counterbalance adverse impacts through cash payment, replacement in kind, provision of substitutes, etc. Compare *mitigation*.

Environment The totality of the natural and human environments, including both biophysical and socio-economic aspects and components.

Environmental Management Plan A plan to undertake an array of follow-up activities which provide for the sound environmental managment of a project so that adverse environmental impacts are minimized and mitigated; and beneficial environmental effects are maximized. The Plan will examine and try to maximise sustainable development. Typically, projects will have aspects which are sustainable, aspects which are not, and aspects for which sustainability cannot be assessed with current information.

Impact A project's impacts consist of: all changes that the project causes to the environment; all changes that the environment causes to the project; and all cumulative impacts to which the project contributes. Impacts of the Regional Plan are defined in terms of the difference between the future-with-Plan (FW) situation in 2015 and the future-without-plan (FWO) situation in 2015.

Initial environmental evaluation Pre-feasibility level environmental impact assessment: characterization of potential environmental impacts at a level of information and analysis consistent with parent pre-feasibility-level study. Emphasis is on (1) making sure that all potentially significant impacts are identified and characterized to an indicative level, typically on the basis of available secondary data and past experience in both local and other locations, and (2) identifying environmental management issues and options. Subsequent EIA included in feasibility studies then consists of a review of IEE impact identification, impact assessment including collection of needed primary field data, and preparation of detailed technical and institutional designs for environmental management measures.

Important environmental components (IECs) Those components of the biophysical or socioeconomic environment of importance to one or more of the interested parties (including future interested parties who cannot participate in the scoping)that could be impacted by the proposed intervention.

Interested parties	Includes all with an interest in the project and in the environment that could be affected by it: residents of the project area and external areas subject to project impacts; elected representatives; government officials; professionals; representatives of non-governmental organizations (NGOs); the general public; donor organizations; international agencies.
Mitigation	Elimination, reduction, or control of the adverse environmental impacts of a project. Compare *compensation*.
Proponent	With respect to a project: persons, bodies, authorities, governments, or donors that propose the project, are responsible for preparation of the project, including the environmental assessment or are responsible for project implementation.
Residual impact	Impact that remains after implementation of the project and all associated mitigation and other environmental management measures.
Scoping	Process by which important environmental issues, project alternatives, and important environmental components are identified by the interested parties.

BANGLA TERMS

aman	Rice grown in the monsoon (Kharif-II) season.
aus	Rice grown in the late dry/early monsoon (Kharif-I) season.
beel	Permanent water body; lake.
boro	Rice grown in the dry season.
boro mach	Large fish.
chara	Hill stream.
chotto mach	Small fish.
duar	Deep water scour holes in river beds, important as overwintering habitat for fish brood stock.
haor	River back swamp.
jal	Fishing net.

jalmohal	Geographical/administrative unit of (dry season) openwater fishery habitat, such as a *beel* or group of *beels*, or a section of river or channel.
katha	Piles of tree branches and bushes set on river and *beel* bottoms which attract fish by providing shelter from predators and increased bark and periphyton food supply.
khal	Channel.
nirbahi	Executive.
nodi	River.
parishad	Council.
rabi	Dry season.
thana	Administrative unit.

NERP DOCUMENTS

The Northeast Regional Water Management Plan is comprised of various documents prepared by the NERP study team including specialist studies and pre-feasibility studies of the various initiatives. A complete set of the Northeast Regional Water Management Plan Documents are shown below. Reports shown in italics were prepared in final form; other reports are to remain as working documents.

Northeast Regional Water Management Plan

- *Main Report*
- *Appendix: Initial Environmental Evaluation*

Specialist Studies

- *Participatory Development and the Role of NGOs*
- *Population Characteristics and the State of Human Development*
- *Fisheries Specialist Study*
- *Wetland Resources Specialist Study*
- *Agriculture in the Northeast Region*
- *River Sedimentation and Morphology*
- *Study on Urbanization*
- *Surface Water Resources*
- Local Initiatives and People's Participation in the Management of Water Resources
- Regional Water Resources Dev. Status
- Water Transport Study
- Nutrition Study in the Northeast Region
- The People of Kaliagota Haor
- Social Dynamics in Kangsha River Basin
- Northeast Regional Model
- Ground Water Resources on the Northeast Region

Project Monitoring Programme (PMP)Studies

- Manu River FCDI Project
- Shanir Haor FCD Project

Public Participation Documentation

- Proceedings of the Moulvibazar Seminar
- Proceedings of the Sylhet Seminar
- Proceedings of the Sunamganj Seminar
- Proceedings of the Sherpur Seminar
- Proceedings of the Kishorganj Seminar
- Proceedings of the Narsingdi Seminar
- Proceedings of the Habiganj Seminar
- Proceedings of the Netrokona Seminar
- Proceedings of the Sylhet Fisheries Seminar

Pre-feasibility Studies

- *Kalni/Kushiyara River Improvement Project*
- *Fisheries Management Programme*
- *Fisheries Engineering Measures*
- *Northeast Region Environment Management, Research, and Education Project (NEMREP)*
- *Upper Kangsha River Basin Development*
- *Flood- and Erosion-Affected Villages Development Project (FEAVDEP)*
- *Improved Flood Warning (Concept Paper)*
- Jadukata/Rakti River Improvement Project
- Baulai River Improvement Project
- Mrigi River Drainage Improvement Project
- Narayanganj-Narsingdi Project
- Narsingdi District Development Project
- Pond Aquaculture
- Applied Research for Improved Farming Systems
- Manu River Improvement Project
- Upper Surma-Kushiyara Project
- Surma Right Bank Project
- Surma-Kushiyara-Baulai Basin Project
- Kushiyara-Bijna Inter-Basin Development Project
- Dharmapasha-Rui Beel Project
- Updakhali River Project
- Sarigoyain-Piyain Basin Development
- Habiganj-Khowai Area Development

Table of Contents

2º

TABLES

Executive Summary

Overview

This Appendix presents the Initial Environmental Evaluation of the *Northeast Regional Water Management Plan*, which is the final product of Phase I (1991-93) of the Northeast Regional Water Management Project (NERP). NERP is Component 6 of the Flood Action Plan (FAP) and one of five regional water management studies within the FAP.

The purpose of this IEE is to characterize the potential environmental impacts of Plan implementation, at a level of information and analysis consistent with the Plan itself. To this end, all potentially significant impacts are identified and characterized to an indicative level on the basis of available secondary data supplemented with rapid rural appraisal and case study field data, with reference to prior experience in the region and, as reported in the literature, in other settings. At this stage, environmental management issues and options are identified and discussed but an Environmental Management Plan is not delineated in detail.

The major sections of this report are:

- *Regional Plan Description*
- *Description of Existing Environment*
- *Scoping — Public Consultation and Identification of Important Environmental Components*
- *Overview of Key Biophysical Response and Impact Processes*
- *Assessment Methodologies, Data Sources, Assumptions, and Information Deficiencies*
- *Assessment of Future-Without-Plan Scenario*
- *Assessment of Regional Plan Impacts*
- *Cumulative Impacts and Sustainability Analysis*
- *Environmental Management Plan (EMP)*

Most of the information presented here derives from work done as an integral part of the regional planning exercise, rather than from work done separately in the service of EIA/IEE. This reflects the nature of the regional planning exercise, which exhibited numerous features which are also typical of EIA/IEE. The process and team were multi-disciplinary and multi-sectoral, with specialist studies in each discipline forming the foundation for the planning process. "Long-term economic," "socio-economic", "development" and "resource management" themes with proper consideration of their ecological importance played a central role in planning decisions. A public consultation programme (documented in detail in this volume) was undertaken to ensure that local input was incorporated. Also, the regional planning phase of the project included project-by-project IEEs of potential projects identified during the planning.

A master list of important environmental components (IECs) and generalized project activities were derived from information assembled during the regional planning process and these,

27

augmented by project-specific additions as and when needed, was used for all the IEEs, both project and Plan. Assessment methodologies were also developed out of knowledge gained during the regional planning process. At this level of assessment, impacts were bounded spatially in somewhat general terms, but in a hierarchy in keeping with the architecture of the Plan: for project benefits, nominal project area boundaries were used; for unintended effects of single projects, impacted areas outside project boundaries were added; and for cumulative effects, subregions, river systems, and the region as a whole were used.

Future-Without-Plan (FWO) Main Assessment Findings

Operation of the proposed Tipaimukh Dam/Cachar Plain Project on the Barak in India would moderate flows along the Kushiyara River and upper Surma River, decreasing monsoon flood levels and substantially increasing dry season flows. Impacts during reservoir filling could be even more significant. Ramifications for biophysical and socioeconomic environmental components include changes in monsoon cropping, reduced infrastructure and homestead flood damage, slower post-monsoon drainage, increased dry season in-channel fisheries habitat and improved migration access in the pre- and post-monsoon seasons, and so on.

The lower Kushiyara-Kalni River will continue to aggrade, as a result of upstream channel shifts, impacts of past loop cutting, and alteration of the river's flow regime. This will increase spills into the Baulai River and eventually lead to a partial avulsion from the Kalni River near Ajmiriganj towards the Baulai River. Pre-monsoon flood levels between Madna and Sherpur will increase, affecting 5,000 km^2 of the central Sylhet Depression, including fourteen existing submersible embankment projects. Sediment deposition in the channel and adjacent floodplain will adversely affect fisheries and navigation. Similar but lower-magnitude changes are also expected on the Baulai.

The cumulative effects of the foregoing (Tipaimukh Dam plus aggradation on the Kushiyara-Kalni and Surma-Baulai) would be increased winter discharges and siltation along the Kalni River, with pre- and post-monsoon water levels higher by as much as 1.5 m at Markuli, but peak monsoon water levels higher by only 0.3 m. Ramifications include greater depth and extent of monsoon flooding, retarded post-monsoon drainage, and earlier and more severe pre-monsoon flooding of unprotected areas adjacent to the river.

Major avulsions appear to be either in progress or imminent on the Dauki-Piyain, Dhalai Gang, Jadukata and Someswari Rivers. However, channel avulsions are inherently unpredictable and could occur on any of the fans in the region over the Plan period. Avulsion from the Someswari down the Atrakhali would impact over much of the Kangsha River basin all the way down into the Central Basin, with flood conditions reduced in one area but intensified in other areas. The impact of the other ongoing and potential avulsions mentioned would be largely restricted to the fan areas.

The ongoing *Systems Rehabilitation Project* has proposed to raise, by over 1 m, submersible embankment heights in several projects in the Central Basin. NERP and SRP recognize that this increase in embankment design heights will result in embankment crests, including freeboard, at or above the 1:2 monsoon flood levels. The result will be increasing confinement of flows and sediment to the river channels, even if project areas are filled after the *boro* harvest. Post-monsoon drainage and fisheries could be adversely affected. [For these reasons, SRP will recommend that rehabilitation of these projects be deferred until after implementation of the NERP initiatives *Baulai River Improvement* and *Kalni-Kushiyara River Improvement*, which should decrease Central Basin pre-monsoon flood levels significantly.]

Future-With-Plan (FW) Main Assessment Findings

The FCD projects in the Plan portfolio will profoundly alter the spatial and temporal distribution of water, and through these hydrologic impacts will produce significant beneficial and adverse impacts across the range of water-linked systems. The non-FCD projects in the portfolio, in contrast, have very limited potential for adverse impacts. Indeed, almost all of them are targeted to benefit either specific environmental systems that tend to be adversely affected by FCD development, or to enhance environmental quality directly, through non-structural or localized minor structural means.

FCD project impacts

Homesteads on a total of 400 ha, occupied by 36,000 persons, and cultivation on 4,500 ha would be displaced by project works (embankments, structures, and larger channels). This is 0.9% and 0.3% respectively of total settlement and cultivated areas within project areas.

Homestead flood damage protection, raising existing homesteads, and creation of new homesteads would compensate and enhance regional homestead area. A total of 6,400 ha of formerly flood-affected homestead land, occupied by 1.4 million persons would be protected from flooding. This is 9.7% of the total regional homestead area of 65,000 ha, and 52% of the 12,000 ha of formerly flood-affected homestead area within project areas. A total of 700 ha of new homesteads would be created and existing homesteads raised using dredging and excavation spoil.

Within FCD projects, food production would change as a result of:

- Increased annual paddy production by 570,000 or 10% of present regional annual production of 5.6 million tonnes, mainly by reducing flood risk and damage to crops and altering land types;

- Increased annual production of other food crops by 123,000 tonnes, 12% of current annual production of 1.0 million tonnes;

- Fodder production as a second or third crop on 26,000 ha;

- Increased homestead agricultural production (spices, fruit trees, vegetables, livestock, etc.) on 7,800 ha (net of homesteads protected from flood damage, created and raised with spoil, taken from project works);

- Decreased annual openwater fish production by 10,600 tonnes or 11% of current regional annual production of 96,000;

- Increased annual aquaculture fish production by 1,600 tonnes (counting only effects of flood risk and damage averted) or 8.8% of current regional annual production of 18,000 tonnes; and

- Decreased winter grazing area (winter fallow dry lands) by 54,000 ha or 7.0% of the current area of 779,000 ha.

Quantifiable employment impacts would mirror changes in food production: 66,000 new jobs would accrue to landowners and 16,000 jobs to hired labourers (that is, landless people). Additional jobs in downstream post-harvest activities would also be created. Within the hired labour category, 41,000 jobs in the openwater fishery (about 12% of jobs in the sector) would be lost, overbalanced by a gain of 57,000 jobs in agriculture.

Water quality (as experienced by domestic consumers, fisheries, and wetlands) changes cannot be quantified, but would be affected in a number of ways. Drainage improvement would tend to improve water quality, by increasing flushing and flushed volume and duration, and decreasing stagnant water volume and duration. Flood control would improve water quality at some times and places, by eliminating flooding of domestic-supply tube wells and pit latrines for example, and worsen it at others, by decreasing flushing and increasing stagnant water volume and duration. The FCD-led increment in pesticide use (47 tonnes, or 9% of current usage of 530 tonnes) would contribute to water contamination, especially in low pockets surrounded by HYV cultivation. The FCD-led increment in fertilizer use (46,000 tonnes, 20% of current usage of 226,000 tonnes) would increase nutrients available to the openwater fishery, but could also aggravate eutrophication problems.

Navigation would be benefitted by river and channel excavation, and disbenefitted by the 48 closures of major and minor channels at embankments and across spill channels.

Wetland areas (i.e. fallow areas with sufficient moisture to support hydrophytic plants) would decrease, in winter by 7,000 ha or 5.7% of the regional total of 124,000 ha, and in summer by 50,000 ha or 11% of the regional total of 440,000 ha. About half (250 ha) of the region's remaining floodplain grassland (550 ha) could be adversely affected by *Surma Right Bank Project*. Hakaluki Haor, a key wetland site and mother fishery, would be adversely affected by sediment deposition as a consequence of the *Manu River Improvement Project*; Tangua Haor and Companyganj key wetland and mother fishery sites would be partially protected from sediment infilling by *Jadukata-Rakti Project* and *Sarigoyain-Piyain Project* respectively.

In some river systems, channelization of floodplain flows will increase river water levels, discharges, and velocities. These in turn may increase the cost of flood control measures (embankments will have to be higher and stronger) and infrastructure maintenance. If designs and maintenance are not upgraded enough, infrastructure may fail more frequently due to greater erosion and more frequent overtopping. When and where infrastructure fails, damage to crops, homesteads, and roads may be greater than in the unprotected situation because levels will be higher. Also, three areas in the region — the Mogra basin, Hakaluki Haor, and the lower Sarigoyain River basin — will remain both outside of flood control embankments and may be vulnerable to displaced flooding from Plan FCD projects, which could cause increased flood damage to crops, homesteads, and roads in these unprotected areas. Channelization, by raising river water levels, may in some cases result in improved conditions for river navigation and fisheries.

As for impacts outside the region, there would be no hydrologic or sediment impact on areas downstream, given conditions at the region's outfall. A possible exception could be transient effects due to turbidity from dredging. Pesticide loadings of regional drainage flows would increase, proportional to usage increases. Migrating waterfowl populations will be adversely affected by the overall reduction of winter wetland areas and adverse impacts on Hakaluki Haor. This could be somewhat compensated by positive impacts on Tangua Haor and Companyganj area.

Non-FCD Project Impacts
Non-FCD Plan projects — many of which mitigate, compensate, or enhance environmental components adversely impacted by the FCD projects — address rural and urban water supply, sanitation, and rural hygiene education; biodiversity and surface water quality management; aquaculture; ground water management; applied research to improve farming systems in the deeply flooded area; openwater fisheries engineering and management; improvement of homestead platforms and village afforestation and habitat restoration to control wave erosion and generate biomass inputs (fuel, building materials, etc.) to village systems; navigation; flood warning; and institutional strengthening in selected areas. Impacts are generally relatively straightforward and relate closely to intended project benefits. Some of these projects exhibit specific possible adverse impacts, all of which appear to be mitigable or otherwise manageable with reasonable effort. Examples of such possible impacts include displacement impacts associated with minor construction, regressive socioeconomic equity impacts, and intensification of social conflicts over resource management and control.

EX-PLAN CUMULATIVE IMPACTS

Plan impacts will act in a cumulative manner with the expected impacts of ongoing large-scale processes external to the Plan. Such processes include population growth, urban infrastructure development in and in-migration to urban areas, climate change, energy production and consumption trends, and increasing contamination of water supplies from domestic, industrial, and agricultural discharges.

Plan implementation is expected to contribute to developmental trends which are thought capable of contributing indirectly to slowing of population growth. This conclusion rests on the interpretation that population growth rates are highly dependent upon parents' perceptions of ideal or desired family size; perceived insecurity in old age; and acceptance of and access to effective family planning. These factors are in turn strongly influenced by income, child mortality, women's status, and access to family planning services (World Bank, 1992). All but the last (which clearly lies entirely outside the ambit of water management planning) would be impacted by Regional Plan implementation. This model is not, of course, universally accepted. Under a neo-Malthusian scenario, which NERP does not endorse, increasing food production and public health improvements, as would be achieved under the Plan, simply fuel further population growth. In practice, a population growth rate was applied as a boundary condition to the regional water management planning exercise. That is, an expected growth rate was assumed for the region, to be taken into account in formulating the Plan. This amounts to a linearization of the Plan-population growth relationship.

Plan implementation is expected to accelerate urban infrastructure development and in-migration to urban areas. Many urban areas in the Northeast Region, and in Bangladesh as a whole, are located in areas which are vulnerable to flooding. Thus provision of flood control to urban and peri-urban areas could paradoxically increase total flood damage, integrated over floods of all recurrence intervals: with less risk from more frequent, lower magnitude floods, people will increasingly settle and invest in areas which remain vulnerable to less frequent, high magnitude floods. In addition to this, however, flood control may act to reduce hidden costs associated with flood exposure, such as the cost of low productivity due to low investment. At the level of FCD project feasibility studies, there will be a need to investigate both the direct and hidden flood damage costs associated with a range of project and urban development scenarios.

The air temperature and sea level components of anthropogenic climate change will not be perceptible over the 20 year period of the Regional Plan, (i.e. the presumed rates of increase of both are too slow to be discerned over this short time interval), but future rainfall trends could be of significant magnitude, judging from the tendency observed over recent decades for increasing rainfall and increasing rainfall variability. Impacts of a cumulative nature (Plan + increasing rainfall) relate mainly to increased river discharges and water levels (e.g. embankments + increased rainfall), leading to morphologic changes (wider channels, aggradation/degradation waves propagating through the system, and increased channel instability and type switching). Other aspects of Plan interventions would tend to mitigate affects of rainfall increases: drainage improvement could reduce system drainage overloading, habitat conservation and restoration could ensure that development options (swamp forest) suitable for the new conditions are preserved, and so on. Increasing rainfall would also have important environment-on-project impacts: water management could become increasingly difficult, infrastructure maintenance increasingly costly, and the relative feasibility of various water management and development options could shift. Drainage improvement would increase in importance relative to flood control, and fisheries and swamp forest could become viable over greater areas as damage to rice crops reduces yields. Decreasing rainfall would lead to impacts opposite in sign and type.

Plan implementation would impact regional patterns of energy production and consumption. Energy supplies in the region derive from a wide range sources, many of which are inter-related: a great variety of biomass fuels from natural sources; animal draught power; human muscle power; solar energy; and fossil fuels. Changes in fodder and biomass fuel production as a result of Plan implementation have already been mentioned. Fossil fuel usage, of particular interest because such they are non-renewable, contribute to environmental pollution, and tend to be imported, and increasing dependence on them increases external dependence, economic unsustainability, and public health and ecological problems. Direct increases in fossil fuel usage as a result of the Plan would however be very small, with direct fuel consumption for pumped irrigation increasing by 1%. Indirect increases include that for manufacture of fertilizer, for which usage would increase by 9%.

Plan implementation would impact regional water quality through increased agrochemical usage (mentioned above), and through direct measures to manage contamination sources and water supplies.

SUSTAINABILITY

A sustainability analysis of Plan interventions indicates a number of areas for concern. Some of the impacts associated with FCD infrastructure may be or will be irreversible. These impacts include in particular the impacts of *Manu Diversion Project* and *Surma Right Bank Project* on biodiversity values at Hakaluki Haor and Bara Haor. Plan FCD projects have a net negative impact on the openwater fishery, a system which is already under considerable stress; some of the Plan non-FCD projects address this area, but their success is not a foregone conclusion. Production, management, and consumption of biomass materials (for example, rice straw and husks. manure for energy, wetland products) for fodder, fertilizer, building materials, is benefitted by the Plan, but more systematic management improvements may be necessary to ensure that local needs are met sustainably.

ENVIRONMENTAL MANAGEMENT PLAN

The emphasis at the IEE, pre-feasibility, level is on identifying issues and options, to guide the detailed design of specific EMP measures as part of programme and project feasibility studies.

The architecture of the Plan portfolio includes mitigation of adverse FCD impacts by some of the non-FCD projects. Thus acceptable environmental performance is contingent upon implementation of the portfolio in a balanced and correctly phase manner.

Important areas for environmental management will include: management of displacement impacts, including cash compensation and resettlement activities, and raising and construction of homesteads from spoil; proper management of dredging activities; mitigation and compensation of adverse openwater fisheries impacts; compensation of wetland and biodiversity impacts through regional biodiversity enhancement; and attention to socioeconomic equity and conflict issues in FCD projects, and in projects dealing with common-property and government-owned fishery and wetland resources.

22

REVIEW PROCESS

This document is subject to review procedures described in the FPCO and MOWR *Guidelines for Environmental Impact Assessment* (1992), which involve review activities by a Project Review Committee, composed of proponent representatives and by the Department of Environment, which has final authority to review and approve EIAs for projects in Bangladesh.

28

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The Flood Action Plan is the first stage in the development of a long-term water management plan for Bangladesh. It is comprised of a phased programme of initiatives to control flooding, supported by special studies, surveys, and pilot projects. The Northeast Regional Water Management Project (NERP) is Component 6 of the Flood Action Plan (FAP) and one of five regional water management studies within the FAP. A map of the region is shown in Figure 1.

NERP consists of two phases. Under Phase I, recently concluded, a Regional Water Resources Development Plan was prepared, using a strategic planning process based on specialist studies of key areas including existing water resources development, hydrology, ground water, river sedimentation and morphology, agriculture, fisheries, water transport, biodiversity (wetland and upland), human resources development, and institutions.

The *Regional Plan* proposes a water management strategy for the development of regional water management systems through 2015. The strategy includes a portfolio of 44 specific projects for implementation over the next 20 years by a variety of government, non-governmental, and private agencies.

NERP Phase II will consist of feasibility study and implementation of one or more of these projects.

1.2 REGIONAL PLAN RATIONALE AND OBJECTIVES

The basic rationale for regional planning of water resources development is the desire to improve upon planning undertaken on a project-by-project basis. Regional planning provides the opportunity for both broader (over more disciplines and a greater area) and deeper (with more information and analysis) investigation of present conditions, likely future trends, and opportunities for intervention. In particular, regional planning provides opportunities to look at issues at a macro level, such as trade-offs between sectors, overall programme phasing, improvements common to many projects (e.g. provision of fish passes in embankments), and relationships between projects.

The overall objective of the Project, as stated in the Terms of Reference, is:

> ". . . to assist the GOB in planning and guiding the development of the project region and to provide criteria for the selection , design, implementation, operation and maintenance of individual water-management projects benefitting the agricultural, fisheries, and related sectors, with due attention to the growing landlessness of the rural population. In accordance with the objectives of the Action Plan, the Project is to provide the basis for the management of the Northeast Regions' water resources with a view to creating an environment for........ social improvement."

2d

1.3 RELATIONSHIP OF IEE TO REGIONAL PLAN

The purpose of the IEE is to characterize the potential environmental impacts of Plan implementation, at a level of information and analysis consistent with the Plan itself.

More fundamentally, the regionally planning exercise itself requires adequate understanding of (1) current biophysical and socioeconomic conditions; (2) important future trends; and (3) the potential benefits to be gained from, and adverse effects of, potential development interventions. In the language of EIA/IEE, these are (1) baseline conditions, (2) future-without-project conditions, and (3) impacts, respectively.

Readers of the IEE are assumed to have ready access to a copy of the *Regional Plan*. In particular, the IEE includes references to *Regional Plan* figures.

1.4 TEAM, BUDGET, AND LEVEL OF EFFORT

Most of this document derives from work done as an integral part of the regional planning exercise, rather from work done separately in the service of EIA/IEE. Indeed, this IEE summarizes information and analysis generated by the NERP team as a whole during the entire two-year Phase I period. The IEE team, budget, and level of effort, then, are essentially the same as and cannot be separated out from the Phase I budget. The only input which related solely to the IEE was that required in drafting this document — about four person-months, involving five people.

1.5 IEE METHODOLOGY

Within the context of the preparation of the Regional Plan, the main steps in undertaking this IEE were as follows. Public consultation and expert input are integral throughout.

For the portfolio as a whole, the tasks were:

- Develop a master list of the important environmental components (IECs) that could be impacted by Plan implementation, from the mass of information generated regarding current conditions, driving forces, issues, strengths, weaknesses, opportunities, and threats, and proposed projects. The IECs used here are shown in Table 5.1.

- Develop a master list of potential project activities that could have impacts on the environment (see Section 3.7).

- Construct an environmental screening matrix of potential project activities vs. IECs, to be used in screening and scoping each individual project (Figure 2).

- Devise a list of possible interactions between and among different projects in the portfolio (see Section 9.5).

- Devise a list of external, non-Plan processes or projects whose impacts overlap with those of the Plan projects (cumulative impact assessment; see Section 10.1).

- Devise a list of external processes or projects whose impacts could affect the infrastructure or operation of Plan projects (environment-on-project impacts; see Section 9.6).

- Identify suitable sustainability criteria.

- Determine which impacts can be quantified. The remaining impacts would be described qualitatively and ranked.

- Devise a methodology for quantifying each quantifiable impact (see Chapter 7). Methodologies range from pure estimation based on subjective expert judgement based on secondary data to highly sophisticated objective (numerical) models based on data from extensive field studies.

- Devise a methodology for scoring non-quantifiable impacts (see Section 7.2.8).

- Devise projects for inclusion in the Plan to address important environmental management issues to ensure that the Plan is implemented in an environmentally sound manner. Examples of such projects include *Northeast Region Environment Management and Research Project (NEMREP)*, *Fisheries Management*, *Fisheries Engineering*, *Flood- and Erosion-Affected Villages Development Project*, and others.

Then, for each project,

- Screen to make a preliminary identification of potential impacts (project-on-environment, environment-on-project, project-on-project); this is done by the multi-disciplinary study teams using the screening matrix (Figure 2) and detailed IEC list (Table 5.1).

- Establish the spatial and temporal boundaries that the assessment of each impact will include. Temporal bounds are usually closely related to the causative activity (when will the activity occur, how long will it last). Spatial bounds must include all impacted areas and communities. Particular care should be taken in bounding so as to include impacts on areas outside the nominal project area.

- Characterize (investigate and then quantify or rate) each impact.

- Devise project-specific environmental management activities required to ensure that the project is implemented in an environmentally sound manner. These can include mitigation, compensation, monitoring, contingency implementation-phase public participation, accountability and reporting, and institutional strengthening and training measures and recommendations.

- Iterate through the above steps to enhance positive impacts and mitigate adverse impacts ('anticipatory planning').

- Prepare the IEE document for each project.

Finally, for the Plan as a whole,

- Prepare the Plan IEE document, including an analysis of the sustainability of Plan activities and impacts, in the context of the total developmental environment.

Identification of project activities, IECs, interactions between them (project-on-environment impacts), environment-on-project impacts, and cumulative impacts was initially exhaustive rather than selective. Thereafter, estimates of quantity and quality of impacts, periodically updated, were used to focus and refocus assessment efforts on the most important impacts. Impacts whose relevance or magnitude remained uncertain were carried forward rather than dropped.

1.6 LIMITATIONS

This is an IEE, not an EIA, and thus important limitations are the depth of study, the dependence on secondary information, and the restriction of environmental management planning to identification of issues and options only. These limitations should be dealt with as the FAP and individual Plan projects move forward.

Another limitation is that the IEE was prepared by the same team as that responsible for the Regional Plan. On the one hand, the planning team can make use of the in-depth understanding which has been developed during the planning period; on the other, it can be argued that an independent team would provide a fresh perspective and greater objectivity, and thus would be more able to identify possible adverse impacts and other problems.

1.7 IEE REVIEW PROCESS

The latter limitation mentioned above can in part be addressed by full and thorough review of the Regional Plan and IEE.

The *Regional Plan* has been accepted by FPCO contingent upon acceptance of this IEE. EIA/IEE review procedures for FAP projects are outlined in the *Guidelines for Environmental Impact Assessment* (FPCO and MOWR, 1992):

> "Project reports should be submitted jointly [study plus EIA/IEE] and should be subjected to three separate reviews by:
>
> - Local government agencies, community groups, and NGOs operating in the project area;
> - A Project Review Committee comprising representatives from MOI, other concerned ministries, knowledgeable NGOs working and selected professionals/academics, and
> - The Department of Environment which is the final authority to review and approve EIAs and for giving environmental clearance to all projects in Bangladesh."

The Regional Plans and their IEEs are subjected only to the latter two levels of review; the local review applies to project-level EIA/IEE reports. The *Guidelines* go on to provide additional details regarding this process (pp. 37-8).

1.8 REPORT STRUCTURE

The organization of this report is derived from an outline presented in the *Manual for Impact Assessment* (FAP 16, 1992). The major sections are:

- Chapter 2, *Regional Plan Alternatives*
- Chapter 3, *Regional Plan Description*
- Chapter 4, *Description of Existing Environment*
- Chapter 5, *Scoping — Public Consultation and Identification of Important Environmental Components*
- Chapter 6, *Overview of Key Biophysical Response and Impact Processes*
- Chapter 7, *Assessment Methodologies, Data Sources, Assumptions, and Information Deficiencies*
- Chapter 8, *Assessment of Future-Without-Plan Scenario*
- Chapter 9, *Assessment of Regional Plan Impacts*
- Chapter 10, *Cumulative Impacts and Sustainability Analysis*
- Chapter 11, *Environmental Management Plan (EMP)*
- *References*, and
- Annex A, *Figures*.

1.9 GENERAL REMARKS

FCD projects profoundly alter the spatial and temporal distribution of water and have a recognized potential to produce both significant beneficial and adverse impacts across the range of water-linked systems. By contrast, the non-FCD projects in the portfolio have very limited potential for adverse impacts. Indeed, almost all of them are targeted to benefit either specific environmental systems that tend to be adversely affected by FCD development, or to enhance environmental quality directly, through non-structural or localized minor structural means.

Thus, to ensure that the most fundamental purpose of IEE is achieved, which is to identify and characterize all potentially significant adverse impacts, this document concentrates on the FCD projects.

This preoccupation with FCD, a necessary characteristic of the IEE, is not shared by the Plan itself.

CHAPTER 2: REGIONAL PLAN ALTERNATIVES

2.1 FUTURE-WITHOUT-PLAN SCENARIO

The future-without-Plan (FWO) scenario is described in Chapter 8.

2.2 REGIONAL PLAN ALTERNATIVES AND SELECTION OF ALTERNATIVES

A key step in the planning of individual projects often includes making a selection from among several more or less well-defined alternatives.

This was not the case in the development of the *Regional Plan*. The problem here was to identify ways to contribute to regional development, broadly defined, through strategic interventions in the internal planning environment (water), in the context of the external environment (everything else). The planning was undertaken by a multidisciplinary team over a two-year period, culminating in team strategy sessions to define and rank strategic thrusts, to which individual projects were assigned and ranked.

A strategic planning method was used, in which the planning problem was defined in terms of internal and external environments. The internal environment here is the water system of the Northeast Region, and the external environment consists of regional systems other than water, plus relevant national and international systems. In addition, the strategic planning method stresses action, in particular action focused on key points of intervention.

The steps or elements of the planning process are described below, more or less in the order in which work was begun on each of them.

The *policy context* consisting of overall national development policies and FAP goals and objectives, was reviewed and summarized.

An *interpretive description of the region* was prepared, to provide a profile of the region in terms of what is most important - from a development perspective - to understand, rather than on comprehensiveness. The information based for this is the NERP specialist studies which included review of existing secondary data and documentation, meetings with key informants, plus primary field-based research at NERP field stations and case study sites.

Major *driving forces* likely to be significant in shaping the region's future development were identified. Some driving forces are internal to the regional water system; some are external to the water system but internal to the region; still others are national or international in scope. This analysis relies on forecast data on regional, national, and international trends, content analysis of key media, interviews with influential and informed persons, review of futurist media, and modelling.

Key development issues were defined and articulated. Key inputs to this task are the driving forces, as these are often excellent indicators of issues that will emerge during the planning period. Issues reflect official policies, feedback from official and the populace in the field, collected secondary and primary data or documentation, and NERP team concerns.

The *regional analysis* began with the formulation of two *mission statements,* one for regional development and one for regional water management planning. These provided guidance during the regional analysis, which looked at *strengths, weaknesses, opportunities, and threats* in the regional development system and in the regional water system. Strengths and weaknesses were derived from the issues previously identified, covering the areas of perception and profile of issues (including private and public commitment to addressing issues), policy frameworks, institutional form and processes, financial resources, natural resources, human resources, present trends, and other aspects as required. Opportunities and threats, again of the regional development system and the regional water system, were analyzed. These were derived form the driving forces, and include competitors, environmental forces, international trading and business environments, international commodity markets, trends in future development aid flows, the Northeast Region's likely future role in Bangladesh and internationally, and other aspects as required.

The *future regional development context*, that is, the future-without-plant scenario, was characterized, emphasizing major areas of change and uncertainty.

The *regional water management strategy* opens with *objectives* for overall regional development and the regional water management plan. These were tentatively formulated as a first step in developing the strategy to provide guidance; once the strategy was finalized, they were revised to reflect the likely achievements and impacts of the strategy. The strategy was prepared as a set of interventions cross-referenced by strategic thrusts. Identification, conceptualization, and acceptance into the final portfolio was carried out on the basis of technical feasibility, public consultation, economic feasibility, acceptability of biophysical, social, and economic impacts, and contribution to regional water management strategic thrusts and objectives.

CHAPTER 3: REGIONAL PLAN DESCRIPTION

3.1 PLAN OVERVIEW

The Plan is described in the concluding chapters of the *Regional Plan* document. The Plan consists of eight strategic thrusts which identify key developmental themes for water resources development in the region, plus a portfolio of 44 projects which address these. This IEE assesses the impacts of these 44 projects. Impacts associated with other elements of the strategic thrusts have not been characterized at this time.

Most of the projects in the portfolio are documented in pre-feasibility studies produced by NERP. A few are documented in other NERP reports or, in cases where NERP is endorsing the proposals of other agencies, reports by other entities.

The description of the Plan and the project portfolio are summarized in Figure 24 and Table 21 of the *Regional Plan*. *Regional Plan* Figure 24 provides, for each project in the portfolio, the primary strategic thrust, the implementation priority, the project type and objectives, presence of structural and non-structural measures, project area planning subregion, documentation status, implementing agency, and cost. *Regional Plan* Table 21 provides aggregate indicators of the scale of the FCD projects proposed, relative to existing FCD projects.

3.2 OVERALL SCALE OF PROPOSED MEASURES

The overall scale of the proposed measures is documented in *Regional Plan* Section 9.2.

3.3 BASIC PRINCIPLES OF FCD AND RIVER IMPROVEMENT INTERVENTIONS

3.3.1 Introduction

This section provides background information on how FCD and river improvement measures are intended to function in a generic sense. This information leads logically into the description of how biophysical systems respond to FCD and river improvement (Chapter 6), the assessment methodologies (Chapter 7) and the characterization of these measures' biophysical impacts (Chapter 9).

3.3.2 Flood Control and Drainage

Flood control, drainage (FCD) and river improvement projects produce desired social and economic outcomes through their impacts on, and the responses of, biophysical systems: for example, changes in water level set the stage for farmers to modify their choices of crops.

The purpose of flood control and drainage improvement projects is to reduce the depth or occurrence of water over a certain area. Both the flooding and the inadequate drainage conditions cause an excess of water and as such are interdependent.

Projects designed to control flooding throughout the year are called *Full Flood Control and Drainage Projects*; projects designed to delay flooding (that is, control pre-monsoon floods) are called *Partial Flood Control and Drainage Projects*.

