DGIS/DANIDA GOB

MINISTRY OF WATER RESOURCES

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA ESTUARY STUDY

DRAFT MASTER PLAN

VOLUME 1 : MAIN REPORT

November 1998

DHV CONSULTANTS BV

in association with

KAMPSAX INTERNATIONAL
DANISH HYDRAULIC INSTITUTE

DEVELOPMENT DESIGN CONSULTANTS
SURFACE WATER MODELLING CENTRE
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LIST OF ABBREVIATIONS

ADCP	Acoustic Doppler Current Profiler
ADP	Annual Development Plan
BADC	Bangladesh Agricultural Development Corporation
BIWTA	Bangladesh Inland Water Transport Authority
BWDB	Bangladesh Water Development Board
CDSP	Char Development and Settlement Project
CERP	Coastal Embankment Rehabilitation Project
CIP	Chandpur Irrigation Project
CMG	Canal Maintenance Group
CPP	Cyclone Protection Project
DAE	Department of Agricultural Extension
DDCC	District Development Co-ordination Committee
DLS	Department of Livestock Services
DOE	Department of Environment
DOF	Department of Forestry
EGIS	Environmental Geographical Information System
EIA	Environmental Impact Assessment
EMG	Embankment Maintenance Group
FAP	Flood Action Plan
FD	Forest Department
FFYP	Fifth Five Year Plan
FPCO	Flood Plan Co-ordination Organisation
GOB	Government of Bangladesh
GPP	Guidelines for People's Participation
HYV	High Yielding Variety
ICZMP	Integrated Coastal Zone Management Plan
LAED	Land Accretion and Estuary Development Division (of BWDB)
LCS	Landless Contracting Society
LGED	Local Government Engineering Department
LRP	Land Reclamation Project
MES	Meghna Estuary Study
MHW	mean high water
MLW	mean low water
MPO	Master Plan Organisation
MWR	Ministry of Water Resources
NEMAP	National Environmental Management Action Plan
NWMP	National Water Master Plan
O&M	Operation and Maintenance
PMU	Project Management Unit
RIDP	Remote Island Development Programme
RRI	River Research Institute
RTK	Real Time Kynematic
SDE	Sub Divisional Engineer
SMG	Structure Maintenance Group
SO	Sectional Officer
SRP	Systems Rehabilitation Project
SWMC	Surface Water Modelling Centre
TDCC	Thana Development Co-ordination Committee
TNO	Thana Nirbahi Officer
WARPO	Water Resources Planning Organisation
WMB	Water Management Board
WMC	Water Management Committee
WUA	Water User Association
WUG	Water User Group

1. INTRODUCTION

1.1 Background

The Meghna Estuary Study (MES) was drawn up as a component of the Flood Action Plan (FAP) which was developed by the former Flood Plan Co-ordination Organisation (FPCO) of the Ministry of Water Resources. FPCO was subsequently merged with the Master Plan Organisation (MPO) to form the Water Resources Planning Organisation (WARPO). The MES is being implemented for the Bangladesh Water Development Board (BWDB), which also comes under the Ministry of Water Resources.

The FAP projects were formulated after the severe floods of 1987 and 1988 and mainly concentrated on inland areas, but the coastal areas of the country were given more prominence after the April 1991 cyclone. The cyclone caused far more significant loss of human life (120,000 deaths) and damage than the 1987 or 1988 floods. Under the FAP division of the country, the MES forms FAP 5B, with the South East Regional Study that was previously known as FAP 5 being reassigned as FAP 5A. The locations of these study areas are shown in Figure 1.1 and the delineation of the Study Area is outlined in Section 1.3.

The MES is funded by the Government of the Netherlands and, up until September 1998, the Government of Denmark. Work on the MES commenced in November 1995 and was completed by September 1998. The MES follows on from the work of the Land Reclamation Project (LRP), which studied the accretion processes in the delta from 1978 and looked at possible interventions. The land based activities of the LRP have subsequently been taken over by the Char Development Settlement Project (CDSP), whilst the more marine based aspects have been studied by the MES.

1.2 Objectives of the study

The objectives of the study as per revised Terms of Reference are:

- planning of the development of the project area, giving due attention to:
  - **Surveys.**
    Carrying out a systematic programme of surveys to build up a reliable data base for assessing estuarine behaviour.
  - **Master plan.**
    Enhancing the optimum exploitation of the potentials of the area in terms of land reclamation and land use, thus providing new land to landless people.
    The master plan is expected, in due course, to lead to an enhanced morphological stability and eventually to a shortened coast line. It thus aims at a safer environment for sustained human habitation.
  - **Land and water use.**
    Mitigating the destructive forces of storm surges(cyclones), thus providing a higher degree of safety to the population and property and improving the productivity of the coastal islands by introducing better systems for drainage, salinity control and water management(development plan). This would include those areas which are at present not protected and which are not covered by FAP 7.

- Enhancing understanding of the natural forces that shape the physical properties of the area and which largely determine the potential for settlement and development. To the extent that information is available from other FAP studies, of the possible impact of flood protection works along the major rivers on hydraulic and morphological conditions in the rivers, related consequences for the Meghna Estuary should be assessed.

- An early start to implementation of priority projects and programmes that are compatible with the phased long term and/or development plan. Implementation of works beyond the stage of practical experiments is not included in MES.

- Practical solutions for an effective continuation of surveys and studies, aimed at sustained and co-ordinated actions to update and progressively implement the long term plan.

- Reinforce the capacity of the concerned institutions to survey, investigate, plan, design and implement MES, its projects and long term plan.

The Terms of Reference (TOR) for the MES emphasise the need to improve the physical safety and security of the resident population. Of prime concern is the need to reduce the effects of cyclones and storm surges on people resident in the area, whilst also recognising that bank erosion can be a significant impoverishing factor. There is an overall objective of improving residents' welfare through strengthening their economic livelihoods.

The objective of the study is to draw up a planning framework for the area and develop a 25 year outline Master Plan. The Master Plan aims to identify the priority issues in the study area, like physical safety and socio-economic security and propose ways of addressing them which are technically, economically, environmentally and socially feasible and sustainable. Pilot trials are to be carried out to test certain types of intervention. The first five years of the Master Plan programme are to be studied in detail and presented as a Development Plan for the area.

The planning process is to follow the framework of the Guidelines for Project Assessment drawn up for the FAP (Ref: FPCO, May 1992). To ensure environmentally sound and sustainable development planning, the proposed interventions are to be subject to an environmental assessment process as outlined in the EIA Guidelines (Ref: FPCO, October 1992) and the associated EIA Manual (Ref: ISPAN, 1995). In addition there is a requirement for public participation in the planning process, including consultation with interested and affected parties.

1.3 Definition of the study area

The MES area is shown in Figure 1.2 and covers a gross area of 11,000 km^2. The study area includes all of the land and water of the Lower Meghna River system south of Chandpur town and extending west to Barguna and south eastwards to the Karnafuli river mouth. This river system has the third highest peak discharge of any river in the world and the highest sediment load. The study area also includes a notional 500 metre strip of the defined mainland so as to address the need for provision, rehabilitation and retirement of any main river bank flood protection embankments and the need for foreshore management.

In some cases, such as at Haimchar, it has been necessary to increase the limit further inland to include all those areas predicted to erode during the 25 year planning horizon. The island of Bhola is excluded from the MES area, as it has already been subject to study under FAP 4 and another project. However, it is obviously incongruous to draw up a 25 year Master Plan for the area without including it. The derived area development strategy thus includes the bank edge strip of the main part of Bhola Island.

The MES area is bounded on the west by the FAP 4 South West Regional Study, to the north east by the FAP 5A South East Regional Study and to the south east by the proposed FAP 5C Chittagong Coastal Area Study.

1.4 Objectives and structure of the Master Plan Report

One of the objectives of this Master Plan report is to give the planning framework, criteria for selection and the sequencing for drawing up the 25 year rolling intervention programme for the area. An Interim Master Plan was drawn up in November 1997 and presented at a workshop in March 1998. The Interim Master Plan outlined the proposed planning process for drawing up the criteria for intervention selection.