Full flood control and drainage projects
Full flood control projects are associated with high flood embankments constructed above the annual flood level. These projects are designed to protect a certain area from the inflow of external floods, while allowing accumulated rainfall runoff to flow along internal channels to either gravity drainage structures or pumps.[1] Depending on topographical and flooding conditions, the area can be protected with a ring embankment, a linear river embankment, or a bottom-open embankment. The ring embankment encircles the area and is used in flatter areas; the linear river embankment runs along a river and protects the adjacent area from river spills; and the bottom-open embankment protects the upper sides of a sloping area affected by flood spills from above, while leaving the lower end open for drainage, fish migration, and navigation.

According to BWDB guidelines, high full flood control embankments that are meant to protect agricultural land are designed for a 1:20 year frequency of flooding, while embankments meant to protect infrastructure and populated areas are designed for 1:50 or 1:100 year flood frequency. Internal drainage channels are designed to convey within banks the project basin flood from the 5-day, 1:10-year return period rainstorm. In anticipation of siltation, the channel section is usually designed to be 20 to 30% larger than this.

The capacity of the gravity drainage structures should match the design discharge of the drainage channels. Structures are designed for operation under a hydraulic head of up to 0.30 m. Pumping station capacities are determined from an economic optimization exercise that involves flood frequency, flood damages, and the station's capital and O&M costs.

FWO flood levels are determined mainly from existing river gauge records, usually located on the periphery or outside the project area. Flooding from ponded rainwater (flatter areas) and from flood waves from rivers (both sloping and flatter areas) are both considered. Sometimes temporary gauges are established in the project area. Existing hydrological data may be adjusted to reflect known trends, such as rising flood levels, increasing rainfall, or siltation. The flood levels so obtained are then verified by field observations and interviews with local people. The extent of flood damage to crops, homesteads, and infrastructure is initially estimated from the flood levels and then cross-checked in the field.

FW flood levels can be determined from a water balance analysis (inputs less outputs), in the case of ring or river embankments; or from backwater analysis, in case of bottom-open embankments.

High embankments always increase discharges and water levels outside the project area, by confining to the river channel flood discharges that otherwise would spill onto the floodplain. Full confinement (high embankments on both sides of a river channel) means that the total flow is contained within the river channel; if a significant proportion of the flow was across the floodplain before the project, water level increases can be dramatic.

---

[1] Pumping stations exist in the region. No new stations are proposed as part of the *Regional Plan*.

Partial flood control and drainage projects
Partial flood control is a special type of project designed to protect agricultural crops, usually *boro* rice, grown in the winter season and harvested during the pre-monsoon.

The crop protection is effected by lower, smaller-section 'submersible' embankments intended to protect against pre-monsoon floods until *boro* rice harvesting is completed, and then to be overtopped by the higher monsoon floods, when the area is inundated and the monsoon floods pass over it. At the end of the monsoon, water from the basin drains back to the river system.

The current practice is to design submersible embankments to protection against 1:10-year return period external floods expected before the 15 May. Normally the crest of the embankment is 0.3 m above the design flood.

Flushing/drainage regulators are provided in the embankments to facilitate (1) filling in (flushing) of the project with water after the *boro* harvest is complete, so as to reduce the damage of embankments during overtopping, and (2) drainage in the post-monsoon period. Structure size is determined by:

- Pre-monsoon flushing requirements. The capacity of the structures should be sufficient to allow the basin to fill in up to 0.3 m below the embankment crest by the time the embankments are overtopped, to limit damage to the embankment during overtopping, and

- Post-monsoon drainage requirements. The head difference across the structure should not exceed 0.3 m, to discourage farmers from cutting the embankments to accelerate drainage.

Normally, the expected flushing flows are larger than drainage flows and therefore determine the size of the structures. The internal drainage system is designed for the pre-May 15, 5 day, 1:10-year return period rainstorm.

Partial flood control projects should not, in theory, reduce monsoon floodplain storage and thus should not increase monsoon flood levels. The recent trend at some locations, however, has been for pre-monsoon flood levels to increase, to the point where they are approaching monsoon flood levels. In parallel with this, embankments designed to protect from pre-monsoon floods are increasing in height; in fact they are becoming improperly designed full flood embankments, with insufficient set-back distance and weak cross sections. For example, raising a number of submersible embankments is planned under the Systems Rehabilitation Program to levels such that overtopping will occur only every second or third year (see also Section 8.4.2 below).

The local and systemic implications of this trend can be quite serious as projects increasingly produce full flood control impacts rather than partial flood control impacts: decreased monsoon floodplain storage, much greater magnitude negative impacts on fisheries, greater drainage congestion (greater water volume must be evacuated through structures), water quality deterioration, and so on.

Dry season water levels in flood control projects
How much water is retained, given the physical parameters of the drainage channels and structures and external water levels, may depend on how structures are operated, which can be a sociopolitical matter between different interest groups (as it may be in the FWO condition if

earth closures are being constructed and cut under local initiative). Low-lift pumps are widely used to redistribute water to allow *boro* plantation, for irrigation, and to facilitate fishing operations.

3.3.3 Channel Re-Location and Loop Cuts

Typically, loop cuts and channel re-locations are made to shorten channel length, thereby improving navigation, or to increase channel slope, thereby increasing flow velocities and reducing flood levels. Loop cuts are also made to arrest bank erosion associated with channel shifting or meander migration. Figure 3 shows an example of artificial loop cuts on the Baulai River.

Some past projects that have utilized loop cuts include:

- Kalni River, six loop cuts made between 1978-1983, shortening the river by 6 km;
- Kushiyara River near Sherpur, two loop cuts made between 1952-1963;
- Baulai River, eight loop cuts made between 1978-83, shortening the river by 12 km;
- Surma River between Sylhet and Sunamganj, isolated loop cuts made to reduce bank erosion at bends;
- Khowai River between Chunarghat and Shaistaganj, 6 km of loop cuts and channel re-locations made between 1970-1981 for flood control purposes.

In most cases, a relatively narrow pilot channel is excavated through the neck of the bend. The river is diverted into the pilot channel and then allowed to enlarge by bank erosion and scouring until it approaches the river's full channel dimensions. In the Northeast Region, loop cuts are typically constructed in the dry season by manual excavation and then diverted into the new channel during the start of the monsoon season.

Pilot channels will not enlarge satisfactorily if the water level difference across the neck of the bend is too small, or if the bank materials in the pilot channel resist erosion. Where this is the case, a local constriction may develop in the channel and water levels may increase rather than decrease as a result of the works, particularly if the former main channel becomes silted in. Local constrictions of this type have developed along the Kalni River and Baulai River at former loop cuts, probably as a result of cohesive bank materials in the channels. At such sites, excavation or dredging is required to enlarge the channel to its full cross sectional area. In the past, this has seldom been considered feasible, due to the large volume of excavation required and short length of the construction season.

Methods for designing the initial dimensions of pilot cuts so that they will enlarge to full cross sections are available (Petersen, 1986), but the geotechnical and hydraulic information required for this type of analysis is rarely available. As a result, loop cuts in the Northeast Region have not followed formal design procedures.

Whether loop cutting and channel re-location are beneficial depends on the specific setting. Planning of these types of intervention needs to include assessment of both local, short-term impacts and longer-term impacts upstream and downstream of the project.

3.4 IMPLEMENTATION PRIORITIES, PHASING, AND SCHEDULING

Prioritization and scheduling are documented in Section 9.3 of the *Regional Plan*. Scheduling is shown in *Regional Plan* Figure 22.

3.5 SUBREGIONS

Section 9.9 documents the impacts received by each of six subregions: Eastern Seasonally Flooded Area, Northern Alluvial Fans, Central Basin, Western Seasonally Flooded Area, Southern Piedmont Floodplain, and Peri-Urban Area. This purpose of this presentation is to relate Plan impacts to particular settings within the region.

3.6 STATUS OF PLAN COMPONENTS DURING IEE STUDY

The status of each of the 44 initiatives in the Plan portfolio is:

- One initiative (*Improved Flood Warning*), is documented in a NERP concept paper.
- Two initiatives (*Ground Water Investigation, Institutionalize Public Consultation*) are documented in Specialist Studies or the Training Plan.
- Two initiatives (*Bhairab Bazar Erosion Protection* and *Jamuna Floodplain Floodproofing*) are included in work to be carried out under other FAP projects, FAP 9B and FAP 23 respectively.
- Three (*Urban Potable Water, Urban Sanitation, Village Water Supply*) are endorsements of ongoing DPHE/UNICEF projects.
- All sixteen of the FCD initiatives are described in separate pre-feasibility studies. The measures described in these reports are non-overlapping, with the exception of the *Baulai River Improvement* pre-feasibility study, which includes drainage improvement measures also mentioned in the *Surma-Kushiyara-Baulai Project* and *Jadukata-Rakti Project* studies.
- Four non-FCD initiatives (*Pond Aquaculture, Applied Research for Improved Farming, Fisheries Engineering, and Fisheries Management*) are described in separate pre-feasibility studies.

- Fifteen initiatives are described in pre-feasibility studies which document two or more initiatives grouped together. The studies are:

  — *Flood- and Erosion-Affected Villages Development* documents two initiatives (*Improvement of Homestead Platforms* and *Village Afforestation*);

  — *Water Transport Study* documents two initiatives (*Dredging for Navigation* and *Support to Country Boats*); and

  — *Northeast Regional Environmental Management, Research, and Education Project* documents the remaining 11 initiatives.

The initiative *Singar Beel Project* which appeared in the draft *Regional Plan* document was dropped from the portfolio because it is currently being implemented.

3.7 PROJECT ACTIVITIES

3.7.1 Purpose

The purpose of this section is to identify any and all normal and abnormal project activities that could cause environmental impacts (project-on-environment impacts), or that could be affected by environmental processes (environment-on-project impacts). The activities listed here appear as row headings in the environmental screening matrix (Figure 2).

3.7.2 FCD Projects

Preconstruction activities

Preconstruction activities on FCD projects can include:

- Surveying,
- Land acquisition, and
- People's participation activities.

Construction activities

Normal construction activities on FCD projects can include:

- Site preparation (vegetation removal; infrastructure removal/relocation; removal/resettlement of inhabitants/squatters; levelling; installation of temporary structures such as access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)
- Manual canal excavation (labour and material mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving)
- Mechanical dredging (dredger operation, spoil deposition)
- Embankment construction (labour and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving)

- Structure (sluice gate, culvert, pump house, etc.) construction (labour and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling turfing, paving)
- Tube well installation (boring, distribution facilities, electrification)

Abnormal occurrences could include:

- Suspension of construction before completion, construction delays
- Incorrect construction practices or techniques

Infrastructure components
Infrastructure components consist of:

- Full flood embankments
- Submersible flood embankment
- Channel closures (in embankments)
- Regulators
- Weirs
- Re-excavated and new drainage/flushing rivers and channels
- River diversion structures and channels
- Roads
- Bridges
- Culverts
- Irrigation inlets
- Fish passes
- Boat passes

Operation and maintenance activities
Operation and maintenance activities can include:

- Pre-monsoon flood protection
- Monsoon flood protection
- Surface water irrigation
- Ground water irrigation
- Drainage
- Water retention behind regulators
- Agricultural activities resulting from project
- Water management activities

Abnormal occurrences could include:

- Unintended pre-monsoon flooding due to extreme event, infrastructure failure
- Unintended monsoon flooding
- Embankment overtopping
- Under- and over-drainage
- Improper operation (public cuts, mistiming of scheduled O&M events such as gate opening/closure)

Abandonment activities
Abandonment activities for FCD projects can include:

- Re-occupation of infrastructure sites
- Reclamation of materials

3.7.3 Other Types of Projects
Project activities for the non-FCD projects were identified on a project-by-project basis and are identified in the various project studies.

CHAPTER 4: DESCRIPTION OF EXISTING ENVIRONMENT

The Regional Plan provides a brief interpretive description of the region in Chapter 3 (pp. 11-32), which '. . . presents what is developmentally most important to understand within the region.' Subsequent chapters present discussions of driving forces (Chapter 4, pp. 33-46); regional issues (Chapter 5, pp. 47-54); and the strengths, weaknesses, opportunities, and threats in the region's water system and in its development system (Chapter 6, pp. 55-76).

Additional regional-level details on many topics are provided in the various Specialist Studies. These are cited below. These citations refer to draft final versions of these studies.

Project-scale information is provided in the FCD and other project pre-feasibility studies. Each FCD study includes chapters describing the biophysical setting (usually Chapter 2), and settlement, development, and resource management (usually Chapter 3).

4.1 NATURAL PHYSICAL ENVIRONMENT

4.1.1 Atmospheric Environment and Climate

For information on climate and rainfall, see *Surface Water Resources of the Northeast Region*, Section 2.2, Climate, and Chapter 3, Rainfall.

4.1.2 Water Resources

For information on regional hydrology and each river system, see *Surface Water Resources of the Northeast Region*, Chapter 2, Hydrological Overview; Chapters 4 through 9, for a description of the river systems; and Chapter 10, Flood Frequency Analysis.

For information on open water bodies and ponds, see *Fisheries Specialist Study*, Section 2.1, Fisheries Environments.

For information on river morphology, see *River Sedimentation and Morphology Specialist Study*, Chapters 5 through 7.

For information on ground water resources, see *Ground Water Resources of the Northeast Region*, see Chapter 2, Preceding Studies and Data Sources, and Chapter 3, Ground Water Potential and Availability for Future Development.

For information on water quality, see *Fisheries Specialist Study*, Section 3.2, Water Pollution; and the NEMREP pre-feasibility study, Section 2.2.5, Regional Surface Water Quality, and Chapter 6, section on surface water quality management.

4.1.3 Land Resources

For a detailed description of agro-ecological zones and land use, see *Agriculture Specialist Study*, Chapter 2, Agro-ecological Zones, and Chapter 3, Land Use.

For information on watershed processes, geomorphology and landforms, and sediment problems, see *River Sedimentation and Morphology Specialist Study*, Chapters 2, 3 and 4 of these names.

4.2 NATURAL BIOLOGICAL ENVIRONMENT

4.2.1 Wetland and Upland Biological Systems

For information on wetland biodiversity (species, habitats, ecosystems), wetland values, and key wetland sites, see the *Wetland Specialist Study*. The final version will be renamed *Wetland and Upland Biodiversity Specialist Study*, and information on upland biological systems added.

4.2.2 Openwater Fishery

For details on openwater fishery biodiversity and key fisheries sites, see *Fisheries Specialist Study*, Section 2.2, Fish Biodiversity, (pp. 25-33).

4.3 SOCIOECONOMIC ENVIRONMENT

4.3.1 Economic Development

For a description of regional agricultural development, see *Agriculture Specialist Study*, Chapter 4, Present Production System.

For a description of openwater and aquaculture fisheries production, see *Fisheries Specialists Study*, Section 2.5, Fish Production Trends; Section 2.6, Post-harvest Sector.

For a description of water transport systems, see *Water Transport Study*.

For an overview of existing FCD and irrigation development and descriptions of each project, see *Regional Water Resources Development Status*.

4.3.2 Social Development and Quality of Life

For information on demography, quality of life indicators, and human resources development, see *Population Characteristics and the State of Human Development*.

For information on urban centres, manufacturing, and urbanization, see *Study on Urbanization*.

For information on the role of NGOs, see *Participatory Development and the Role of NGOs*.

For information on local initiatives and people's participation in the management of water resources, see the study of this title.

For information on village social anthropology case studies, see *Social Dynamics in Kangsha River Basin*, *The People of Kaliagota Haor*, and the Project Monitoring Programme (PMP) Studies entitled *Manu River FCDI Project* and *Shanir Haor FCD Project*.

For information on local people's dependence on natural wetland products and services, and on institutions with roles in wetland management and exploitation, see *Wetland Resources Study*, Section 3.3.4, Plant Utilization, and Section 3.5.5, Wildlife Utilization. Additional information from village case studies at six sites in three key wetland sites will be added to the final version of this study.

For information on fishing employment, income, and welfare, and fisheries institutions, policy, and projects, see *Fisheries Specialist Study*, Sections 2.7 and 2.8, titled accordingly.

4.4 PEOPLE'S PERCEPTIONS

People's perceptions of the existing environment are documented in most of the studies cited above. Additional information is presented in the proceedings of the seven NERP district seminars and the NERP Haor Fisheries Seminar. Some of this information is summarized in Chapter 5 below.

CHAPTER 5: SCOPING — PUBLIC CONSULTATION AND IDENTIFICATION OF IMPORTANT ENVIRONMENTAL COMPONENTS

5.1 INTRODUCTION

Scoping is the process by which the important environmental issues, project alternatives, and important environmental components are identified by the interested parties (p. 6-4, *Manual for Environmental Impact Assessment*; FAP 16, 1992). It is an early step of environmental assessment which is designed specifically for public involvement. Public consultation, in addition to providing access by the public to the assessment process, is also intended to create the opportunity for a two-way information exchange between the project team and interested parties outside it (p. 3-10).

5.2 PUBLIC CONSULTATION PROCESS

5.2.1 Introduction

The preparation of the Northeast Regional Water Management Plan is an initial phase in a longer term development process that aims to improve the region's water management systems and infrastructure. The regional water management plan process was carried through pre-feasibility analysis of the various identified initiatives. Subsequent phases of this process will include *inter alia* feasibility level analysis, detailed design, implementation, and operation and maintenance of water management projects.

In this context, the goal of the public consultation undertaken during the regional planning exercise was to lay the foundation for an ongoing dialogue between the public and the technical and policy-making entities involved in water development planning. The elements of this foundation are:

- Obtain local knowledge and ideas relating to the development of the project plan;
- Provide local people with the opportunity to have a voice in the exploration, planning, implementation, monitoring, and evaluation of the projects;
- Involve people in assessing likely project impacts and in anticipating unexpected outcome or side-effects;
- Uncover potential social conflicts arising from the project interventions early and gauge the likelihood of satisfactory resolution through negotiation; and,
- Identify a framework for appropriate institutions and procedures to enable local people to participate in the planning, construction, operation, and maintenance phases of the project.

The consultation process involved interaction with regional water management stake holders at various levels and included: case studies, public seminars, FAP interim conferences, informal field meetings between multi-disciplinary teams and residents, and specialist seminars. These are described in the following paragraphs. In addition, NERP planning took into consideration the results of the National Conservation Strategy, National Environment Management Action Plan, and the Forestry Master Plan, each of which had its own public consultation inputs and ran concurrently with NERP.

5.2.2 Case Studies

Social Anthropology
The first level of interaction was through four detailed social anthropology case studies, each in a different agro-ecological zone; two of which were conducted within the boundaries of existing water management projects, and two of which were conducted in areas not directly associated with any infrastructure. This exercise involved placing a team composed of approximately half male and half female researchers within the area under study for a period of three months at each location. The researchers worked to a certain extent with structured survey instruments, but the primary intent was that informal relationships be established within the communities in which they were involved. Through these relationships, the complex interactions among the various groups were examined and analyzed in an effort to better understand how people interacted with their immediate physical environment and what was considered of highest priority in terms of attempting modifications to this environment. This intensive level of interaction involved between 300 and 500 people at each study location. Because of the gender composition of the research teams, women constituted about one-half of the constituents with whom the research team interacted. Other major (and sometimes overlapping) categories of constituents included landless persons, farmers, and fishermen.

Wetland Resource Utilization and Management
As input to the *Wetland Resources Specialist Study*, village-level case studies of wetland resource utilization and management were carried out over a period of three months at six sites in three of the key wetlands, by a team of three female and four male field workers.

5.2.3 Public Seminars

The second level of interaction was through a series of seven public seminars organized in the major communities within the region. While these were open to the general public, invitations were issued to community leaders and representatives of special interest groups. For each community these included: the members of Parliament, deputy commissioners, officials from the various government and semi-government agencies with offices in the community, *thana nirbahi* officers, chairmen of farmer cooperatives, union *parishad* chairmen, the press, teachers, and NGO representatives. On average, about 150 persons were invited to each of the public seminars; actual attendance ranged from 200 to 300 persons at each.

In preparation for each meeting, a technical brief was prepared and circulated in both English and Bangla, along with formal letters of invitation. Each meeting had a duration of one day (about seven hours). Following a short inaugural session, the study team would present, based on the technical analysis, what they considered priority intervention points in local surface water systems. Each of the members of Parliament then formally responded to these suggestions and in many cases countered with other suggestions. This was followed by an open discussion session. Following a break for lunch, the plenary would be divided into four or five small groups and these smaller groups would undertake a more detailed discussion on various aspects of the problems and solutions which had been defined in the earlier sessions. This was followed by a session in which the representatives of the small groups reported back to the plenary.

The sessions were mainly conducted in Bangla. In all cases, the sessions were audio-taped (in some cases they were also videotaped) and the audiotapes were transcribed and published in a series of proceedings. Prior to finalizing the proceedings, drafts were circulated back to the key speakers to ensure that the proceedings accurately reflected the discussions. Copies of the proceedings were then made available to participants.

5.2.4 FAP Interim Conferences

The third level of public consultation occurred in the context of two interim conferences which were organized by the Flood Plan Coordination Organization and held in Dhaka. Each had a duration of about five days and were conducted to allow interaction among interested members of the national and international community with an interest in the issues surrounding the Flood Action Plan. Conference participants included the prime minister, ministers, members of Parliament, senior representatives from the various governments and funding agencies actively involved in the Flood Action Plan, representatives from the international and national NGO community, representatives from various government agencies directly and indirectly associated with the Flood Action Plan, the press, and independent scholars and professionals.

Each forum consisted of presentations followed by a question period; different topics were covered each year. The proceedings of these conferences were audio-taped, transcribed, and copies made available to conference participants.

5.2.5 Informal Meetings

The concerns identified in the more formal consultations described above (and in other ways) were followed up at the pre-feasibility study stage through informal personal interviews, group discussions and meetings with various cross sections of people. These discussions were undertaken by the pre-feasibility study multi-disciplinary teams, which were composed of a mix of water resource planners, sociologists, fisheries specialists, river engineers, agriculturalists, and environmental scientists. A significant amount of their time in the field was spent in dialogue with local residents. These discussions formed the basis for the intervention concepts for each of the initiatives. The meetings took place in villages, farmers fields, fishermen communities throughout the impacted area. A decided advantage of this approach was that immediate physical verification of information was often possible.

Some of the specialist study field investigations, in particular the fisheries, wetland resources, and existing water resources development studies, also made significant use of informal meetings, in the field with local residents and with other interested parties, to gather information and identify issues.

5.2.6 Specialist Seminars

Fisheries Seminar

A seminar was organized with an explicit focus on (and participation by representatives of) the community who either earn their livelihood directly or indirectly from open water capture fisheries or who had a strong and vested interest in the sector. The general format of this meeting was similar to that of the public hearings. As with the public hearings, discussions were

89

documented, proceedings were published and made available to interested persons or groups. An estimated 200 people attended this seminar which was held in Sylhet.

Aquatic Wastewater Treatment Seminar
A half-day seminar on aquatic wastewater was organized in early 1993, which was attended by about 20 representatives of government agencies and NGOs.

Seminar on Biodiversity, Wetlands, and Surface Water Quality of the Northeast Region
This seminar in April 1994 was organized to present NERP's findings and recommendations in these areas to the policy-making and technical community for their information and comments. The meeting was attended by about 150 persons, including the Minister of Irrigation and the Minister of Environment and Forests, other government officials, NGO and donor representatives, and others.

5.3 PUBLIC RESPONSE — SUMMARY OF CONCERNS

Through the process described above, there were a number of common themes which emerged in relation to water management requirements. These are summarized below.

Prevent crop damage resulting from flooding and drainage congestion
Damage occurs mainly to *boro, aus* and b *aman* rice due to flash floods in the pre-monsoon season and to *aman* rice due to monsoon flooding. The effect of the floods is further aggravated by inadequate drainage of localized rainfall and slow drainage in the post-monsoon season. The latter inhibits production of *rabi* crops and delays transplanting *boro* seedlings exposing the crop to damage from early flash floods. Where farmers are unable to transplant *boro* seedlings by the end of January because of poor drainage, the land remains fallow throughout the year.

Reduce silting of rivers and beels
Rivers and channels are losing their conveyance capacity as they infill with sediment. In addition to inhibiting drainage, this restrict fish migration and hampers navigation. In some hydraulic regimes, this phenomena results in rivers or channels avulsing and considerable damage is caused as the river assumes a new course. Beel siltation reduces the volume and area of dry season aquatic habitat, and has effectively converted some beels from a permanent wetland status to a seasonal status. This loss of habitat negatively affects fish production. Agricultural production is also negatively impacted in these areas since farmers, because of a shortage of water for irrigation, are compelled to shift from *boro* which potentially has high yields to b *aman* which produces lower yields.

Control sand deposition on cultivated land
Sand deposition on agricultural land which occurs during flash floods, destroys standing crops and negatively impacts on soil fertility. The end result is that the affected land is no longer suitable for crop production.

Recognize the importance of navigation
Concern was repeatedly expressed that boat transportation between the *haors* and the rivers was being disrupted at critical points. A major cause of this included past embankments which were constructed without regard for navigation. To accommodate the need for navigation,

embankments are frequently cut but this can have adverse impacts on other production sectors. The need to improve and maintain river transportation along the alluvial fans was also regarded as a high priority.

Improve openwater fisheries management
Poor fishermen have been badly affected by their exclusion from open water fishing which is imposed by powerful *jalmohal* lease-holders who are frequently not part of the local community. It has generally been found that local fishermen will ensure the sustainability of a local resource and that the system should afford some preference to local lease-holders. Fishermen considered that de-watering of *jalmohals* was one of the major causes of long term declining trends in fish production.

Provide treatment for industrial effluent
Fishermen expressed concern that the industrial effluent being dumped into the Surma River at Chhatak by the Sylhet Pulp and Paper Mill and into the Kushiyara River at Fenchuganj by the fertilizer factory[2] is affecting their livelihood. Introduction of these chemicals into the river system is killing fish or rendering them unfit for human consumption.

Assist in protecting homesteads from wave action
Damage to homesteads by monsoon season wave action was reported as a major problem, particularly in the deeply flooded area. Many villages in deeply flooded areas are eroding rapidly.

Reduce disruption of fish migratory routes
Indiscriminate road construction was identified as disrupting the natural drainage system and obstructing fish movement. Closures and embankments were also identified as being responsible for disrupting fish migratory routes. This is contributing to declining fish production.

Introduce measures to conserve wetlands
The need for conserving the remaining wetlands and fish sanctuaries were highlighted by the local people.

5.4 INTEGRATION OF PUBLIC CONCERNS INTO REGIONAL PLANNING

As described above, water management problems and potential remedial interventions were broadly discussed at the more formal public hearings. Intervention concepts were then refined based on a combination of technical analysis and field investigations, including dialogue organized on an informal basis with individuals or community groups.

The results of these discussions were reflected in each of the pre-feasibility studies prepared around the various intervention concepts as part of the regional planning process. These were distributed to community representatives for their information. Public concerns were integrated into intervention concepts in numerous ways, some novel for Bangladesh.

[2]Closed December 1993. A new factory is planned for the site.

To protect crops from flooding and drainage congestion, structural and non-structural measures are used, often in combination depending on the situation in each location. Structural measures include water control structures, dwarf embankments, bottom-open embankments, high embankments, re-excavation of rivers and *khals*. Non-structural measures include improved flood forecasting and warning, flood proofing, and institutional strengthening. Given that structural measures introduce negative as well as positive impacts, these are suggested only in circumstances where they are considered essential. Bottom-open embankments are generally a preferred option since they protect crops from upstream early monsoon flooding with minimal disruption to navigation and fish. Structural measures are designed to reduce silting in *beels* and to protect cultivated areas from sand deposition. Fish pass structures are proposed on a pilot basis to reduce the disruption to migratory fish. If successful, these could become an integral part of many existing and new structural initiatives.

Mechanical dredging of rivers and manual re-excavation of rivers and *khals* was suggested in places where these were considered to be beneficial. The dredging and channel re-excavation would make a substantial contribution to improved drainage and improved navigability in the region, but would need to be carried out in concert with other structural measures such as embankments and river training works to be fully effective. Utilization of dredged material could be used to construct embankments or to raise village platforms. Lowland afforestation has been identified as a means to reduce erosion of village platforms. This would improve fisheries habitat leading to increased fish production.

The Regional Plan includes several initiatives that are expected to increase fish production. The objective of the *Fisheries Management Programme* is to improve biological management of the floodplain fishery through direct interventions in fisheries habitats and indirectly through assistance to New Fisheries Management Policy (NFMP) fishermen associations leading to improvements in management of community fisheries. *Fisheries Engineering Measures* would maintain or re-establish migration routes by providing fish pass structures in embankments; and protect selected beels from sedimentation and increase *beel* water by constructing protective embankments. *Pond Aquaculture* is expected to increase fish production through concentrated and highly supervised demonstration ponds, and to improve the socio-economic situation of small and landless farmers.

The *Northeast Region Environment Management, Research, and Education Project* (NEMREP) includes several initiatives aimed at biodiversity protection, surface water quality management, including institutional issues in these two areas. The concerns expressed in respect of conservation of key wetland sites and pollution from industrial effluent are addressed through these initiatives. The biodiversity initiatives include restoration and improved management of key habitats, reflecting the close relationship between biodiversity and forestry.

5.5 IMPORTANT ENVIRONMENTAL COMPONENTS

IECs are simply those components of the biophysical or socioeconomic environment of importance to one or more of the interested parties (including future interested parties who cannot participate in the scoping) that could be impacted by the proposed intervention.

Impacts of a proposed intervention on the total set of IECs are typically represented using a subset of selected IECs, chosen such that the range of important effects will be captured. The use of such a subset allows an impact assessment to be more focused and manageable for both its preparers and audience. Particularly useful types of IECs include those which function as indicators for a number of other components, species, or characteristics (including surrogate measurements), those key to systemic structures or functions, and those related to rare, endangered, sensitive, unique or other biophysical or socioeconomic (including ecological, cultural, aesthetic, scientific, and biodiversity) assets (p. 3-9, *Manual for Environmental Impact Assessment*; FAP 16, 1992).

A preliminary set of IECs, grouped under ten major headings, was defined for use in the FCD pre-feasibility studies; these are listed in Table 5.1. The major groups appear as the column headings in the environmental screening matrix used by the pre-feasibility study teams (Figure 2). IECs were added to this core set as the need arose in individual project studies and in assessing the Plan.

92

Table 5.1: Important Environmental Components

Agriculture
- Rice cropped area
- Non-rice cropped area
- Rice cropped area without flood damage
- Cereal production
- Non-cereal production

Openwater Fisheries
- Floodplain area
- *Beel* area
- River and channel area
- Number of river *duars*
- Migration access (i.e. effects of channel closures, fish passes)
- River/channel volume (i.e. effects of sedimentation, dredging/re-excavation)
- Mother fishery area
- Habitat condition
- Biological management
- Production

Culture Fisheries
- Pond area
- Flood risk to ponds
- Production

Water Quantity
- River water levels
- River discharges
- Floodplain water levels and flows — date of pre-monsoon flood onset, post-monsoon river water levels, drainage regime: fully embanked/submersibly embanked/open embankments/not embanked
- Least available depths on navigation routes
- Ground water and surface water irrigation availability and usage

Water Quality
- Water quality effects of water quantity changes — impacts of flushing, stagnation, dilution, transport changes
- Pesticide usage
- Fertilizer usage
- Industrial discharges
- Disposal of human wastes — rural and urban
- Access to safe domestic water supply — rural and urban

Human Health
- Food availability by type
- Access to safe domestic water supply

Social Issues
- Owner employment
- Hired agricultural employment
- Fishing employment
- Displacement of homesteads
- Resource management conflicts (farmers/fishermen/boatmen)
- Socioeconomic equity of impacts
- Gender equity of impacts

Wild Plants and Animals
- Key wetland sites conditions
- Threatened ecological communities (swamp forest, reed land, floodplain grassland) area and conditions
- Threatened species populations
- Summer wetland habitat area
- Winter wetland habitat area
- Regional biodiversity

Hazards
- Modification of floodplain flood risks/damage to settlements, infrastructure, agriculture, aquaculture
- Modification of homestead erosion
- Modification of piedmont catastrophic flash flood risk
- Modification of risks associated with earthquakes

Other
- River morphology (channel degradation/aggradation, avulsions)
- Other impacts outside of project area
- Effect of embankments/closures on navigation
- Road transportation impacts of embankments
- Mechanization and fossil fuel consumption

CHAPTER 6: OVERVIEW OF KEY BIOPHYSICAL RESPONSE AND IMPACT PROCESSES

6.1 INTRODUCTION

This chapter discusses in general terms how key biophysical systems are thought to respond to and be impacted by the kinds of measures included in the Regional Plan portfolio of initiatives. The terms 'respond' and 'response' are used here to capture the dynamic nature of some of the processes. The issues and components discussed here are in respect of river morphology; regional surface water; water quality; fisheries; and grazing lands, wetlands, and threatened ecological communities.

This discussion picks up from the description of basic principles of FCD and river improvement projects (Section 3.2), and leads into the presentation of assessment methodologies (Chapter 7) and the impact assessment (Chapter 9).

6.2 HYDROLOGY, HYDRAULICS, AND RIVER MORPHOLOGY RESPONSES TO FCD

6.2.1 Introduction

This section reviews past findings and experience concerning physical impacts of flood control works. These comments are intended to illustrate some of the main physical processes that take place when FCD projects are constructed. The main topics in this section include hydrologic, hydraulic, and morphologic responses. These physical responses are important because they may govern the nature of many other environmental impacts such as changes in habitat characteristics and water quality.

Potential hydrological, hydraulic and morphologic impacts have been considered for four types of interventions:

1. Construction of full flood control embankments and/or closure of distributary spill channels;
2. Construction of submersible embankments;
3. Loop cutting and channel re-locations; and
4. Drainage improvement by channel re-excavation.

6.2.2 Full Flood Control Embankments

River discharges are normally confined to the main channel until flows approach or exceed bankfull conditions. In most naturally formed river systems unaffected by downstream controls or backwater effects, the channel's bankfull discharge capacity tends to correspond to a relatively frequently occurring annual flood. Although conditions vary according to local hydrology and geological setting, bankfull conditions on many rivers throughout the world have been found to correspond to an annual recurrence interval of between two to five years. Similar conditions have been found on several rivers in the Northeast Region outside the deeply flooded Central Basin which is affected by backwater from the Meghna River system.

Once bankfull conditions are approached or exceeded, water and sediment will spill onto the floodplain by several mechanisms, including direct overtopping of banks, through breaching of banks, or as spills through distributaries or *khals* that connect the main channel with the lower-lying flood basins. A portion of the fine sediment load will be deposited overbank in flood basins where velocities are low, while some of the sand load is deposited as natural levees or crevasse splays near the main channel.

Floodplains are important hydrologically because they provide overbank conveyance and storage which can reduce peak flows and attenuate flood hydrographs. The magnitude of these floodplain flows can be substantial. Discharge measurements were made in the Kushiyara floodplain in 1993 at three locations where the floodplain discharges are reasonably confined; at Sheola, Fenchuganj, and Sherpur. These measurements demonstrate that the floodplain discharge in a major flood can be as large as that in the main river channel (at Fenchuganj), or, stated another way, that the floodplain can carry as much as one-half of the total discharge. Floodplain flows in the Central Basin are more difficult to measure, but model results indicate that as much as three-quarters of the total flow is carried on the floodplain during the monsoon season and very little in the main channel.

An illustration of the storage effect is provided in Figure 4, which compares the 1991 water year total inflow to the Northeast Region with the outflow at Bhairab Bazaar. The inflow hydrograph includes all the border stream inflows, which were mostly determined by direct measurement, plus local runoff from ungauged areas within Bangladesh as calculated with the NAM rainfall-runoff model. From these hydrographs, it can be seen that inflow and outflow volumes are equal over the year, but that peak outflows are considerably damped and delayed. Up to 25 km^3 of water was stored on the floodplain during the peak of the monsoon season during 1991. Runoff peaks are attenuated by storage effects, such that the individual flood events are not apparent in the outflow hydrograph. It can also be seen that without floodplain storage, the peak outflow from the region would be approximately 50% higher that at present.

Cutting off floodplain spills by means of embankments and *khal* closures will increase main channel discharges due to direct flow confinement. Examples of such project impacts can be provided from several past developments in the region.

For example, full embankments and *khal* closures have been constructed along the Kushiyara and the Surma left bank since the 1960's. One effect has been to reduce floodplain discharge. This change can be seen in Figure 5, which shows the floodplain discharge and Kushiyara River at Sheola discharge (note that the Sada Khal floodplain gauge was discontinued in 1977 but has recently been reactivated). Floodplain discharge has declined while river discharge has increased.

Impacts on water levels are apparent in Figure 6 which shows Sheola water levels since 1949. It would appear from this graph that Sheola peak water levels have risen by approximately 0.5 m during that time period, mostly before 1978, which coincides generally with the history of embankment works along the river and changes in floodplain discharge.

Another example of embankment impacts can be illustrated from experience with the Khowai River Project near Habiganj. Full flood control embankments along the Khowai were constructed in the 1970's and early 1980's. Figure 7 and 8 show time series of historic water levels and discharges at various locations along the Khowai since 1964. In the un-embanked upper reaches, water levels do not show noticeable trends over time, whereas in the embanked reach levels and peak discharge have risen dramatically.

Once embankments are in place, river channel geometry, longitudinal profile, and morphology will respond, subject to various types of physical constraints, to the changed hydrologic regime. Figure 9 illustrates an idealized case of river responses following construction of embankments. Initial hydraulic changes include:

- Increased main channel velocities and depths during large floods. Water surface slopes will increase through the embanked reach, producing an afflux, with the greatest water level rise occurring at the embankments' upstream end;

- An M-1 type backwater profile upstream of the embankments due to higher water levels in the embanked reach.[1] Levels will gradually converge to pre-project levels upstream of the embankment.

- Increased sediment loads during high floods through the embanked reach due to higher velocities, depths, and slopes. The implications of this for river erosion can be considerable, since sediment transport in fine sand-bed channels is quite sensitive to small changes in velocity or stream power. As a result, the channel will tend to degrade through the embanked reach, since its transport capacity will exceed the sediment supply from upstream.

After embankments are constructed, most of the sediment will tend to be flushed through the confined reach, due to higher in-channel velocities. However, rapid aggradation may occur downstream of the confined reach, particularly if there are large spills onto the floodplain or if the slope decreases appreciably below the confined reach. In some situations, sediment deposition will take place primarily overbank on the floodplain, so that overall impacts to the main channel may be relatively minor. In the long term, downstream aggradation may initiate further slope adjustments along the river, eventually causing backwater effects to propagate upstream, leading to further increases in water levels in the embanked reach.

The preceding comments describe the response of the river bed in the main channel. Additional changes may occur to the berms, the overbank section of the river between the embankment and the top of the channel bank. It is commonly perceived that berms aggrade rapidly after embankments are constructed. However, it is difficult to verify this claim with the available historic survey data. In fact, berm elevations along embanked sections of the Surma River and Kushiyara River do not appear to have changed much over the last 20 years. Overbank deposition rates are probably highest when high-velocity main channel flows breach through inner banks and spill into low basins or slack water floodplain areas. On most past projects in the region, the embankment set-back distance has been very small leaving narrow berms. As a

[1] An M_1 water surface profile is created when the water is backed up upstream of a constriction or barrier.

result, the overall hydraulic impacts of berm deposition tend to be relatively small in comparison to the initial confinement effect associated with embankment construction.

Flood embankments also affect the lateral stability of rivers. Natural rivers flowing through alluvium are found to adjust their channel geometry to accommodate a dominant discharge. Observations on many rivers throughout the world show the average top width (*W*) of an alluvial channel is related to the dominant or bankfull discharge, *Q*, by:

$$W \propto Q^{1/2}$$

where dominant discharge *Q* is represented by a relatively frequently recurring flood discharge (typically, return period of 18 months to two years).

Full embankments lead to an increase in in-channel flood discharge, which effectively raises the dominant discharge in the confined reach. Consequently, if the banks are not protected, the channel will tend to widen over time as a result of bank erosion. Table 6.1 shows the expected change in width (expressed in percent) for various changes in channel-forming discharges. Observed changes in top widths after completion of embankment projects along the Upper Surma, Upper Kushiyara, Manu, and Khowai Rivers generally agree with estimates derived from simple regime-type equations.

In fact, enlargement of channel cross section appears to be one of the principal responses in embanked reaches of the region. This enlargement may partially offset confinement effects from the embankments, particularly at moderate flow conditions. For example, most specific gauge plots in embanked reaches indicate that river stages have decreased slightly over time, when compared at any given discharge.

The long-term response of a river channel to increased flood flows due to confinement can be considerably more complex, particularly when local geomorphic controls are present. For example, long-term increases in flood discharge and sediment inflow can cause a change in channel type, not just size: a previously meandering channel can change into a predominantly split or anastomosing one, for example. A transformation of this kind produces major changes to channel geometry, channel migration pattern, and sedimentation patterns.

6.2.3 Submersible (Partial Flood Control) Embankments

Submersible embankments reduce floodplain discharges and increase in-channel discharges, especially during the pre-monsoon period. They tend to concentrate floodplain discharges and overbank spills into fewer locations and more specific spill points, often at locations where embankments are eroded and channel erosion/deposition problems are occurring.

Further, while water level and discharge effects may be negligible for individual submersible embankment projects, several such projects occurring together within a drainage system can produce significant cumulative effects on water levels and flows.

In the past in the Northeast Region, this potential for cumulative impacts was not appreciated and numerous submersible embankment projects were built throughout the Central Basin without planning for systemic drainage and other requirements. As it has turned out, their potential for cumulative impact has been not been fully realized as a result of frequent embankment breeches, wave damage, public cuts, and incomplete structures and embankments. It is expected that if these projects became fully operational (as could happen if in the future they were rehabilitated), they would have significant impacts on pre-monsoon and in some cases monsoon water levels and flows.

Table 6.1: Effect of Confinement on Channel Width

% Increase in Dominant Discharge	% Increase in Channel Width
10	5
20	10
30	14
50	22

The assumption that monsoon conditions are less affected by submersible embankments than by full flood embankments holds good where monsoon water levels are distinctly higher than pre-monsoon water levels. For example, the difference between a 1:10 year pre-monsoon flood and an average monsoon flood varies between one to three metres in the region. In locations with only one metre difference, submersible embankments having normal freeboard allowances will begin to encroach on the lower-magnitude monsoon flood flows. In these cases, the kinds of impacts associated with full flood control embankments will begin to be experienced.

Outside the Central Basin, morphologic impacts from submersible embankments are expected to be relatively minor in comparison to full flood control embankments since the structures are designed to be overtopped during the period of highest flows. Berm deposition could be accentuated since the submersible embankments will tend to trap fine sediments carried overbank during the monsoon season.

Impacts of submersible embankments on rivers flowing through the deeply flooded Central Basin may be appreciable. Most sediment transport on these rivers takes place during the pre-monsoon season (April and early May), when channel velocities and water surface slopes have their highest values. Later, during the monsoon season, backwater from the Meghna River drowns the rivers and reduces their slopes, channel velocities, and sediment transport capacity. Thus, through their effects on discharges and velocities in these rivers during the morphologically active pre-monsoon period, submersible embankments could conceivably have an appreciable effect on sediment transport regimes and channel responses similar to those described above for full flood embankments i.e. initial degradation and channel enlargement in the embanked reach).

6.2.4 Loop Cuts

Loop cuts reduce the effective length of the river, particularly during low-to-medium flows, thereby increasing river slopes and lowering upstream water levels. Hydrologic impacts of individual loop cuts depend on the initial river slope and the channel length reduction relative to original channel length. Impacts tend to be relatively small in the Northeast Region where river slopes are relatively low.

Impacts of loop cuts are reduced during flood stages when a large portion of the flow passes onto the floodplain and is therefore not affected by the channel changes. These changes become more significant when the loop cuts are combined with adjacent embankments which modify the overbank flows.

The main morphologic impacts from loop cuts arise from the change in slope through the shortened reach. These impacts are illustrated in Figure 10, which shows a simplified model of a9

channel changes from a series of loop cuts on a piedmont river. In the artificially straightened reach, the slope will be increased, water levels will be lowered and the water surface will develop an M-2 type drawdown profile. As a result, the velocity and sediment transport capacity will increase through the straightened reach. This will initiate channel degradation, leading to further reductions in water levels. This secondary degradation will initiate further slope adjustments upstream, leading to a transient degradation wave progressing along the river.

If the natural channel slope flattens out downstream of the straightened reach, there can be appreciable aggradation immediately downstream of the loop cut. This aggradation occurs because the lower reach's sediment transport capacity will be substantially less than the transport rate in the straightened reach.

Loop cut impacts can be very unpredictable. If the excavated pilot channel runs near inerodible plugs or through highly variable bed and bank materials, the pilot cut will not enlarge uniformly and a channel of highly irregular width and depth may develop. If the bed and banks contain cohesive materials, the channel will not enlarge to a full cross-section, which will produce a local high-velocity constriction. This situation appears have occurred at loop cuts on the Kalni, Baulai, and Khowai Rivers.

Loop cuts may also impact lateral channel processes by modifying the channel pattern and sinuosity and by initiating new bank erosion.

6.2.5 Drainage Improvement

Drainage improvement here refers to widening and/or deepening drainage channels.

Hydrologic impacts are primarily limited to the provision of faster post-monsoon drainage which results in water levels falling more quickly after monsoon peaks have passed. Impacts on pre-monsoon and monsoon flood levels are generally smaller in magnitude, but this depends on the nature of the drainage constriction and the magnitude of the channel changes. Drainage works can also be designed to provide lower water levels to drain *beels* and other low-lying areas, but in such cases water control structures regulators are generally provided to allow control of drainage rates and water levels.

6.3 WATER QUALITY IMPACTS

The ecology of water quality is, of course, extremely complex. Important considerations include, but are not limited to: inputs of chemical and biological contaminants; flushing and dilution rates; *in situ* physical, chemical, and biological processes involving, among other things, micro- and macrophytes, sediments, and vector biology; and end users' requirements and water handling practices.

A number of the Regional Plan initiatives address water quality. The intervention point varies. *Ground Water Investigation* and *Regional Surface Water Quality* address the need to improve the management of water quality, starting with better information about water quality and water quality ecology. *Urban Sanitation, Urban Water Supply, Village Water Supply and Sanitation*, and *Aquatic plant-Based Wastewater Treatment* address the need to improve public health through safe domestic water supplies, improved management and treatment of human wastes, and rural hygiene education. *Pulp and Paper Mill Effluent Treatment* and *Pollution Abatement at Smaller Industrial Facilities* address the need to protect public health and environmental systems from industrial pollutants.

Many more Regional Plan initiatives indirectly affect water quality. Each of the water resources infrastructure development projects can be expected to change spatial and temporal patterns of water volumes and discharges, which in turn will affect flushing and dilution directly, and other processes indirectly. These latter include important water quality problems posed by the *intensification* of agriculture, which implies increasing use of fertilizers, pesticides, and irrigation water, and by the *extension* of agriculture (*boro* rice) into *beel* areas.

Habitat restoration programmes can be expected to improve water quality through biological and mechanical processes associated with or supported by them.

6.4 OPENWATER FISHERIES IMPACTS

The *Fisheries Specialist Study* describes the response of the openwater fishery to environmental processes, including the various types of water resources development interventions in a series of case studies of areas within and outside existing FCD projects in the Northeast Region (Section 3.1 and Appendices H through K). This information is very briefly summarized here.

Non-FCD negative factor complex

Openwater fisheries both inside and outside of FCD projects have significant problems. An analysis of numerous FCD and non-FCD case studies suggests that, independent of FCD-related stresses, the openwater fishery is under stress from a complex of negative, non-FCD, factors.

The major factors appear to be:

- Overfishing from the use of *karent jal*. This is a small mesh 2 to 5 cm stretched monofilament net used to catch small species and juveniles. It is considered to be one of the most important causes for fish decline. Other illegal nets are also a problem.

- Reduction of dry season water volume, area, and duration, and obstructions to timely migration from siltation in *beels* and rivers. (The siltation in beels and rivers can also be a FCD related negative impact.) Fish movement is particularly affected by the siltation which naturally occurs at the outfalls of dying channels.

- Destruction of *beel* habitat from de-watering to allow *boro* to be grown in low pockets where residual moisture is plentiful, accompanied by deteriorating water quality in remnant *beels* surrounded by *boro* cultivation.

- Reduction in *boro mach* production due to the decrease from three years to one year of the interval between *katha* harvests. *Katha* are piles of tree branches and bushes set on river and *beel* bottoms which attract fish by providing shelter from predators and increased bark and periphyton food supply.

- Destruction of productive fish habitats, in particular stands of swamp forest and reed swamp vegetation.

Other contributing factors include:

- Fish ulcerative disease.
- Declining wild water fowl populations — droppings are an important source of nutrients.
- Problems with *jalmohal* system: declining lease terms, conflicts between lessees.
- Surma River: water pollution from Sylhet Pulp and Paper Mill and formerly Fenchuganj fertilizer factory.
- Hakaluki Haor and Bara Haor: occasional mass river fish mortality which local people think may be caused by poisonous plants entering the river upstream in India.
- Hakaluki Haor: poor water quality in the April/May breeding season due to decomposition of rice plant roots and stems.
- Lubha River: dynamite fishing.

This negative factor complex contributes to the FWO scenario. Elements of it are addressed by the *Fisheries Management Programme*.

Flood control
Flood control projects in the region are of two types: full flood control and partial flood control. The very different fisheries impacts of existing projects of the two types are discussed below.

While reading the discussion that follows, it is important to bear in mind that the *actual* operation and impacts of many flood control projects differ from the *intended* operation and impacts. Most of these operational problems tend to reduce negative fisheries impacts: this is the case for premature overtopping of submersible embankments; embankment breaches; and public cuts. The only operational problems which tend to exacerbate fisheries losses are delay or failure to open water control structures, and failure to retain water (both of which commonly occur with the widely-used fall-board type of structure).

Full flood control
Two-thirds of existing full flood control projects studied were found to have negative or mixed (part positive, part negative) impacts on the openwater fishery. Negative impacts centred on general reduction and disruption of aquatic habitat and area, and on interference with fish migration and reproduction. Case studies of 19 full flood control projects, with and without provision for pumped drainage and including four projects that channelized rivers, found seven projects with no impacts, three with mixed impacts, and nine with negative impacts.

Partial flood control
Existing partial flood control projects were found to be much less harmful to fisheries than full flood control. One-half had no impact. Of the rest, only one-third had mixed or negative impacts, while one-fifth were thought to have had positive effects, arising from higher dry season water levels, which improve *katha* fisheries, and from protection from siltation. Case studies of 18 partial flood control projects found four projects with positive fisheries impacts, eight with no impacts, two with mixed impacts, and four with negative impacts.

Drainage improvement
Of the limited number of existing river and *khal* re-excavation projects in the region, all were reported to have had no or positive impacts. Benefits are probably due to greater habitat depth, better flow regime, and improved connections with other habitats and fish stocks. Case studies

of six drainage improvement projects found two projects with positive fisheries impacts and four with no impacts.

A caution would be that, assuming these results are significant (they may not be, given the small number of projects), drainage improvement is benign but of limited benefit for enhancing fisheries habitat and for mitigating fisheries damage from FCD or other processes. To increase positive fisheries impacts, there may be a need incorporate specific fisheries elements in the detailed design of drainage improvements (e.g. variations in depth, non-straight channels, artificial habitat enhancement, etc.), to create preferred habitats — assuming that this would be feasible, or could be made so through technical means.

Fish passes and beel embankments
Fish pass structures are intended to permit fish migration despite structural measures controlling or preventing flows of water. *Beel* embankments are intended to protect *beels* from sedimentation and increase water storage. Neither measure is currently in use in Bangladesh; they would be developed under the initiative *Fisheries Engineering*.

6.5 IMPACTS OF FCD ON ECOLOGICAL COMMUNITY

Ecological communities of the region are impacted in both quantity and quality by habitat loss and changes due to flood control and drainage projects, and unplanned intrusion of agricultural crops. All are directly related to the effects of a burgeoning human population attempting to fulfill basic needs for food, clothing and shelter. The ecosystem mainly impacted is the wetland ecosystem of the areas under FCD.

The International Wetland Research Bureau (1992) has listed an extensive number of functions and services provided by wetlands, all of which are applicable to Bangladesh. These include groundwater recharge and discharge, flood storage and desynchronization, shoreline stabilization and reduction of erosion, sediment trapping, nutrient retention/removal, support for food chains, fisheries production, and habitat for wildlife.

Previous developments which have affected wetlands, were planned and executed without any consideration for their impacts to wetland habitats or population. Construction of flood control and drainage projects dating back to the 1950s considered only the agricultural benefits, chiefly cereal production, during project feasibility studies. To date about 27% of the total land within the region has been enclosed within full flood control projects, approximately 33% under partial flood control and 5% under drainage improvement projects. Irreversible ecological changes in wetlands such as the haor basin of Sylhet have been predicted unless remedial steps are taken (AWB/IWRB 1992).

The wetland ecosystem has been markedly impacted in both quantity and quality by habitat destruction and conversion due to FCD interventions and corresponding rice monoculture based agriculture.

Loss of wetland areas occur through drainage for producing more agriculture land. An example is the drainage of Dubail beel in Surma-Kushiyara project, which caused a major part of the wetland to be lost after the *boro* crop was extended.

Changes in wetland status and quality have occurred through the diversion of water for irrigation, domestic or industrial purposes. Reductions in water quality occur through inflows of urban sewage, and agricultural and industrial effluent. The intensifying levels of agriculture practiced in the region require increasing quantities of nitrogenous fertilizers, much of which is manufactured within the country by plants which discharge ammonia, sulfuric acid and caustic soda to water bodies. Pulp mills, some of them even outside the national borders, discharge chlorinated phenols and mercury to mainstream rivers. DDT and other chlorinated hydrocarbons are still in use, often illegally, and high concentrations of such pesticides have been found in water and fish tissues. Sedimentation reduces depth in water bodes (*beels*) and adversely affects bottom fauna and flora. Suspended sediment loadings in rivers are normally high because of the high rate of erosion throughout the river basins, but the additional increases in sedimentation in some areas appear to be related to the increasing incidence of flood control embankments.

Introduction of exotic fish species as an attempt to bolster declining fish harvests is being financed by the multilateral development agencies and has caused concern for further declines in native stocks through competition and over-fishing.

Introduction of exotic plant species or mono practices of plants on or near embankments, new roads and flood protected areas has caused a decline in plant and wildlife diversity.

Some ecosystems need immediate preventive measures to protect the extinction of some endangered and threatened flora and fauna. Duars, swamp forest, reed lands and floodplain grasslands are economically and ecologically the most threatened ecosystem of the region. These areas need annual inundation to accomplish the life cycle of the micro and macro plants and animals. Some of these areas are used exclusively as breeding places of internationally and nationally recognized endangered species of flora and fauna.

Conservation of the remaining key wetlands and sustainable management of wetlands under conditions of increasingly intensive land and water management requires updated and accurate information and appropriate institutional support. Major problems with wetland conservation and management in the region include the absence of an acceptable database from which to determine priorities, and a lack of an acceptable approach for economic assessments so that the values of wetlands are fully reflected in projects. Because of the high human population densities and the intensive uses made of wetlands, their conservation and retention as viable habitats for fish and wildlife will have to depend on sound multiple use and adequate environmental planning for such use.

CHAPTER 7: ASSESSMENT METHODOLOGIES, DATA SOURCES, ASSUMPTIONS, AND INFORMATION DEFICIENCIES

7.1 INTRODUCTION

This chapter describes the specific methods used to assess impacts and key assumptions underlying the assessment.

Methods consist of:

- Tools used to plan and understand localized hydrologic impacts;
- Regional surface water model used to understand regional hydrologic impacts;
- Morphological impact assessment methodology;
- Agricultural impact assessment methodology;
- Fisheries production impact model;
- Wetland and grazing land impact model; and
- Qualitative ranking methodology

7.2 ASSESSMENT METHODOLOGIES AND DATA SOURCES

7.2.1 Hydrology

Data sources
Data used in the engineering analyses included existing topographic maps, historic climatological and hydrological records, river and *khal* cross-sections surveyed by BWDB Morphology Directorate and by SWMC, BWDB reports, MPO reports, personal field observations, and interviews with project area residents, and the recommendations of local representatives and BWDB officials.

Localized impacts
Many or most of the impacts of an FCD project stem from the primary changes the project induces in water levels and flow rates. Some of these impacts affect the project area; some the adjacent external rivers or floodplains; and others more remote downstream and sometimes upstream areas.

The impact of FCD projects on flooding in the internal project area is assessed by comparing the area's future-without-project (FWO) and future-with-project (FW) hydrological conditions. Areas under different depths of pre-monsoon and monsoon flooding are derived from superimposing corresponding FW and FWO water levels on the area-elevation curve. The differential areas are used as the basis for identifying potential improvements in agriculture, flood damage to homesteads, roads, and other infrastructure, and potential impacts on fisheries, wetlands, navigation channel depths, and so on.

Another key indicator is improvement or closure of existing water channels, which can have profound impacts on drainage, water quality, fisheries, and navigation.

The impact of FCD projects on dry season water levels are estimated from structure designs, physical changes to the drainage channels, and external water levels; and assumptions about how structures will be operated and how the project will affect pumping, redistribution, and consumption of water.

Regional impacts

Regional hydrologic impacts were assessed using the Northeast Regional Model, which was developed by the Surface Water Modelling Centre (SWMC) and the NERP modelling team. It has been calibrated to the 1991, 1992, and 1993 water year observed levels and flows.

The 1991 water year was used as the basis for the simulations. This year was selected because it was a relatively severe year, and because it had been used during model development and calibration. The 1991 floods had return periods ranging from two to 25 years; conditions were relatively severe during the pre-15 May pre-monsoon season.

Three scenarios were modelled: present conditions, future without Plan (FWO), and future with Plan (FW). Both future scenarios reflected the major changes expected to occur by 2015: implementation of the Tipaimukh Dam/Cachar Plain irrigation project in India, and expected morphological changes in the Kalni, Baulai, Khowai, Someswari-Shibganjdhala, and Jadukata Rivers. The FW scenario also included all the Plan FCD projects.

A number of limitations of this exercise should be kept in mind. Regional hydraulic and hydrologic processes are extremely complex, as is the model itself. Information on Tipaimukh Dam/Cachar Plain irrigation design and operation is sketchy. Changes in river morphology are difficult to predict accurately. The area at high risk from channel instability and erosion makes up less than 20% of the Region's land area, mainly in the alluvial fan areas, some piedmont streams, and parts of the haor and flood basin lands. Most of the region, particularly the flood plains of the Surma, Kushiyara, Meghna and Old Brahmaputra is morphologically stable. Channel beds are assumed to be fixed, so the model does not capture interactions between river morphology and water levels and discharges. In reality the channels will adjust to changing discharges by eroding or deposition, and this may reduce the impact of the projects on water levels. Pre-feasibility information was used for Plan FCD project design and operation characteristics. Further, the model approximates individual project's characteristics well enough for regional impact assessment, but not for assessment of individual projects' impacts. Datum corrections were undertaken based on information from the NERP/SOB second-order levelling program.

Therefore, the modelling results should be considered to be indicative of the changes which are to be expected rather than being absolutely correct.

Tipaimukh Dam break impacts

Modelling of a potential dam break is commonly done as part of the design of a large dam (in all likelihood a more detailed analysis has already been completed by the Indian authorities). In this study, the DAMBREAK module of the MIKE-11 computer model was used here to create model waves for illustrative purposes only. DAMBREAK simulates the dynamic behaviour of a flood wave given the dimensions of the reservoir and of the valley downstream of the dam and the dimensions and rate of formation of the breech. Previous experience demonstrates that modelling can reproduce dambreak flood wave characteristics reasonably well if the failure mode is adequately calibrated. We cannot and do not claim adequate calibration for these illustrative calculations.

7.2.2 Morphology

Some kinds of morphologic responses are reasonably predictable, but many others arise from stochastic processes whose predictability is intrinsically limited. For example, the long-term response of overall channel geometry (width and depth) to increased flood discharges can be estimated using empirical regime equations. But, if the river responds by avulsing and developing a new course or new channel pattern, these adjustments will be of secondary importance.

Other examples of unpredictability are provided by the instabilities of river systems on alluvial fans or aggrading river channels. In these settings, even small, local interventions can induce major perturbations. These disturbances can then propagate many kilometres downstream, initiating new impacts and new channel changes along the system.

These kinds of processes, which can greatly effect FCD infrastructure, are largely unpredictable over the time span considered by the Regional Plan, except in terms of general hazard identification and risk assessment.

Therefore, future morphologic characteristics in the region were assessed primarily qualitatively, using results of case histories from past project impacts, interpretive assessments using geomorphic methods and from simple regime theory calculations. General principles of river response prediction are based on information provided by Lacey (1929), Simons and Albertson (1960), Henderson (1963), de Vries (1971), and Joglekar (1971). In a few cases (such as on the Khowai, Kalni, and Someswari-Kangsha Rivers), additional computations were made using sediment transport predictors, or by conducting test calculations with a one-dimensional morphologic model (HEC-6). The hydrometric, hydraulic, and sediment transport data in the Northeast Region is simply inadequate for reliable region-wide assessments based on morphologic simulations using numerical models.

7.2.3 Agriculture

A description of current, FWO, and FW agricultural conditions for each project were prepared on the basis of secondary data, augmented by some primary data collected during brief field visits. Secondary agricultural data sources included the *Land Resources Appraisal for Agricultural Development in Bangladesh (Agroecological Zone Reports)* for soils, Water Resources Planning Organization data on agricultural input, maps, and area-elevation curves and water levels derived by NERP engineers from BWDB data.

The steps followed to predict changes in agricultural production were:

1. Determine changes in land type from the engineering analysis by superimposing current, FW, and FWO water levels on the area elevation curve;
2. Use the present crop distribution on each land type as the minimum achievable level for future crop distribution on each land type; and
3. Establish future yields on the basis of existing yields under conditions where no flood damage occurred.

All of the above steps were carried out in consultation with a cross-section of farmers. It is considered that this analytical approach is quite conservative. Greater increases in agriculture production than those suggested are technically possible. Changes in market forces of supply and demand will have implications on crop distribution and preferences.

Primary data on cropping patterns as a function of land type and crop damage, and on agricultural trends, was collected using Rapid Rural Appraisal (RRA) techniques. An experienced professional agronomist, accompanied by a multi-disciplinary team, followed several traverses cutting across different land types in the project area and interviewed groups of farmers on each land type, collecting information on yields and on cropping patterns and crop damage using an *anna* (one-eighth of a Taka) unit familiar to farmers. These farmer estimates were then converted to percentages of land types under each cropping pattern and percentage of each land type/cropping pattern combination damaged. For FWO and FW assessments, pre-project conditions were used as a guide: it was assumed that current associations between cropping pattern and hydrologic conditions would hold true in the future (that farmers' current and future cropping choices for a particular hydrologic regime would be the same).

7.2.4 Water Quality

Secondary data on water quality data for the region is extremely limited, and NERP did not undertake any water quality field measurements. The approach taken here is limited to qualitative characterization of incremental changes in biological and chemical contaminant inputs. For example, it is recognized that FCD-led intensification of agriculture will increase the amounts of pesticides and fertilizers used; that urban water supply will greatly increase urban sewage drainage volumes; that wastewater treatment will reduce effluent contaminant loadings; and so on.

7.2.5 Openwater Fisheries

Data sources

Both primary and secondary data were used. Secondary data sources included existing topographic maps, BFRSS data, and previous studies and reviews of the openwater fishery in Bangladesh, in particular Ali (1991), Azadi (1985), BCAS (1989), SLI/NHC Joint Venture (1989, 1990), Chong *et al*. (1991), Rahman (1989), Tsai and Ali (1985), and World Bank (1991).

Primary data was collected during case history field studies of FCD project and non-FCD areas; and long-term monitoring of fisheries at a partial flood protection project (Shanir Haor) and at a full flood protection project with pumped drainage and irrigation (Manu River Irrigation Project) (*Fisheries Specialist Study*, 1993). A fisheries specialist also participated in rapid appraisals of proposed project sites as a member of the multi-disciplinary teams.

FWO trends in fish production

Observations of past fish production indicate that production is declining by 1% to 3% per year overall. Conversely, estimates of future fish production taking into account interventions to improve biological management of the fishery suggest that increases in fish production are possible. To assess project fish impacts (FW production minus FWO production), some assumption must be made about FWO trends. If the FWO trend is assumed to be negative, project negative impacts on fish production will be of significantly smaller magnitude than if the FWO trend is assumed to be positive.

Lacking any way to decide between these two scenarios, impacts of all the projects should be assessed assuming that FWO production is equal to present production. The high estimate 'worst case' (FWO increasing trend) should fall within the range covered by the fish production impacts sensitivity test of the economic model.

Production model

Initial model. In a few of the earlier FCD pre-feasibility studies, a simple flooded-area model was used:

Impact = FW - FWO production =

$$[(R_1 - R_0) * P_{R0}] + [(B_1 - B_0) * P_{B0}] + [(W_1 - W_0) * P_{W0}]$$

where

sub-0 and sub-1 refer to FWO and FW respectively

R, B, and W are river/channel, *beel*, and floodplain (F1+F2+F3) areas, in hectares

P is the unit FWO production in kg ha^{-1} for the respective habitats. Estimated regional average values are 175, 410, and 44 for river, *beel*, and floodplain respectively.

The pre-feasibility teams found this model difficult to use, in particular because it lacks provision to estimate impacts on migration access and water quality. While keeping in mind that our qualitative and quantitative understanding of fishery impact processes is very limited, it was felt to be desirable to develop a slightly more sophisticated fisheries impact model, which at the very least would be easier to use.

Improved model — introduction. A slightly more complicated model was used for the later studies. It was developed based on the following thinking. First, the model should incorporate system processes and parameters/parameter groups about which we have some information and understanding: it should include all that we do know. Second, it should exclude processes/parameters that are purely speculative or uncharacterizable: it should exclude all that we do not know. Third, it should be flexible enough to reflect real, known variations between projects and project areas. Fourth, it should be uniform across projects with regard to parameters/processes about which we know very little. In summary, optimal complexity and optimal generality/specificity are desirable. (Thus, as understanding of the system improves, the model should also be improved.) The pre-feasibility studies identify issues needing further investigation in the feasibility study (that is, weaknesses in our current understanding).

System processes. The major system elements at this level of understanding appear to be (Table 7.1):

- Migration access and timing. It seems to be accepted that:
  - A multiplicity of access points is desirable (i.e. that closing any or some channels is still deleterious),
  - The most important channels are those at the downstream end (that with flood onset, fish mainly migrate upstream and onto the floodplain, and downstream out of the beels into the river), and
  - Delay of flooding, as in partial flood control schemes, is highly disruptive
- Overwintering (dry season) habitat. Numerical models of tropical openwater fishery systems show that total system production is far more sensitive to dry season habitat than to wet season habitat.

Table 7.1: Impacts on openwater fisheries production by intervention type

Intervention > / Parameter	Full flood control	Partial flood control	Bottom-open spill protection	Drainage improvement
Observed production impact in existing projects[1]	Of 17 case study projects: 0 — positive impacts 6 — no impact. 11 — project contributed to decline. Working estimate of impact: -90%	Of 19 case study projects: 4 — positive impacts (higher water level for *katha*, prevents siltation) 8 — no impact. 3 — decline, project not cited 4 — project contributed to decline. Working estimate of impact: -50%	Not available.	Of 6 case study projects: 2 — positive impacts 4 — no impact.
Wet season habitat	Negative. On net decrease in floodplain area (F1+F2+F3+F4), 100% of pre-project fish production lost	Usually a one-month (about a one-sixth) reduction of flooded area duration and thus productivity	Negative. Depending on embankment type provided, as for full or partial ring embankments (see previous columns)	Usually negative, if floodplain area (F1+F2+F3) and flood duration can decrease
Dry season habitat	Direct: usually no impact. Indirect: often reduces extent, if supports conversion of beel areas to boro cultivation or increased irrigation abstractions	Direct: usually no impact on extent unless an increase due to water retention behind structures. Indirect: usually reduces extent if supports conversion of beel areas to boro cultivation or increased irrigation abstractions	Direct: usually no impact. Indirect: negative if supports conversion of beels to boro cultivation and increased irrigation abstraction	Usually positive, reflecting increased channel area, depth, and volume from the excavation. Negative impact on beel area if over-drainage occurs.
Migration access	Up to 100% negative, depending on proportional blockage by embankments and structures of khals during migration windows. $M = 0.3$.	Can be very negative, if embankments/structuresblock all khals for a significant part of the migration window. $M = 0.7$	Since the lowest and ostensibly most important access routes are kept open, negative impacts should be less than in ring-dyke full or partial flood protection. $M = 0.8$	Can be positive if offtakes are desilted, dead channels re-activated. $M > 1$
Water quality	Negative. Directly restricts circulation and flushing, and indirectly supports increased agrochemical and irrigation water usage associated mainly with HYV boro rice cultivation. $Q = 0.5$	Negative. Directly restricts flushing/circulationfor one month as floods are delayed, and indirectly supports increased agrochemical and irrigation water usage. $Q = 0.7$	Somewhat negative as number and volume of spills are less. $Q = 0.8$	Usually positive. Dry season volumes and flushing increases, contaminant concentrations decrease. $Q > 1$
Potential Mitigation Measures	Combining with drainage improvement, operational measures (controlled flushing, water retention behind regulators), and fish passes if these prove feasible	Combining with drainage improvement, operational measures (controlled flushing, water retention behind regulators), and fish passes if these prove feasible	Combining with drainage improvement, operational measures (controlled flushing, water retention behind regulators), and fish passes if these prove feasible	None.

[1]Source: *Fish. Spec. Study*, Fisheries Environment Issues.

- Wet season habitat. Production depends on floodplain grazing area and duration. A linear dependence on hectare-months of flooded land is a reasonable simplification. Beyond this, it is suspected that production also varies as a function of land type (F1, F2, F3), to wit that shallower (F1, F2) land is more productive than deeper (F3) land, but data to show this is lacking. In addition, and independent of this, there are likely other spatial variations in production, reflecting habitat quality, fishing pressure, etc.

- Water quality. This would appear to be most relevant during low volume/flow periods, and during the times of flood onset and recession when contaminants can disperse or accumulate.

- Spawning. Production outside the directly impacted area can be impacted indirectly, if habitats suitable for spawning are adversely affected. It is believed that most of the region's fish production stems from spawning occurring in: mother fishery areas, which are those exhibiting extensive, well-interconnected, and varied habitats with good water quality; key *beels*; and river *duars*. *Duars* are somewhat a separate problem as they are located in rivers and larger channels, not on the floodplain.

Impacts on system parameters by intervention type. Table 7.1 documents how each of the above system parameters (except spawning) is impacted by each intervention type. It should be noted that:

- A particular project can include a mix of intervention types, in particular flood control plus drainage improvement. In this case the impacts of the project would be intermediate between the effects of the two type interventions.

- The specific configuration of each project, including mitigation measures, strongly affects its expected fisheries performance relative to the type interventions. For example, partial flood control without winter water retention (e.g. *Updakhali*) will have an overall negative fisheries production impacts, whereas a similar project (e.g. *Dharmapasha*) with water retention may have a positive impact.

The spawning/mother fishery impacts for all intervention types are in proportion to wet and dry season habitat, migration access, and water quality disruption.

Model algorithm
The foregoing was translated into an algorithm:

FWO project area production = $(R_0 * P_{R0}) + (B_0 * P_{B0}) + (W_0 * P_{W0})$

FW project area production = $[M * Q * (R_1 * P_{R0})] + [M * Q * (B_1 * P_{B0})] +$

$[M * (W_1 * P_{W0})]$

FWO production outside the project area dependent upon spawn exported from mother fishery within project = $T * A_0 / A_T$

FW production outside project area dependent upon spawn exported from mother fishery within project = $T * (A_1 * M * Q) / A_T$

Thus,

$$\text{Impact} = \text{FW - FWO production} = \{ [(M * Q * R_I) - R_0] * P_{R0} \} +$$

$$\{ [(M * Q * B_I) - B_0] * P_{B0} \} + \{ [(M * W_I) - W_0] * P_{W0} \} +$$

$$\{ [(M * Q * A_I) - A_0] * T \}$$

where:

M, the quality-weighted migration access remaining. Range: 0.3 to 1 for negative impacts; >1 for positive impacts. Note that even with zero migration access to areas outside the project, there will still be fish production from species that can survive and breed in the isolated habitats remaining within the project area. Values for type interventions are shown in Table 7.1.

Q, the FW acceptability of water quality relative to FWO conditions (range 0 to 1 for negative impacts; >1 for positive impacts). Values for type interventions are shown in Table 7.1.

T, 50,000 tonnes yr^{-1}, the estimated annual regional fish production (100,000 tonnes) weighted by 50% to reflect the proportion that participates in migration away from mother fishery areas.

A_T, 100,000 ha, the total regional mother fishery area.

A, the estimated area of mother fishery/*beel* within the project

7.2.6 Grazing, Wetland, and Threatened Ecological Communities

Data sources
Secondary data relevant to these topics is limited to existing topographical maps and a few previous studies of wetlands, wetland birds, and wild plants and animals, which are reviewed in the *Wetland Resources Specialist Study*. Most of the primary data collection program is also described in this volume; briefly, it included two regional surveys for wetland and regional ornithology appraisal; a year-long program of floral studies at 19 sites; wildlife surveys at key wetland sites; and monthly surveys to observe seasonal variations in waterfowl populations and habitat conditions. In addition, a biologist participated as a member of the multi-disciplinary teams in rapid appraisals at proposed project sites.

7.2.7 Social Impacts
Indicators of social impact were assessed as follows.

Employment
Quantification of the increments in owner employment and hired agricultural employment were integrated into the economic model through the labour requirements for each crop. The model

evaluated economic and employment impacts of cropping changes in parallel. This ensures that the economic and employment estimates are consistent within and between projects.

Fisheries employment was estimated as the incremental net financial value of production, divided by a standard Tk 50 wage (same wage as assumed for agriculture). This produces a highly nominal estimate of the real impact, for a number of reasons: much of the nominal net value is appropriated by *jalmohal* lessees, and actual wages in cash or in kind vary by season, habitat, and class of fishing labour (traditional professional vs. subsistence fishing).

Displacement
For the purpose of homestead flood protection and displacement impacts, the number of people occupying homestead land is estimated on the basis of 266.5 persons per homestead hectare, which is the regional average homestead density.