Figure 1.1: Delineation of MES Study Area

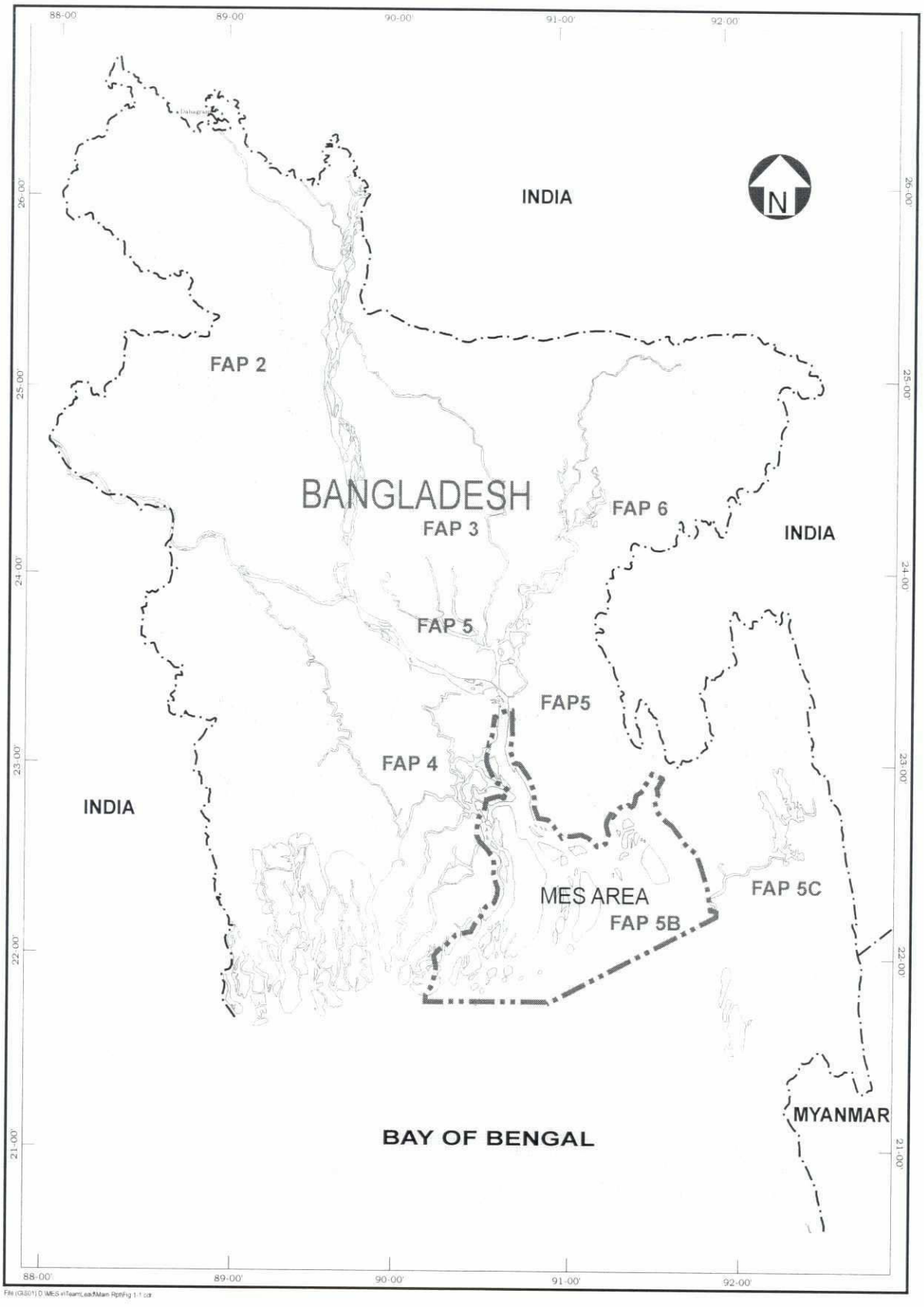
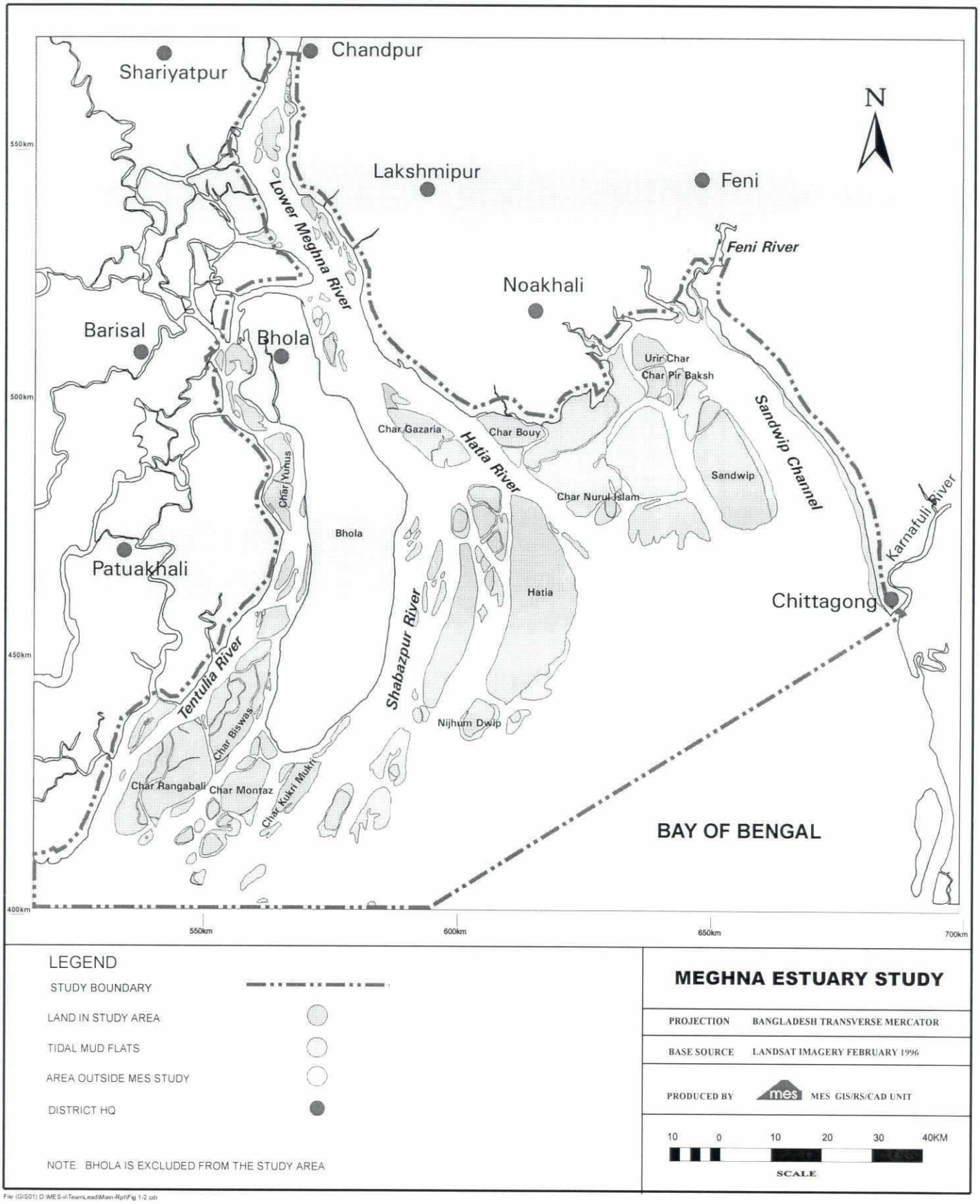


Figure 1.2: MES study area



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The Master Plan consists of 8 volumes, the Main Report in Volume 1 and seven supporting volumes arranged by discipline:

Volume 1	Main Report
Volume 2	Morphological Processes
Volume 3	Water Management and Drainage
Volume 4	Rural Development
Volume 5	Agriculture and Farming Systems
Volume 6	Fisheries and Aquaculture
Volume 7	Forestry
Volume 8	Environmental Profile and Assessment

Volume 8 gives an overall Environmental Profile of baseline conditions in the MES area, which are summarised in Section 2 of this Master Plan Main Report. More details on each subject may be found in the relevant supporting volumes.

The Master Plan is drawn up in five yearly intervals which allows for rolling revision to be made. The Development Plan concentrates on the first five years, and includes the feasibility studies for projects for early implementation and the pre-feasibility studies for years six to ten.
The Development Plan comprises the following volumes:

Volume 1		Main Report
Volume 2	Part 1	Feasibility Study Haimchar Erosion Control Project
Volume 2	Part 2	Initial Environmental Examination Haimchar Erosion Control Project
Volume 3	Part 1	Feasibility Study Nijhum Dwip Integrated Development Project
Volume 3	Part 2	Environmental Impact Assessment Nijhum Dwip Integrated Development Project
Volume 4	Part 1	Feasibility Study Char Montaz - Kukri Mukri Integrated Development Project
Volume 4	Part 2	Environmental Impact Assessment Char Montaz - Kukri Mukri Integrated Development Project
Volume 5		Pre-feasibility Studies Land Development
	Part 1	Rangabali - Char Biswas
	Part 2	Hatia - Manpura
	Part 3	Urir Char- Char Pir Baksh
Volume 6		Reconnaissance Studies Erosion Control
	Part 1	Bhola Northeast Bank Lines
	Part 2	Bhola East Bank Lines
	Part 3	Bhola West Bank Lines
	Part 4	Lakshmipur-Ramgati Bank Lines
	Part 5	Hatia North Coast Line
	Part 6	Sandwip West Coast Line

1.5 Expected outputs

The main output of the Master Plan is the 25 year rolling programme for the development of the ~~development of the~~ Meghna Estuary. However, in order to arrive at this output, a planning process has been followed which includes the steps of data collection and production of a baseline profile which identifies present and likely future conditions without any intervention and then allows isolation of key issues and constraints to development in the area.

The data collection process for the MES has been significant and much of the information is given in the following Technical Notes, Data Volumes and Map Boxes:

MES-001	Tidal Volume and Sediment Transport Patterns
MES-002	Schematization of Wave Climate
MES-003	Analysis of Water Level Data and Harmonic Components
MES-004	Salinity Distribution in the Estuary
MES-005	Sediment Analysis Procedures
MES-006	Nijhum Dwip Cross Dam Pilot Scheme
MES-007	Char Alexander Bank Protection Pilot Scheme
MES-008	Static GPS Survey
MES-009	Time Series Analysis of Erosion and Accretion
MES-010	Estuarine Survey Procedures
MES-011	Assessment of Marine Survey Capabilities
MES-012	Frequency Analysis of Water Levels in Feni Estuary
MES-013	Assessment of Sedimentation Fields
MES-014	Climate Change and Water Level Rise
MES-015	Surveys in Bay of Bengal
MES-016	Estuarine Surveys
MES-017	Numerical Modelling
MES-018	Rapid Assessment of Mangrove Forestry Resources
MES-019	Innovative Bank Protection Measures
MES-020	Installation of Haimchar Erosion Control Project
MES-021	Installation of Khorki Erosion Control Project
MES-022	Gravitational Circulation Shabazpur Main Channel
MES-023	Time Series Analysis of Erosion and Accretion - Addendum
MES-024	Status Survey Vessels and Equipment
MES-025	Monitoring of Haimchar Erosion Control Works
MES-026	Monitoring of Khorki Erosion Control Works

MES-101	Inventory of LRP Data
MES-102	Cross Section Data
MES-103	Water Level Data - Part 1
MES-104	Water Level Data - Part 2
MES-105	Morphology and Hydrodynamics Data - Part 1
MES-106	Morphology and Hydrodynamics Data - Part 2
MES-107	Morphology and Hydrodynamics Data - Part 3
MES-108	Char Level Fisheries Data
MES-109	Socio - Economic Survey Data - Part 1
MES-110	Socio - Economic Survey Data - Part 2
MES-111	Water Management and Drainage Data

MES-201	Bathymetric Maps
MES-202	Digitised LRP Maps

This information has been used to undertake relevant analysis, the results of which are in the supporting volumes. From quite early on in the Study it was apparent that the main issues were erosion, accretion, cyclones, floods and salinity.

In order to draw up an appropriate plan for the area, existing and proposed policy objectives at the national level and for the differing sectors were studied. A range of possible interventions have been drawn up and these have been used as sub-components of specific strategies to tackle issues such as flood prevention, erosion, accretion, land development and water management. The proposed interventions have been subjected to an environmental assessment as well as an economic and financial analysis plus a multi-criteria analysis which includes consideration of social benefits, many of which are difficult or impossible to quantify or value.

The intervention strategies have been applied to a division of the study area into planning zones and units and an area based phased development programme has been drawn up. The institutional structure required for planning and implementing such a programme, which requires an ongoing and sustainable inter-disciplinary approach, has also been outlined.

2. PRESENT SITUATION

A baseline profile of the defined MES area has been drawn up, as part of the environmental profile, using existing information and newly collected data from the MES work and is presented in Volume 8. A summary is given below, following the order laid out in the ISPAN/WARPO EIA Manual and emphasising the main conclusions. Considerably more detail is available in the supporting volumes to the Master Plan, especially for morphology and hydrology, rural development, agriculture, fisheries and forestry. A detailed summary for hydro-morphology is given in chapter 3 of the Master Plan.

2.1 Natural physical environment

2.1.1 Climate

Climatic data is available for many meteorological stations in the MES area over quite long periods, in many cases over 100 years. The mean monthly figures for a 27 year period have been obtained and analyzed. The most important parameter is rainfall and an isohyet map has been prepared which shows the variation in mean annual rainfall from peaks of 3,600 mm on the islands of Sandwip and Hatia reducing further inland. Rainfall is concentrated in the monsoon season, with peaks in July and near rainless conditions in January. Peak daily rainfall amounts can be very high indeed and often cause short lived local flooding. Humidity is greatest in the off-shore islands and unlike the rest of Bangladesh remains high throughout the year.