Conflicts and equity
Project and Plan intensification or easing of resource management conflicts between farming, fishing, navigation, and other interests were flagged on the basis of public consultation, and on the basis of lessons learned from water resources development. A few examples of such lessons include: dry season water management is problematic in areas where *boro* cultivation and *beel* fisheries are both important; closures of channels important for fish migration and navigation are vulnerable to public cuts; and, embankments are vulnerable to public cuts by people living or cultivating in the floodway or other nearby unembanked areas.

Examples of socioeconomic equity criteria relate mainly to impacts on resources (agriculture, fisheries, wetlands) relative to their current share of production and employment, and their importance to vulnerable groups. Examples of gender equity criteria relate to homestead vs. field benefits, since most women's lives and productive activities (child raising, post-harvest processing and agricultural activities) occur within the homestead; and to opportunities created or lost for employment in post-harvest (agricultural and fisheries) processing.

7.2.8 Qualitative Impact Scoring

Qualitative impacts were scored on an 11 level scale of -5 to +5. The scoring procedure is analogous to that used in the FAP 16/FAP 19 EIA case study for the Compartmentalization Pilot Project (December, 1992), but simplified to eliminate half-point scores (1.5, 2.5, 3.5, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each 'true' counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative. The criteria are:

- High sensitivity. Sensitivity is defined as the readiness with which (an) important environmental component(s) (IEC) receives the impact. High sensitivity occurs when a small increment in the impacting function causes a large increment in the impact on the receiving IEC.

- High magnitude. Magnitude is defined as the relative size of the increase or decrease in (an) IEC(s). In addition, any direct threat to human life, internationally recognized endangered species, and environmentally sensitive areas is considered high magnitude.

92

- Immediate. Immediate refers to an impact that is effective within one year of the occurrence of the impacting activity.

- No mitigation required/possible. For a positive impact, this criterion is true if the impact is sustainable without mitigation. For a negative impact, this criterion is true if no mitigation or management is possible.

Qualitative impacts were defined on a project-by-project basis as needed. These are documented in the Evaluation sections of each project pre-feasibility study. Plan qualitative impacts are included in the discussions presented in Chapter 9, Assessment of Regional Plan Impacts.

7.2.9 Remarks on Bounding

Conceptually, five types of spatial bounds were used in assessing impacts:

1. Individual project (a) nominal gross areas and (b) directly impacted areas. The latter encompasses, for example, areas on opposite river banks expected to experience higher flood level; areas to which rivers would be diverted; and so on, but excludes areas subject only to indirect or cumulative impacts. Areas affected only by these types of impacts are included in higher-order bounds described below.

2. River system. Projects in the Surma-Kushiyara system and those in the Kangsha-Someswari system were grouped together.

3. Subregions. Impacts received by a set of subregions (Tripura Piedmont, Meghalaya Fans, Western Seasonally Flooded, Eastern Seasonally Flooded, Central Basin/Deeply Flooded, Peri-Urban) were examined.

4. Region. Impacts were tallied for the whole region.

5. Extraregional/national/global. Specific project-on-environment and environment-on-project impacts affect or emanate from outside the region (rainfall/climate trends, flash floods, Tipaimukh Dam).

7.3 ASSUMPTIONS

Any assessment of impacts must make many assumptions. The reasons for this hardly bear repetition: data is unreliable, often second-hand, and difficult to interpret; environmental processes, such as weather and climate, not to mention ecological systems, exhibit great unpredictability; and social phenomena are very complex.

The essential assumptions are that the IECs used are representative; and that the methodologies used do produce adequate representation of impacts. Yet some set of IECs must be chosen, methodologies must be used. It has been our aim to state these fully and clearly so that they can be challenged and improved upon.

7.4 INFORMATION DEFICIENCIES

The information used here was assembled mainly for the purpose of regional planning and project pre-feasibility studies. The inherent unpredictability of many of the biophysical and social processes suggests that additional information *per se* would not greatly improve the impact assessment. Looking forward, there is a need for ongoing studies of environmental processes, so that as these unpredictable processes unfold, development strategies and projects can evolve with them. Since the need is for better analysis leading to better understanding, monitoring programmes should be designed based on needs identified by particular analysts with respect to specific analytical methods.

CHAPTER 8: ASSESSMENT OF FUTURE-WITHOUT-PLAN SCENARIO

8.1 INTRODUCTION

A summary of the overall future-without-Plan (FWO) scenario is presented in Chapter 7 of the Regional Plan, Future Regional Development Context (pp. 77-97).

The information presented in this chapter reiterates and adds to the technical information, discussion, and scenario assessment for biophysical systems (hydrology, morphology, and biodiversity). Additional information beyond that presented in the Regional Plan is not available for social and institutional systems.

The information presented here pertains to (1) aspects of the FWO environment which will differ from the existing environment described in Chapter 4, and (2) additional information on earthquake and catastrophic flash flood hazards.

8.2 POSSIBLE RAINFALL AND FLOODING TRENDS AND IMPACTS

Future rainfall and rainfall variability cannot be predicted, not even as to whether they would increase or decrease. Observed trends over the past few decades are disturbingly large, however, and future increases or decreases could be similar in magnitude. Over the period 1901 to 1991, the shape of the seasonal rainfall distribution pattern in the region was remarkably stable, but annual rainfall increased moderately (10%), and its variability from year to year increased markedly (50%).[3] Also, over the period 1964 to 1989, one-day rainfalls increased rapidly (70%).

Increases in rainfall and rainfall variability are consistent with predictions that monsoon circulations intensify with global warming (specifically, with increasing longitudinal temperature gradient). This is somewhat academic, however, as the current and future status of global warming is still a matter of substantial uncertainty, and its potential impacts on this particular region are unknown. Climate varies on all timescales for a variety of reasons and causality of phenomena can be difficult to establish.

Rainfall and flooding influence regional morphology, through their influence on sediment supply and runoff characteristics. The most sensitive subregions are the Meghalaya fans in the north and the Tripura piedmont streams in the south. The main lowland rivers such as the Upper Kushiyara

[3]Annual rainfall data at 51 stations for the years 1901-1991 was used (see Figure 9, *Surface Water Resources of the Northeast Region Specialist Study*. To investigate the variation over time of the rainfall pattern, each station's data was averaged in three 30-year bins (1901-1930, 1931-1960, 1961-1991) and three maps generated. The rainfall trend is estimated by a three point time series of the 30-year and 51-station annual rainfall mean. The variability trend was calculated by taking the standard deviation of each year's 51-station mean from the relevant 30-year 51-station mean.

9a

(upstream of the Manu), the Upper Surma (upstream of Sylhet), and the Meghna will be less sensitive.

If rainfall and rainfall variability:

- Stay at present levels, then conditions such as those experienced in the late 1980s and 1990s would prevail. Morphologic processes in the fans, piedmont streams, and elsewhere would continue at current rates.

- Continue to increase, then existing water control structures would be overwhelmed with increasing frequency and with ever more disastrous results. Pre-monsoon flood damage to winter crops would increase, though wetter winter seasons could also directly benefit the *boro* crop and crop diversification. Fisheries and wetlands would benefit, particularly from wetter conditions in the critical low period. As peak flow magnitudes increase, sediment yields to the region will also increase. Higher rates of lateral channel instability and aggradation are also likely to be experienced on alluvial fans and the lower portions of piedmont rivers.

- Decrease back towards historic (pre-1960s) levels, then the flooding situation would improve and structural failures would be less frequent. Drier winter seasons would decrease base flows, constraining *boro* production and crop diversification. Fisheries and wetlands would be adversely affected. As flood flows decrease, channels will tend to be more stable and the rate and magnitude of morphologic processes will be less.

8.3 TIPAIMUKH DAM/CACHAR PLAIN IRRIGATION PROJECT IN INDIA

8.3.1 Project Description

India has recognized the potential for constructing a major dam on the Barak River at Tipaimukh gorge for many years. In recent years a proposal has been advanced for a multi-purpose project that would provide hydro-power and flood control (see *Regional Plan*, Chapter 4, for project data). Information obtained through the Joint Rivers Commission provides a minimally adequate description of the project which has been used to make preliminary assessments of impacts on the region. Construction was proposed to start by 1993 but has been delayed pending resolution of various issues including the effects of flow regulation on Bangladesh. Regulation of the Barak's flow by Tipaimukh Dam would provide India with the opportunity to irrigate the Cachar Plain; this India proposes to do. Since this will involve a loss of water from the Barak, it is a matter of concern to the Northeast Region of Bangladesh. No statement is available as to how much water India proposes to take from this scheme. For the purposes of this study it has been assumed that the total depth of irrigation water to be applied is 1 m and that the water is diverted on a continuous basis during the six dry months (November through April).

8.3.2 Impacts

Operational period

Based on this information it is clear that significant impacts on the region will result from implementation of the Tipaimukh Dam and Cachar Plain Irrigation scheme. During an average flow year these impacts would include:

- Flood flows on the Barak River will be moderated, with peak flows at Amalshid being reduced by about 25% and flood water volumes being reduced by 20%. The corresponding water levels at Amalshid would be reduced by about 1.6 m. Similar changes would be expected along the Kushiyara River and upper Surma River. This should reduce the frequency of spills from the Kushiyara and Surma Rivers, reduces the extent of inundation in the Sylhet Basin and reduce channel erosion and sediment transport rates along the two rivers.

- Dry season flows will be increased substantially (for example, average flows of the Barak River at Amalshid would be 4.2 times larger in February and overall dry season flow volumes would increase by 60%). This would increase water levels by 1.7 m at Amalshid. Increases in dry season water levels would also occur on the Kushiyara and Surma Rivers (for example, water levels during March should increase by 1.5 m at Sherpur). These increased dry season flows will provide benefits for navigation, irrigation, and fisheries, but could also reduce drainage from some areas.

These effects are documented further below in Section 8.7, Hydrologic Changes, which presents the results of the FWO regional surface water model runs.

Proposals for other dams on the Sonai and Dhaleswari Rivers (tributaries of the Barak) are not thought likely to be taken up before 2015. Therefore, no discussion of these proposals has been included in this study.

During reservoir filling (pre-operational period)
Impacts experienced during the filling of the reservoir depend entirely on the operational rules adopted during the filling phase. Unusually low flow releases during reservoir filling can cause serious impacts on environmental systems in downstream areas; an example is the filling of the reservoir behind the Bennett Dam on the Peace River in Canada, which adversely affected ecosystems on the Peace-Athabasca delta. Filling as quickly as possible is done to maximize certain project benefits such as hydropower generation; slower filling represents a trade-off with other considerations such as downstream fisheries and farming.

Dam failure
This is documented in Section 8.8.2, Tipaimukh Dam Failure.

8.4 FWO STATUS, REGIONAL WATER RESOURCES INFRASTRUCTURE

8.4.1 Range of Possible Scenarios and Most Likely Scenario

The FWO status of regional water resources infrastructure (embankments, water control structures, and river improvement works) is a matter for speculation. The range of possibilities is illustrated by the following sequence of alternative idealized future-without-plan scenarios, presented in order of declining water sector investment:

1. *Frozen existing infrastructure + ongoing projects + plus business-as-usual new projects.* Existing water control infrastructure stays in its 1993 condition; maintenance and repair just keep up with deterioration. Ongoing projects would be completed. These include Singar Beel and possibly extensive embankment raising in the Central Basin under the

97

Systems Rehabilitation Project (SRP, described below). Beyond this, investment in implementation, operation, and maintenance of water control infrastructure continues much as it has in the past.

2. *Frozen infrastructure + ongoing projects*. Existing water control infrastructure stays in its 1993 condition; maintenance and repair just keeping up with deterioration. Ongoing projects would be completed. Beyond this, no new projects; no further rehabilitation.

3. *Deteriorating infrastructure + ongoing projects*. Maintenance is inadequate and as a result existing infrastructure deteriorates over time. Ongoing projects would be completed.

4. *Frozen infrastructure*. Existing water control infrastructure stays in its 1993 condition; maintenance and repair just keeping up with deterioration.

5. *Deteriorating infrastructure*. No new water control infrastructure is built. Maintenance is inadequate and as a result existing infrastructure deteriorates over time.

In real terms, either Scenario 2 or 3 is the most likely future scenario during the Plan.

8.4.2 Rehabilitation Activities Proposed Under Systems Rehabilitation Project

Rehabilitation of water resources infrastructure throughout the country is being addressed by SRP; this ongoing activity appears in Scenarios 1, 2, and 3 above. For the Northeast Region, SRP prepared feasibility studies of the rehabilitation of nine submersible embankment projects in the deeply flooded Central Basin (Table 8.1). Of these, five involve raising embankment design heights by over 1 m, over a total embankment length of 160 km. This is necessary because the gap between the pre-monsoon and monsoon flood levels has been decreasing. These five projects enclose a gross area of 27,000 ha, which is about 16% of the 172,000 ha within existing submersible embankment projects. If this approach is continued under subsequent phases of SRP, some or all of the other 14 submersible embankment projects in the region (gross area 90,375, embankment length 500 km) could be candidates for this type of upgrading as well.

NERP and SRP recognize that an increase in embankment design heights of 1 m or more will result in embankment crests (including the freeboard allowance above the expected pre-monsoon flood levels) at or above the 1:2 monsoon flood levels. The result will be increasing confinement of flows and sediment to the river channels, even if the areas are filled after the *boro* harvest. Post-monsoon drainage and fisheries could be adversely affected. For these reasons, SRP is recommending that rehabilitation of these projects be deferred and re-considered later, after implementation of the NERP initiatives *Baulai River Improvement* and *Kalni-Kushiyara River Improvement*, which are expected to decrease pre-monsoon flood levels significantly.

9F

Table 8.1: SRP Feasibility Studies, Northeast Region Submersible Embankment Projects

Project	Area (ha)		Embkt length (km)	Design Height (m PWD)		Earthwork	
	Gross	Net		Old	New	Volume (m^3)	Cost (Mtk)
Karchar Haor	5513	4987	11.4	6.10	7.56	93860	4.68
Shanir Haor	7761	6721	33.5	6.10	7.30	419834	20.94
Matian Haor	4819	3590	53.0	6.10	7.30	768935	30.76
Mohalia Haor	645	490	15.0	6.10	7.30	350930	14.04
Halir Haor	8023	6234	46.0	6.10	7.30	730040	35.41
Totals, greater than 1 m embankment height increase	*26,760*	*22,021*	*157.9*			*2,363,601*	*104.83*
Dhankunia Haor	1692	1486	18.0	6.10	6.34	102250	5.10
Joydhona Haor	355	292	12.4	6.10	6.34	25275	1.26
Chandra Sonarthal	5714	4724	55.5	6.10	6.34	370849	18.50
Chaptir Haor	5061	4125	24.0	7.30	7.30	315984	16.26
Totals, less than 1 m embankment height increase	*12,822*	*10,627*	*109.9*			*814,358*	*41.12*
TOTAL	**39,582**	**32,648**	**267.8**			**3,177,959**	**145.95**

8.5 FWO CONDITIONS USED IN PROJECT PRE-FEASIBILITY AND REGIONAL SURFACE WATER MODEL STUDIES

The FWO conditions used in the project pre-feasibility studies are:

- Historic rainfall and discharges
- No Tipaimukh Dam. Projects which would be significantly affected by dam implementation are *Upper Surma-Kushiyara*, *Surma Right Bank*, *Surma-Kushiyara-Baulai Basin*, and *Kushiyara-Bijna Interbasin*
- River morphology — avulsions in progress are noted for affected projects (*Dharmapasha-Rui Beel*, *Updakhali*, *Jadukata-Rakti*, *Upper Kangsha*), and aggradation in progress is

noted (*Kalni-Kushiyara* and others with less severe effects), otherwise current morphology is assumed

- Scenario 4 for future water resources development (impacts of ongoing projects neglected, existing infrastructure assumed frozen in 1993 condition).

The regional surface water model was run in two FWO configurations, one with and one without Tipaimukh Dam. The other prescribed FWO conditions were:

- 1991 water year

- River morphology — as at present (1991), except for
  - Khowai: aggradation of the reach between Shaistaganj and Habiganj
  - Someswari: siltation of the Shibganjdhala channel and enlargement of the Atrakhali channel (that is, progression of avulsion)
  - Jadukata: progression of avulsion
  - Kalni-Kushiyara: aggradation

- Scenario 4 for future water resources development (existing infrastructure).

8.6 OVERALL MORPHOLOGIC CHANGES

Construction of flood control embankments, loop cuts, channel closures as well as ongoing channel changes over the last 20 years are responsible for a number of morphological adjustments that are currently underway in the region. These adjustments may take several decades to run their course, with impacts propagating long distances from the original point of disturbance. The most serious impacts will result from ongoing aggradation of the lower Kushiyara-Kalni River which is occurring as a result of several factors including upstream channel shifts, impacts of past loop cutting and alteration of the river's flow regime. Future developments would include:

- Increased spills into the Baulai River and possibly a partial avulsion from the Kalni River near Ajmiriganj towards the Baulai River;

- Increased pre-monsoon flood levels between Madna and Sherpur, affecting 5,000 km^2 of the Central Basin, including fourteen existing submersible embankment projects.

- Increased overbank spills, causing greater floodplain sedimentation and infilling of beels adjacent to the channel in a zone 40 km long by 1 km wide, with negative impacts to fisheries.

- Elimination of existing *duars* in the aggrading reach between Markuli and Madna, with additional negative impact to fisheries;

- Reduced navigation along the Kushiyara River during the dry season and eventual isolation of ports such as Ajmiriganj.

Similar channel changes also appear to be occurring on the Baulai River near Kaliajuri. However, aggradation rates appear to be lower than on the Kalni and have only occurred during the last five to ten years.

The future sediment loads supplied to the region will depend primarily on future climatic conditions and the extent of land-use disturbances in the catchments. There is evidence from satellite photos that sediment yields from the Tripura Hills and Meghalaya Hills have increased in the last few decades. The main impacts from increased sediment yields would be reduction of land area suitable for agriculture, increased hazards to infrastructure and further reduction of fish habitat such as *duars* and *beels*. Increased sediment yields from Tripura will affect Piedmont streams such as the Juri, Manu, Dhalai, Karangi, Sutang, and Lungla Rivers. Increased sediment yields could accelerate ongoing sediment aggradation within flood control embankments on rivers such as the Khowai River and Chillikhali River. The overall affected area amounts to about 960 km^2 or about 4% of the region.

Increased sediment yields from Meghalaya, on the northern boundary of the region, will increase channel shifting and sedimentation on the alluvial fans which extend from the Dauki-Piyain River in the east to the Someswari River in the west. The total affected area is about 1,400 km^2 or about 6% of the region. Naturally occurring patterns of instability on alluvial fans will result in abandonment of some existing channels and development of new channels over time spans of ten to 20 years. For example, major avulsions appear to be either in progress or imminent on the Dauki-Piyain, Dhalai Gang, Jadukata and Someswari Rivers. However, channel avulsions are inherently unpredictable and could occur on any of the fans in the region over the Plan period.

In most cases, the impact of avulsions will be largely restricted to the fan areas. However, in the case of the Someswari River, an avulsion down the Atrakhali River would impact over much of the Kangsha River basin. For example, regional surface water model simulations indicated the avulsion would decrease discharges in the Kangsha River at Jaria Janjail by 250 $m^3 s^{-1}$, or 20 % of the monsoon peak and reduce flood levels on the Kangsha River by 0.3 to 0.5 m. This reduction would be offset by an increase in the eastward spills via the Atrakhali and Old Someswari Rivers. In other words, flood conditions will be reduced in one area but will be intensified in other areas.

A similar change is developing on the fan of the Jadukata River, where an avulsion is causing peak flows to spill westwards into Matian Haor and Tangua Haor. If trends continue, virtually all of the low flows will pass down the avulsion channel and Jadukata River will become essentially a dry channel most of the year. Important wetland habitat such as Tangua Haor will decrease in size as a result of the rapid sediment infilling that will occur after the channel shift is completed.

The net effects of such changes will result in both positive and negative societal impacts. Infrastructure, agriculture, and local residents near the newly developed channels will be seriously affected by increased flooding, erosion and overbank sediment deposition. Near the site of the abandoned channels, flood levels will be decreased while navigation will be impaired.

8.7 OVERALL HYDROLOGIC CHANGES

8.7.1 Overview

This section summarizes the results of the FWO regional surface water model runs.

The cumulative effects of Tipaimukh Dam flow regulation, plus channel aggradation on the Kushiyara-Kalni River and Surma-Baulai River, would increase winter discharges and siltation along the Kalni River, and have the potential for raising the pre- and post-monsoon water levels by as much as 1.5 m at Markuli. During the monsoon season, however, the effects of channel aggradation and Tipaimukh flow regulation largely offset each other, so that the peak water levels were increased by about 0.3 m. The result of all this would be greater depth and extent of flooding during the monsoon season, retarded drainage during the post-monsoon season and earlier and more severe pre-monsoon flooding of unprotected areas adjacent to the river.

Changes along the Surma-Baulai River were found to be similar in nature but smaller in magnitude than on the Kushiyara-Kalni. For example, at Sukdevpur on the Baulai River, water levels during the monsoon season were found to be virtually unchanged from existing conditions. During the post-monsoon season, water levels were raised by about 0.8 m. At Bhairab Bazar, on the Meghna River, water levels and discharges were found to be only slightly affected by upstream changes in a year similar to 1991, but may be more significant during drier years.

8.7.2 Detailed Water Levels and Discharges by River System

The information presented in this section is based on the output of the Northeast Regional Model simulations based on the 1991 water year (see Section 7.2.1). The changes noted are relative to current conditions.

Surma-Kushiyara system

The Tipaimukh Dam/Cachar Plain Project on the Barak in India will substantially alter discharges of the Barak where it enters Bangladesh at Amalshid. Available information suggests that monsoon peak flows would decrease by about 30% (from 5250 to 3500 $m^3 s^{-1}$). Winter flows would double or triple, increasing 100 to 200% (from between 170 and 250 to 500 $m^3 s^{-1}$). Of the monsoon peak decrease, monsoon flow in the Surma and Kushiyara Rivers would decrease by 800 $m^3 s^{-1}$. Surma-Kushiyara and Surma-Sarigoyain floodplain discharges would decrease by the remainder of 1150 $m^3 s^{-1}$.

The Surma and Kushiyara Rivers along their entire lengths, and part of their tributaries, are also affected. At Fenchuganj on the Kushiyara, for example, model monsoon peak flows decreased by about 20% (from 2900 to 2400 $m^3 s^{-1}$). Peak levels decreased by 1 m (*Regional Plan* Figure 21A). Model winter flows increased by about 80% (from 250 to 450 $m^3 s^{-1}$). Levels increased by almost 2 m.

Further downstream in the Kalni-Kushiyara, model water levels *increased* by as much as 0.3 m in the monsoon and 1.5 m in the winter and pre-monsoon periods, as a result of sediment deposition. The affected reach extends as far as Ajmiriganj. By Bhairab Bazar, model flows and levels are almost unchanged from current conditions. In a simulation based on a drier year than 1991, however, model winter flows might increase significantly; simulated discharge hydrographs show that Bhairab Bazar winter flows are highly variable due to tidal effects.

Similar but somewhat smaller changes occur on the Surma (*Regional Plan* Figure 21B). At Kanaighat, model monsoon levels decrease by 0.5 m, while winter levels increase by 1 m or more. At Sukdevpur model water levels are almost unchanged from current conditions.

Someswari-Kangsha system
Someswari-Shibganjdhala siltation and growth of the Atrakhali, a new distributary of the Kangsha, will reduce Kangsha discharges along a 50 km reach from Sarchapur and Mohanganj, centred on Jaria Janjail (*Regional Plan* Figure 21B). At Jaria Janjail, model monsoon water levels decreased by 0.3 to 0.5 m, and monsoon peak flows decreased by 20% (from 1250 to 1000 $m^3 s^{-1}$). Discharges in the Atrakhali and the Old Someswari channels *increased* by similar amounts, reflecting the diversion of flow away from the Kangsha and into the Atrakhali-Old Someswari.

Jadukata River
As the ongoing avulsion into the Patnaigang continues, Jadukata non-peak flows will eventually cease and it will become essentially a dry channel most of the time. Two-thirds of peak discharges would flow along the Patnaigang into Matian Haor, and the remainder would flow along the Jadukata.

Khowai River
The model incorporates estimated future aggradation in the reach from Shaistaganj downstream to Habiganj. As a result of this, model water levels increase 1 to 2 m near Habiganj and slightly near Shaistaganj. These higher levels imply embankment overtopping and greater risks of breaches in this reach. If the aggradation were extended further up/down the river, the higher levels would extend with them.

Changes in other boundary rivers
Only localized changes in other boundary rivers are expected, therefore these were not incorporated in the model.

Summary and conclusions
The most significant changes are those associated with:

- The potential Tipaimukh Dam/Cachar Plain Project, which the model indicates would decrease upper Surma and upper Kushiyara monsoon peak levels by 1.5 m and increase winter discharges by 100 to 200%, for conditions similar to those in 1991.

- Expected sediment deposition in the Kalni and lower Baulai, which the model indicates would increase pre-monsoon and post-monsoon water levels by as much 1.5 m.

8.8 LIKELIHOOD AND POSSIBLE IMPACTS OF HAZARDS

8.8.1 Earthquakes
The region is known to be vulnerable to earthquakes. These events, though relatively rare are extreme in intensity, and can reverse existing morphologic trends and even induce re-configuration of the drainage system. The likelihood that during 1991-2015 the region would experience an earthquake of magnitude 7.6 (similar to the 1918 event, return period of 30 to 50

years) is between 40 and 60%; of magnitude 8.7 (similar to the 1897 event, the largest on record, return period of 300 to 1000 years) is perhaps 2 to 5%, assuming the events are random and can be described with a simple binomial probability model.

On past evidence, river channels and sedimentation patterns in the Northeast Region may be subject to major disruptions following a severe seismic event. During past earthquakes, instances of ground liquefaction, landsliding, rapid subsidence, collapse of river banks, and changes to river courses have been documented (District Gazetteer, 1917). The effects of earthquakes along the Brahmaputra River were described by Oldham (1899), reproduced in Chapter 4 of French Engineering Consultants (1989):

- Strong ground shaking triggers liquefaction of river cross-sections in a few seconds; underwater slopes slide towards the stream axis, the bottom of the river heaves, and the banks become lowered;

- Water immediately starts to rise and overflows the banks and adjacent zones where infilling of the channels takes place. Natural sills form, causing temporary lakes to develop;

- Channels gradually re-open by scouring where currents are strong enough, and consequently water levels decrease. Where channels remain blocked, streams desert their old channels to form new ones; and

- In subsequent years, the huge amounts of sediment poured into the river as a result of the earthquake gradually move downstream. Sediment transport is higher than previously and siltation conditions are therefore modified.

Earthquakes are believed to have also induced landsliding and slope failures in headwater catchments in the Shillong Plateau, which could greatly increase the amount of sediment supplied to the region for long periods of time.

Joglekar (1971) described apparent impacts of major earthquakes on the upper Brahmaputra in Assam, India. After the severe earthquakes of 1947 and 1950, the bed level near Dibrugarh rose substantially. Between 1947 and 1951, low water levels rose by as much as three to four metres; thereafter they were steady.

8.8.2 Tipaimukh Dam Failure

Assessment of this type of risk and risk management planning should be undertaken by a qualified dam safety specialist, and we are uneasy as hydraulic and environmental specialists making comments on this subject. This risk is however a significant issue relating to future environmental management of the Northeast Region water system which we feel a responsibility to mention here.

A dambreak is a catastrophic failure of a dam which results in the sudden draining of the reservoir and a severe flood wave that causes destruction and in many cases death downstream. While such failures are rare and are not planned they have happened to dams, large and small, from time to time. The International Commission on Large Dams (ICOLD) has identified 164 major dam failures in the period from 1900 to 1965 (Jansen, 1983).

With respect to the safety of the proposed Tipaimukh Dam, it is our impression that well-designed and constructed rockfill dams are perhaps the safest type for large heights (Tipaimukh would be among the largest of such dams in the world; see rockfill dams listed by Cooke, 1984), but we imagine that local circumstances may be much more important in this respect than dam type.

Two examples illustrate the types of failures that have been reported. The most famous, the Teton Dam in the United States, was a 90 m high earth-fill dam which failed in 1.25 hours. The flood wave which was released had a peak discharge of 65,000 m3 s^{-1} at the dam and a height of 20 m high in the downstream canyon. The Huaccoto Dam in Peru was 170 m high, similar to the Tipaimukh Dam; it failed over 48 hours due to a natural landslide in the reservoir.

Generally, a flood wave travels downstream at a rate in the order of 10 km hr^{-1} although velocities as high as 30 km hr^{-1} have been reported near failure sites. From these wave velocities, it would appear that the initial flood wave could travel the 200 km distance from Tipaimukh Dam site to the eastern limit of Bangladesh within 24 hours having a height of perhaps 5 m. Peak flooding would occur some 24 to 48 hours later. High inflows would persist for ten days or longer and the flooded area would likely take several weeks to drain.

The Tipaimukh reservoir is huge (15,000 Mm^3) compared with experience reported in the literature. In the event of a significant unplanned discharge, the river system in Bangladesh would respond (drain) rather slowly, as characterized by the outflow rate relative to the floodplain storage volume), such that most of the water released would remain ponded over the Northeast Region for some time. Assuming a release volume of 10 Mm^3 and a ponded area of 100 km^2, the depth of flooding would be an average of 1.0 m above the normal flood level.

There will be a need for Bangladesh and India to cooperate in formulating and implementing risk management measures. A wide range of risk management measures are normally undertaken (Jansen, 1983), including: regular inspections by independent engineering teams, instrumentation and plans for warning downstream populations of deteriorating conditions of a dam, evacuation plans, and so on. As and when India's plans proceed, there will be a clear need for Bangladesh to avail itself of expert technical assistance from dam safety specialists experienced with very large dam/reservoir systems and trans-border risk management.

For illustrative purposes only, we show modelled flood waves for a test case of a instantaneous failure, 50 m wide extending to 100 m below the crest of the dam. Discharge and water level hydrographs are presented for three locations (Figure 11): at the exit from the mountain valley (km 80), at Silchar (in the middle of the Cachar plain, km 140) and at Amalshid (km 200). It can be seen from this that substantial attenuation of the flood wave would occur upstream of Amalshid and that the flood wave at Amalshid is a long-duration event. Depending on the breech geometry and peak discharge, the flood peak would occur at Amalshid approximately 2 to 3 days after the dam break had occurred and flooding would continue for ten days or more. The flood levels at Amalshid would rise to approximately 25 m PWD, which is at approximately 8 m above the floodplain level. This flood level depends on the boundary assumptions which were made and could be less depending on floodplain conveyance.

8.8.3 Catastrophic Flash Flood Events in the Meghalaya Alluvial Fans and Tripura Piedmont

Five river reaches in the Meghalaya border area and four in the Tripura border area were identified as vulnerable to catastrophic flash flood events. Each channel is a nodal reach, lying between an upstream basin fed by dendritic tributaries, and a downstream aerial delta. Interviews with inhabitants along these reaches and theoretical studies strongly suggest that flash flood events in these reaches take the form of bores or walls of water, which generate forces sufficient to capsize boats and to sweep away people in or near the river channel. These catastrophic impacts are in addition to flood damages to infrastructure, crops, and so on, which also occur when water levels rise more gradually.

The annualized death rate from catastrophic flash flooding, totalled over the 2600 villages along the nine vulnerable river reaches (total population 2 million) could be on the order of 100 to 1500 persons per year (Figure 12). This estimate is based on reports of 49 flash flood fatalities in 1988 in five villages on the Meghalaya rivers (of which 45 were from a single boat capsize accident), and four fatalities in 1993 from four villages on the Tripura rivers (*Improved Flood Warning*, NERP concept paper). The implied death rates are 15 per thousand and 1 per thousand for these two events respectively, using regional average figures for households per village (130) and persons per household (5.4). The corresponding annualized death rates are 100 to 1500 persons per year, if return periods for these death rates of 1:100 and 1:10 years respectively are assumed. An increasing rainfall trend could lead to a dramatic increase in death rates.

CHAPTER 9: ASSESSMENT OF REGIONAL PLAN IMPACTS

9.1 INTRODUCTION

This chapter describes the expected impacts of implementation of the Regional Plan.

The residual impacts of Plan implementation represent the sum total of numerous factors:

A. Direct impacts of flood control and drainage measures

B. Mitigating/compensating impacts of mitigation/compensation measures incorporated into individual FCD projects

C. Direct impacts of non-FCD projects

D. Cumulative impacts of FCD projects

E. Interactions among FCD projects (project-on-project impacts)

F. Environment-on-project impacts

G. Mitigation and compensation of adverse FCD impacts by non-FCD projects

Impacts in categories *A, B,* and *C* are documented in individual project pre-feasibility studies. Quantifiable impact indicators from these studies are tabulated and totalled in Table 9.1 and Figure 13.

Impacts in categories *D* through *G*, are documented in Sections 9.2 to 9.5 of this chapter.

Expected residual impacts are then described in Section 9.6. The implications of partially or differently-phased implementation of the Plan are discussed in Section 9.7. Impacts are characterized for each subregion in Section 9.8.

Mitigation measures are summarized in Section 11.2.

38

Table 9.1: Summary of quantifiable impact indicators for Plan FCD projects

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD projects	Baseline	Total/ Baseline (%)	BASELINE VALUES Definition and Source
5	PROJECT EXTENT				
6	— Gross area (ha)	1,792,270	2,420,000	74.06	Region area. *Regional Plan*, Interpretive Description of the Region.
7	— Net cultivable area (ha)	1,442,937	1,605,867	89.85	Region net cropped + current fallow areas. *Agric. Spec. Study*, Land Use Pattern.
8	% previously developed				
9	Area prev devel (ha)	312,000	286,100	109.05	Area within existing FCD projects. *Water Res. Thematic Study*.
10	— Benefitted area (ha)	456,483	1,442,937	31.64	Benefitted cropped areas. Sum of values on lines 53, 54, 55, and 56.
11	FCD BENEFIT / PROJECT TYPES				
12	— Full flood control (urban/agri)	3	27		
13	— Partial flood control	3	33		
14	— Mixed: full and partial f/c areas	5	n/a		
15	— Controlled flooding	1	n/a		
16	— Drainage improvement (only)	14 (4)	5		
17	— Irrigation distribution	0	2		
18	— Irrigation water flushing/retention	5	n/a		
19	PHYSICAL COMPONENTS				
20	— Full flood embankments (km)	474			
21	— Submersible flood embankments (km)	394			
22	— River diversions (destination)	4			
23	— Loop cuts (no.)	26			
24	— Channel excavation (km) For m^3 see line 80	738			
25	— Channel closures (no.) Repeated on line 79	48			

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD projects	Baseline	Total/ Baseline (%)	BASELINE VALUES Definition and Source
26	FLOOD PROTECTION IMPACTS ON HOMESTEADS, POPULATION, AND ROADS + NEW/RAISED HOMESTEADS FROM SPOIL				
27	— Settlement area (ha)				
28	Total	46,190	65,330	70.70	Regional homestead area. *Agric. Spec. Study*, Land Use Patterns.
29	FWO flood-affected	12,220	46,190	26.46	Homestead area within Plan FCD project areas. Previous line.
30	Flood-free area gain/loss	7,123	65,330		Regional homestead area. *Agric. Spec. Study*, Land Use Patterns.
31	FCD protected	6,386	12,220	52.26	FWO flood-affected homestead area in Plan FCD project areas. From line 29.
32	Could be constructed, raised using spoil (50% of excavation vol. / 5 m)	737	12,220	6.03	FWO flood-affected homestead area in Plan FCD project areas. From line 29.
33	— Rural population (2015, in '000s)				
34	Total	14,510	17,400	83.39	Regional rural population (2015). *Regional Plan*, Future Regional Development Context.
35	FWO flood-affected	2,470	14,510	17.02	Rural population within Plan FCD projects (2015). Previous line.
36	FW-FWO flood-free gain/loss	1,233	2,470	49.92	Rural population within Plan FCD projects prone to homestead flooding (2015). Previous line.
37	— Urban (incl thana HQ) population (2015, in '000s)				
38	Total	5,834	9,000	64.82	Regional urban population (2015). *Regional Plan*, Future Regional Development Context.
39	FWO flood-affected	1,862	5,834	31.92	Urban population within Plan FCD projects (2015). Previous line.
40	FWO-FW flood-free gain/loss	1,180	1,862	63.37	Urban population within Plan FCD projects prone to homestead flooding (2015). Previous line.
41	— Total population (2015, in '000s)	20,344	26,400	77.06	Regional population (2015). *Regional Plan*, Future Regional Development Context.
42	— Roads (km)				
43	Total	3,555			
44	FWO flood-affected	1,608	3,555	45.23	Roads within Plan FCD projects. Previous line.
45	FW-FWO flood-free gain/loss	578	- 3,555	16.26	Roads within Plan FCD projects. Previous line.