Peak lunar tidal range varies greatly across the MES area, with extremes of 7m at Feni, 2.7 metres east of Kukri Mukri, 3 metres on the west side of Hatia at Char Chenga and the lowest being 0.75 metre at Chandpur. The timing of spring and neap tides relative to cyclone surges and monsoon river levels is critical in determining flood risks in the area. The cyclone risk is high but varies across the area. The greatest risk, based upon an analysis of landfall sites, is on the eastern coast. The peak cyclone risk times are September/October and April, the worst years being 1970 and 1991, although 1960 was also serious because the track of the cyclone was south to north up the Meghna with a significant funnelling effect. Cyclone surges were 5 metres high with 2 metres of wave action in 1991. The highest surge levels are often further inland and on the leeward side of off-shore islands.

2.1.2 Hydrology

Hydro-dynamics

A hydro-dynamic model of the MES area has been developed by the SWMC using the newly collected MES bathymetry data and the Digital Elevation Model (DEM) derived from the Finmap 1:10,000 topographic maps of 1990. Outputs of the model were used for the MES feasibility studies and more details are given in MES working papers. Water level data clearly demonstrates the seasonal effect of monsoonal flow in the river system superimposed upon the lunar tidal pattern. The effects of predicted sea level rise (0.27 metre by the year 2030) are discussed in Section 2.7 below.

Salinity

Regular, historical water quality monitoring exists only for sites at Chittagong and Chandpur. Some one-off data was carried out under FAP 4 and for two of the MES feasibility studies. The most important parameter is salinity, with the interface moving according to seasonal flow in the main river system, being furthest out to sea during October and closest inland during May. Salinity intrusion to the land is one of the most significant environmental constraints in the MES area. See Figure 2.4.

Salinity intrusion is caused by the inflow of sea water during cyclones and lunar high tides and is the major constraint to agricultural development in the study area. The construction of embankments with adequate drainage facilities and adequate water management can reduce this problem.

Figure 2.1: Bathymetry of the Meghna Estuary used in the hydro-dynamic model

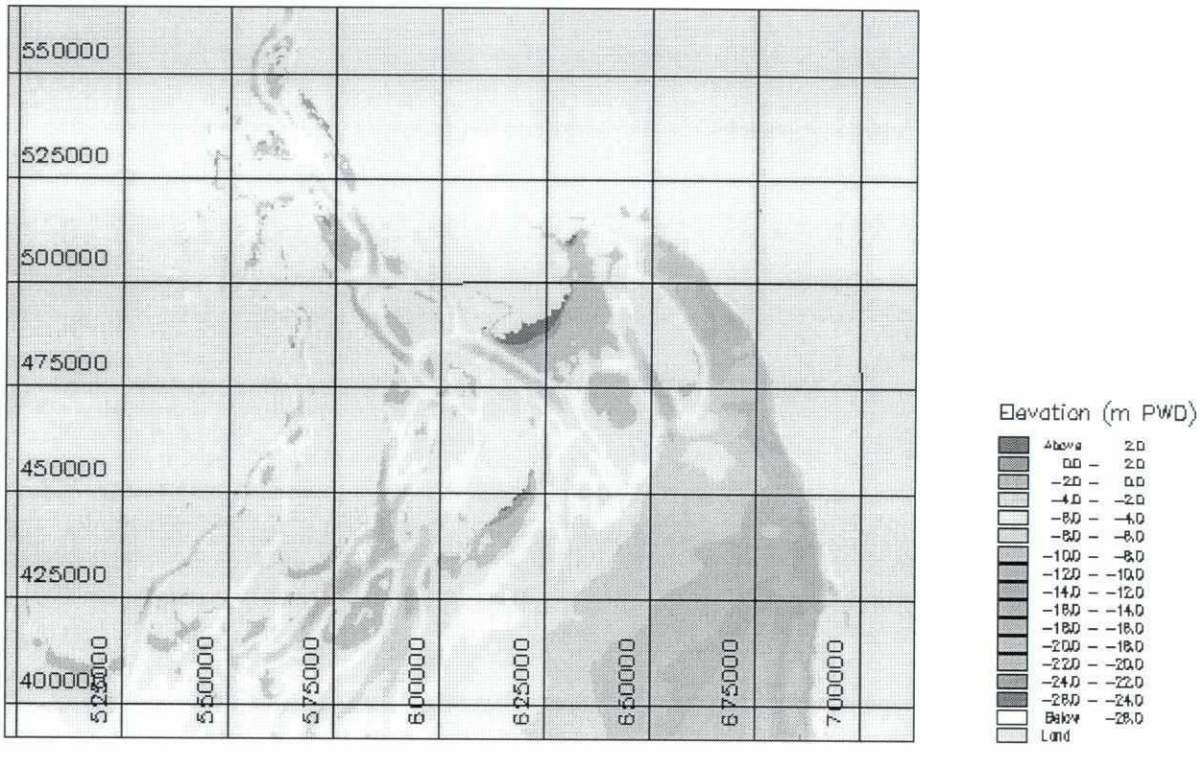
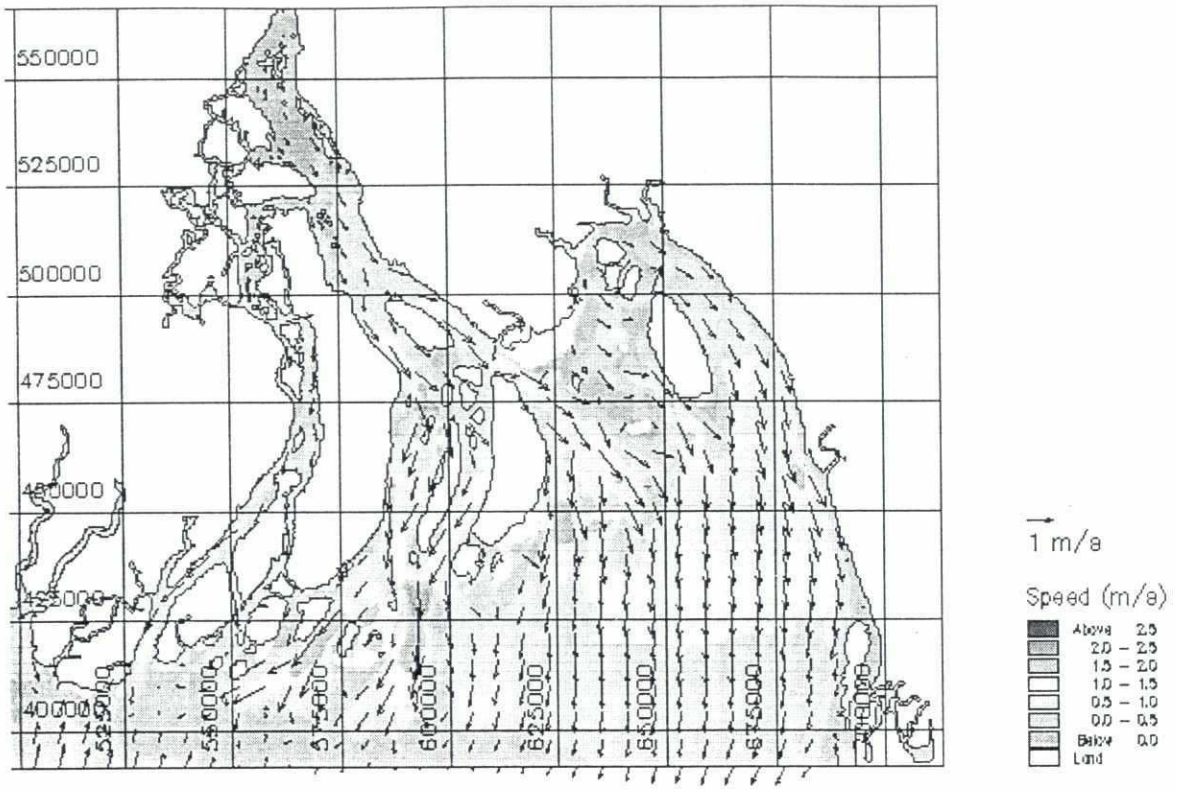


Figure 2.2: Maximum velocity pattern in the Meghna Estuary Study area.
Ebb at spring tide during the dry season.



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Flood at spring tide during the dry season.