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD projects	Baseline	Total/ Baseline (%)	BASELINE VALUES Definition and Source
46	DISPLACEMENT IMPACTS				
47	— Area to be taken for project works (ha)				
48	From cultivated area	2,985	1,442,937	0.21	Net cultivated area within Plan FCD projects. From line 7.
49	From settlement area	403	46,190	0.87	Homestead area within Plan FCD projects. From line 28.
50	— Persons displaced (number, at 1991 reg'l avg. of 226.5 persons per homest. ha)	36,000	10,462,035	1.03	Population within Plan FCD projects (1991) Computed from previous line, times 226.5 persons per homestead ha (1991 regional average).
51	AGRICULTURAL IMPACTS				
52	— Cropped area gain/loss (ha)				
53	Rice	38,282	1,882,560	2.03	Regional rice cropped area. *Agric. Spec. Study*, Crops.
54	Damaged area	-324,169	676,998	-47.88	Regional flood damaged area in worst year (1988). *Agric. Spec. Study*, Crop Damage by Flood.
55	Other food crops	67,547	337,440	20.02	Regional cropped area less rice cropped area. *Agric. Spec. Study*, Crops.
56	Fodder crops	26,485			
57	— Production gain/loss (tonnes/year)				
58	Paddy + other cereals	566,920	5,618,462	10.09	Regional paddy production (1992). *Agric. Spec. Study*, Crops. Rice = 0.9 * 0.65 * paddy.
59	Non-cereal	123,449	1,030,089	11.98	Regional production of other crops except sugar cane (1992). *Agric. Spec. Study*.
60	IRRIGATION IMPACTS				
61	— Surface water				
62	Irrigated area gain/loss (ha)	855	351,096	0.24	Regional surface water irrigated area (1992). *Agric. Spec. Study*, Inputs.
63	Usage increment (Mm^3, @ 0.013Mm^3 / ha)	11			
64	— Ground water				
65	Irrigated area gain/loss (ha)	3,290	223,044	1.48	Regional ground water irrigated area (1992). *Agric. Spec. Study*, Inputs.
66	Usage increment (Mm^3, @ 0.013Mm^3 / ha)	43			
67	— Mechanized area gain/loss (ha)	2,677	383,189	0.70	Regional area mechanized irrigation (1992). *Agric. Spec. Study*, Inputs.
68	— Irrigation diesel increment ('000 litres)	534			

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD projects	Baseline	Total/ Baseline (%)	BASELINE VALUES Definition and Source
69	WATER QUALITY / POLLUTION IMPACTS				
70	— Agrochemical usage (tonnes/year)				
71	Pesticides	47	530	8.87	Regional pesticide usage (all types, 1992). *Agric. Spec. Study*, Inputs.
72	Fertilizers	45,569	225,687	20.19	Regional chemical fertilizer usage (all types, 1992). *Agric. Spec. Study*, Inputs.
73	OPENWATER FISHERIES IMPACTS				
74	— Habitat gain/loss (ha)				
75	Floodplain	-49,499	1,190,527	-4.16	Regional F1+F2+F3+F4 area. *Agric. Spec. Study*, Crops.
76	Beels	67	60,000	0.11	Regional *beel* area. *Fish. Spec. Study*, Profile of the Region's Fisheries.
77	Rivers and channels	1,439	35,488	4.05	Regional river+channel area. *Agric. Spec. Study*, Land Use. *Fish. Spec. Study* reports 83,200 ha.
78	Mother fisheries	-4,700	100,000	-4.70	Regional mother fishery area. *Fish. Spec. Study*.
79	— Channel closures (no.)	48			
80	— Channel excavation ('000 m^3)	73,628			
81	— Migration impact coefficient, *M*				
82	— Water quality impact coefficient, *Q*				
83	— Production (tonnes/yr)	-10,554	96,000	-10.99	Regional openwater fish production. *Fish. Spec. Study*.
84	— Net financial value (Tk '000)	-406,186	3,429,000	-11.85	Financial value, regional openwater fisheries production. *Regional Plan*, Interpretive description of the region. Finan. val. = econ. val. / 0.7.
85	AQUACULTURE IMPACTS				
86	— Flood prone ponds (district %)				
87	— Total pond area (ha)	14,990	18,700	80.16	Regional pond area. *Fish. Spec. Study*, Profile of the Region's Fisheries.
88	— Flood-free ponds gain/loss (ha)	1,552	18,700	8.30	Previous line.
89	— Production gain/loss (tonnes/yr)	1,552	18,075	8.59	Regional pond fish production (1992). *Fish. Spec. Study*.
90	GRAZING, WETLAND, THREATENED COMMUNITY IMPACTS				
91	— Winter grazing area (ha)	-54,348	779,298	-6.97	Regional grazing area (1991). Computed from values in *Agric. Spec. Study*.
92	— Winter wetland area (ha)	-6,994	123,765	-5.65	Regional winter wetland area (1991). *Agric. Spec. Study*.
93	— Summer wetland (ha)	-50,440	443,633	-11.37	Regional summer wetland area (1991). *Agric. Spec. Study*.
94	— Lowland forested area (ha)	0	1000	0.00	Regional swamp forest area (1992). *Wetland Res. Study*

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD projects	Baseline	Total/ Baseline (%)	BASELINE VALUES Definition and Source
95	— Reed land (ha)	0	8000	0.00	Regional reed swamp area (1992). *Wetland Res. Study*
96	— Floodplain grassland (ha)	-250	550	-45.45	Flood plain grassland area (1992). *Wetland Res. Study*
97	EMPLOYMENT IMPACTS				
98	— Owner labour gain/loss ('000 pd/yr)	13,216	268,657	4.92	Owner labour inputs computed using NERP economic model and regional cropped areas for all crops.
99	— Hired labour gain/loss ('000 pd/yr)				
100	Agricultural labour	10,954	80,528	13.60	Hired labour inputs computed using NERP economic model and regional cropped areas for all crops.
101	Fisheries labour (net value fisheries production / Tk 50 daily wage)	-8,125	68,580	-11.85	Regional openwater fisheries labour. Computed as net value of total regional openwater fish production, divided by Tk 50/day standard wage. Alternative value would be 23,000 '000s pd/yr, based on 115,000 commercial fisherman equivalents (*Fish. Spec. Study*) times 200 days per year.
102	Wetland labour	-44			
103	Quarrying labour	334			
104	Total hired labour	3,119	149,108	2.09	??
105	— Owner+hired gain/loss ('000 pd/yr)	16,335	417,765	3.91	Regional owner + hired agricultural and fisheries labour (1991). Sum of values on lines 98 and 104.

৭২

9.2 INTERNAL CUMULATIVE IMPACTS OF PLAN INTERVENTIONS

9.2.1 Interpretive Description of Cumulative Physical Impacts

The initiatives which will produce the greatest physical impacts in the region fall into three broad categories:

- Controlled flooding (full flood control with controlled flushing) and partial flood control projects along the Surma-Baulai and Kushiyara-Kalni Rivers which extend from Amalshid on the east to near the outlet of the Central Basin in the southwest (*Upper Surma-Kushiyara Project, Surma Right Bank Project, Surma-Kushiyara-Baulai Basin Project*).

- Major drainage improvement schemes along the lower reaches of the Kalni and Baulai River systems (*Kalni-Kushiyara River Improvement Project, Baulai River Improvement Project*)

- Controlled flooding projects on the piedmont rivers (Manu, Bhogai-Kangsha) which involve either flood control embankments or flow diversions (*Manu River Improvement Project, Upper Kangsha River Basin Development Project, Habiganj-Khowai Area Development Project*).

Spills of water and sediment to the low-lying Surma-Kushiyara inter-basin will be reduced by construction of the *Upper Kushiyara Project*. Right bank spills from near the Lubha River will be eliminated by the *Surma Right Bank Project*. This will increase in-channel discharges and water levels along reaches of the Surma and Kushiyara during the monsoon season. The greatest impacts will occur near Kanaighat, where monsoon flood levels will rise by approximately 0.6 m after breaches at the existing embankment are closed (*Regional Plan* Figure 21B). Further downstream, regional surface water model results showed monsoon flood levels will rise by on the order of 0.2 m from Sylhet to Sunamganj, and will be virtually unchanged downstream of the Old Surma River junction (near Nilpur). Model simulations indicated water levels will rise by generally 0.5 m or less on the Kushiyara upstream of Sherpur during the monsoon season. Rates of channel migration and bank erosion will be increased along the upper Surma and upper Kushiyara and some channel degradation may be expected.

Spills will also be reduced into the Central Basin after completion of the *Surma-Kushiyara-Baulai Basin Project* and the *Kushiyara-Bijna Interbasin Project*. Sedimentation rates in this main *haor* area will decline due to the reduced inflows. Re-excavation of the interior drainage network (such as Old Surma River and Darain River) will result in some local erosion/deposition.

Construction of partial and full flood control embankments will increase in-channel discharges slightly along the Baulai and lower Kushiyara-Kalni Rivers during the monsoon season. The increased confinement will tend to raise monsoon flood levels (particularly on the Kalni River where submersible embankments will approach the level of an average monsoon flood). This confinement will be offset by other dredging initiatives. Confinement will also increase the channels' sediment transport capacity which will flush more of the incoming sediment load through the Kalni into the upper Meghna and more sediment from the upper Baulai into the lower Baulai-Ghorautra system.

River improvement initiatives along the Kalni-Kushiyara and Baulai will reduce the variability of depths and will produce a more uniform, incised single channel pattern. Spoil from dredging

26

may raise ground levels on the floodplain or in side channels and beels. Associated river training works will produce local scour and erosion at shoals and in constricted reaches so that considerable local channel re-organization can be anticipated. Pre-monsoon and post-monsoon water levels will be lowered in the dredged reaches and upstream. As shown in *Regional Plan* Figure 21A, water levels at Markuli will be reduced by as much as 1.5 m during the winter and pre-monsoon periods. Monsoon peak water levels will be reduced by 0.1 m to 0.2 m, while the channel discharge will be increased by as much as one-third. Dredging on the Baulai was found to have less impact, with pre-monsoon water levels lowered by 0.2 m and post-monsoon water levels lowered by 0.5 m. It should be noted that water levels and discharges at Bhairab Bazar on the Meghna were not impacted by these initiatives.

Dredging of the Kalni and Baulai appears to mitigate the effect of higher discharges in the post-monsoon season due to Tipaimukh Dam. Actual impacts would have differed if other upstream dam/irrigation scenarios had been adopted in the simulations. The model results clearly illustrate that upstream flow regulation of the Barak River in India will have a major impact on the Northeast Region. Therefore, scheduling of some initiatives along the Surma and Kushiyara Rivers will have to fully consider future developments in the Barak River basin.

The *Manu River Improvement Project* will divert a portion of flood flows into Hakaluki Haor to reduce discharges at Moulvibazar. This will alter the regime of both the Manu River and the area around Hakaluki Haor. Sediment deposition may occur on the Manu River below the diversion since the river's sediment transport capacity will be reduced. The diversion flows will also produce sediment deposition in Hakaluki Haor. This deposition will occur by development of a delta into the haor and by channel switching across the low-lying land. Rapid sedimentation is expected when the diversion is operating.

Major impacts to water levels, discharges, and channel regime are also anticipated due to the construction of embankments and the flow diversion associated with the *Upper Kangsha River Basin Development*. Full flood control embankments will reduce spills along the Kangsha River and will produce higher in-channel discharges. Model simulations indicated peak water levels could be raised by more than 1 m at Sarchapur bridge and that impacts will extend as far downstream as Jaria Janjail (*Regional Plan* Figure 21B). Water levels and flows were also forecast to increase on the Kangsha between Jaria Janjail and Mohanganj due to closure of the Atrakhali spill channel. This will flush more sediment into the lower Kangsha River and will contribute to infilling of the dredged reach along the Baulai River.

A second component of *Upper Kangsha River Basin Development Project* involves diverting some flows from the Chillikhali and Malijhee Rivers through an excavated channel into the upper Mogra River. This diversion will increase the discharge on the Mogra River and may increase flood stages at Netrokona. Actual water level changes at Netrokona were found to be very sensitive to the assumed project layout so additional analysis will be required to firmly establish these impacts. The increased discharges could lead to some enlargement of the Mogra River by channel erosion and degradation. The increased flows will also flush fine sediment into the Dhanu-Baulai River system.

9.2.2 Regional Surface Water Model Results by River System

Upper Meghna
At Bhairab Bazar, regional surface water model water levels were unchanged from the FWO simulation.

Kushiyara River
Upstream of Sherpur, model water levels increased 0.5 m or less as a result of embankments and channel closures which confine flows in the Kushiyara by reducing spills onto the Kushiyara floodplain. Further downstream, model winter and pre-monsoon water levels at Markuli decreased by 1.5 m, as a result of Kalni-Kushiyara River improvement (*Regional Plan* Figure 21A).

Surma River
The situation in the Surma is similar to that in the Kushiyara. Near Kanaighat, model water levels increased 0.6 m as a result of embankments and channel closures above this point. Working downstream, from Sylhet to Sunamganj, model water levels increased 0.2 m; at Nilpur, no change occurred; at Sukdevpur, model water levels were unchanged or slightly lower but discharges increased, reflecting the impacts of Baulai River improvement. At the lower end, model winter water levels decreased by 0.5 m, and pre-monsoon levels decreased by 0.2 m.

Kangsha River
In the reach upstream of Jaria Janjail, model water levels increased as a result of the confinement of the lower Bhogai and upper Kangsha; Sarchapur water levels increased by 1.5 m. Between Jaria Janjail to Mohanganj, model water levels increased 0.5 m as a result of the closure of the Shibganjdhala; this represents a return, approximately, to current conditions.

Mogra River
In the Mogra, model discharges and water levels increased significantly as a result of works on the upper Kangsha which would divert Chillikhali River and Malijhee River flows into the Mogra. This result is however highly dependent on details of the simulation and further investigation is required.

Khowai River
In the Khowai, model flood peaks increased by 200 $m^3 s^{-1}$, reflecting the net result of decreased spills from the Khowai into the Karangi River, and diversion of flows from part of the Khowai basin into the Sutang River. This is a preliminary result and further investigation is required for design purposes.

Jadukata River and Patnaigang
With closure of the Patnaigang, model Jadukata flows, especially in the post-monsoon and winter periods, increased at the expense of model Patnaigang flows.

9.3 INTERACTIONS AMONG FCD PROJECTS

Figure 14 shows a screening matrix of project interactions. This plot identifies projects which will produce impacts on other initiatives, as well as those projects which will receive impacts.

ə a

Project interactions have been classified according to their expected magnitude using a simple ranking, with *A* representing the strongest interactions and *C* representing minor or no interaction. Cumulative scores provide a crude means of ranking projects that have the greatest overall impact to the development plans in the region as well as identifying projects that will be highly sensitive to other initiatives. Impacts have been assessed for the future condition (2015) with the assumption that Tipaimukh Dam will be constructed. Therefore, in terms of long-term interactions, the initial phasing of individual projects is not very critical.

Projects which have either no interactions or only a minor interaction with a single other project were treated as essentially independent initiatives. These projects include:

- *Mrigi Drainage Improvement*
- *Upper Kangsha Project*
- *Narayanganj-Narsingdi Project*
- *Narsingdi District Project*
- *Manu River Project*
- *Habiganj-Khowai Project*
- *Sarigoyain-Piyain Project*

9.4 ENVIRONMENT-ON-PROJECT IMPACTS

9.4.1 Introduction

9.4.2 Usual and Customary Events (Current Conditions)

Usual and customary events which cause environment-on-project impacts include erosion of embankments and homestead platforms by river and floodplain flows and by wind-generated waves. The intensity of this erosion is a key determinant of maintenance and rehabilitation requirements. If maintenance is inadequate, embankments will breach, greatly multiplying the infrastructure damage, and homestead erosion will accelerate with decreasing platform heights and increasing frequency of inundation.

Historically, public cuts have been a common occurrence in the region. In some cases, these amount to a rational (if illegal), low-technology, locally-controlled, inexpensive means of water management, with local farmer groups working together to cut an embankment for local drainage and then repairing it to prevent flood inflows, sometimes over a series of years. It is to be expected that such activities will continue in the future, and it would be desirable for environmental/water resources management systems to develop capabilities for monitoring, evaluating, and where needed negotiating modifications to them.

The case of public cuts undertaken at times of crisis are discussed below in Section 9.4.4.

9.4.3 Trends (Future Conditions)

Future trends which could contribute to environment-on-project impacts are:

- Tipaimukh Dam — reservoir filling and operation. Included in the FWO scenario (Section 8.3.2). Further environment-on-project/Plan impacts discussed in Section 9.7.1.

- Increased rainfall and rainfall variability (climate change) and increased flood levels and discharges (cumulative effects of infrastructure development + climate change). Environment-on-project/Plan impacts discussed in Section 10.1.5.

- Changes in upland land use. Upland deforestation in the smaller river basins associated with the alluvial fan and piedmont river basin areas may increase runoff and sediment inputs in these systems. Significant effects on the main river systems (Kangsha, Surma/Kushiyara, Meghna) are not expected because of the sediment and runoff buffering effects of headwater systems.

- Population growth, urbanization, industrialization leading to increased pressure on and social conflicts over biophysical resources and increased water contamination.

9.4.4 Hazards

The region's water systems and Plan projects are vulnerable to:

- Earthquake. Impacts on Plan projects would be similar to impacts on existing infrastructure and other systems. These are discussed in Section 8.8.1.

- Catastrophic flash floods on the Meghalaya and Piedmont rivers. Discussed in Section 8.8.3.

- Tipaimukh dam failure. This would completely overwhelm existing and proposed infrastructure and other systems. Discussed in Section 8.8.2.

- Public cuts in response to flooding, conflicts between interested parties, and as sabotage (for political or personal reasons) or vandalism. Such cuts can cause massive flows and inundation, and infrastructure damage. Anticipatory planning based on extensive public consultation can minimize but probably not eliminate risks.

9.5 MITIGATION, COMPENSATION, AND ENHANCEMENT OF FCD IMPACTS BY NON-FCD PROJECTS

The Plan portfolio includes several projects which would mitigate, compensate, or enhance impacts of Plan FCD projects. This type of mitigation, compensation, and enhancement is in addition to mitigation, compensation, and enhancement measures incorporated within individual Plan FCD projects.

There is a need to maintain a balance between structural and non-structural initiatives in the implementation schedule. Consideration should be given to placing more emphasis on implementing non-FCD projects.

Under the *Fisheries Engineering Project*, an attempt would be made to develop fish passes to mitigate fish migration impacts of embankments, closures, and water control structures. Other structural measures would protect *beels* from sedimentation and increase dry season water storage.

৯৭

Under the *Fisheries Management Programme*, biological management of the floodplain fishery would be improved through interventions in fisheries habitats, assistance to New Fisheries Management Policy (NFMP) fishermen associations, and improvements in management of small community fisheries (*mohalshamil jalkar*, <1.2 ha in area).

Under the *Northeast Region Environment Management Research and Education Project* (NEMREP), which is composed of 11 of the 44 initiatives proposed in the Plan, measures would be undertaken to preserve and enhance regional biodiversity and to improve the management of regional surface water quality, through measures in the field and through institutional strengthening. As the NEMREP initiatives are pilot projects, follow on action will need to be taken. The NEMREP measures (with follow on action) compensate in part for adverse impacts of Plan FCD projects in these areas.

Ground Water Investigation addresses ground water management issues. The direct impacts of Plan FCD projects on ground water abstraction are very slight, but they may in some areas contribute to over-exploitation.

Dredging for Navigation and *Support to Country Boats* would act synergistically with the major river improvement (drainage improvement) projects to enhance navigation.

9.6 RESIDUAL PLAN IMPACTS

9.6.1 Biophysical Impacts (FCD and non-FCD) by Environmental Component

Displacement impacts

FCD projects
Project physical works (embankments, structures, and larger channels) would displace cultivation and settlement (homesteads) on a total of 3,000 and 400 ha respectively in the region. This would be 0.2% and 0.9% of total cultivated and settlement areas within project areas. Lost agricultural production from these cultivated and homestead areas is included in the Agriculture section below. The population displaced from settlement areas is discussed in Section 9.6.2, Socioeconomic Impacts.

Other projects
Displacement of FWO land usage on very small areas could occur in the construction of wetlands or other facilities for wastewater treatment, and in the *Bhairab Bazar Erosion Protection Project* (see box).

There would be no displacement impacts from any of the other non-FCD projects.

Displacement impacts (non-FCD)

Industrial Pollution Abatement at Smaller Industrial Facilities
Aquatic Plant Wastewater Treatment
Pulp and Paper Mill Effluent Treatment
Bhairab Erosion Protection Project

Settlement and road impacts

FCD projects
A total of 6,400 ha of settlement area (homesteads) would be protected from flood damage (nominal 1:10 return period). This would be 9.7% of the

total regional homestead area of 65,000 ha, and 52% of the 12,000 ha of FWO flood-affected homestead area within project areas. Proportionate numbers of people (rural population) would be protected; this is covered in Section 9.6.2, Socioeconomic Impacts.

Spoil from manual excavation and dredging could be used to create new and raise existing homesteads on 740 ha.

Flood damage would be reduced in four of the eight major urban centres (Narsingdi, Narayanganj, Habiganj, Moulvibazar) and fourteen of the 74 *thana* centres. Patterns of future development, and effectiveness of future flood-zoning efforts, will greatly influence the functional future impact (population and urban infrastructure protected) of the urban flood protection provided. Urban population protected is discussed in Section 9.6.2, Socioeconomic Impacts.

Rural settlement impacts (non-FCD)

Regional Water Quality Characterization
Aquatic Plant Waste Treatment
Ground Water Monitoring
Jamuna Floodplain Floodproofing
Pond Aquaculture
Pulp and Paper Mill Effluent Treatment
Locally-Based Management of Key Wetland Sites
Threatened Ecological Community Recovery
Threatened Species Recovery
Village Water Supply and Sanitation
Village Afforestation
Improvement of Homestead Platforms

Flood damage to roads would be reduced. Assuming that future and existing road networks would be the same, in the absence of site information for future additional roads, there would be 3600 km of roads within projects' gross areas; of which 1,600 (45%) would be FWO flood-affected; of which 580 km (16%) would benefit from flood protection.

Other projects - rural settlements
Rural settlements' biophysical environment would be positively impacted by a number of projects (see box).

There would be no negative impacts on rural settlements from non-FCD projects.

Other projects - urban settlements
Urban settlements' biophysical environment would be benefitted by a number of projects (see box).

The *Urban Potable Water Project* has the potential for adverse biophysical impact, since it would greatly increase the volume of urban domestic wastewater. Urban wastewater treatment is addressed by the initiative *Aquatic Plant-Based Wastewater Treatment*. There would be no negative impacts on urban settlements from any of the other non-FCD projects.

Urban settlement impacts (non-FCD)

Urban Potable Water
Urban Sanitation
Regional Water Quality Characterization
Industrial Pollution at Smaller Industrial Facilities
Aquatic Plant Wastewater Treatment
Bhairab Bazar Erosion Protection
Ground Water Monitoring
Jamuna Floodplain Floodproofing

ঠঠ

Other projects - roads etc.
With the exception of erosion protection in the Bhairab Town Erosion Protection project, road impacts would be nil.

Agricultural impacts

FCD projects
Annual regional paddy and other grain production would increase by 570,000 tonnes, or 10% of the present production of 5.6 million tonnes. Rice-cropped area would increase by 38,000 ha, or 2.0% of the present area of 1.9 million ha. Flood (again, 1:10 year) damage to crops would be reduced on 320,000 ha.

The incremental rice area and annual rice production given here reflects 12,000 tonnes of lost annual production on 5,200 ha of farmland that would be converted to other land uses:

- Up to 700 ha converted to homestead use by spoil deposition to create new homestead platforms;
- 1,500 ha converted to channel area as a result of re-excavation; and
- 3,000 ha converted to embankments and other project infrastructure.

This is a maximal estimate of the adverse impact on agricultural land use, in that it is assumed that the area to be converted to channels is 100% under rice cultivation and already owned by BWDB (i.e. all acquired land to be used for embankments and other project infrastructure). In fact, not all land along channels is cultivated, not all cultivated land is under rice, and some acquired land would be used for channel re-excavation.

Annual regional production of other food crops would increase by 123,000 tonnes, or about 12% of the present production of 1.0 million tonnes; this includes all non-grain crops except sugar cane, excluded on account of its anomalously high mass yield per hectare and low nutritional and economic value per unit mass. Other-food-crops cropped area would increase by 68,000 ha, or about 20% of the present area of 340,000 ha.

Crop diversity as represented by the ratio of other-food-crop to rice production by mass, would increase slightly from 0.183 to 0.186.

FCD-led increases in irrigation expansion would be modest. Ground water irrigated area would increase by 3,300 ha, 1.5% of the current area of 223,000 ha, and usage by 43 Mm^3. Minor surface water irrigated area would increase by 900 ha, 0.2% of the current area of 351,000 ha, and usage by 11 Mm^3. The area irrigated by mechanized means would increase by 2,700 ha, 0.7% of the current area of 383,000 ha. These impacts are composed of substantial decreases in irrigation (all types) in the *Baulai River Improvement Project* and the *Kalni-Kushiyara River Improvement Projects*, reflecting a net shift from winter to summer crops, balanced by modest increases in irrigation in most of the other projects (Figure 13).[4]

[4]As this report goes to prss, the *Kalni-Kushiyara River Improvement* pre-feasibility study is being finalized, and the loss of irrigated area is now in doubt.

Annual diesel fuel consumption for irrigation would increase accordingly by 0.5 million litres, 0.7% of current requirements of 76 million litres.

Annual agrochemical use — of interest for reasons of ecologic/water quality, human health, economic, etc. — would increase. Annual pesticide use would increase by 47 tonnes, or 9% of current usage of 530 tonnes. Annual fertilizer use would increase by 46,000 tonnes, 20% of current usage of 226,000 tonnes.

Agriculture impacts (non-FCD)

Ground Water Monitoring
Jamuna Floodplain Floodproofing
Applied Research for Improved Farming Systems

Soil quality would need to be managed more carefully in areas provided with full flood control/controlled flooding facilities, and in areas converted to HYVs.

Fodder supplies would shift, with some increasing and others decreasing. There would be increases in biomass byproducts (straw, husks, and so on) proportionate to increases in primary agricultural production described previously. Also, provision for fodder as a second or third, additional, crop on 26,000 ha has been included in *Baulai River Improvement Project* and *Kalni-Kushiyara River Improvement Project*. Winter grazing area (defined as F0, F1, and F2 winter fallow plus perennially fallow highlands) would decrease by 54,000 ha or 7.0% of the current area of 779,000 ha.

Homestead agricultural (spices, fruit trees, vegetables, livestock, etc.) production would increase on 6,700 ha or 10% of current regional homestead area of 65,000 ha, due to new and raised homesteads from spoil (700 ha), reduced flood damage on flood-protected homesteads (6,400 ha), minus homestead area taken for project works (400 ha).

Other projects
Agriculture would benefit from several projects (see box).

The projects *Applied Research for Improved Farming Systems*, *Fisheries Biological Management*, *FEAVDEP* and *NEMREP* each imply diversification of land use away from field crops, in particular rice cultivation, to uses such as agroforestry, and swamp forest reed land, and flood plain grassland for fish habitat, village erosion protection, and production of biomass products (fuel, building materials, fodder, green manure, and so on). The areas under these non-agricultural usages would expand into areas now occupied in part by agriculture, in particular (mainly highly flood-damage prone) rice cultivation. Impacts as a percentage of regional rice cropped area and rice production would be small. The impact on agriculture is therefore negative, but the overall biophysical and socioeconomic impact is positive.

Water quality impacts

FCD projects
Water quality (as experienced by domestic consumers, fisheries, and wetlands) changes cannot be quantified, but would be affected in a number of ways. Drainage improvement would tend to improve water quality, by increasing flushing and flushed volume and duration, and decreasing

202

stagnant water volume and duration. Flood control would improve water quality at some times and places, by eliminating flooding of domestic-supply tube wells and pit latrines for example, and worsen it at others, by decreasing flushing and increasing stagnant water volume and duration. The FCD-led increases in pesticide use (see above) would contribute to water contamination, especially in low pockets surrounded by HYV cultivation. The FCD-led increases in fertilizer use would increase nutrients available to the openwater fishery, but could also aggravate eutrophication problems.

Other projects
Water quality would be improved by a number of projects (see box).

Water quality impacts (non-FCD)

- Urban Potable Water
- Urban Sanitation
- Regional Water Quality Characterization
- Industrial Pollution Abatement at Smaller Industrial Facilities
- Aquatic Plant Wastewater Treatment
- Ground Water Monitoring
- Pulp and Paper Mill Effluent Treatment
- Village Water Supply and Sanitation
- Threatened Ecological Community Recovery

As has been mentioned, the *Urban Potable Water Project* would increase urban domestic waste water volume. There would be no negative impacts on water quality from any other non-FCD projects.

Openwater fisheries impacts

FCD projects
Open water fisheries habitat and production would be altered:

- Floodplain (defined as F1, F2, F3, and F4 areas, based on monsoon flooding) would decrease by 49,000 ha, or 2.3% of the total current regional floodplain area of 1.2 million ha.

- *Beel* area would increase by 70 ha, or 0.1% of the total current regional *beel* area of 60,000 ha, reflecting the impacts of *beel* bunding and water retention behind regulators, less *beel* area lost to other land uses.

- River and channel area will increase by 1,400 ha, or 4.0% of the current regional area of 35,000 ha, reflecting excavation of 74 million cubic meters of channel sediment.

- The number of river duars will increase by 42 or 14% of the FWO total of 310, reflecting mitigation of duars that would be lost in the FWO scenario due to siltation in the Baulai and Kushiyara Rivers. Impacts on production would be positive, but have not been quantified.

- Major and minor channels will be closed permanently at 48 locations, eliminating fish migration along these routes.

- The *Surma-Kushiyara-Baulai Project* has the greatest quantifiable negative impact on fish production (-3,900 tonnes annually). This is due to the project's large size (320,000 ha gross area), and the pessimistic assumption that the overall migration impact will be -20%

($M = 0.8$). The project includes dredging for habitat rehabilitation in the Kaliajuri mother fishery and key wetland site, and flood control works designed to preserve the ecological character of the fishery by leaving the lowest and most important migration routes open.

- The *Manu River Improvement Project* has the next greatest negative impact on fish production (-2,900 tonnes annually). Assumed impacts on Hakaluki Haor, a key wetland and mother fisheries site, account for most of this: it has been assumed pessimistically that Hakaluki Haor would be completely destroyed as a mother fisheries site by sediment deposited there during diversion events. Some mitigation appears to be possible, in the form of structural confinement of sediment deposition to selected areas.

- Dredging implementation-phase impacts on fish populations are not known and need to be investigated during feasibility studies. Dredging would be performed in the dry season (wet season velocities are too high) when turbidity under normal conditions is low and stresses on fish populations are already at their highest. A key issue will be possible disruption, particularly of benthic biological communities, due to sedimentation and high-velocity turbid plume flows; and the spatial and temporal scale of the fisheries impact. Some methods are in use to mitigate aquatic impacts of dredging, for example, use of booms and curtains to protect valued areas.

- For manual excavation, fisheries impacts occur during the site preparation phase when channels are drained out usually resulting in total catch of fish populations in the affected reach. The regional biophysical and economic impacts of this activity are not readily distinguishable from normal fishing activities, however.

The overall quantified impact on openwater fisheries annual production would be a decrease of 10,600 tonnes or 11.0% of current regional annual production of 96,000 tonnes, with over half due to losses due to flood protection measures included in the *Surma-Kushiyara-Baulai Project* and the assumed destruction of Hakaluki Haor by the *Manu Diversion Project*. The overall quantified impact includes FCD-induced changes in migration access and water quality for most of the projects.

No impact on the three fish species thought to be threatened is anticipated, but further study of these species would be needed to confirm this.

Other projects
Openwater fisheries would benefit from a number of projects (see box). Benefits from these projects would help to mitigate the adverse fisheries impacts of the FCD projects; in terms of overall openwater fish production, the net impact (FCD+other) would be significantly positive.

The same concerns that were mentioned above with respect to FCD dredging would apply to *Dredging for Navigation*. There would be no

Openwater fish impacts (non-FCD)

Regional Water Quality Characterization
Industrial Pollution Abatement at Smaller Facilities
Applied Research for Improved Farming Systems
Fisheries Engineering Measures
Fisheries Management Programme
Pulp and Paper Mill Effluent Treatment
Biodiversity Initiatives (4)
Village Afforestation

206

negative impacts on openwater fisheries from any other non-FCD projects.

Aquaculture impacts

FCD projects
Flood-free pond area would increase by 1,600 ha or 8.3% of the regional total of 18,700 ha. The potential increment in annual aquaculture production would be 1,600 tonnes, 8.8% of the current regional production of 18,000 tonnes.

Other projects
Aquaculture would benefit from several projects (see box).

There would be no negative impacts on aquaculture from non-FCD projects.

Aquaculture impacts (non-FCD)

Aquatic Plant Wastewater Treatment
Pond Aquaculture
Applied Research for Improved Farming Systems

Navigation impacts (non-FCD)

Dredging for Navigation
Support to Country Boats
Pilot Project to Institutionalize Public Consultation
Rural Infrastructure Planning

Navigation impacts

FCD projects
Navigation would be benefitted by river and channel excavation, and disbenefitted by the 48 closures of major and minor channels at embankments and across spill channels.

Other projects
Navigation would benefit from several projects (see box).

There would be no negative impacts on navigation from non-FCD projects.

Biodiversity impacts

FCD projects
The impact on biodiversity would be mainly adverse:

- Winter wetland area (defined as F3 land lying fallow in winter, plus perennially fallow lowlands, plus *beels* and channels) would decrease by 7,000 ha or 5.7% of the regional total of 124,000 ha.

- Summer wetland area (defined as F1, F2, and F3 land lying fallow in summer, plus perennially fallow lowlands, plus *beels* and channels) would decrease in area by 50,000 ha or 11% of the regional total of 440,000 ha.

- Key wetland sites: *Manu River Improvement Project* would adversely affect Hakaluki Haor. *Jadukata-Rakti Project* and *Sarigoyain-Piyain Project* could benefit the key wetland sites and mother fisheries at Tangua Haor and Companyganj by reducing sediment infilling.

- Swamp forest and reed swamp would not be affected. About half (250 ha) of the region's remaining floodplain grassland (550 ha) could be adversely affected by *Surma Right Bank Project*.

- No threats to particular threatened and commercially threatened plant and animal species are apparent with the information currently available, except for the obvious threat to floodplain grassland-dependent species. Further study would be required to understand species impacts of the elimination of one of the two remaining areas of this community. Further study of the other threatened and commercially threatened species would be needed to confirm lack of impact.

Biodiversity impacts (non-FCD)

Regional Water Quality Characterization
Industrial Pollution at Smaller Industrial Facilities
Aquatic Plant Wastewater Treatment
Applied Research for Improved Farming Systems
Pulp and Paper Mill Effluent Treatment
Biodiversity initiatives (4)
Village Afforestation
NEMREC
Biodiversity Strategic Planning for MOEF

Openwater fishery biodiversity impacts were discussed above.

Other projects
Biodiversity would benefit from a number of projects (see box). Benefits from these projects would help to mitigate adverse impacts of the FCD projects on biodiversity, including migratory waterfowl populations (see below). There would be no negative impacts on biodiversity from non-FCD projects.

Impacts on areas outside flood protection within the region; areas outside the region; and migratory populations

FCD projects
Three areas in the region — the Mogra basin, Hakaluki Haor, and the lower Sarigoyain River basin — will remain both outside of flood control embankments and may be vulnerable to displaced flooding from Plan FCD projects, which could cause increased flood damage to crops, homesteads, and roads in these unprotected areas.

There would be no hydrologic or sediment impact on areas downstream of the region, given conditions at the region's outfall. A possible exception could be transient effects due to turbidity from dredging.

Migrating waterfowl populations will be adversely affected by the overall reduction of winter wetland areas and the adverse impacts on Hakaluki Haor. This could be somewhat compensated by positive impacts on Tangua Haor and Companyganj area.

Pesticide pollution of regional surface water outflows would increase slightly.

209a

Other projects
Areas outside the Northeast Region would benefit from improved water quality of regional surface water outflows due to a number of projects (see water quality box). Migratory fish populations would be benefitted by a number of projects (see openwater fish box).

Other biophysical impacts
Dredging could have other adverse impacts, in addition to the fisheries impacts mentioned above. It involves movement of vast quantities of spoil, initially in the form of a water/sediment slurry, which must be properly managed (proper settling basins, deposition in acceptable locations, and so on), or negative impacts can be considerable: spoil deposited in areas where it is not wanted or destructive, turbid flows into the original dredged or other water body with unwanted effects, and so on. Another concern may be a need to check sediments for toxic chemicals, in channels downstream of industrial facilities. Proper environmental management will be key. Incentive to handle slurry/spoil properly should be built into contracts (pay per volume moved will be an invitation to carelessness).

9.6.2 Socioeconomic Impacts

Displacement impacts
Some rural residents will be very directly impacted through impacts on homestead lands. FCD works will displace 36,000 people from rural homesteads. In these projects, compensation of the impact on the regional stock of homestead land would be achieved by constructing new homestead areas from excavation spoil.

Homestead flood protection
The 6,400 ha of homestead which would be protected from flooding are occupied by 1.4 million residents, who would experience less flood damage to possessions, including the homestead plot itself and to homestead agricultural production.

Urbanization and migration impacts
There is limit to which agriculture would be able to absorb the increasing labour force that would migrate to urban areas. The Regional water management plan laid emphasis on protection of urban areas leading to growth of industries and better living conditions for these rural to urban migrants.