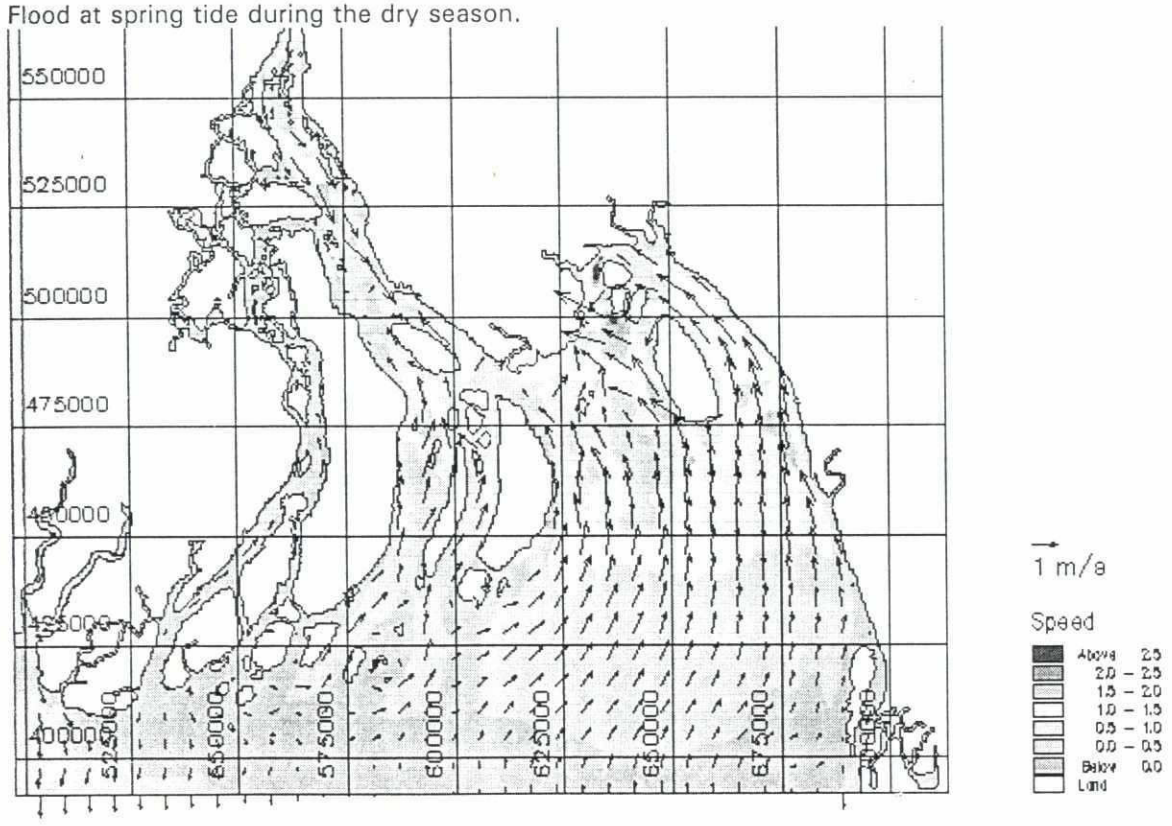

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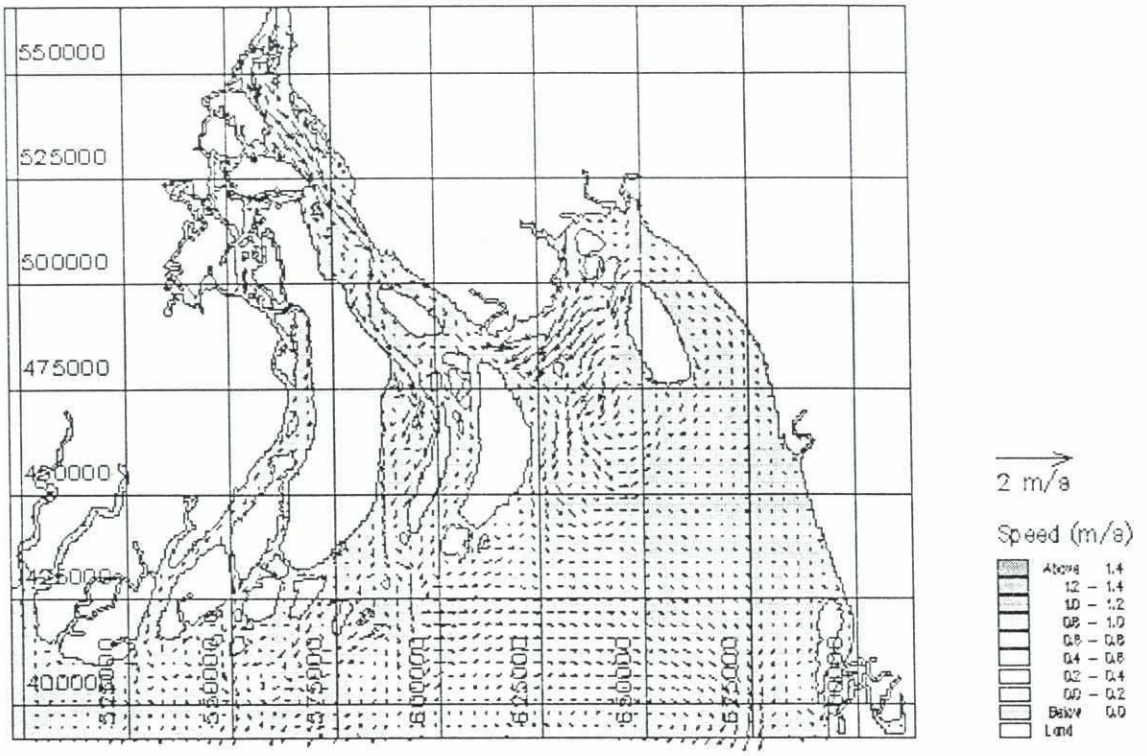
Figure 2.3: Net flow pattern in the Meghna Estuary Study area.

Spring tide during the dry season



Spring tide during monsoon

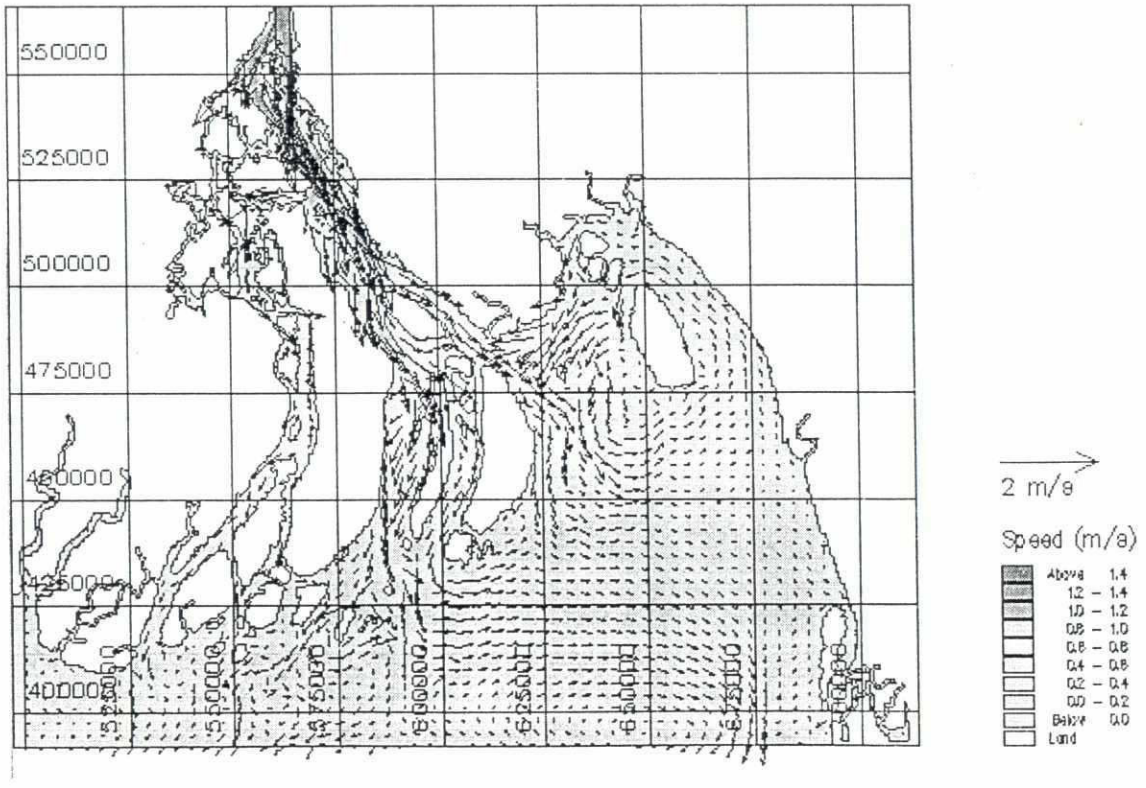
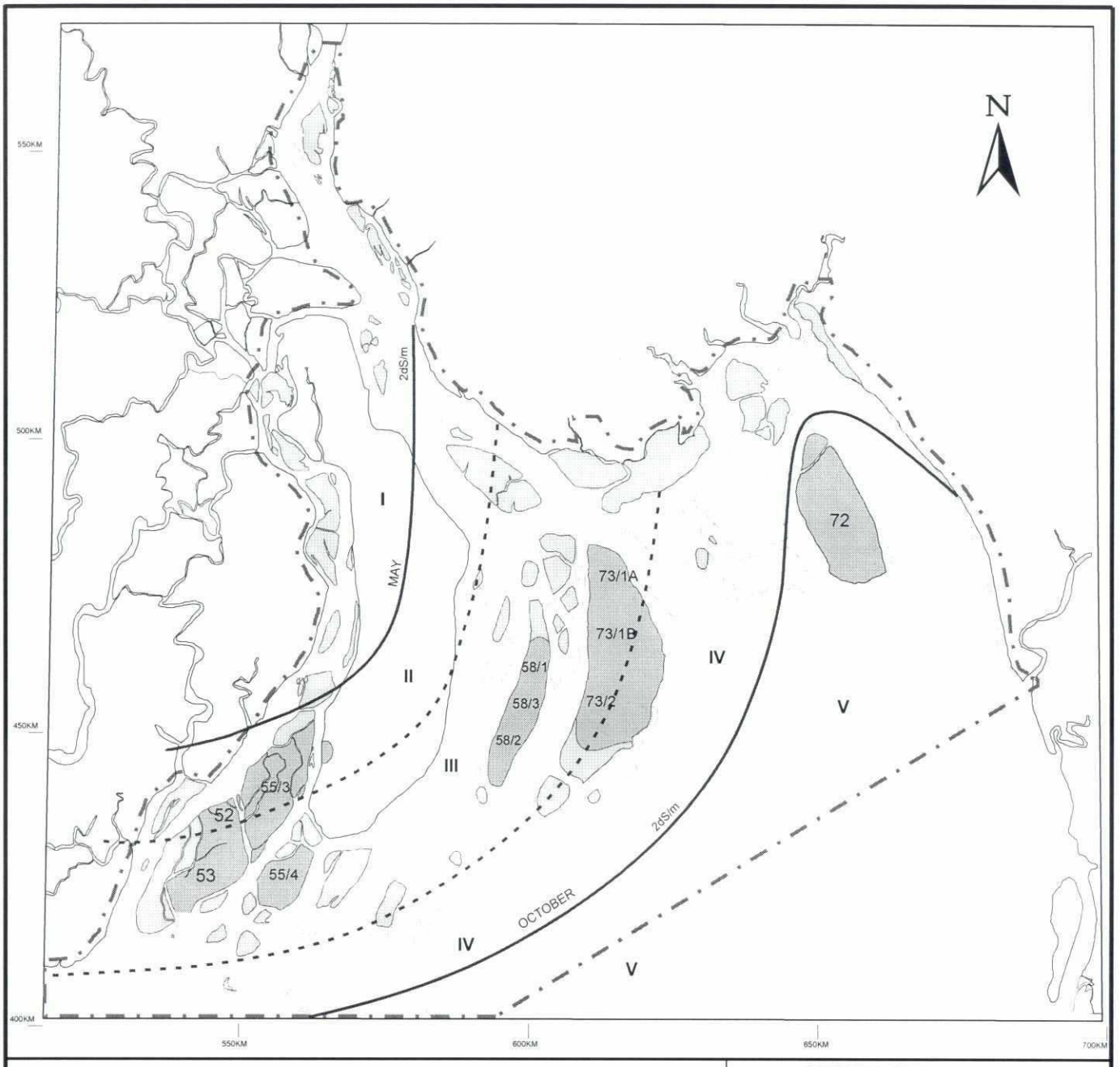


Figure 2.4: MES Surface Water Salinity Map



LEGEND

STUDY BOUNDARY

STUDY AREA

TIDAL MUD FLATS

REMARK: BHOLA IS EXCLUDED FROM THE STUDY AREA

MEGHNA ESTUARY STUDY

MES surface water salinity map

PROJECTION	BANGLADESH TRANSVERSE MERCATOR
SOURCE	LANDSAT IMAGERY FEBRUARY 1996
PRODUCED BY	MES WM, GIS/RS/CAD UNIT

10 0 10 20 30 40KM

SCALE

EMBANKED LAND

NON EMBANKED LAND

2 dS/m SALINITY ISOHYET

SALINITY ZONE BOUNDARY

SOURCE: LRP

I Permanent fresh water area, no limitation for surface water irrigation

II Scope for surface water irrigation if embanked.

III Scope for marginal embankment against salinity intrusion by tidal floods.

IV Mainly saline water area.

V Permanent saline water area.

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Erosion

River bank and coastal erosion processes and the human responses to them constitute the most important issue in the study area. These processes are described in Volume 2, Morphological Processes, with a summary in chapter 3, below. The analysis of satellite imagery shows that whilst for the period 1973 to 1998 the overall amount of land lost to erosion (88,000 ha) is significantly less than that gained by accretion (107,900 ha), the rate of erosion is very variable and has recently been increasing. Between 1973 and 1998 the mean area eroded per year was 3,500 ha but this was up to 19,400 ha a year between 1993 to 1996. Another factor is the difficulty in defining exactly what constitutes land that has accreted, as a significant proportion of it is tidal mudflats which are of limited economic use, being submerged for over 50 per cent of the time.