Strategy implementation would tend to accelerate urbanization, some of which would occur as rural areas shift over to urban economic activities, and some as rural-to-urban migration. Both urban and rural economic and environmental conditions would improve over the FWO forecast, but improvement in urban conditions would proceed more rapidly. One result would be that per-household rural income would improve, with incremental rural gains being shared among a smaller number of people. In particular, it is expected that the *Narsingdi-Narayanganj Project* and the *Narsingdi District Project* would boost urban population in this area by 1 million. Some of this represents more rapid urbanisation of rural landless people already within the area (especially as villages along the Dhaka-Sylhet and Dhaka-Chittagong corridors urbanise), and the rest represents in-migration from other areas. Integration of this area with the Dhaka mega-urban field will be accelerated as well.

Socioeconomic equity and impacts on landless people
The strategy will reduce the total number of rural landless people in the region compared to the FWO situation, mainly by boosting the urban population of the Narsingdi-Narayanganj area through faster urbanisation of local landless people and increased in-migration to urban areas of rural landless people from other areas.

The benefits of strategy implementation will accrue to different sections of the society in varying proportions. FCD initiatives will mainly benefit landowners, which should slow down the overall rate at which small farmers become marginalized and eventually landless. The strategic thrusts for improved urban environment and improved liveability of rural settlements will benefit all strata of the population with optimum equity.

In FCD projects, the net incremental increase in employment in project agriculture less employment lost in fisheries, is composed of 66,000 jobs which would accrue to landowners and 16,000 jobs which would accrue to hired labourers (that is, landless people). Additional jobs in downstream post-harvest activities would also be created.

The overall figure for hired labourers masks the fact that as many as 41,000 jobs in the openwater fishery (about 12% of jobs in the sector) could be lost. Additional downstream jobs in post-catch processing would also be lost. This represents a significant negative impact on fishing families, particularly poorer families dependent upon subsistence fishing, as a group.

Gender equity
The strategic thrust to improve liveability of rural settlements would improve the conditions in which most women spend most of their lives and perform most of their work. This would also support expansion of household-based employment. The initiatives on potable water, both rural and urban, will benefit women, who collect and use most domestic water, more than proportionately.

Several of the strategic thrusts would support crop diversification, which could be positive for women, in the sense that adoption of non-traditional crops might provide an opportunity for eased cultural constraints on women's involvement in field activities in agriculture.

Otherwise, the other strategic thrusts benefit women mainly as members of households; to the extent that women share in the total work, income, assets, and so on of their households, to that extent they will benefit from the strategy. The other strategic thrusts neither fortify nor transform the social construction of gender roles as these would exist in urban and rural settings.

Literacy
The strategy will not impact literacy directly, but the improvement in general economic conditions and better living conditions in rural and urban areas will have positive impact on the people's attitudes towards and ability to afford education for their children. The elasticity of income for education is believed to be greater than one at the above-subsistence level: once basic food requirements are met, people spend more on education.

Well-protected settlement areas will prevent disruption of education from flooding of school buildings and roads.

As higher education facilities are concentrated in urban areas, improved protection of the roads and water links between the villages and urban centres would have some impact on higher enrolment in secondary and college level education. This is particularly true for Sylhet Region which has few colleges compared to other areas; these are mostly concentrated in urban centres where female enrolment is low.

While improved access will help to increase gross enrolment rate, increased household income is expected to reduce the dropout rate significantly.

Water and sanitation
The implementation of the proposed strategies on improved urban environment and improved liveability of rural settlements will contribute to achieve the national goal for universal coverage of potable water for drinking. With improved accessibility and motivation, the use of tube well water for all purposes can be expanded. This will help to reduce the incidence of water-borne diseases and will have positive impact on health and personal hygiene.

Tube well maintenance by women will enhance their role and status in the community. In addition, increased accessibility will reduce the labour in drawing and managing domestic water supplies, traditionally women's work.

Proposed initiatives (Urban Sanitation, Rural Water and Sanitation), will also contribute to improved sanitation through proper disposal of human waste and waste treatment.

Nutritional status
Enhanced production systems including pond aquaculture in seasonally flooded areas and integrated development of the deeply flooded areas will contribute to increased production of high value nutritious crops, fish, and livestock and will increase their availability in the market.

The FCD projects alone would result, relative to FWO conditions, in food availability per person increasing by 10% for rice, by 12% for other crops, and decreasing by 11% for fish. The impacts of the total strategy would be significantly more favourable than this. Increased aquaculture fish production (increase of 11% with fewer ponds at risk of regular flooding) would partly offset decreasing openwater fish production, but will provide little consumption benefit to poorer groups.

Income is directly correlated with nutritional status. With increased per capita income, the extent of child malnutrition (stunting, wasting, underweight) would decline. The impact on nutritional status will be less in rural than urban areas due to the lower impact of strategy implementation on rural incomes.

Increased household income would be accompanied by increased expenditure for food. This will contribute to ensure minimum caloric intake for the vulnerable population. The average incremental income would be sufficient to overcome absolute poverty (defined as Tk 4,800 per person per year), but many poorer households' income would remain below this level.

Life expectancy
The increase in aggregate household income expected as a result of strategy implementation would directly contribute to overall improvement in living conditions, particularly through

improvement in health and nutritional status. It is likely that with increased household income, per capita expenditure on nutritious food, sanitation and health care will increase. All these together will have positive impact on life expectancy, particularly on the reduction of infant and child mortality.

Socioeconomic impacts of biodiversity and wetland changes
People dependent on floodplain grassland and on wetlands will be adversely affected, in proportion to the impacted areas noted above. This impact will be localized and will mainly affect poorer people who are most dependent on these types of resources.

9.7 MODIFICATION OF EXPECTED IMPACTS BY PARTIAL AND/OR DIFFERENTLY PHASED IMPLEMENTATION

9.7.1 Projects Affected by Tipaimukh Dam

Four projects (*Upper Surma-Kushiyara River Project, Surma Right Bank Project, Surma-Kushiyara-Baulai Basin Project* and *Kushiyara-Bijna Interbasin Project*) would be affected by Tipaimukh Dam. For phasing purposes, these projects are grouped together (*Regional Plan* Section 9.3, Group SED) for implementation commencing in Year Four, to allow additional time for resolution of the Tipaimukh Dam issue.

If the Tipaimukh Dam/Cachar Plain Project is delayed beyond this point (i.e. is neither implemented nor definitely dropped), then implementation of the Group SED projects would be delayed further. This would significantly alter the nature of the impacts produced by several other initiatives. For example, if the *Upper Surma-Kushiyara Project* and *Surma-Kushiyara-Baulai Basin Project* were not implemented, large magnitude spills (possibly increasing over time due to channel changes) would continue to occur into the Central Basin from both the Surma River and Kushiyara River. This would significantly reduce the effectiveness of initiatives such as the *Baulai River Improvement Project* and *Kushiyara-Bijna Interbasin Project*.

In the case of extended delay in resolution of the Tipaimukh Dam issue, one approach would be to proceed with key components of the *Upper Surma-Kushiyara Project* and *Surma-Kushiyara-Baulai Basin Project* which would be feasible to construct during the extended interim period. Such components of the *Upper Surma-Kushiyara Project* involve regulation of spill channels and *khals* that divert water from the Surma River into the Kushiyara River system. Key components of the *Surma-Kushiyara-Baulai Basin Project* involve regulation of spill channels from the Surma River into the deeply flooded Central Basin, and re-excavation of important distributary channels which drain the inter-basin and discharge into the Baulai River. Components that might be postponed until after a final decision on the dam is reached includes raising and upgrading full flood control embankments on the Upper Surma-Kushiyara Rivers and upgrading and construction of new submersible embankments on the lower Surma-Baulai River and Kushiyara-Kalni River.

9.7.2 Projects Affected by Alluvial Fan Instability

The *Piyain Improvement Project*, *Jadukata-Rakti Improvement Project*, and *Upper Someswari River Basin Project* all contain measures for improving the stability of land affected by alluvial fans. However, at present, the channels on these fans are all poised to develop avulsions which could substantially alter the downstream hydrological regime and drainage patterns in the project area. The effectiveness of the proposed measures and the nature of the impacts from these projects will be strongly dependant on the timing for their implementation. This is because the tendency for channel changes will not remain constant over time but is generally progressive. For example, an avulsion path may originate as a small *khal* or spill channel and then enlarge during successive floods by bank erosion as flow is captured from the old channel. If the avulsion path is closed early on, before it develops into a major channel, relatively minor measures may be required. If the works are delayed until most of the flow is carried by the new avulsion channel, it may be no longer feasible to close it. Furthermore, even if a closure can be made, the scale of the impacts from this work may be substantial, both on the newly formed channel and the old channel. Therefore, the control measures described in these projects implicitly assume immediate implementation. If the work was not implemented immediately, the overall concept for stabilizing the fan would have to be re-assessed. In this case, a decision to delay the work is equivalent to assuming it will not be implemented at all.

9.8 IMPACTS BY SUBREGION

9.8.1 Introduction

This section describes the main physical impacts from Regional Plan initiatives in various geographical sub-regions. The object of the discussion is to illustrate the spatial distribution of impacts of the Plan in the region. Several different classification schemes can be used to delineate sub-regions, such as physiography, land-use, or depth of flooding. For the purposes of this discussion, the region has been divided (primarily on the basis of physiography), into six main sub-regions:

- Eastern seasonally flooded floodplain land
- Northern alluvial fans
- Central Basin
- Western seasonally flooded floodplain land
- Southern piedmont floodplains
- Peri-urban areas

The general extent of these sub-regions is can be seen in *Regional Plan* Figures 2, 4, and 14 (Peri-Urban Area).

9.8.2 Eastern Seasonally Flooded Floodplain

The eastern seasonally flooded areas include the floodplain of the Surma-Kushiyara Rivers and the inter-basin lands adjacent to the main rivers. The sub-region extends from Amalshid on the east where the Barak River bifurcates at the Indian Border, to near Chhatak on the Surma River and near Sherpur on the Kushiyara River. Projects in this sub-region include:

Upper Surma-Kushiyara River Project
Surma Right Bank Project
Sarigoyain-Piyain Project

These projects will eliminate spills from the main rivers during both the pre-monsoon and monsoon season so that during the flood season, runoff in the low-lying inter-basins will be derived only from internal rainfall. The closure of major spill channels will increase the relative distribution of flows carried by the Surma River. However, flow regulation from Tipaimukh

Dam will reduce the flood inflows, so that the flood magnitudes will be reduced on both the Surma and Kushiyara Rivers. Consequently, the inter-basin lands will be more isolated from the main rivers since banks will not be overtopped, and inflows of water and sediment from spills will be eliminated. The main rivers will adjust to the reduced flood magnitudes, lower sediment inflows and increased lateral confinement. It is expected that some reaches (particularly the Kushiyara River) will transform into smaller, more stable channels with fewer deep scour holes and larger, more prominent sand bars.

9.8.3 Northern Alluvial Fans

The alluvial fans bordering the Meghalaya Hills extend from the Dhalaiganj River near Companyganj in the east to the Someswari River in the west. Projects that fall in this sub-region include:

Sarigoyain-Piyain Project, Dhalaiganj improvement component
Jadukata-Rakti River Improvement Project
Upper Kangsha River Basin Project, Someswari River component

The Plan recognizes the inherent instability and high risks that are associated with developments on fans. Therefore, the Plan has avoided initiatives that would attempt to confine the fan channels by narrow embankments. Instead, it is recommended that the fans be allowed to occupy a wide active floodway, which will be used for storing sediment and conveying flood flows. Initiatives have been restricted to (1) stabilizing inactive or less active portions of the fan so they will be safe from future avulsion hazards, or (2) preventing new avulsions from developing by closing spill channels that threaten to capture the main river flows. Therefore, the negative impacts of projects in the fans should be small. However, this also implies that damages from flooding, erosion and sedimentation will continue to occur to existing developments within the active floodway of the fans.

9.8.4 Central Basin

The projects in the Central Basin include:

Surma-Kushiyara-Baulai Basin Project
Baulai River Improvement Project
Kalni-Kushiyara River Improvement Project
Kushiyara-Bijna Inter-Basin Project
Jadukata-Rakti River Improvement Project
Updakhali Project
Dharmapasha-Rui Beel Project

Impacts from these developments will be primarily felt during the pre-monsoon and post-monsoon season. Project impacts are expected to be minor during the monsoon season when the sub-region, and the initiatives will be inundated.

The main project impacts in this sub-region derive from three factors:

- Spills of pre-monsoon floods from main river courses into the low-lying haor basins will be reduced due to regulation of spill channels and completion of new submersible embankments along the major rivers. Consequently, during the pre-monsoon season, drainage requirements will be primarily determined from local runoff rather than from externally generated flood inflows. The key project that accomplishes this regulation of spills into the Central Basin is the Surma-Kushiyara-Baulai Basin Project. In addition, the Upper Surma-Kushiyara River Project, although located outside the sub-region, also is critical to reducing inflows along the Kushiyara River.

- Runoff in the Central Basin will be organized and conveyed into several major drainage channels that will discharge into the main rivers. At present, much of the existing drainage system has been obstructed by past channel closures, channel changes due to morphologic processes or local siltation. The initiatives includes a major program to restore the drainage capacity of the basin lands through a program of channel re-excavation and re-alignment.

- Shoals and obstructions on the main river channels will be excavated to lower pre-monsoon water levels (to reduce spills into the Basin) and post-monsoon water levels (to hasten post-monsoon drainage).

Consequently, it is expected that the Central Basin will become a more stable, low energy environment, since the magnitude of the driving forces (the water and sediment inflows) will be reduced considerably.

9.8.5 Western Seasonally Flooded Floodplain

This sub-unit includes the floodplain of the Old Brahmaputra River as well as Piedmont floodplains draining the Susang Hills. The projects in this sub-unit include:

Upper Kangsha Project
Mrigi River Drainage Improvement Project

The proposed works on the Mrigi River involve channel re-excavation and drainage improvements while the works in the *Upper Kangsha River Project* involve construction of full flood control embankments, a flow diversion to Mogra River and a major program of channel straightening and loop cutting. Impacts from the Mrigi project will be minor, while major impacts are expected to occur from the *Upper Kangsha River Project*, both in the direct project area and further downstream outside the project area.

9.8.6 Southern Piedmont Floodplain

This sub-unit includes all of the piedmont streams draining the Tripura Hills in India. Projects in this sub-unit include:

Manu River Improvement Project (Manu River and Dhalai River)
Habiganj-Khowai Improvement Project (Khowai River, Karangi River and Sutang River)

The primary effect of these projects will be to reduce monsoon season flooding by either confining main channel flows and preventing spills (*Habiganj-Khowai Project*) or by reducing flood magnitudes by diverting flows into an adjacent basin (*Manu River Improvement Project*).

The magnitude of the impacts from both projects is expected to be large. However, the nature of the impacts will be very different. For example, spills from the Khowai River into adjacent Karangi River will be greatly reduced by extending the Khowai embankments upstream.

Therefore, impacts will be associated with reduced flooding on the Karangi River and increased flood flows on the lower Khowai River. The main impacts on the *Manu River Project* will be associated with the reduced flood discharges below the diversion along the Manu and the impact of the diversion of water and sediment into Hakaluki Haor.

9.8.7 Peri-Urban Area

This sub-unit includes the districts of Narayanganj and Narsingdi, which are expected to take on the role of market gardens for the Dhaka urban and peri-urban population, as urban development spreads to the northeast and displaces market gardening from current closer-in areas. Projects in this sub-unit are:

Narsingdi-Narayanganj Project
Narsingdi District Project

These projects are intended to protect these peri-urban areas for flooding, to facilitate high-value agriculture and reduce flood damage to homes and businesses. They are not expected to affect hydrologic or morphologic conditions outside the project areas.

CHAPTER 10: CUMULATIVE IMPACTS AND SUSTAINABILITY ANALYSIS

10.1 CUMULATIVE IMPACTS

10.1.1 Introduction

This section examines how Plan impacts add to (or subtract from) the impacts of non-Plan activities and processes.

10.1.2 Cumulative Impacts of Plan Projects

Implementation of the various Plan projects implies an accumulation of impacts across the portfolio. This type of accumulation is internal to the Plan, and has been discussed in Section 9.2 above.

10.1.3 Plan + Increasing Population

What effects could Regional Plan implementation (i.e. water management development over the next 20 years) have on population growth in the Northeast Region?

Many of the Regional Plan strategies and initiatives address income, public health, and nutrition objectives, and through them could affect birth, death, and thus population growth rates. A straightforward (Malthusian) interpretation suggests that increasing food availability and improved public health would raise the population growth rate. A more nuanced interpretation of recent experience in developed and developing countries suggests that population growth rates are highly dependent upon parents' perceptions of ideal or desired family size; perceived insecurity in old age; and acceptance of and access to effective family planning. These factors are in turn strongly influenced by income, child mortality, women's status, and access to family planning services (World Bank, 1992). All but the last (which very clearly lies entirely outside the ambit of water management planning) would be impacted positively by strategy implementation. However, other studies have shown that population growth rates have risen when populations perceived a relatively small improvement in economic conditions. Increases in family size were attributed to parents' perceptions that they could now afford to support more children, and this factor apparently dominated over reduced concern for old-age security, which might tend to lead to reduced family size.

In practice, a population growth rate was applied as a boundary condition to the regional water management planning exercise. That is, an expected growth rate was assumed for the region, to be taken into account in formulating the Plan. This amounts to a linearization of the problem: the assumed population growth rate incorporates *a priori* approximations of Regional Plan and other development impacts. Also, the positive relationships between reduced population growth, income growth for poor households, reduced child mortality, and improved status of women (which have been incorporated into national development planning through the Fourth Five Year Plan 1990/1 - 1994/5), were recognized in defining Plan objectives.

10.1.4 Plan + Growth of Urban Populations and Infrastructure

In addition to the urbanization and migration impacts noted previously in Section 9.6.2, flood control will accelerate infrastructure development and in-migration into flood-prone urban and peri-urban areas. Over time, this may increase total flood damage, integrated over floods of all recurrence intervals: damage from more frequent, lower magnitude floods will be somewhat less, but damage from less frequent, high magnitude floods which overwhelm water control infrastructure will be much greater because of the increased population and investment. In addition to this, however, flood control will reduce hidden costs associated with exposure to frequent flood damage, such as the cost of low productivity due to low investment; that is, there is a trade off between incremental flood damage and incremental productivity gains.

As the bias of national development in general, and FCD in particular, shifts away from agriculture and toward urban-based sectors, there is a need to strengthen the planning, development, and management of urban areas. One aspect of this would be to raise awareness among involved public and private institutions (municipal corporations, financial institutions, major industrial firms, and small entrepreneurs) about flood risks and proper methods for assessing flood risks. This would enable involved parties to make informed investment decisions. And, at the level of FCD project feasibility studies, there will be a need to investigate both the direct and hidden flood damage costs associated with a range of project and urban development scenarios.

10.1.5 Plan + Climate Change

Over the 20 year period of the Regional Plan, air temperature and sea level will remain effectively constant (i.e. the presumed rates of increase of both are too slow to be discerned over this short time interval).

The tendency observed over recent decades of increasing rainfall and increasing rainfall variability, whether or not this is the expression of anthropogenic changes to the atmosphere, serves well as a prototype for possible future rainfall trends in the region. Impacts of a cumulative nature (Plan + increasing rainfall) relate mainly to:

- Increasing river discharges and water levels (embankments + increased rainfall), leading to morphologic changes (wider channels, aggradation/degradation waves propagating through the system, and increased channel instability and type switching).

- Mitigation of increasing rainfall impacts — drainage improvement could reduce system drainage overloading, habitat conservation and restoration could ensure that development options (swamp forest) suitable for the new conditions are preserved, and so on.

If, on the other hand, rainfall decreases to or below previous levels:

- Existing and Plan FCD investments will produce less benefits relative to the without-project situation, and

- Some existing and Plan partial flood control projects might function as full flood control projects and thus significantly more adverse effects on fisheries, navigation, and possibly other environmental components.

10.1.6 Plan + Tipaimukh Implementation

The impacts of the Tipaimukh Dam/Cachar Plain Irrigation project are included in the FWO scenario. Thus, in principle, cumulative impacts of Plan + Tipaimukh implementation are already reflected in the discussions in Chapter 9 and in the Plan impacts discussed above. In practice, however, the project pre-feasibility studies of the four projects affected by the dam used historical (no dam) data, and thus their impacts were quantified in terms of [FW (no dam) - FWO (no dam)]. This introduces unknown errors in impacts and in project design and costs.

10.1.7 Plan + Changing Patterns of Energy Production and Consumption

Bangladesh has access to a rich variety of energy sources, including:

- Biomass fuels from natural sources (wetland plants, natural forest logs, branches, undergrowth, and leaf litter, and so on), from 'mines' of peat and buried wood, from agricultural residues (rice straw, rice husks, jute sticks), and from dried manure; mainly for cooking;

- Animal draught power for ploughing, threshing, and transportation;

- Human energy inputs to post-harvest processing, planting, weeding, fishing, gathering, traditional irrigation, and many other activities;

- Fossil fuels (domestically-produced natural gas and derivatives, imported fuels), including those used to generate electricity, for lighting, mechanized irrigation, transportation, navigation, rice-milling, brick kilns, lime burning, and many other industries, and other uses;

- Solar energy for drying grain, and, potentially at least, cooking.

Many of the potentially renewable supplies are dwindling as the population grows. The swamp forests and reed swamps, which have been the major stock of biomass fuels and major contributor to peat and buried wood formation, are being consumed. Animal draught power is dependent on biomass production, and is actually a relatively inefficient but versatile means of energy conversion. It is declining in availability because of increasing human population size and pressure to grow rice.

Fossil fuel usage is of particular interest, because such fuels are imported (except for domestically-produced natural gas and its derivatives), non-renewable, and contribute to environmental pollution. Increasing dependence on them increases external dependence, economic unsustainability, and public health and ecological problems.

Fossil fuel consumption is expected to remain very low in Bangladesh compared even to other developing countries, and staggeringly so in comparison to the older and newly industrialized countries. Because the contribution of Bangladesh to global fossil fuel consumption is so insignificant, concern for local energy/fossil fuel use issues logically takes precedence over concern for global issues (e.g. CO_2 emissions).

Local energy issues include: access to and management responsibility for sustainable energy supplies by the poor; local self-reliance; national vulnerability to fossil fuel price and supply swings; foreign export costs; improved management of the national draught and dairy herd; and emphasis on appropriate-technology sustainable energy supplies and energy conservation.

Numerous Plan interventions would promote agricultural intensification (in particular irrigation pumping), accelerate urban and industrial development, and alter wetland productivity both negatively (most FCD) and positively (habitat conservation and restoration). These changes imply alterations in the type and quantity of energy sources exploited. Agricultural intensification will greatly increase by-product (mainly rice straw) mass. It will also slightly increase fossil fuel usage, both directly for mechanized irrigation, and indirectly through fossil fuel-derived inputs such as fertilizers and pesticides. Urban and industrial development will greatly increase demands on electric generating capacity and thus fossil fuel usage. Wetland productivity changes will alter supplies of natural biomass fuels; some interventions will cause increases, and others will cause decreases.

At the same time, other developmental trends independent of water management development will also alter energy production and consumption patterns, in particular increasing fossil fuel usage.

To date there has been little if any meaningful national energy planning. In the absence of such a framework, it was not possible to orient Plan interventions specifically toward energy-related objectives, other than through economic analyses which incorporated costs for irrigation, pumped drainage, and the like. Proposed interventions are not highly sensitive to marginal changes in fossil fuel prices.

10.1.8 Plan + Increased Water Contamination

The primary water quality issue is bacteriological contamination, related to inadequate sanitation and unsafe water supply, accompanied by deficient hygiene practices. This issue would be addressed through continuations of ongoing DPHE/UNICEF programmes, which are included in the Plan project portfolio.

Industrial pollution will be an area of increasing concern, if industrial development accelerates during the Plan period as targeted by Government. Industrial development could be accelerated through Plan investments in urban flood control. Industrial pollution is addressed directly through the NEMREP project.

10.2 SUSTAINABILITY ANALYSIS

10.2.1 Introduction

This section addresses the following questions:

1. How will Plan interventions help to meet near-term needs of the present without compromising the ability of future generations to meet their own needs, in particular the essential needs of the poor, given technological and social systems' capabilities to satisfy needs from the environment? (p. 43, *Our Common Future*, 1987).

2. How will Plan interventions affect rates of resource use? These should not exceed regeneration rates or the rates of development of sustainable substitutes. (p. 3-16, *Manual for Impact Assessment*, Volume 1; FAP 16, March 1992).

3. How will Plan interventions affect pollution rates? These should exceed rates of assimilation and breakdown.

4. Will Plan interventions have, contribute to, or prevent irreversible impacts, especially those affecting ecosystem viability, species survival, and life-sustaining processes, placing the ability of future generations to meet their own needs at risk?

10.2.2 Question 1: Overall Sustainability

Will Plan interventions:

- Help to *meet the near-term needs* of the present,
- Without compromising the ability of *future generations* to meet their own needs,
- In particular the essential *needs of the poor*,
- Given technological and social *systems' capabilities* to satisfy needs from the environment?

Meet near-term needs: As reflected in Plan objectives (*Regional Plan*, Section 8.2).

Future generations: Some of the FCD interventions have the potential for compromising options of future generations. For example, embankments and the Manu Diversion could have irreversible impacts on river morphology, settlement, and urban development patterns, reduction of key wetland habitats, and loss of regional biodiversity. For each proposed intervention, key subsidiary themes need to be explored, relating to:

(1) What the precluded options might be,

(2) What their value to future generations might be,

(3) Which individuals of these generations could be affected, and

(4) Whether alternative means exist to preserve these options.

Essential needs of the poor: These include secure access to safe air and water, adequate food, clothing, and shelter, essential health, education, and family planning services, based on access to appropriate economic resources and opportunities, in the context of respect for human rights.

The potential of proposed Plan interventions to compromise these needs is examined as part of the project and Plan environmental evaluations' socioeconomic sections, where employment impacts, displacement impacts, socioeconomic equity, gender equity, and impacts on conflicts are assessed. The findings of these assessments indicate that most if not all the FCD projects have some potential for negative effects on (compromise the essential needs of) individuals belonging to poorer socioeconomic groups. These potential effects include exercising right of eminent domain on homesteads belonging to poor people to allow embankment construction and channel excavation; reducing total employment opportunities for hired labourers, or reducing employment opportunities in fishing or for poorer women; and creating or exacerbating conflicts between interest groups (in which the less powerful, which usually means the poorer, group would be expected to lose out). Potential mitigation or compensation measures have been identified in some instances, but not in others. Feasibility studies of these projects will need to investigate these issues further if sustainability with regard to this criterion is to be achieved.

System capabilities: Proposed Plan interventions took technological and social system capabilities into account as follows. Existing technological and social systems of resource exploitation and management were extensively studied, in the areas of water management, agriculture, river manipulations, fisheries, navigation, wetland resources, water quality, and village social systems. These systems were then analyzed in terms of strengths, weaknesses (needs for change), opportunities for change, and threats (undesirable changes which could occur unless action is taken). Potential interventions were formulated based on this information. As the proposed projects are studied and developed further, issues related to social and technological system capability will need continued attention.

Proposed Plan interventions have taken technological and social system capabilities into account in two ways. First, existing technological and social systems of resource exploitation and management were extensively studied, in the areas of water management, agriculture, river manipulations, fisheries, navigation, wetland resources, water quality, and village social systems. Second, potential interventions were formulated reflecting an analysis of these systems' strengths, weaknesses (needs for change), opportunities for change, and threats (undesirable changes which could occur unless action is taken).

For example, it was recognized that maintenance and operation of FCD projects has been weak, and that improvements in this area will be needed if both existing and proposed FCD projects are to realize their full potential; thus increased attention has been paid to this area in each of the proposed FCD project pre-feasibility studies. Another more direct example are the NEMREP initiatives which address pollution abatement; these reflect the recognition that the enhanced industrial development sought by the Government will contribute to seriously unsustainable levels of environmental contamination (i.e. above rates of breakdown and assimilation) unless action is taken.

As the proposed projects are studied and developed further, issues related to social and technological system capability will need continued attention.

10.2.3 Question 2: Sustainability of Resource Use

How will Plan interventions impact rates of resource use, and will the Plan contribute to rates which exceed regeneration rates or the rates of development of sustainable substitutes?

Affected resources include:

- Agricultural resources. Shifts from local to high-yielding varieties and intensification of cropping increase risks of soil depletion, of higher plant pest and disease infestation levels. Sustainable management of these impacts may be possible based on improved soil and pest management based on locally-generated inputs (e.g. improved management of manure, green manures, integrated pest management). Some such measures are already an integral part of ongoing Ministry of Agriculture research and development programs.

- Openwater fisheries. The openwater fisheries of the region are under increasing stress from many factors. In seasonal terms, dry season survival of broodstock is a critical factor for the survival of the fishery, and management of quality, quantity, and exploitation pressure on dry season habitat will be key. FCD contributes to the stresses on the fishery and causes reduced production, mainly through impacts on wet season habitat.

- Wild plants and animals. Especially high concentrations of biodiversity remain at the key wetland sites and in threatened community areas. *Manu Diversion Project* would adversely impact Hakaluki Haor, and *Surma Right Bank* could adversely affect Bara Haor. It may be possible to compensate for these impacts under the *NEMREP* project through interventions to enhance biodiversity at other sites provided the scope of *NEMREP* is expanded to take it beyond pilot-level efforts.

- Quarry materials. Depletion of quarry materials does not appear to be a problem.

- Energy resources. Discussed above in Section 10.1.7.

10.2.4 Question 3: Sustainability of System Capacity to Assimilate and Break Down Pollution

Plan implementation will increase pesticide use by 9% and fertilizer use by 20%. Despite this, use rates in the Northeast Region are and will remain very low even by developing country standards. Thus, the key issues in this area will relate to regulation of pesticide imports to prevent dumping of materials barred by industrialized countries for environmental reasons, and better public education to improve handling (e.g. not to reuse pesticide containers for water or food) and to ensure compounds are applied at minimum effective levels.
NEMREP initiatives would improve management of industrial and domestic effluents.

10.2.5 Question 4: Irreversible Impacts

Some of the ongoing natural and man-made processes in the region are irreversible. These include earth filling projects, obstructions, and changing and loss of existing wetlands. Conversion of land from one specific type to another (e.g. forest land to agricultural land) and loss of land due to bank erosion or changing river course are irreversible. These above physical changes subsequently impact adversely on the biological and human resources of the changed or lost areas which might be also irreversible. If the change is abrupt or rapid, biological resources can not adapt for survival. Loss of habitat and disappearance of species from a certain area or from the globe is irreversible. Introduction of exotic species might cause irreversible damage for the indigenous species.

Flood control and drainage project interventions cause irreversible impacts to ecosystem sustainability, species survival, and human life-supporting processes. Change of occupation due to interventions may be irreversible for certain sectors (e.g. fishermen may have to work as agricultural labourers due to loss of wetland areas caused by a project intervention). Mono-culture based agricultural or plantation practices are also irreversible impacts for certain varieties or species of flora and fauna.

222

CHAPTER 11: ENVIRONMENTAL MANAGEMENT PLAN (EMP)

11.1 INTRODUCTION

This chapter is composed of information related to the Environment Management Plan (EMP). An EMP consists of:

- Environment Protection Plan (mitigation plans and contingency plans). Purpose is to reduce impacts and risks. Issues related to existing legislation, codes of good engineering practice, proponent commitment, and the like are also discussed here.

- Summary of Residual Impacts and Risks. These are the actual expected impacts and risks of the projects, which will need to be managed, monitored, and reported.

- Impact Management and Environmental Enhancement (compensation and enhancement plans). Purpose is to balance adverse impacts by providing alternate benefits to adversely impacted persons or biophysical systems.

- Environmental Effects Monitoring (monitoring plans).

- Impact Reporting.

Addition sections of this chapter document:

- Implementation of Environmental Management Plan
  - Institutional strengthening needs
  - Training and technical assistance needs
  - Public participation
  - EMP Implementation Schedule
  - EMP Costs

- Linking With the Project Assessment Process.

The emphasis at the IEE, pre-feasibility, level is on identifying issues and options, to guide the detailed design of specific EMP measures as part of programme and project feasibility studies.

11.2 ENVIRONMENTAL PROTECTION PLAN

11.2.1 Mitigation of Pre-Construction and Construction Phase Impacts

Significant pre-construction and construction activities and impacts are associated with the FCD and river improvement projects.

Land acquisition and site preparation

Land acquisition and site preparation activities and thus impacts occur during the pre-construction phase. For the Regional Plan, the magnitude of these impacts (number of people, hectares of

226

land affected) are small in regional terms, but the impacts can be severe for the particular *de facto* land and resource users who are affected, including renters, share-croppers, grazers and gleaners, and squatters, with or without legal status.

Impacts can be minimized mainly through careful planning at feasibility and detailed design stages to minimize land use conversion, and to choose infrastructure sites of least value in current use (Shahabuddin, 1994). Residual impacts will require compensation (see below).

Temporary adverse impacts during construction of water control structures

During the construction of water control structures, it appears that temporary adverse impacts on drainage, fish movement, navigation, and road transport are possible. To our knowledge, systematic mitigation measures have never been applied to this type of impact in Bangladesh; they are simply accepted by the receiving communities. Project feasibility studies should investigate these considerations, and if these impacts are significant, detailed mitigation measures proposed.

Dredging and re-excavation spoil disposal

Dredge spoil disposal will be a major issue for the regional drainage improvement projects. If the spoil were simply dumped back in the river, then some of the benefits of the work could be lost. Furthermore, inadequate disposal methods could produce undesirable impacts to fisheries habitat and agricultural land. Formulation of dredge disposal plans as part of each of the projects having a dredging component will require the gathering of a considerable amount of site-specific primary information which is currently unavailable.

Previous experience gained from the Dredged Material Research Program of the US Army Corps of Engineers has shown that:

> ". . . no single disposal method is necessarily suitable for a given region or project. What is desirable for one project may be completely unsuitable for another, and each project must be evaluated on a case by case basis. Also, each project evaluation must consider long-term as well as short-term disposal needs and possible interactions among projects."

The following comments are intended to illustrate some of the issues that would need to be considered. Much of the general information is summarized from Petersen (1986). The appropriate methods for disposing of the spoil will depend on:

- Quantity of the dredge material;
- Grain size and organic content;
- Degree of contamination and its toxicity;
- Soil permeability and the depth to the water table at the disposal site.
- Land use in the vicinity of the site and public acceptance of spoil disposal; and
- Presence of critical habitat or wetlands.

Probably some of the most convenient disposal sites include old abandoned loop cuts and ox-bows that are adjacent to the river channel. These isolated ponds and water bodies would confine the slurry of sediment and water so that most of the solids could settle out before the water spilled back into the river. As the sites were gradually filled in, the newly created land could be used for agriculture or for habitation. However, potential impacts to fisheries would have to be considered.

Land disposal normally involves placing some form of confinement dyke to retain the dredged solids while allowing excess water from the slurry to be discharged from the disposal area. The dredged material is ponded for a period of time until enough of the suspended solids have settled out to meet the required effluent specifications. The return water can then be discharged over a temporary weir back to the river. However, during a site inspection to a BWDB operation, it was observed that no effort was made to confine the spoil. Instead, the slurry was discharged on the land and allowed to spread over a wide area until the water eventually seeped into the ground.

11.2.2 Mitigation of Operation & Maintenance Phase Impacts

Regional hydrology and morphology mitigation measures
River improvement is mitigative of flood control and loop cut impacts on river morphology and water levels.

Fisheries mitigation measures
Fish passes, water retention, bottom-open embankment design, and water control operational measures, including the inclusion of fishermen on project committees, are each mitigative of flood control impacts on fisheries. The *Fisheries Engineering Project* (other than fish passes) and *Fisheries Biological Management* may also provide mitigation, but their main thrust is compensation and enhancement (see Section 11.4 below).

Navigation mitigation measures
Boat passes should be provided as part of individual projects' infrastructure where warranted.

Physical maintenance of infrastructure
Maintenance requirements will increase, due to the larger amount of infrastructure in the region and increasing channelization accompanied by higher water levels and velocities on some rivers. Improved maintenance will require greater involvement of local people and local ownership of projects. A local project committee is proposed for each of the Plan FCD projects as a means to achieve these ends. Development of adequate responses will be a challenge.

11.3 SUMMARY OF RESIDUAL IMPACTS

The residual impacts of Plan implementation, reflecting the mitigation measures documented here, are described in Section 9.6.

11.4 IMPACT MANAGEMENT AND ENVIRONMENTAL ENHANCEMENT

11.4.1 Introduction

This section discusses compensation of residual impacts and environmental enhancement. There is no hard boundary between the two: a measure is compensatory if an adverse impact exists elsewhere that it balances, otherwise it is enhancing. General considerations and issues are identified here. Preparation of detailed compensation plans should be included in project feasibility studies as needed.

22d

11.4.2 Compensation of Displacement Impacts

An analysis of land acquisition and resettlement experience and legal arrangements is presented in the FAP 15 final report (1992). The study notes a number of deficiencies in current arrangements and provides a comprehensive set of recommendations for an improved compensation framework. This appears to be the first step in a series of actions that will be necessary to achieve adequate compensation of displacement impacts.

11.4.3 Compensation of Impacts on Regional Stock of Homestead Land

In terms of the total amount of homestead land available with in the region, loss of homestead land to infrastructure construction would be compensated under the NERP initiative *Flood and Erosion Affected Villages Development Project (FEAVDEP)*. This project proposed to use dredge and re-excavation spoil as a resource to construct new village platforms above the level of the monsoon flood in the deeply flooded Central Sylhet Basin. The aim of this project is to raise and enlarge homesteads belonging to families that are vulnerable to flooding and erosion. The most affected victims would be resettled onto new homestead platforms. A typical new village was planned to contain 130 households (700 persons). It was also assumed that the platforms would be constructed up to 5 m above the surrounding floodplain land and each platform would occupy around 2.6 ha for households and 0.65 ha for public land. Therefore, each village platform would require roughly 189,000 m^3 of fill material. This volume corresponds approximately to three months operation from an existing BWDB dredger. The proposed work could approximately double the number of village sites along dredged river reaches.

This program of village construction would be a major undertaking, requiring a considerable amount of detailed planning and field work. Additional planning and assessment would be required during feasibility studies and possibly through pilot project investigations. Technical issues such as ensuring the stability of the platforms, and avoiding hazards such as wave erosion and river erosion would have to be addressed. Means for acquiring land and preparing the sites for settlement would also have to be demonstrated. In order to successfully re-settle people into the new villages, it would be important to ensure the sustainability of the new settlements. This implies at a minimum, ensuring their social viability and economic viability. Means for providing adequate project management, and formation of a strong resettlement authority would have to be demonstrated. At this time it is not clear whether the social and resettlement aspects of the work should be carried out as part of each of the river improvement projects separately or under a central separate project such as FEAVDEP.

11.4.4 Fisheries Impact Compensation and Enhancement

Improved fisheries management, including habitat restoration. Poss. dredging designs could be fish friendly (increase habitat).

11.4.5 Navigation Impact Compensation and Enhancement

Overall, the Plan places greater emphasis on drainage improvement than was evident in past water resources development. The projects *Dredging for Navigation* and *Support to Country Boats* would act synergistically with the major river improvement (drainage improvement) projects to enhance navigation.

11.4.6 Wetland and Biodiversity Impact Compensation and Enhancement

The *Northeast Region Environment Management Research and Education Project* (NEMREP) addresses improved wetland management at key sites and threatened community and species recovery. The *Flood- and Erosion-Affected Villages Development Project* (FEAVDEP) includes afforestation and habitat restoration under village management.

11.4.7 Water Quality Impact Compensation and Enhancement

The *Northeast Region Environment Management Research and Education Project* (NEMREP) includes actions to reduce regional water contamination from domestic and industrial sources.

11.4.8 Disaster Management

The project *Improved Flood Warning* addresses management of catastrophic flood risks in the Tripura and Meghalaya piedmont areas. This is a pre-existing (FWO) hazards which does not affect and is not affected by any other Plan projects. [Note that floodplain flooding is not defined as a 'hazard' for the purposes of this IEE.]

Disaster planning and other risk management measures for Tipaimukh Dam failure should be dealt with under the auspices of the Joint Rivers Commission.

11.5 ENVIRONMENTAL EFFECTS MONITORING

Monitoring can be effected at a variety of temporal and spatial scales. At the micro end of the spectrum, the Department of Environment makes point measurements of river pollution. Another example of somewhat larger scope is provided by the Project Monitoring Component of NERP Phase I in which biophysical and socioeconomic data was collected for two years in two existing FCD projects (Shanir Haor and Manu River Project). At the opposite extreme, the Bangladesh Bureau of Statistics (BBS) is engaged in ongoing collection of national data.

To monitor the effects of Plan implementation, it would be desirable to:

- Upgrade existing national monitoring systems (BBS, BFRSS, DOE). Recommendations on this are beyond the scope of NERP, however

- Incorporate appropriate monitoring measures into each Plan FCD project, as an integral part of the project operation and management activities of the local project committees, with external technical assistance as needed. Detailed designs should be developed as a part of feasibility studies.

- Incorporate appropriate monitoring into each non-FCD project. Detailed designs should be developed as a part of feasibility studies.

- Design and institute specialized new monitoring systems and activities in specific areas where these are needed. One such system which has been identified by NERP is the need for all floodplain infrastructure development (embankments, closures, roads, bridges, culverts, etc.), by all agencies and local communities, to be centrally logged. This would allow observed river morphology changes to be understood, and in some cases, diagnosed before they occur.

229

11.6 IMPACT REPORTING

The levels at which reporting would be done parallel the monitoring levels: national, Plan FCD and non-FCD project, and by specialized monitoring system. The existing and likely near-term future institutional framework all but ensures that such reporting will be on an *ad hoc* basis, that is, with reference to particular donor conditionalities and executing agency guidelines.

11.7 IMPLEMENTATION OF ENVIRONMENTAL MANAGEMENT PLAN

11.7.1 Public Participation

Under the *Pilot Project to Institutionalize Public Consultation*, and as an integral part of individual FCD project study and implementation, ongoing public participation activities would be carried out, building upon the public consultation activities described in Chapter 5, and on the FPCO guidelines for public participation.

11.7.2 Institutional Strengthening, Training, and Technical Assistance Needs

BWDB can and should be expected to acquire the institutional and technical capabilities required to incorporate EMP measures which are integral to the activities which it performs or for which it has responsibility. These and other areas would be addressed under the project *BWDB Strengthening*. EMP related strengthening of other national institutions such as DOE is necessary but beyond the scope of this study, though the institutional initiatives addressing biodiversity and surface water quality strategic planning would partially address EMP capabilities in these areas.

11.7.3 EMP Implementation Schedule

Detailed schedules for implementation of the wide range of EMP measures discussed above will be dictated by the phasing of Plan implementation (given that there is mitigation, compensation, and enhancement between and among Plan projects) and by individual projects' detailed schedules, developed during feasibility.

11.7.4 EMP Costs

Some costs associated with Plan implementation clearly should be counted as EMP costs. Other Plan components have both a primary developmental function and an environmental management function (e.g. major river improvement). Keeping this in mind, EMP costs could include any or all of the following (overall total US$361.3 million, 34% of total Plan costs):

- EMP study and implementation costs included in Plan FCD initiatives' budgets: US$42.7 million.
- Total costs of Plan non-FCD projects which mitigate, compensate, enhance, or monitor environmental components subject to potentially adverse impacts from Plan FCD projects: US$239.2 million.
- River improvement project costs (exclusive of EMP costs quoted above): US$75.9 million.
- Total costs of institutional strengthening projects not already included: US$3.4 million

A detailed breakdown is shown in Table 11.1.

Table 11.1: Environmental Management Plan Costs
(costs in US$ millions)

EMP costs included in individual FCD projects' budgets	
Land acquisition costs (displacement compensation, partial resettlement costs)	25.30
Allowance for EMP design costs, 10% of feasibility study costs (1.5% of project base + contingency costs)	2.34
Allowance for EMP implementation, 40% of physical contingency costs (10% of project base costs)	15.07
Subtotal	***42.71***
Mitigation, compensation, enhancement, and monitoring projects	
Fisheries Engineering Project	8.09
Fisheries Management Programme	32.00
Flood- and Erosion-Affected Villages Development Project (FEAVDEP)	162.10
Northeast Region Environment Management Research and Education Project (NEMREC)	11.20
Dredging for Navigation	14.90
Support for Country Boats	10.00
Ground Water Investigation	0.90
Subtotal	***239.19***
River improvement projects (exclusive of EMP costs quoted above)	
Kalni-Kushiyara River Improvement	35.01
Baulai River Improvement	34.51
Jadukata-Rakti River Improvement	6.42
Subtotal	***75.94***
Institutional strengthening projects not already included under NEMREP	
Pilot Project to Institutionalize Public Consultation	0.50
Improved Flood Warning (disaster management)	2.66
BWDB Strengthening	0.25
Subtotal	***3.41***
TOTAL	**361.25**

11.8 LINKING WITH THE PROJECT AND PLAN ASSESSMENT PROCESSES

The results of an environmental impact assessment of a project need to be transferred or linked to the overall project assessment process. The goal is to make sure that environmental concerns are given due weight in deciding whether a project warrants investment.

The tool used by NERP, and more broadly by the FAP, is the multi-criteria analysis. This is to include quantitative and qualitative indicators of all important environmental and economic impacts and criteria.

Explicit MCAs were included in the final chapters of most of the project pre-feasibility studies.

260

REFERENCES

Ali, M. Youssouf, 1991: National conservation strategy of Bangladesh, towards sustainable development — fisheries resources of Bangladesh. Min. Environ. For, Nat. Conservation Strategy Secretariat, and Bangladesh Ag. Res. Council, Dhaka. 96 pp.

Anderson, F.P., 1900: The effects of the earthquake in 1897 on the Shaistaganj division of the Assam-Bengal Railway. Minutes Proc. Inst. Civil. Engrg., 141, pp.258-261.

Azadi, Mohammad Ali, 1985: Spawning of commercial freshwater fish and brackish and marinewater shrimps of Bangladesh. Fish. Info. Bull., 2(2). 74 pp.

Bangladesh Cent. Adv. Stud., 1989: Experimental project for new and improved management of open water fisheries in Bangladesh. Dhaka. 313 pp.

Cooke, J. Barry, 1984: Progress in rockfill dams. Eighteenth Am. Soc. Civ. Engg. Terghazi Lecture.

Chong, K.-C., Nazrul Islam, and Monowara Begum, 1991. Analysis of the constraints to and potential and opportunities for expanded fish production in Bangladesh. UNDP/FAO Institutional strengthening in the fisheries sector in Bangladesh, proj. BGD/87/045, field doc. 91/07. 129 pp.

de Vries, M. 1971: Solving river problems by hydraulic and mathematical models. Delft Hydraulics Lab., Pub. 76-II.

FAP 15, 1992: Land acquisition and resettlement study — final report. Prepared by HIFAB International and Multidisciplinary Action Research and funded by SIDA for the Bangladesh Ministry of Irrigation, Water Development, and Flood Control and Flood Plan Coordination Organization. November. 176 pp.

FAP 16, 1992: Manual for impact assessment, Vol. 1. Prepated by ISPAN for the Bangladesh Ministry of Irrigation, Water Development, and Flood Control and Flood Plan Coordination Organization. March. 7 chapters + 3 appendices.

FAP 19 and FAP 16, 1992: EIA case study, compartmentalization pilot project. Prepared by ISPAN for the Bangladesh Ministry of Irrigation, Water Development, and Flood Control and Flood Plan Coordination Organization. December. 10 chapter + 6 appendices.

FPCO and MOI, 1992: Guidelines for environmental impact assessment. Prepared by ISPAN for the Bangladesh Ministry of Irrigation, Water Development, and Flood Control and Flood Plan Coordination Organization. October. 75 pp.

French Engineering Consultants, 1989: Pre-feasibility study for flood control in Bangladesh, Vol. 2.

Jaez

Henderson, F., 1963: Stability of alluvial channels. Trans. Am. Soc. Civ. Engg., **128**, pp. 657ff.

Jansen, Robert B., 1983: Dams and public safety. Water resources technical publication, U.S. Dept. Interior, Bur. Reclamation.

Joglekar, D. U., 1971: Manual on river behaviour, control, and training. Pub. No. 60, Cent. Board Irrig. Power, New Delhi, 430 pp.

Lacey, G. H., 1929: Stable channels in alluvium. Min. Proc. Inst. Civ. Engg. **229**, London, pp. 259-292.

Petersen, Margaret, 1986: River engineering. Prentice-Hall, New Jersey, 580 pp.

Rahman, A. K. A., 1989: Freshwater fishes of Bangladesh. Zool. Soc. Bangladesh, Dhaka. 364 pp.

SLI/NHC Joint Venture, 1989: Inception report, Haor Development Project Bangladesh — working draft. CIDA proj. 170/13339, September.

SLI/NHC Joint Venture, 1990: Inception report, Northeast Regional Water Management Project. CIDA proj. 170/13339, April.

Simons, D. B. and M. L. Albertson, 1960: Uniform water conveyance channels in alluvial material. Proc. Am. Soc. Civ. Engg., J. Hydraulics Div., **86**, pp. 33ff.

Tsai, Chu-Fa and Liaquat Ali, 1985: Openwater fisheries (carp) management programme in Bangladesh. Fish. Info. Bull., 2(4). 55 pp.

World Bank, 1991: Bangladesh fisheries sector review. Ag. Oper. Div., Washington D.C. 195 pp.

World Bank, 1992: Development and the environment — world development indicators. Oxford University Press, Oxford. 308 pp.

World Commission on Environment and Development, 1987: Our common future. Oxford University Press, Oxford. 383 pp.

ANNEX A

FIGURES

2606

Figure 1

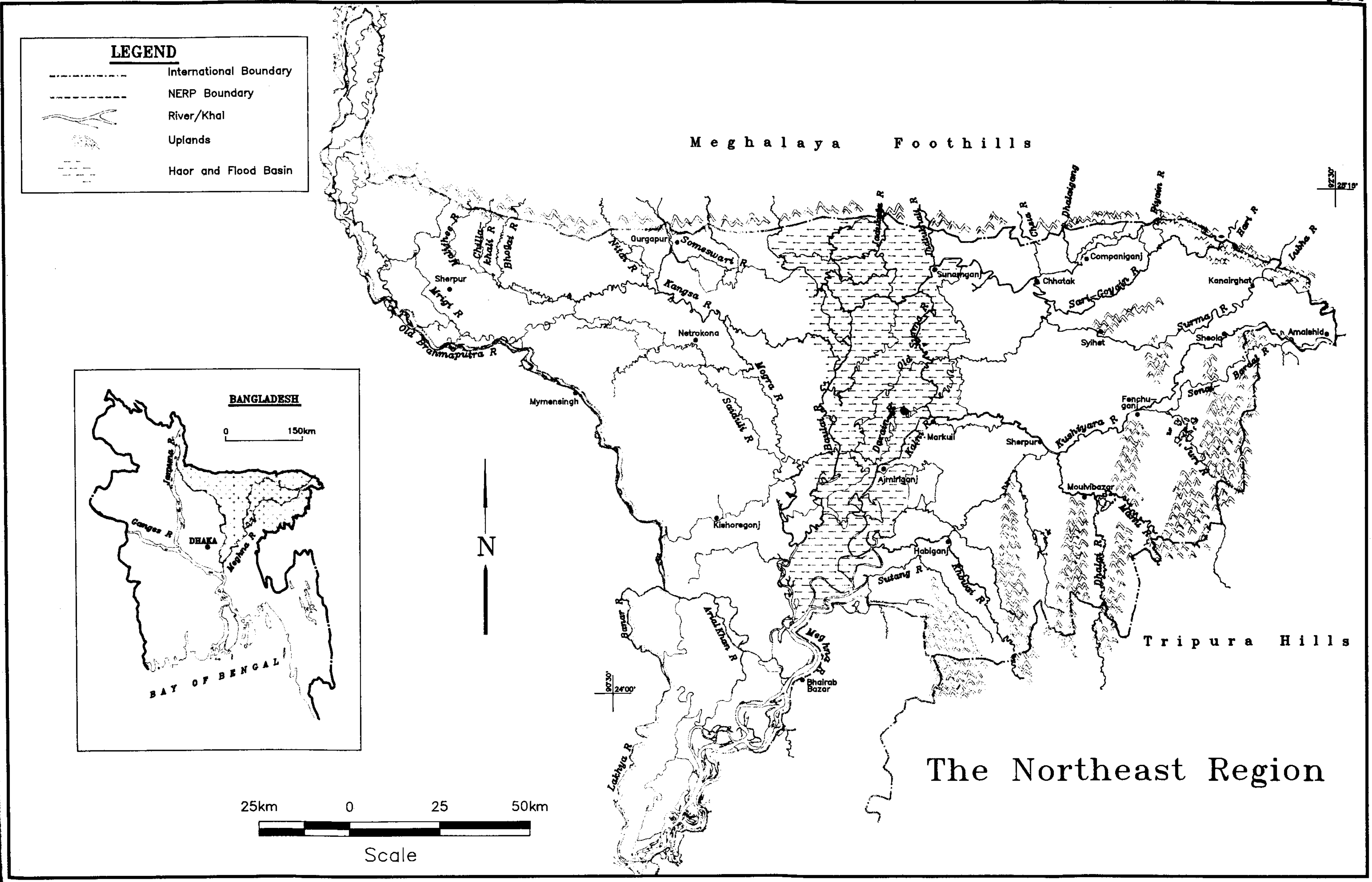


Figure 2: Environmental Screening Matrix

Screening matrix PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition										
		People's participation activities										
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)										
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal										
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving										
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving										
		Tube well installation: boring, distribution facilities, electrification										
	Abnormal	Suspension of construction before completion, construction delays										
		Incorrect construction practices or techniques										

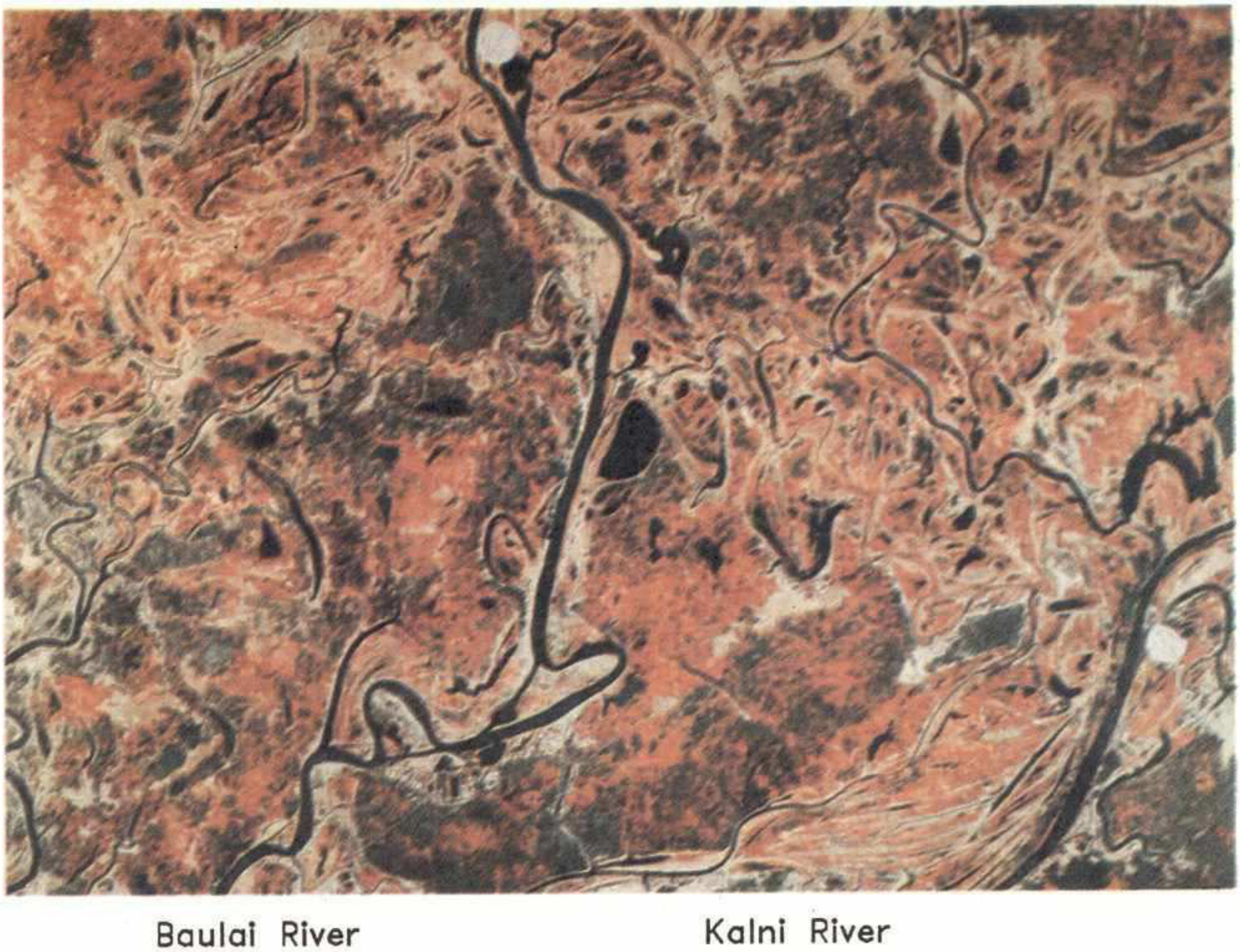
269C

36a

Figure 2: Environmental Screening Matrix (continued)

Screening matrix PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri- culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre-monsoon flood protection										
		Monsoon flood protection										
		Surface water irrigation										
		Ground water irrigation										
		Drainage										
		Agriculture: operation of institutions, extension, credit, seed distribution, fertilizer and pesticide storage and use, farmer groups										
		Water management: activities of BWDB, subproject implementation committee, local water user groups, structure committees and guards										
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)										
		Monsoon flooding (due to extreme event, infrastructure failure)										
		Embankment overtopping										
		Under- and over-drainage										
		Improper operation (public cuts, mistiming of scheduled O&M events etc)										
		Riverbed aggradation/degradation										
Abandonment	Normal	Re-occupation of infrastructure sites										
		Reclamation of materials										
	Abnormal											

Figure 3



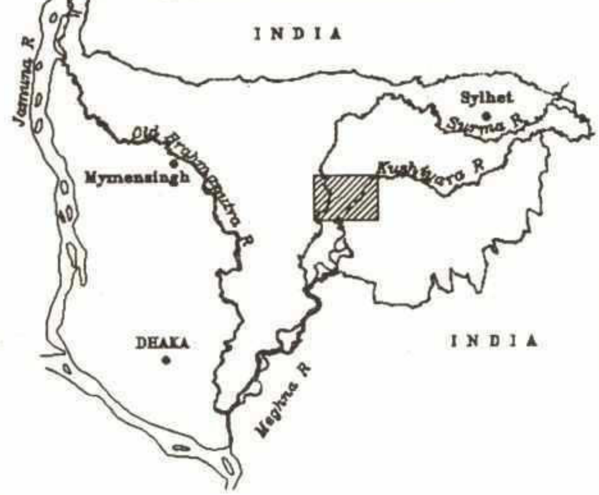
Scale

2 0 2 4 km

Approx.

N

Site Location



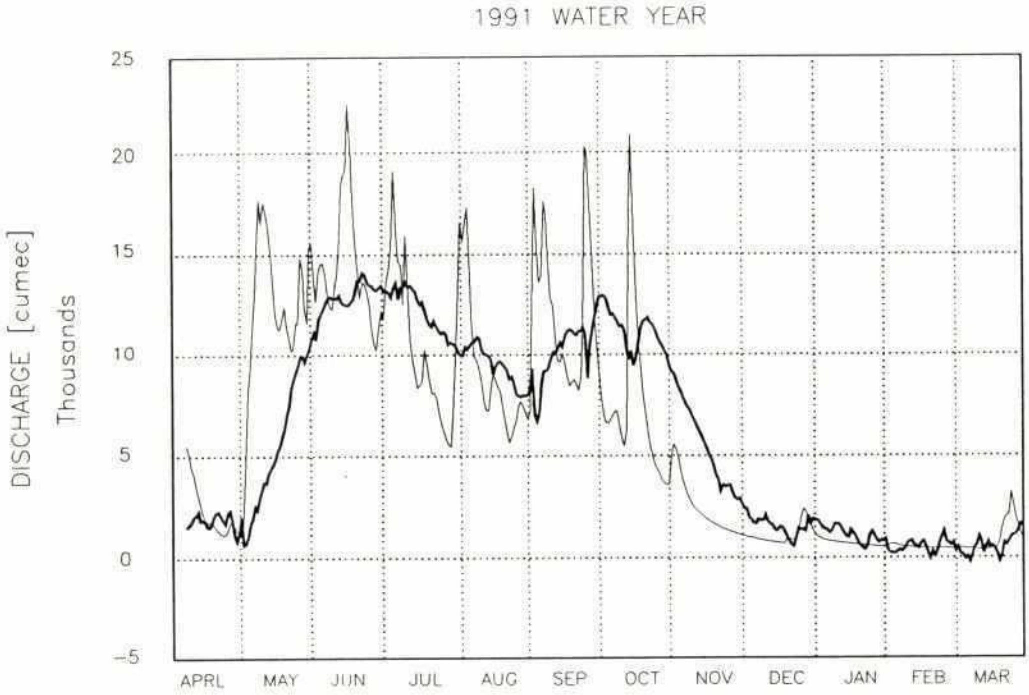
Northeast Regional Project

Channel Pattern on Flood Basin Lowlands

Prepared by: DMc | May 1993

FILE: dm189.DWG

Figure 4



LEGEND

INFLOW (INCLUDING LOCAL RUN-OFF)

OUTFLOW AT BHAIRAB BAZAR

NOTE: HYDROGRAPHS 24- HOUR AVERAGED DISCHARGE

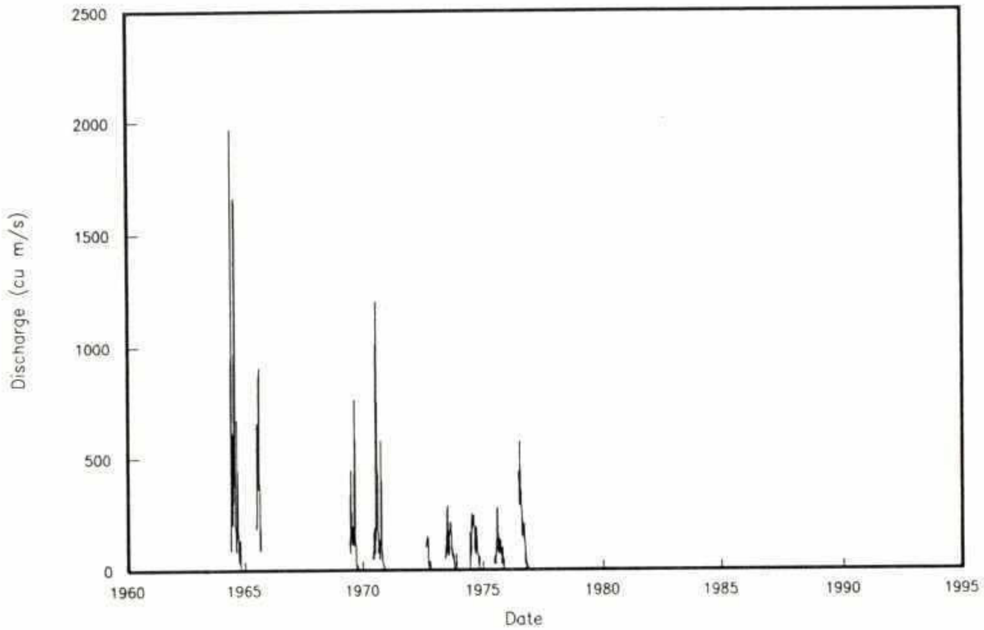
Northeast Regional Project

INFLOW AND OUTFLOW HYDROGRAPH IN THE NORTHEAST REGION

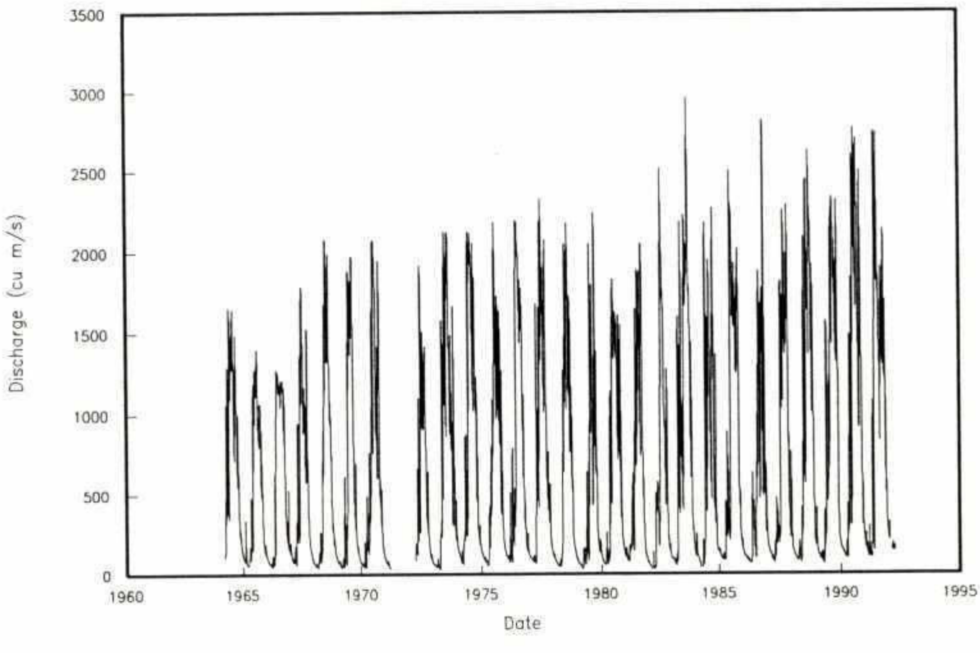
Prepared by: LEB/NMMD | March 1994

FILE: storage.DWG

FLOOD PLAIN DISCHARGE

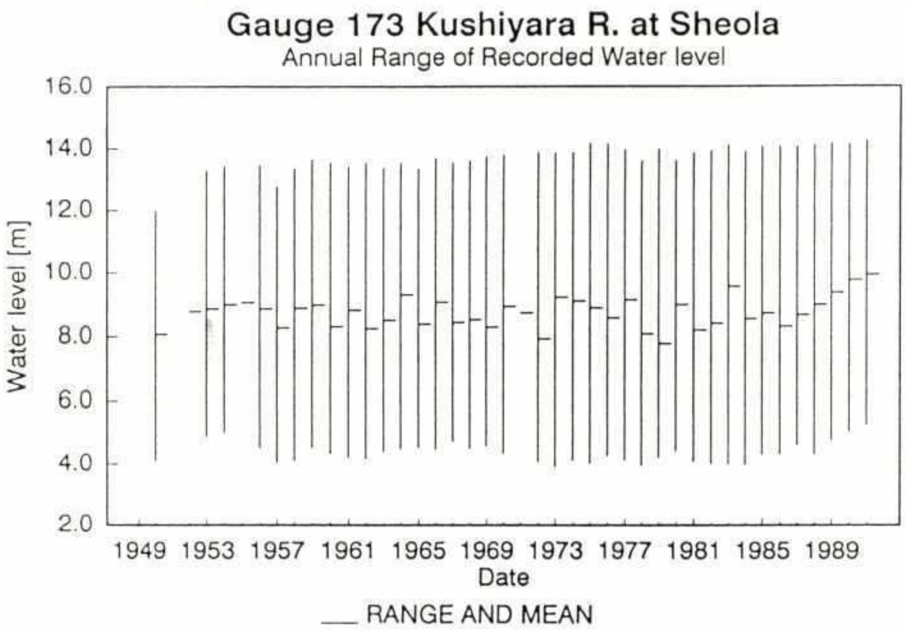


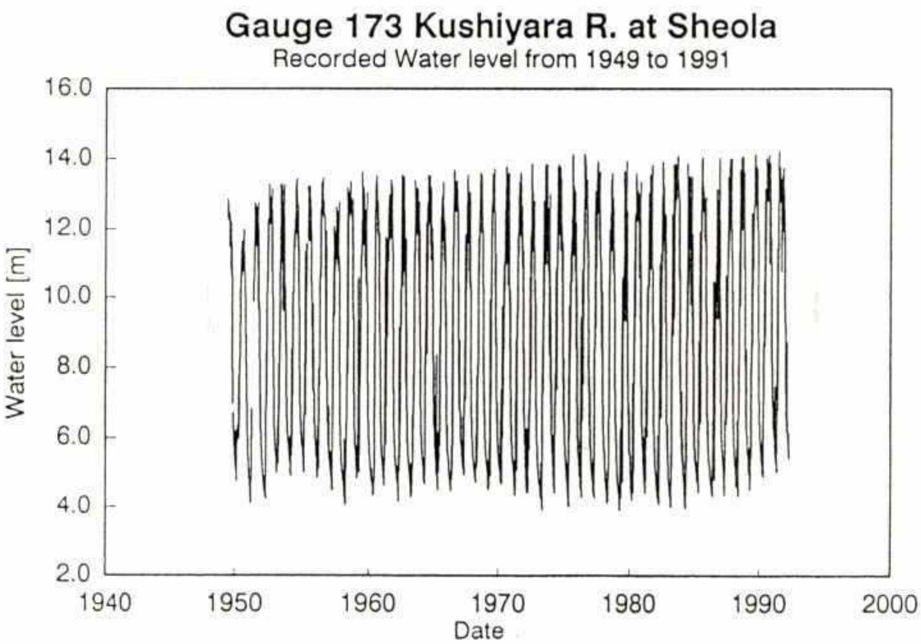
RIVER DISCHARGE



Northeast Regional Project	
CHANGING FLOW DISTRIBUTION AT SHEOLA	
Prepared by: LEB/NAHID	March 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: N1.DWG





Northeast Regional Project

WATER LEVELS AT SHEOLA

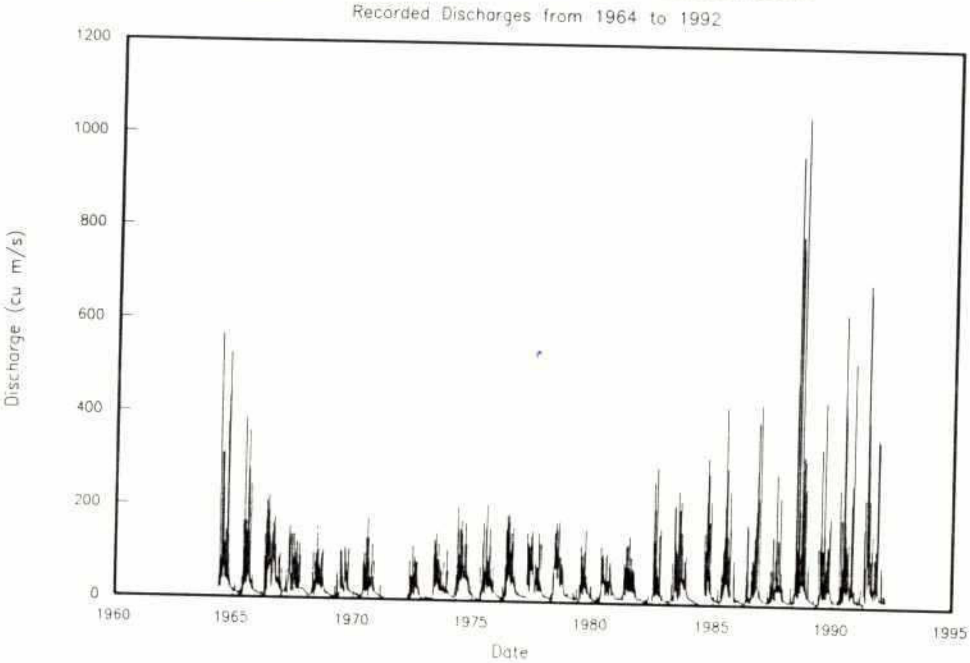
SINCE 1949

Prepared by:	LEB/NAHID	March 1994

Figure 7

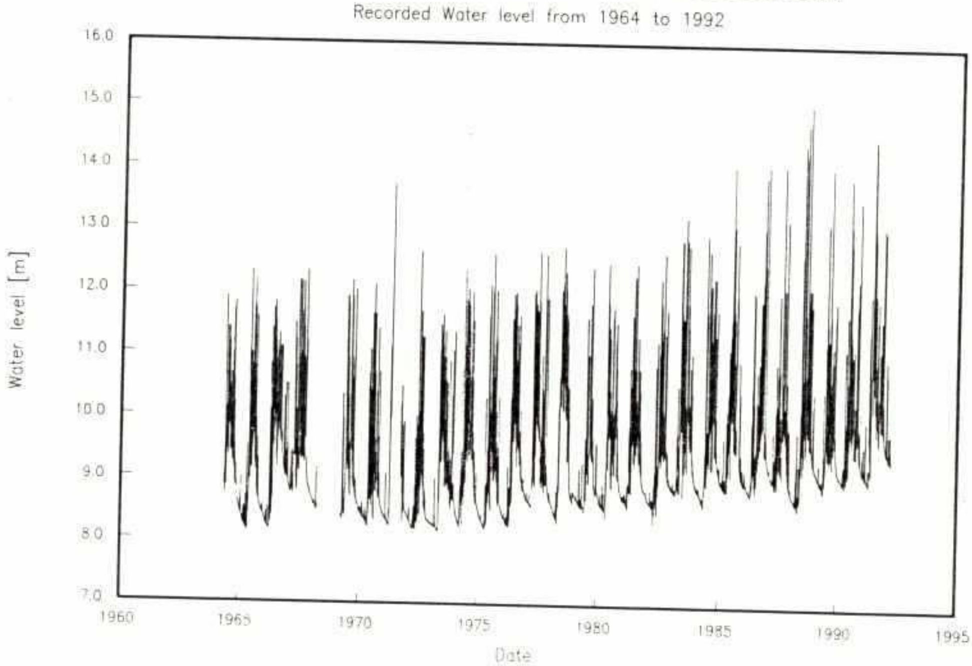
Gauge 158.1 KHOWAI R. at SHAISTAGANJ

Recorded Discharges from 1964 to 1992



Gauge 158-1 KHOWAI R. at SHAISTAGANJ

Recorded Water level from 1964 to 1992



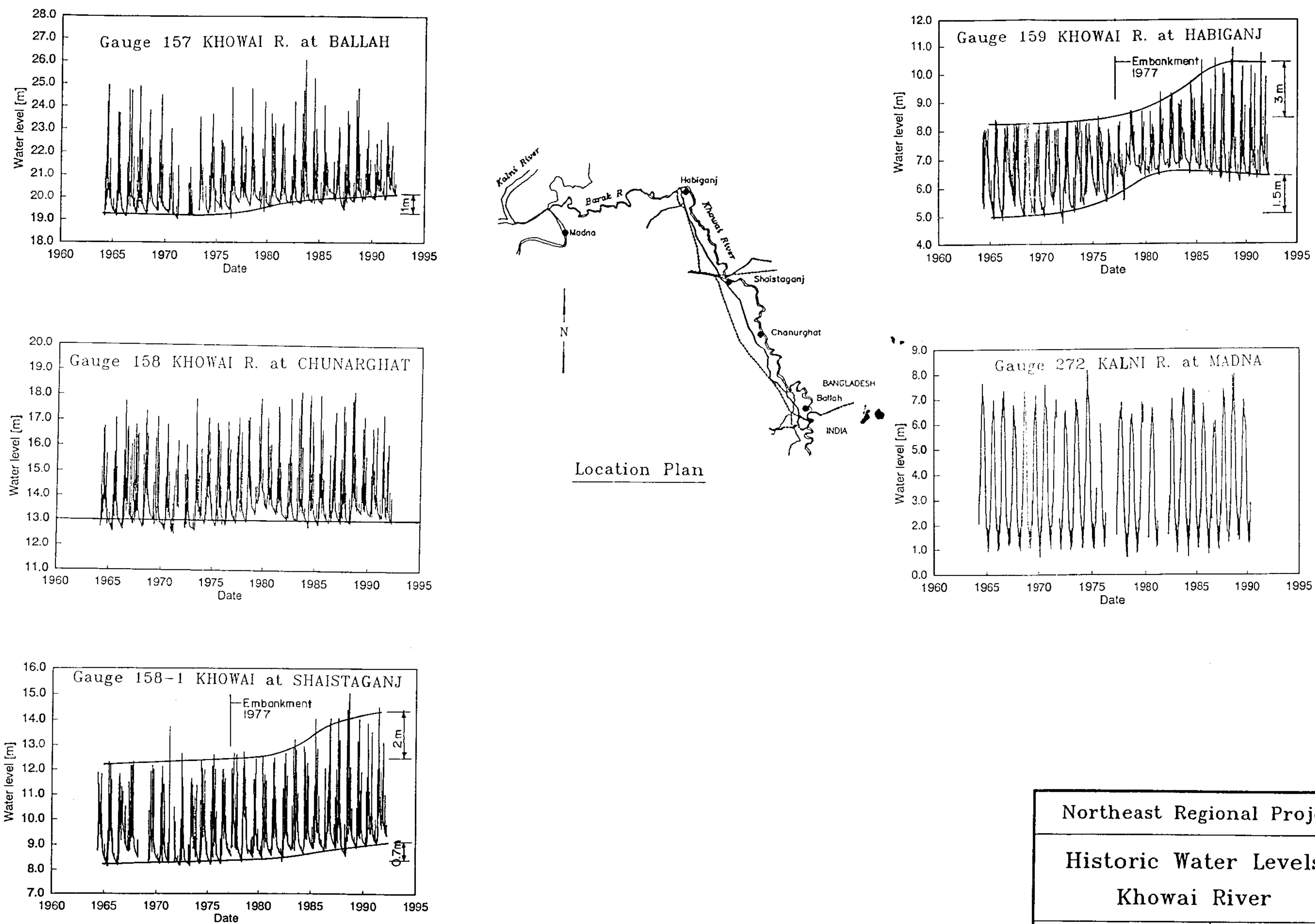
Northeast Regional Project

DISCHARGE AND WATER LEVELS
AT SHAISTAGANJ

Prepared by: LEB/NAHID	March 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: N3.DWG