The same time series of satellite images were used to determine the movements of the river bank and cost lines throughout the estuary in the past 25 years. Based on the results of this study, the maximum movement of the river bank and cost lines in the coming 25 years has been predicated, see Figure 2.5. It is predicated that the Lower Meghna will widen its channels substantially while new chars will be formed in this widened river channel.

The human implications of erosion are very serious, as the majority of the land lost is developed and far more productive than newly accreted land. Erosion creates social and economic disruption requiring re-location, the search for alternative economic livelihoods and often leads to impoverishment. There are also significant economic losses from immovable assets and infrastructure which are swept away, some of which have to be replaced.

Accretion

The erosion in upstream countries of the catchments of the rivers in Bangladesh creates high sediment levels in the river systems which cause considerable accretion in the MES area. The suspended sediment concentrations in the MES have been mapped and indicate that the highest levels (over 2.2 gm/l) are in the north east, south of Feni and Noakhali, medium concentrations of 1.3 to 2.2 gm/l are found in the islands east of Bhola, whilst the lowest concentrations are to the west.

From the satellite imagery analysis the amount of accretion of land between 1973 and 1998 is greater than the area lost by erosion, the mean annual rate of accretion being 4,300 ha. However, there is considerable variation over time, with mean annual accretion rates of 5,200 ha between 1973 and 1996 falling to 4,300 ha per annum between 1973 and 1998. There are also potential inconsistencies due to the differing state of tides for the images as well as problems with defining what constitutes land, as outlined above. Although a considerable amount of land is accreted, it is of poor quality, with low mineralogy and organic matter, as well as being saline. Accretion processes are in the Volume 2, Morphological Processes.

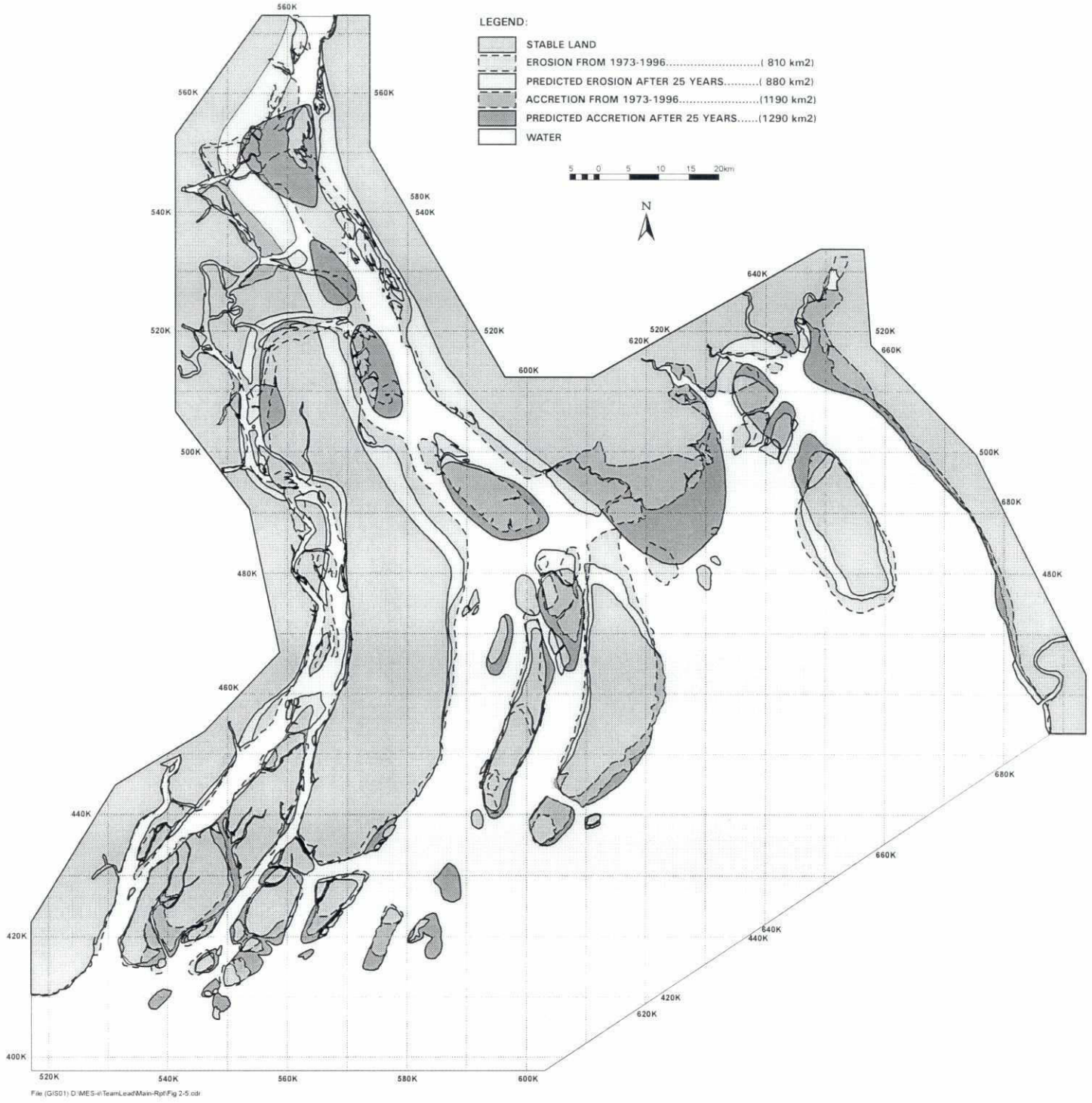
Groundwater

The conclusions of the analysis of the groundwater situation in the MES area are that the depth to non-saline water is in the order of 270 metres and abstraction costs are thus high when compared to the north of the country. As a result, groundwater should be reserved for domestic drinking water supply and not used for irrigation. There are high levels of iron in the north of the study area and recent studies have shown that the Chandpur area has one of the highest incidences of natural arsenic pollution in groundwater in the country.

2.1.3 Land resources

The topography of the study area has been studied using the DEM constructed from the 1990 Finmap work. All of the off-shore islands lie less than 4 metres above mean sea level and many below 2 metres. Topography greatly influences flood risk and land type in Bangladesh. The 1988 FAO Agro-Ecological Zone mapping classified the whole MES area as Young Meghna Estuarine Floodplain, with the exception of the Chittagong Coastal Plain to the east.

Figure 2.5: Past and Future Accretion and Erosion Patterns



The classification of soil types has been compiled from published SRDI maps and the soils are characterised as being relatively young, having low levels of organic matter and being highly prone to residual salinity.

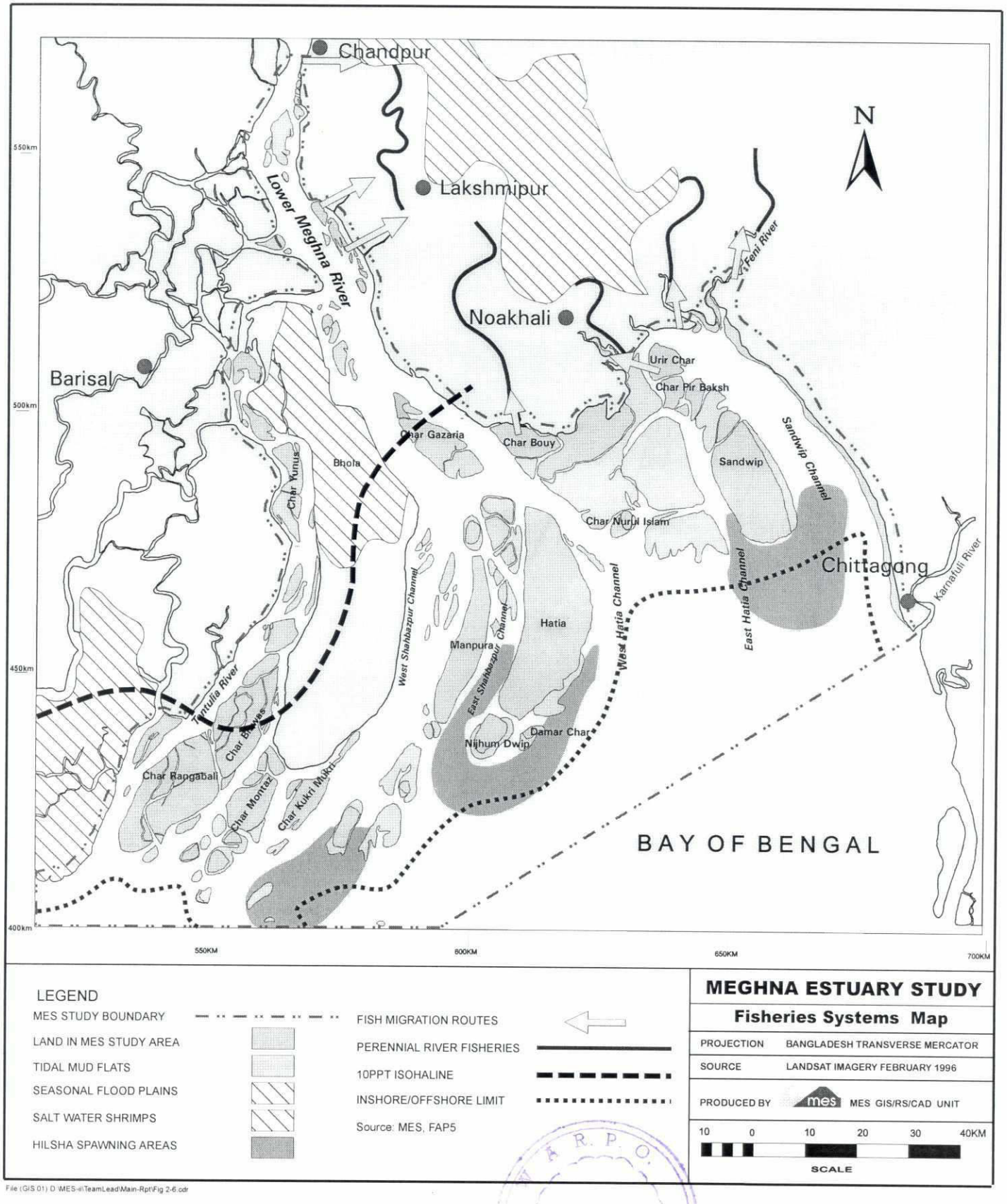
2.2 Natural biological environment

Broad habitats have been identified in the MES area and comprise terrestrial, freshwater, inshore marine and offshore marine. The boundary between freshwater and marine habitats is considered to be the 10 ppm salinity limit and the boundary between in-shore and off-shore habitats has been taken as five kilometres from the nearest land.