Figure 8



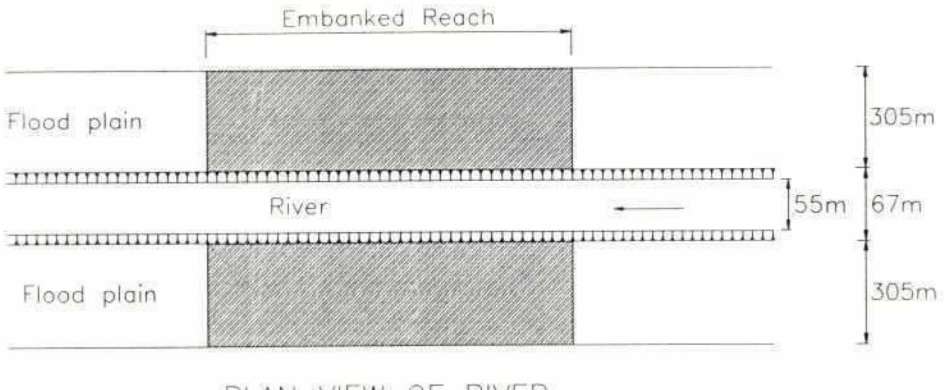
Northeast Regional Project

Historic Water Levels
Khowai River

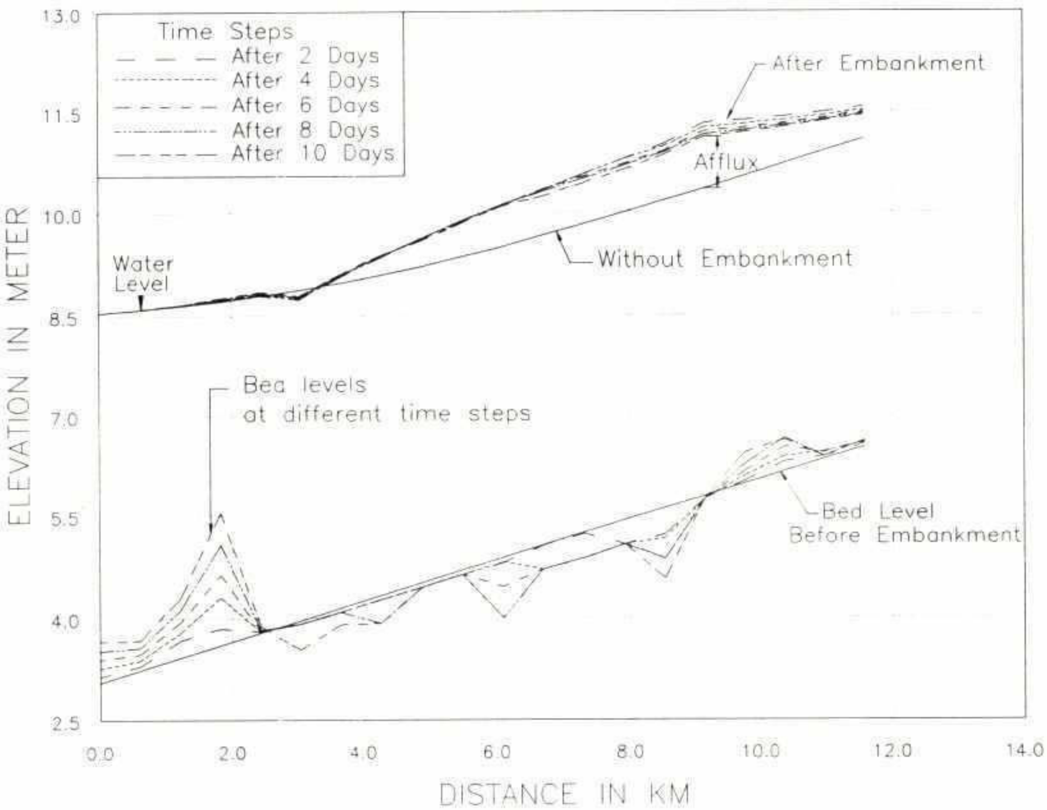
Prepared by: CHW | May 1993

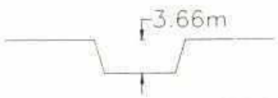
FILE: BORD2.DWG

Figure 9



PLAN VIEW OF RIVER





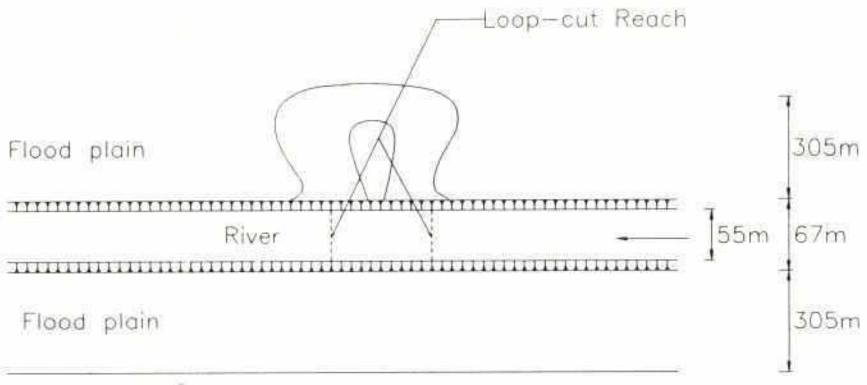
TYPICAL CROSS-SECTION

Note : Q= 734 m³ /s

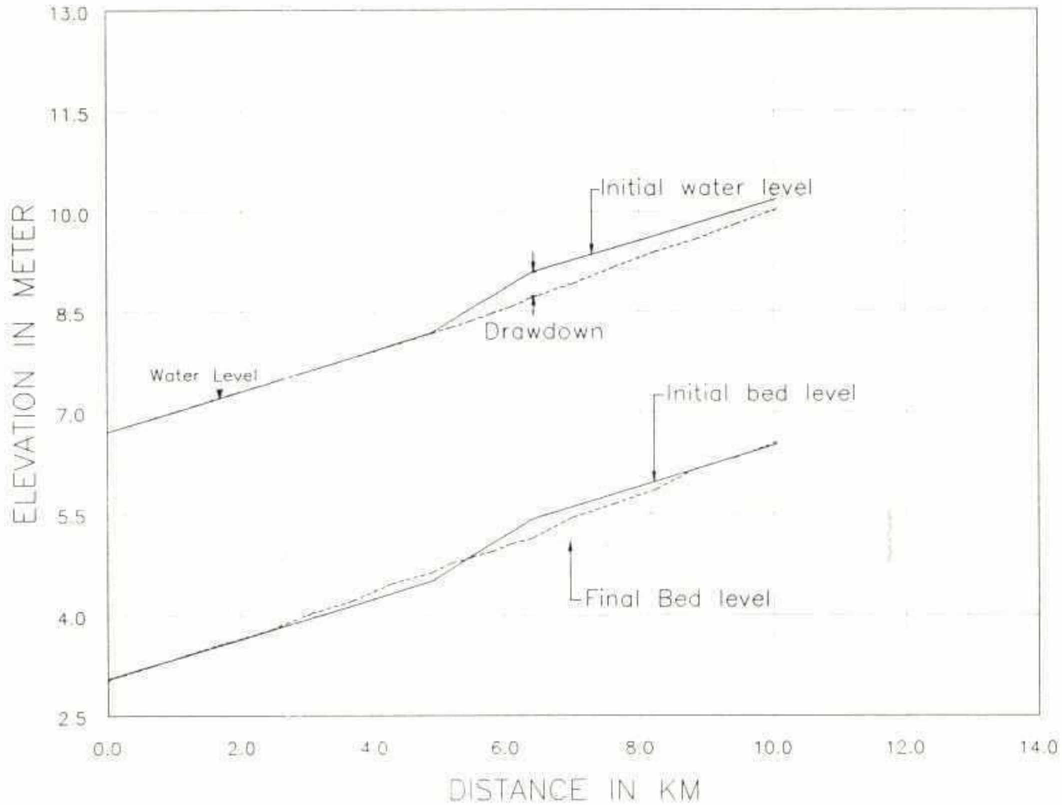
Simulation of channel Morphology and flood levels using HEC-6 Model Scour and Deposition in Rivers and Reservoirs

Northeast Regional Project	
Impact of Embankments Under Backwater	
Prepared by: DMc/[illegible]	May 1993

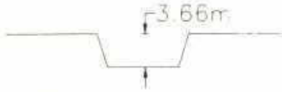
FILE: Embank.DWG



PLAN VIEW OF RIVER



Note: $Q = 339\ m^3/sec$



TYPICAL CROSS-SECTION

Simulation of channel Morphology and flood levels using HEC-6 Model Scour and Depositio- in Rivers and Reservoirs

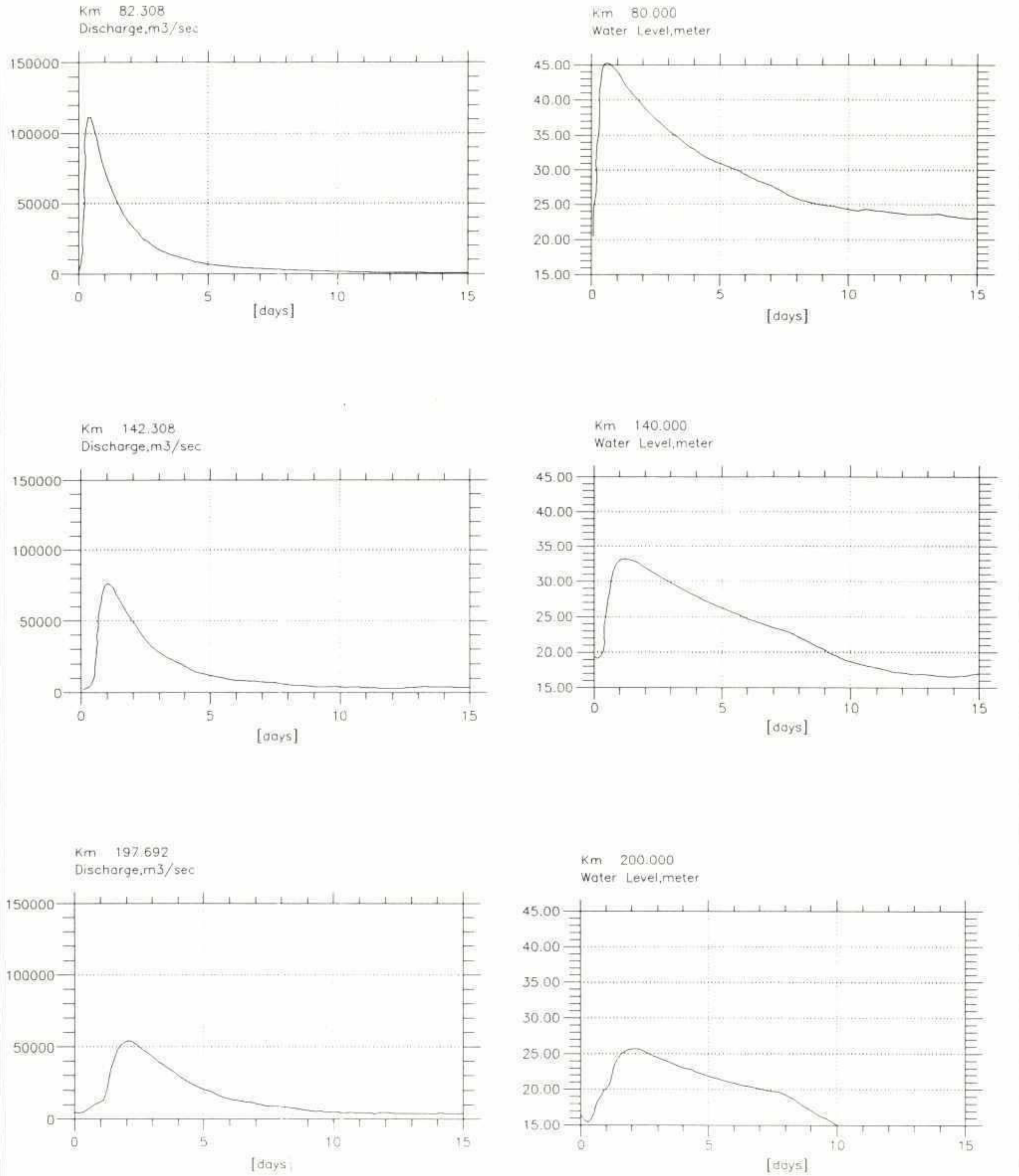
Northeast Regional Project

Impact of Loop Cuts On Channel Morphology

Prepared by: DMc/Tarek May 1993

FILE: dm227.DWG

Figure 11



Note:
Start date of Simulation is June 15,1991

Northeast Regional Project

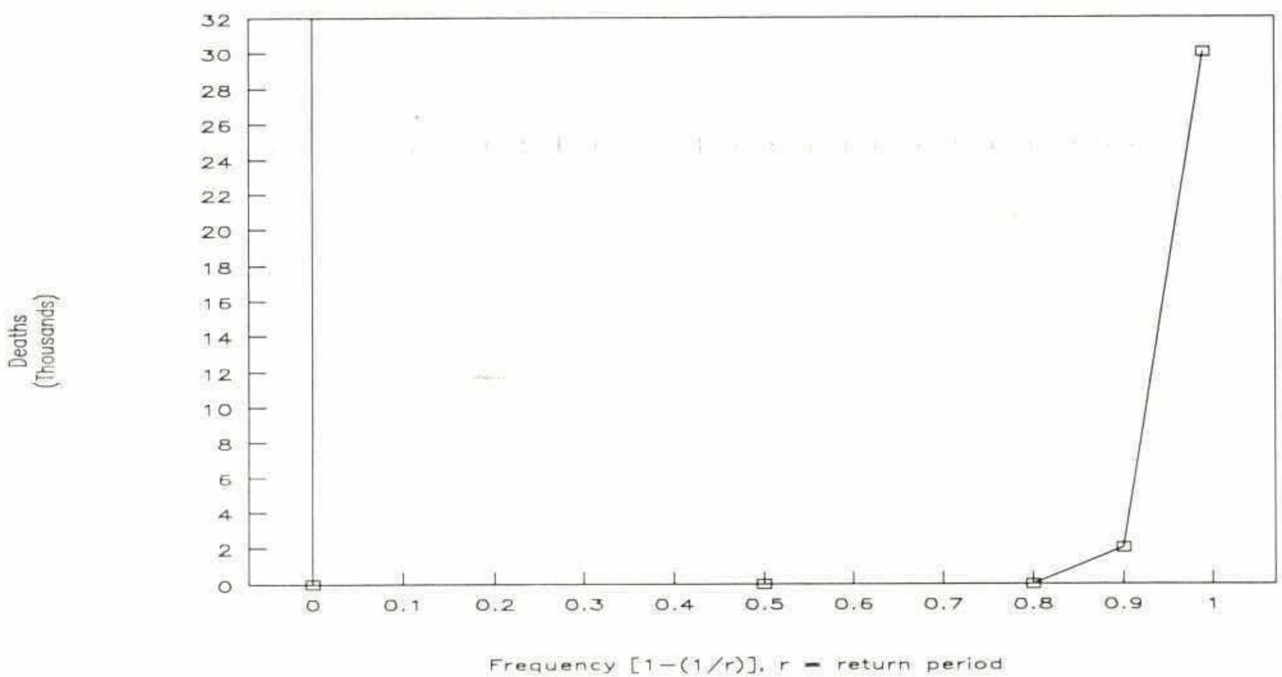
Dambreak Flood Waves Upstream of Amalshid

Prepared by: LEB/JL | March 1994

FILE: WAVE .DWG

FIGURE 12: ESTIMATED DEATH TOLL FROM CATASTROPHIC FLASH FLOODS ON NINE RIVERS IN THE MEGHALAYA AND TRIPURA BORDER AREAS

Return period (yr)	*Freq (non-exceedance)*	*Deaths per thousand*	*Total deaths*	*Annualized deaths*
	0.00		0.00	
1:2	0.50	0.000	0.00	0.00
1:5	0.80	0.000	0.00	0.00
1:10	0.90	0.001	2000.00	100.00
1:100	0.99	0.015	30000.00	1440.00
			TOTAL:	1540.00



Quantifiable Indicators and Impacts, FCD Projects

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD Projects	Baseline (See summary table)	Total/ Baseline (%)	FCDI INITIATIVES: Regional Drainage Improvement		Tripura Piedmont		Eastern Fans + Surma/Kushiyara						Western Fans + Kangsha/Someswari				Peri-Urban Area	
					Baulai R/I	Kushiyra R/I	Manu Diversn	Habiganj-Khowai	Jadukata-Rakti R/I	Sarigoyain-Piyain	Surma Right Bank	Upper Surma-Kush	Kushiyra-Bijna	Srma-Ksh-Baulai	Upper Kangsha	Mrigi R/I	Updakhali	Dhrmpsh-Rui Beel	Nrshngd-Nryngnj	Nrshngd District
5	PROJECT EXTENT																			
6	— Gross area (ha)	1,792,270	2,420,000	74.06	320,300	426,900	52,300	155,932	37,434	12,495	40,000	49,200	100,000	319,289	87,200	24,600	5,960	20,500	40,560	99,600
7	— Net area (ha)	1,442,937	1,605,867	89.85	261,000	362,000	40,800	112,115	30,322	10,865	33,895	33,600	83,640	254,589	68,165	20,400	4,890	17,024	34,832	74,800
8	% previously developed				31	17	45	14	82	0	10	0	1	24	0	0	0	0	1	66
9	Area prev devel (ha)	312,000	286,100	109.05	80,133	61,054	18,600	15,696	24,864	0	0	0	836	61,101	0	0	0	0	348	49,368
10	— Benefitted area (ha)	456,483	1,442,937	31.64	77,509	101,659	29,849	28,854	11,226	8,242	10,102	35,756	28,852	59,766	32,542	7,624	1,780	9,316	7,650	5,756
11	FCDI BENEFIT / PROJECT TYPES																			
12	— Full flood control (urban/agri)	3	27								[illegible]				x				x	x
13	— Partial flood control	3	33											x			x	x		
14	— Mixed: full and partial f/c areas	5	n/a					40%f 60%p		30%f 70%p	30%f 70%p	30%f 70%p	30%f 70%p							
15	— Controlled flooding	1	n/a				100% ffc								x					
16	— Drainage improvement (only)	14 (4)	5		(x)	(x)		x	(x)	x	x	x	x	x	x	(x)		x	x	x
17	— Irrigation distribution	0	2																	
18	— Irrigation water flushing/retention	5	n/a					x		x		x	x					x	x	x
19	PHYSICAL COMPONENTS																			
20	— Full flood embankments (km)	474			0	0	0	124	0	20	13	175	49	0	93	0	0	0	0	0
21	— Submersible flood embankments (km)	394								19			33	267			25	50		
22	— River diversions (destination)	4					Hakaluki Haor	Karangi R. Sutang R.							Mogra R.					
23	— Loop cuts (no.)	26			0	2	0	0	0	0	0	0	0	0	24	0	0	0	0	0
24	— Channel excavation (km) For m^3 see line 80	738			25	131	0	100	24	59	0	38	56	209	0	28	18	50	0	0
25	— Channel closures (no.) Repeated on line 79	48			0	0	0	0	1	1	2	5	8	10	7	0	5	5	0	0

Figure 13 (continued)

Quantifiable Indicators and Impacts, FCD Projects

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD Projects	Baseline (See summary table)	Total/ Baseline (%)	FCDI INITIATIVES															
					Regional Drainage Improvement		Tripura Piedmont		Eastern Fans + Surma/Kushiyara						Western Fans + Kangsha/Someswari				Peri-Urban Area	
					Baulai R/I	Kushiyra R/I	Manu Diversn	Habiganj-Khowai	Jadukata-Rakti R/I	Sarigoyain-Piyain	Surma Right Bank	Upper Surma-Kush	Kushiyra-Bijna	Srma-Ksh-Baulai	Upper Kangsha	Mrigi R/I	Updakhali	Dhrmpsh-Rui Beel	Nrshngd-Nryngnj	Nrshngd District
26	SETTLEMENT AREA, POPULATION, AND ROAD IMPACTS																			
27	— Settlement area (ha)																			
28	FWO total	46,190	65,330	70.70	3,400	6,700	4,020	3,360	750	260	1,010	1,230	1,450	9,600	3,660	1,100	200	275	5,675	3,500
29	FWO flood-affected	12,220	46,190	26.46	0	0	2,650	302	23	78	253	531	435	4,800	542	11	n/a	220	2,270	105
30	Flood-free area gain/loss	7,123	65,330																	
31	FCD protected	6,386	12,220	52.26	0	0	2,650	302	2	39	127	156	218	0	542	11	0	0	2,270	69
32	Could be constructed, raised using spoil	737	12,220	6.03	60	150	42	62	23	14	0	42	20	135	115	23	5	8	22	16
33	— Rural population (2015, in '000s)																			
34	Total	14,510	17,400	83.39	1,827	2,415	263	1,463	130	814	158	652	501	2,062	2,053	258	36	70	624	1,184
35	FWO flood-affected	2,470	14,510	17.02	0	0	170	132	39	244	40	326	150	1.024		3	n/a	56	250	36
36	FW-FWO flood-free gain/loss	1,233	2,470	49.92	0	0	170	132	4	122	40	326	150	0		3	0	0	250	36
37	— Urban (incl thana HQ) population (2015, in '000s)																			
38	Total	5,834	9,000	64.82	273	1,001	175	235	188	136	328	112	314	808	359	152	15	55	789	894
39	FWO flood-affected	1,862	5,834	31.92	123	390	50	66	56	41	82	56	94	274		2	n/a	44	316	268
40	FWO-FW flood-free gain/loss	1,180	1,862	63.37	0	0	50	66	6	21	82	112	94	163		2	0	0	316	268
41	— Total population (2015, in '000s)	20,344	26,400	77.06	2,100	3,416	438	1,698	318	950	486	764	815	2,870	2,412	410	51	125	1,413	2,078
42	— Roads (km)																			
43	FWO total	3,555			610	164	300	270	41	66	48	70	143	543	620	250	40	70	185	135
44	FWO flood-affected	1,608	3,555	45.23	480	130	120	25	12	38	19	12	80	250	107	50	32	63	140	50
45	FW-FWO flood-free gain/loss	578	3,555	16.26	100	13	120	25	0	10	19	0	18	125	0	0	0	0	140	8
46	DISPLACEMENT IMPACTS																			
47	— Area to be taken for project works (ha)																			
48	From cultivated area	2,985	1,442,937	0.21	60	200	446	267	48	98	16	378	358	520	408	0	0	20	126	40
49	From settlement area	403	46,190	0.87	60	200	4	32	0	8	2	8	10	49	0	0	0	0	30	0
50	— Persons displaced (number, at 1991 reg'l avg. of 226.5 persons per homestead ha)	107,400	10,462,035	1.03	15,990	53,300	1,066	8,528	0	2,132	533	2,132	2,665	13.059	0	0	0	0	7,995	0
51	AGRICULTURAL IMPACTS																			
52	— Cropped area gain/loss (ha)																			
53	Rice	38,282	1,882,560	2.03	0	0	5,414	3,734	0	1,108	2,431	12,060	1,873	-621	9,170	865	0	0	3,387	-1139
54	Damaged area	-324,169	676,998	-47.88	-53,750	-53,500	-23,529	-23,500	-10,175	-6,966	-7,401	-23,260	-23,426	-53,750	-21,596	-7,128	-1,780	-8,908	0	-5,500
55	Other food crops	67,547	337,440	20.02	16,541	28,892	906	1,620	1,051	168	270	436	3,553	6,637	1,776	-369	0	408	4,263	1,395
56	Fodder crops	26,485			7,218	19,267	0	0	0	0	0	0	0	0	0	0	0	0	0	0
57	— Production gain/loss (tonnes/year)																			
58	Cereal	566,920	5,618,462	10.09	68,840	132,383	57,944	49,169	8,116	10,562	9,607	46,203	25,560	78,913	37,390	11,209	3,891	7,618	11,828	7,687
59	Non-cereal	123,449	1,030,089	11.98	19,974	24,178	2,775	2,944	1,828	690	1,236	698	11,725	11,487	4,058	-278	0	1,384	35,687	5,063

Figure 13 (continued)

Quantifiable Indicators and Impacts, FCD Projects

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD Projects	Baseline (See summary table)	Total/ Baseline (%)	FCDI INITIATIVES: Regional Drainage Improvement		Tripura Piedmont		Eastern Fans + Surma/Kushiyara						Western Fans + Kangsha/Someswari				Peri-Urban Area	
					Baulai R/I	Kushiyra R/I	Manu Diversn	Habiganj-Khowai	Jadukata-Rakti R/I	Sarigoyain-Piyain	Surma Right Bank	Upper Surma-Kush	Kushiyra-Bijna	Srma-Ksh-Baulai	Upper Kangsha	Mrigi R/I	Updakhali	Dhrmpsh-Rui Beel	Nrshngd-Nryganj	Nrshngd District
60	IRRIGATION IMPACTS																			
61	— Surface water																			
62	Irrigated area gain/loss (ha)	855	351,096	0.24	-4,258	-11,525	1,703	3,504	1,811	143	629	185	4,827	270	2,140	91	0	327	774	234
63	Usage increment (Mm³, @ 0.013Mm³ / ha)	11			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
64	— Ground water																			
65	Irrigated area gain/loss (ha)	3,290	223,044	1.48	-2,839	0	0	1,502	0	16	0	0	1,207	0	2,140	136	0	0	193	935
66	Usage increment (Mm³, @ 0.013Mm³ / ha)	43			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
67	— Mechanized area gain/loss (ha)	2,677	383,189	0.70	-1,420	0	0	751	0	5	0	0	362	0	1,926	95	0	0	116	842
68	— Irrigation diesel increment ('000 litres)	534			-284	0	0	150	0	1	0	0	72	0	385	19	0	0	23	168
69	WATER QUALITY / POLLUTION IMPACTS																			
70	— Agrochemical usage (tonnes/year)																			
71	Pesticides	47	530	8.87	1	2	8	5	1	1	2	6	4	7	4	1	0	1	3	1
72	Fertilizers	45,569	225,687	20.19	2200	2500	2,570	10,588	605	1055	2122	3,806	6,226	2,987	4,779	3,180	151	1276	1,193	331
73	OPENWATER FISHERIES IMPACTS																			
74	— Habitat gain/loss (ha)																			
75	Floodplain	-49,499	1,190,527	-4.16	0	0	-8,160	0	0	-1500	-6,660	-14,600	-2,300	-164	-5,254	-4,515	0	-56	-5,790	-500
76	Beels	67	60,000	0.11	0	0	0	0	0	+80	0	0	0	0	0	-15	0	2	0	0
77	Rivers and channels	1,439	35,488	4.05	100	200	0	90	72	+22	+41	139	87	248	0	300	70	-4	+32	42
78	Mother fisheries	-4,700	100,000	-4.70	0	0	-5000	0	0	+300	0	0	0	0	0	0	0	0	0	0
79	— Channel closures (no.)	48			0	0	0	0	1 weir	4 closures 1 weir	2	5	8	10	7	0	5	5	0	0
80	— Channel excavation ('000 m³)	73,628			6,000	15,000	4,180	6,176	2,300	1,350	36	4,196	2,025	13,535	11,480	2,331	484	750	2,185	1600
81	— Migration impact coefficient, *M*				1.0	1.0	0.3	1.0	1.0	0.9	1.0	1.0	0.8	0.8	0.9	1.1	0.8	0.9	0.6	1.0
82	— Water quality impact coefficient, *Q*				1.0	1.0	0.5	1.0	1.0	0.9	1.0	1.0	0.8	1.0	1.0	1.1	0.8	1.1	1.0	1.0
83	— Production (tonnes/yr)	-10,554	96,000	-10.99	+41	+83	-2,927	+18	+13	+75	-286	-596	-1,602	-3,900	-589	-23	-81	-58	-707	-15
84	— Net value (financial Tk '000)	-406,186	3,429,000	-11.85	+1,125	+2,250	-65,714	+1,170	+814	+1,281	-9,182	-21,428	-75,096	-186,975	-25,411	+3,750	-3,710	-1,986	-26,788	-286
85	AQUACULTURE IMPACTS																			
86	— Flood prone ponds (district %)				40	40	50	0	98	50	50	50	40	20	15	40	40	98	80	30
87	— Total pond area (ha)	14,990	18,700	80.16	2,450	2,300	1,330	1,006	290	910	389	355	700	2,300	1,700	300	60	130	286	484
88	— Flood-free ponds gain/loss (ha)	1,552	18,700	8.30	0	0	665	0	0	137	58	53	84	0	255	0	0	0	229	71
89	— Production gain/loss (tonnes/yr)	1,552	18,075	8.59	0	0	665	0	0	137	58	53	84	0	255	0	0	0	229	71
90	GRAZING, WETLAND, THREATENED COMMUNITY IMPACTS																			
91	**— Winter grazing area (ha)**	-54,348	779,298	-6.97	-20,790	-33,757	2,772	-3,880	-954	-147	4,993	2,179	-1,112	0	417	481	-50	-419	-2,969	-1,112
92	**— Winter wetland area (ha)**	-6,994	123,765	-5.65	4,128	6,703	-1,342	90	-1,364	-195	-5,350	-3,081	-2,592	-100	-1,310	235	0	-256	32	-2,592
93	**— Summer wetland (ha)**	-50,440	443,633	-11.37	-7,097	-11,524	-3,087	-4,330	262	-781	45	-6,856	-3,118	-100	-4,656	-653	0	255	-5682	-3,118
94	**— Lowland forested area (ha)**	0	1000	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
95	**— Reed land (ha)**	0	8000	0.00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
96	**— Floodplain grassland (ha)**	-250	550	-45.45	0	0	0	0	0	0	-250	0	0	0	0	0	0	0	0	0

Figure 13 (continued)

Quantifiable Indicators and Impacts, FCD Projects

	QUANTIFIABLE INDICATORS AND IMPACTS	Total for Plan FCD Projects	Baseline (See summary table)	Total/ Baseline (%)	FCDI INITIATIVES: Regional Drainage Improvement		Tripura Piedmont		Eastern Fans + Surma/Kushiyara						Western Fans + Kangsha/Someswari				Peri-Urban Area	
					Baulai R/I	Kushiyra R/I	Manu Diversn	Habiganj-Khowai	Jadukata-Rakti R/I	Sarigoyain-Piyain	Surma Right Bank	Upper Surma-Kush	Kushiyra-Bijna	Srma-Ksh-Baulai	Upper Kangsha	Mrigi R/I	Updakhali	Dhrmpsh-Rui Beel	Nrshngd-Nrynganj	Nrshngd District
97	EMPLOYMENT IMPACTS																			
98	-- Owner labour gain/loss ('000 pd/yr)	13,216	268,657	4.92	2,238	3,707	676	918	107	217	549	1731	940	690	652	110	21	55	632	-27
99	-- Hired labour gain/loss ('000 pd/yr)																			
100	Agricultural labour	10,954	80,528	13.60	1,453	2,360	829	918	409	181	282	1134	966	561	889	434	31	55	381	71
101	Fisheries labour (net value fisheries production / Tk 50 daily wage)	-8,125	68,580	-11.85	23	45	-1,314	23	16	26	-184	-429	-1,502	-3,740	-508	75	-74	-40	-536	-6
102	Wetland labour	-44			n/a	n/a	-9	-4	-1	-2	-3	-9	-3	0	-6	0	-2	0	-2	-3
103	Quarrying labour	334			n/a	n/a	0	0	+292	42	0	0	0	0	0	0	0	0	0	0
104	Total hired labour	3,119	149,108	2.09	1,476	2,405	-494	937	716	247	95	696	-539	-3,179	375	509	-45	15	-157	62
105	-- Owner+hired gain/loss ('000 pd/yr)	16,335	417,765	3.91	3,714	6,112	182	1,855	823	464	644	2,427	401	-2,489	1,027	619	-24	70	475	35

Figure 13

Projects Producing Impacts \ Projects Receiving Impacts	Baulai River Improvement	Kalni River Project	Manu River Project	Habiganj khowai	Jadukata-Rakti	Sarigoyain-piyain	Surma Right Bank	Upper Surma-Kushiyara	Kushiyara-Bijna	Surma-Kushiyara-Baulai	Mrigi	Upper Kangsha	Updakhali	Dharmapasha Rui Beel	Narayanganj-Narsingdi	Narsingdi District	Scores-Producing Impacts
Baulai River Improvement					B					A			A	A			4
Kalni River Improvement				C					A	A							3
Manu River Project										C							1
Habiganj Khowai																	0
Jadukata-Rakti	B									C							2
Sarigoyain-Piyain										C							0
Surma Right Bank						B		A		A							3
Upper Surma-Kushiyara	B	A				C	A		A	A							6
Kushiyara-Bijna		A								A							2
Surma-Kushiyara-Baulai	A	A			B				A								4
Mrigi																	0
Upper Kangsha	A												B	B			3
Updakhali														A			1
Dharmapasha Rui Beel	B												B				2
Narayanganj-Narsingdi																	0
Narsingdi District																	0
Scores - Receiving Impacts	5	3	0	1	2	2	1	1	3	7	0	0	2	2	0	0	

"A" indicates potential for strong interaction between projects
"B" indicates potential for moderate interaction between projects
"C" indicates minor interaction between projects

Northeast Regional Project

Interactions Between Selected Initiatives

Prepared by: DMc | May 1994

FILE: iee.DWG

Figure 14