Master species lists for flora, fauna and fish have been compiled and there appear to be no threatened species with the exception of Gangetic dolphins. The main threat to dolphins is from human persecution for medicinal use rather than a lack of habitat. There are freshwater fish species which have complex migration, spawning and breeding habits which are not well understood. These include hilsha, the most important economic fish species in the country. The most sensitive areas are the fish breeding grounds south of Sandwip, Nijhum Dwip and Char Montaz. See Figure 2.6.

The creeks in the inter-tidal areas are the habitats of three important species (bagda, golda and pangash) and like the tidal mud flat areas, these habitats are dynamic as creeks silt up and new ones emerge. There is significant over-fishing in the area which poses a considerable threat to the sustainability of the aquatic population. Without concerted action to arrest this, there will be serious economic and nutritional consequences to a significant number of the human population in the study area.

Figure 2.6: Fisheries systems map, Hilsha spawning area



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None of the forested places in the MES area are natural; all have been planted under programmes of the Forest Department. These forested areas provide significant economic and social benefits in dissipating wave energy, particularly from cyclones. The challenge is how now to convert this planting programme into a sustainable managed resource and expand it over all newly accreted areas. The greatest diversity of flora, however, occurs in planted homestead vegetation, including that on embankments planted by erosion displacees who are resident there.

The MES area contains no registered conservation areas, although proposals have been put forward by the Forest Department to give the island of Nijhum Dwip and part of Kukri Mukri some protection status. Enforcement of this would be extremely difficult due to long standing human settlement and in-migration into the area. The task in hand is to manage such areas in a way which benefits both their natural environments and human occupants. The large areas of tidal mudflats are significant bird habitats and are expanding all the time.

2.3 Natural risks and hazards

Cyclones

Cyclones are the major cause of human death from natural disasters in the study area. In 1970 some 240,000 people were lost and in 1991 120,000. Warning systems are in place throughout the area and cyclone shelters have been constructed, although there are insufficient places for all residents. The cost of provision of these shelters is quite high but can be more easily justified when used in a multi-purpose way as health centres, community centres and schools. A considerable number of livestock are also lost in cyclones. Raised platforms (killas) provided as livestock refuges can also be used as elevated market places. A significant conclusion is that no human settlement should be encouraged outside embankments.

Flooding

Flooding in the study area occurs from very different sources: local rainfall, high river levels from upstream catchment rainfall (which can be exacerbated by high tidal conditions) and cyclones. There are monsoon seasonal cycles to these high water levels, as well as lunar ones, plus the higher risks in the cyclone prone times.

Flooding from the river system is controlled by the construction of flood embankments, but in some locations these are at risk from river bank erosion. It is imperative that such embankments are retired early enough to prevent catastrophic flooding when they fail due to erosion.

Saline intrusion

In order to prevent saline intrusion from cyclone surges and lunar high tides it is necessary to have effective embankments with adequate drainage to prevent rainfall flooding inside them. There is a need for adequate drainage provision inside embankments that is well managed and responsive to local needs. The aim is to prevent saline inflow from both cyclones and lunar high tides, yet at the same time allow adequate drainage of rainfall flooding. For this reason it is important that land is allowed to accrete to an adequate level to allow for drainage before embankments are constructed. This level depends upon the local tidal range and is site specific and not uniform across the study area. The retention of the last of the monsoon rainfall in the drainage system can be used for irrigation into the dry season. The embankments should also be multipurpose, with provision for roads and permanent settlement.

Seismic activity

The study area is predominantly in the medium risk zone II. Damaging earthquakes in Bangladesh are infrequent but can be severe. The last major event was in June 1897 but due to the fact that buildings were made of lightweight non-rigid materials the human casualties were low.

The effects of earthquakes in saturated alluvial deposits can be catastrophic for any structure, due to liquefaction. For the MES area, the timing of seismic events relative to the lunar high tide is more important than to the monsoon period. The risk of coastal embankment failure during an earthquake is significantly less than on an internal river embankment, due to the fact that the design slopes are far less steep.

2.4 Human social environment

Details of the human social environment, based upon the detailed socio-economic surveys carried out in the MES area, can be found in the Volume 4, Rural Development. The main features of the area are outlined below, giving a less detailed but wider overview based upon 100 per cent data collected in the 1981 and 1991 national censuses.

The disaggregated Human Development Index (HDI) for Bangladesh indicates that of the 9 districts in the study area only one (Bhola, which is actually excluded from strict definition of the MES) lies in the bottom half of all 60 districts in the country; all the others lie in the top 40 per cent. However, the data hides the fact that many of the island areas have the lowest levels within the districts, with most districts including significant areas of productive and stable mainland.

The administration structure in the study area includes parts of 9 districts and 31 thanas. Key socio-economic BBS data for seven important human environmental parameters down to thana level for both 1981 and 1991 have been collected and analyzed and compared with MES socio-economic survey data. The results are presented below.

Human population

The human population density has been calculated using actual land areas digitised from the satellite imagery for the time of the census data collection. The mean 1991 density including all of the 31 thanas was 862 people per km^2 with the highest rates being at Chittagong (9,043 people per km^2) and Chandpur (2,445 people per km^2). The lowest rates are in the south west (Galachipa at 362 people per km^2) and south (Manpura at 364 people per km^2). Population density increase between 1981 and 1991 was greatest in Chittagong due to rural to urban immigration. The second highest increase was in Manpura and the far south west due to in-migration to newly accreted land. The lowest levels were on Sandwip (at 7 per cent over 10 years way below the national average population growth rate) probably due to higher mortality rates from the cyclone and out-migration. The overall mean household size in 1981 was 5.74 and in 1991 5.61. This is greater than the national figure, but the national reduction between 1981 and 1991 was much smaller.

The results of the needs assessment indicated that women were more concerned than men with improving health service provision and domestic water supply and access to them. In addition women in the some of the remoter parts of the study area requested better communications, particularly those from erosion displaced households who had been forced to relocate but wished to retain contacts with family members.

Settlement pattern and history

The earliest available map of the area dates from 1776. There is a long history of settlement in parts of the study area, including the main towns of Chittagong and Chandpur. Other major settlements, including district headquarters towns, have been relocated as a result of erosion. These include Lakshmipur (Lockipur), Noakhali and Hatia.

Landholding and tenure

In 1991, 60 per cent of households in the mainland part of the study area owned agricultural land. However, the number of households owning land varies greatly, with less than 30 per cent in the urbanised area of Chittagong and between 30 and 50 per cent on the newer accreted islands. In the central and southern parts of the Study Area there have actually been increases in the proportion of households owning agricultural land between 1981 and 1991 which is contrary to the national trend but may be due to allocation of newly accreted land.

With regard to ownership of newly accreted land, the main issue is how allocation of such areas is handled by the local administration. The difficulties in allocating such land have been well demonstrated by the CDSP and have posed a major threat to the progress of their projects in South Noakhali. Secure title to both homesteads and agricultural land is a pre-requisite for sound development and lack of security of tenure has been cited by many people in the study area as a constraint to agricultural development.

The ownership of newly accreted land is vested in the state and the policy of allowing the Forest Department user rights to plant such areas helps prevent illegal occupation. However, the reluctance or inability of the Forestry Department to manage the land sustainably and use the revenues to plant new areas has meant that this valuable opportunity is being lost. In southern Noakhali (the CDSP area) there are severe problems with illegal occupation by large, powerful vested interests, but in the off-shore islands this would appear to be a rare occurrence.

Once an adequate land level has been reached then consideration should be given to embankment construction for both homestead residence and to develop agricultural land with a lessened risk of cyclone damage and saline intrusion. The construction of cluster villages in such newly embanked areas is favoured by some communities but not by others. Such cluster villages should always be located inside the embankment and linked with it by an all season raised road.

Land use

It is evident that at present households in the study area follow a risk minimisation strategy with regard to economic livelihoods, combining agriculture with livestock and fishing. However, most have expressed the wish to be full-time farmers and bearing in mind the present over-fishing in the area, this would seem to be a positive aspiration in terms of resource use.

The conceptual model for land use developed by the LRP follows a succession based upon speed and height of accretion, a decision to plant forestry or not, use of the land for grazing followed by construction of embankments with adequate drainage to allow agricultural land allocation and cropping. This model would seem to be of value and relevance to most of the newly accreted land in the area. However, a decentralised and integrated approach with an appropriate institutional structure is needed to implement such a programme successfully. A major problem is that the costs of embankment construction are high compared to the poor yields and returns from agriculture. The construction cost are also high on a per household basis when compared to other possibilities for economic development in other parts of the country.

In the coastal areas, particularly on newly accreted land, there are still significant common resource rights, including fish, fuelwood, grazing and fodder. All these resources are under pressure but with the exception of fish, nothing like as intensively so as the rest of the country. The newly accreted islands in general have very good rural energy balances.

Water supply and sanitation

The level of provision of "safe" domestic water supply for 1991 was high in urban areas (93 per cent of households in Chittagong) and lowest (60 per cent and lower) south of Chandpur and at Ramgati. The main source of supply is from deep groundwater as shallow groundwater is saline. Provision of surface water in newly accreted land is a necessary pre-requisite for settlement. The incidence of natural arsenic pollution in the middle groundwater aquifer is particularly high around Chandpur in the extreme north of the study area.

Whilst water supply provision has improved in the last 10 years there are problems in maintaining this progress as the sources rely upon pumped deep groundwater. The overall levels of sanitation provision are very low indeed and are a major reason for high levels of diarrhoeal disease.

Human health and nutrition

There were urgent calls for provision of health centres in the remoter island areas. There appears to be high infant mortality in the area and diarrhoeal disease is the most common reported illness. The latter is a result of poor sanitation. In the forested areas there are outbreaks of malaria although they appear to be the milder vivax form.

From the MES survey data it is concluded that, in general, people in the remoter islands were relatively well fed when compared to the rest of Bangladesh, mainly because they had access to good supplies of fish which many caught themselves. However, the level of nutrition in the Haimchar and Chandpur area was poor, which may be related to the large number of erosion displacees and impoverishment due to loss of economic livelihood.

Education and literacy

The literacy rates for the area are low compared to many parts of the country but are making progress. The lowest levels (below 25 per cent) were found in the islands of the south of the study area and also, more surprisingly, in the far north west. Unsurprisingly, the highest literacy levels (over 50 per cent) are in the urban areas of Chittagong and Barisal and their surrounding thanas which have levels in the order of 30 to 40 per cent.

2.5 Human economic environment

Agriculture

Details of the situation with regard to agricultural development are given in Volume 5 of the Master Plan. The proportion of people having agriculture as their primary source of income in 1991 varies greatly across the study area, with the lowest proportions being in the urban areas of Chittagong and the highest in the north west. Contrary to the national trend, Hatia, middle Bhola and the mainland west of Bhola had an increasing proportion of the population working in agriculture between 1981 and 1991.

Cropping patterns vary according to degree of flood risk and availability of surface water for irrigation. Cropping intensity is highest inland where irrigation is possible and the lowest on the islands.

The main constraints to raising agricultural production in the area are poor quality soils (particularly lack of organic matter), residual soil salinity and saline water inflow, with resulting low yields and returns to agriculture. This is not helped by poor marketing networks and large pest losses in some years. Farmers follow a risk minimisation strategy by mixing agriculture with livestock and fishing.

Livestock

The situation with regard to livestock in the study area is dealt with in Volume 5, Agriculture and Farming Systems. There are extensive grazing areas in many places, but these lie outside the embankments and are prone to lunar tide flooding and cyclones. In places of more intensive cropping and when grazing areas are flooded or cropped then animals are stall fed, mainly on crop residues. The cyclones of 1970 and 1991 drowned large numbers of livestock and there is a need for the construction of raised mounds for retreat during cyclones (known as Killas). Small livestock (sheep and goats) which are kept at the homestead, are often the responsibility of women as are poultry, including ducks. The general levels of animal disease are high and extension services, particularly in the remote islands, are poor or non-existent.

Forestry

Details are given in the Volume 7, Forestry and MES Technical note 018. All of the forest cover in the study area is planted, either as blocks of mangrove or in homesteads. It is estimated that in 1996 there were some 56,000 ha of planted mangrove in the Study Area with some 4,000 ha per annum having been planted from the mid 1970s to 1986. Since 1986 the area of new planting per annum has declined and not kept pace with new land accretion.

Planted mangrove provides a very useful function in stabilising mudflats, promoting natural accretion and dissipating wave energy, especially during cyclones. There is an urgent requirement to set up a self-sustaining rolling forestry management programme that allows all newly accreted land to be planted, funded by revenue from sustainable management.

Fisheries

The situation with regard to fisheries in the study area is described in Volume 6 of the Master Plan. A considerable number of households depend upon fishing for their economic livelihood and also directly consumed food. The high levels of fish consumption in the remoter areas are the reason that, despite being financially poor, many households are relatively well nourished.

The main issue is that the availability of such free good fisheries has been declining recently as fishing activity has increased, often as a result of erosion displacees and others being forced into fishing as a livelihood through lack of available alternatives. Without action to address this issue there is a real risk that the fisheries stocks may collapse with serious socio-economic and human nutrition implications. Aquaculture is poorly developed and there is scope to increase this in suitable locations which are protected from flooding and cyclones.

Industry and other non-farm wage paid employment

There is very little significant industry in the immediate study area, the only activities being some agricultural and fish processing which employ very few people. In some places, significant numbers of households are dependant upon members working as boatmen and traders. In urban and peri-urban areas business and other services industries are important.

Infrastructure and transport

The road network is very variable, being surprisingly well developed on some of the older islands such as Hatia but non-existent in the smaller and newer islands. All roads which are to be usable throughout the monsoon season have to be on raised embankments to avoid the risk of flooding. Flood protection embankments are increasingly being taken over by LGED and developed for multi-purpose use, including settlement for both temporary refuge and permanently for erosion displacees. The road system on islands is highly dependant upon links to the water borne transport system.

The main navigation routes through the area are those between Chittagong and Chandpur with a link to Barisal and Khulna, plus Chittagong to Cox's Bazar. These are all affected by changing erosion and accretion patterns and need to be locally rerouted when islands emerge or deeper channels occur. A local network of ferries links the islands; Sandwip, Hatia, Nijhum Dwip, Manpura and Bhola are all highly dependant upon these services. The main difficulties are the narrow tidal windows in some places, erosion of ghats in some locations on the main river bank and extending the link road network through unstable recently accreted land.

2.6 Social risks and hazards

Social risks and hazards include the implications of natural hazards, such as cyclones, flooding, erosion and earthquakes which have already been outlined in Section 2.3. Other risks and hazards include those mentioned below.

Famine

There were famines in the area during 1943 and 1970/71. The 1943 Bengal famine was mainly due to food grains being diverted to the war effort against the Japanese, whereas the 1970 famine was due to the effects of the 1970 cyclone and later compounded by the war with Pakistan.

Disease

Water borne disease is a major cause of death amongst young children and the old in the study area. Diarrhoeal disease has been identified as the highest reported disease in 6 out of 10 thana health centres. Infant mortality rates in the off-shore islands appear to be much higher than the national level, as shown in the population pyramids in Volume 4, Rural Development.

Social instability and conflict

The two main reasons for social instability in the Study Area stem from the morphological processes, namely erosion and accretion. River bank and coastal erosion causes major disruption and conflict as households and whole communities that lose their land are forced to relocate in alternative places, either urban areas, newly accreted land or on the land of another community. The accretion of new land may also create conflict over land claims, both in areas where old rights may still exist or where illegal land grabbing occurs. There are serious problems with this in southern Noakhali but it is relatively uncommon in the off-shore islands, helped by the fact that in the past the Forest Department has planted newly accreted land.

Economic instability

Economic instability occurs after natural disaster, particularly cyclones, flooding and land loss due to erosion. The main problems are the difficulty in re-establishing economic activity and this is often hardest in the case of erosion victims who have to look for completely new alternative livelihoods.

Political instability

The off-shore islands lie beyond the normal day to day control of government functions. However, like many of the river island chars in inland Bangladesh there are rarely serious political problems. The main disputes lie in areas of illegal land grabbing in southern Noakhali.

2.7 External considerations

2.7.1 Upstream constraints

There are proposed or recently constructed projects upstream of the Study Area which may impose some constraints upon the possibilities for its development. A significant issue is the degree any upstream development would change velocities and sediment levels in the river system and the effects that would occur in the Meghna downstream of Chandpur. Specific projects are discussed below.

Jamuna multipurpose bridge

The construction of the Jamuna bridge has resulted in the peak flow width of the Jamuna river being restricted to 4.5 km width instead of 12 km. From the experience of the first two years flood conditions and study of the predictive hydro-dynamic model, it would appear that the main effect has been to increase velocities through the restricted width rather than raise peak flood levels upstream of the bridge. The unknown factor is how much more sediment is likely to be put into transport and for how far downstream of the bridge. However, it would seem unlikely that there would be any significant impact downstream of the confluence with the Padma near Aricha, although the results of the environmental monitoring being carried out for the bridge would need to be studied to verify this.

Ganges barrage and Gorai dredging

The idea of constructing a barrage across the river Ganges just downstream of the Gorai intake has recently been revived, linked to diversion of dry season Ganges flow into the Gorai system. Such an intervention may well affect the velocity and sediment load downstream of the abstraction point and hence into the Meghna at Chandpur. The changes in sediment are unlikely to be that significant, as the Brahmaputra/Jamuna system carries far higher sediment concentrations than either the Ganges/Padma or the Meghna systems. However, any changes in dry season discharge and sediment load could still have limited implications for erosion patterns in the MES area downstream of Chandpur. The more significant impact is likely to be on flow in the dry season which could possibly cause the salinity interface to move slightly further up the Meghna towards Chandpur. The EIA work being carried out for the Gorai projects should address these issues.

Other upstream development possibilities

Other possible upstream interventions include a barrage on the Brahmaputra and development on the feeder rivers in Nepal, China and India, possibly including hydro-power development and abstraction for irrigation. Only an integrated basin planning approach will be able to manage these issues in an environmentally sound and sustainable manner.

2.7.2 Downstream constraints

The main possible downstream constraint is that by changing current patterns and sedimentation in the northern part of the study area, there may be generated impacts to the island chars downstream, specifically changes to the erosion and accretion patterns. Due to the dynamic nature of the area these issues should be studied on a case by case basis, with appropriate hydro-dynamic modelling and satellite imagery monitoring. The EIA work for proposed projects has addressed these issues.

2.7.3 Integrated coastal zone management

There is an urgent need to plan the development of the Meghna Estuary Study area within the context of an integrated coastal zone management framework. This has been discussed with various bodies and is outlined in Section 4.1.3.

2.7.4 Sea level rise

The scenario for sea level change in the Meghna estuary area is for a rise of 0.27 metres by the year 2030. For offshore islands the recent natural rates of accretion are much faster and higher than this. However, the design of any proposed embankments should take the predicted changes in sea level into account, although compared to the requirement to cope with cyclone surges, the added height needed is comparatively small.

2.8 Conclusions

From the environmental profile given in Volume 8 it is concluded that the following issues are the most significant in the MES area, in the following order of priority: erosion, accretion, cyclones, flooding, salinity, drainage, land tenure, land use and human health.

3. HYDRO-MORPHOLOGY

3.1 Past and present accretion and erosion patterns

3.1.1 Past morphological development

The evolution of the Meghna Estuary Study area is subject to strong processes that fully cover the space-time scale. In this chapter the geomorphological development of the Meghna estuary will be discussed in detail for different spatial and time scales to assess long term changes in coastal morphology and to discern patterns and tendencies.

One of the important controlling factors for the Meghna Estuary Study area is the change in relative sea level rise in the coastal area and the effect in the catchment areas of the rivers. The sediment transport capacity of the main rivers and tidal channels and the type of deposits are dependant, among others things, on the rise and the fall of the base level. The base level of the Meghna Estuary Study area is the sea level. In the deltaic reaches, the sea level variation has a far reaching effect, specially on a geologic time scale. During historic times, there have been changes in sea level and based upon the lithological structure of the deposits, the rise of the sea level in the case of Bangladesh coast over the last 12,000 years has been reconstructed.

For the coastal area, another interesting factor in sea level variation is important. This involves seasonal variation in sea level following the monsoon. Analyses of long term time series of water level data indicate that the sea level rises by 0.8 - 3.0 metres due to the monsoon.

Deltas and estuaries generally are known as areas of net deposition of sediments either carried by the river or supplied from the sea. The growth of deltas and the accretion of land in estuaries is a continuous and generally very gradual natural process interfered with by the dynamics of the ever-changing courses in their channels.

A comparison of the 1996 classified satellite image with the 1776 map of J.Rennell shows a completely changed system of channels and river courses but a more or less stable coastline west of the Tetulia River.

East of the Tetulia river, however, a general tendency of seaward growth of the coastline can be recognised, particularly in the region of Bhola and Hatia islands and in the Noahkali district. Although the overall process of accretion is dominant, areas of erosion can be recognised, particularly on the river banks in the northwestern part of the project area (North Bhola-Chandpur). This erosion is the result of the westward migration of the Lower Meghna Estuary system. Sandwip and the coastal area of the Chittagong mainland also show a tendency to erosion. Due to coastal protection measures the erosion trend near Chittagong mainland has been stopped.

The rates of change for coastal Bangladesh were studied over periods of 20 years and more. In all studies a net increase of land was found. The range of net land gain over time periods ranging from 23 to 220 years varies from 4.4 km^2 per year to 16.4 km^2 per year. The rate of change computed by MES for the period 1776-1996 is 9.9 km^2 per year.

A comparison of the rate of change for the period of 1973-1996 with the rate of change for the period 1940-1963 shows that natural processes have been speeded up to some extent by the construction of the two Meghna cross dams (1957 and 1964) in the old course of the Lower Meghna estuary.

3.1.2 Long term trends of accretion and erosion over the last decades

A time series of satellite images from the period 1973 to 1998 has been used to examine the extent of land and intertidal area for each date and to assess the changes in the estuary. The net change over the period shows an overall land gain for the Meghna estuary system as a whole, for the period 1973 to 1998, of about 19,900 ha. The average annual gain for the entire study period is 800 ha per year.

Although the long term trend to gain new land is dominant in the study area, it is noted that a huge amount of old, fertile land is exposed to erosion due to migration and widening of the river system.

The net change of intertidal area by period shows a net gain up to 1984, a period of loss during 1984 to 1990, followed by net gain during 1990 to 1998. The net change of intertidal area for the period 1973-74 to 1998 is 76,300 ha. These results indicate an average long term annual rate of growth of the intertidal area of about 3,000 ha per year.

The changes for the period 1973-74 to 1998 show a vast area of new land off the Noahkali coast and Char Bouy which is associated with an even larger area of mudflat which appears to be emerging land. There are new char areas and new areas of mudflat northwest of Sandwip island. Other large areas of accretion include the very large char in the Lower Meghna Channel which appears to be a consolidation and extension of Char Gazaria.

Extensive accretion has formed in the area north of the Tetulia off-take and the filling and enlargement of the chars in the extreme southwest of the study area, including Char Rangabali, Char Montaz and Char Kukri Mukri. With respect to these areas, the major gain of land took place in the periods 1984 to 1990 and 1993 to 1996. This might be explained by the extremely high river discharges carrying huge sediment loads during 1987/88 and 1995.

Most areas of erosion are associated with widening and migration of the main Lower Meghna and with the Shahbazpur and Hatia Channels. The north and east banks of Hatia and Bhola islands are particularly affected by erosion. It is believed that these areas are sensitive to changes in river and sediment discharges.

3.2 Shore line migration and bathymetry

The shoreline migration in the Chandpur - North Bhola area is strongly related to the lateral migration of the tidal river system. The northern part of the Lower Meghna Estuary river system tends to be a wide, shallow, braided distributary system. Channels bifurcate, are separated by shoals and islands and are choked by sandy sediments.

The average west bank line moved about 4.8 km to the west between 1957 and 1996, while the east shoreline moved about 1.4 km to the east. Between 1974 and 1996 the east shoreline moved steadily eastward along the majority of its length. Only the areas between 508.000 N and 516.000 N and between 533.000 N and 545.000 N remained unchanged: these areas have been relatively stable over recent decades.

The greatest retreat is found downstream of Chandpur, the northeast and east coast of Bhola and near Char Alexander. The average retreat of the shoreline is about 90 to 220 metres per year. The areas correspond to embayments cut by flow deflected around growing bars and new island chars in the second order, east branch of the Lower Meghna river. The history of shoreline shifting indicates that periods of slower than average retreat may abruptly end.

The impact of high monsoon floods during 1987 to 1989 in generating accelerated shoreline retreat can be identified in nearly all sections of the Lower Meghna. The impact of the 1998 extreme monsoon flooding will be assessed at a later stage; however based on recent observations it appears that again the retreat of the shoreline has accelerated.
It can be concluded that the position of the shoreline is very moveable and sensitive to changes in hydraulic conditions. The impact of the extreme flooding on shoreline migration will be studied in detail after the relevant data are available.
The shoreline migration of the west bank of Hatia indicates a net retreat of the shoreline to the east. The rate of erosion varies between 5 and 35 metres per year. The east bank of Hatia also shows a long term trend of shifting in an eastward direction. The greatest bank erosion takes place at the northern head of the island where the average erosion rate is about 40 to 200 metres per year. All data from the transects indicate that the island is migrating to the southeast.

The long term shoreline migration of Manpura shows a similar pattern to Hatia: erosion on the west bank and accretion on the east bank. The migration rate of the shoreline varies from 1 to 30 metres per year along the west bank and from 2 to 20 metres per year along the east bank. The movement of the island indicates a net long term shift to the southeast.

The small islands between Manpura and Hatia are relatively young islands which started to emerge during the 1970s and 1980s. These islands silted up very rapidly and extend in a southern direction. The dynamic behaviour of the shoreline of these islands since their emergence shows a natural tendency to shift to the south.

Nijhum Dwip is a relatively young island which started to emerge in the 1950s. During the 1970s and 1980s the higher parts of Nijhum Dwip silted up rapidly to about mean higher high water level. The coastline migration in recent decades has shown a natural tendency to extend eastwards.

Damar Char is a young island that only started to emerge in the 1980s and the existing uncovered accreted intertidal areas around are tending to silt up rapidly.

The shoreline migration of northern Bhola exhibits a long term trend to erosion. The long term bank erosion rate decreases slightly towards the south and varies from 10 to 150 metres per year. The southern part of Bhola has a tendency to accrete at a rate in the southern part of about 10 to 70 metres per year.

The shoreline migration of the Chittagong mainland has an overall tendency to shift westwards, with the migration rate, which varies from 10 to 200 metres per year, increasing towards the north. The highest migration rate is found around the inlet of the Feni river. During the 1980s and 1990s erosion of the coastline occurred near the entrance of the Karnafuli river but coastal erosion protection measures have now stopped this erosion.

The shoreline on the east and west banks of Sandwip exhibits a tendency to erode. The migration rate is about 10 to 150 metres per year. The shoreline of the northern end of Sandwip tended to erode during the 1970s, but during the 1980s and 1990s this shoreline has had a net trend to silt up rapidly to the northwards. Urir Char is a very dynamic island which tends to move to the northeast but the southwestern part of which has a long term trend to erosion.

The shoreline of the southern part of the Noahkali mainland has, over recent decades, had a long term trend to accrete. The shoreline migration rates vary from 50 to 400 metres per year. Erosion of the shoreline can be recognised near Char Balua due to migration of the tidal channel northwards where the bank erosion rate varies from 200 to 500 metres per year.

Thalweg migration

It is observed that over the course of some years, a few channels in the study area have shifted their main conveyance section from one bank to the other (or from one channel to another channel in the case of composite cross-sections) due to changes in the hydraulic and morphological regime. Consequently, the position of the thalweg has also shifted and this was the most significant change observed within the channel systems. The thalweg is defined by the position of the maximum depth below MSL. It is important to know the position of the thalweg in the sense that, for example, it may sometimes be used in conjunction with the coastline migration rate to ascertain the setback distance of embankments in coastal areas and also to locate a navigation route for vessels that have a large draft.

Over the period 1983 to 1990 the position of the thalweg was always close to the North Hatia bank, which fits very well with the field observation that North Hatia is being continuously eroded. The average migration rate of the thalweg is about 86 metres per year.

The overall trend of thalweg movement is towards Ramgati on the Noahkali mainland. This movement is proceeding at an average rate of about 240 metres per year.

Since 1985, the position of the thalweg in the main Lower Meghna channel has shifted from the Bhola side towards Char Gazaria at an average rate of about 500 metres per year, indicating that the channel position is very unstable.

The channel which connects Sandwip with the Chittagong mainland has a regular shape and the bottom is nearly flat. The position of the thalweg is very moveable and its rate of migration towards the Chittagong coastline is about 220 metres per year.

Since 1985, the thalweg of the channel between Sandwip and Char Pir Baksh has migrated north towards Char Pir Baksh at an average rate of about 360 metres per year.

The analysis of the thalweg migration rates illustrate that the channel morphology and geometry in the selected areas are characterised by rapid and extensive changes over time and space. In general, it can be concluded that the position of the channel is very moveable and sensitive to changes in hydraulic and morphological conditions. Although the migration rates may differ substantially from year to year the long term migration rates often indicate a more explicit trend.

Channel cross-sections

The cross-sectional data contain important information on channel characteristics and horizontal and vertical stability. In the present study, seven cross-sections were selected for detailed analysis considering average and maximum depth and cross-sectional area.

The cross-sectional area of the West Hatia channel at the southern tip of Hatia island has tended to decrease during the last ten years while the average channel depth has tended to increase slightly.

The cross-sectional area and the average channel depth of the East Shahbazpur channel between Char Gazaria and Noahkali mainland have both tended to decrease slightly over the last two decades. However, during the period 1981 to 1994 the cross-sectional area of the West Shahbazpur channel has increased and the average channel depth has decreased.

On the eastern side of the estuary, the cross-sectional area between Sandwip and the Chittagong mainland tended to increase between 1980 and 1994, while for the small channel between North Sandwip and Char Pir Baksh the cross-sectional area decreased slightly between 1981 and 1994.

In the channel between Urir Char and the Noahkali mainland the maximum depth increased from 2 metres in 1982 to 13 metres in 1994. Between Urir Char and Char Lakhi, data on both the cross-section and maximum depth indicate that the channel is tending to silt up rapidly.

3.3 Morphology and sediment transport

The Lower Meghna estuary is the route by which sediment is transported from the major rivers to the Bay of Bengal. On the way down the rivers the grain size distribution of the sediment becomes altered by continual deposition, re-erosion and transport. Much of the coarser sediment becomes trapped on the flood plains of the rivers, only being released at times of flood. The finer fractions are transported into the estuary. There the estuarine processes act as a filter on the sediment input and mixing can take place with sediment brought in from the sea. Additionally, chemical alterations can occur within the estuary that can cause the surface properties of some of the constituent particles to alter, affecting their potential deposition.

Sediment forms a crucial control in the estuarine processes and evolution of the Lower Meghna Estuary. Within the Lower Meghna Estuary suspended sediment concentrations are generally high, the particles are fine, cohesive, and prone to flocculate and they are richly organic.

The long term morphological development of the entire Lower Meghna Estuary system is strongly affected by the river borne sediment inflow from the main rivers Ganges, Jamuna and Meghna.

The sediment budgets of these major rivers dominate the river borne sediment inflow to the study area at Chandpur. However, long term records of sediment transport are not available at Chandpur and in this study the annual sediment transport of coarse and fine sediment (<63 μm) of the Ganges and Jamuna river over the period 1966-1991 were used to characterise the long term river borne sediment inflow at Chandpur.

The averaged total annual sediment discharge of the Jamuna and Ganges over the period 1966-1991 is about 1,100 million tons per year. About 70 per cent of the sediment discharge consists of fine sediment. The sediment discharge of the Meghna is negligible compared to the Jamuna and Ganges. The sediment discharges at the Hardinge Bridge and Bahadurabad stations are strongly related to the river discharge and the availability of the sediment. The morphological development of the Lower Meghna estuary respond to the river borne sediment inflow.

The observed morphological changes derived from the time series of satellite images over the period 1973 to 1990 and the annual sediment discharge indicate qualitatively that the net gain of land is related to the amount of river borne sediment discharge. During periods of high river borne sediment discharge, the net gain of land and intertidal areas is higher than during periods of low river borne sediment discharge.

The major part of sediment consists of a mixture of (very) fine sand and silt. It is continuously moved back and forth along the Bangladesh coast and through the tidal inlets into the system. The relatively coarser material is predominantly moved near the bottom (the bottom transport). The finer particles of sand and the particles of silt and clay are predominantly moved by current as suspended material.

The sediment concentration measurements by MES and LRP indicate a variation of the sediment concentration during a fortnightly cycle of the spring and neap tides. The variation of sediment concentration shows a tendency to increase towards the spring tide when the maximum depth averaged sediment concentration is about 2 to 5 times higher than at neap tide.

Salinity measurements conducted by LRP during low river discharge indicate that the maximum sediment concentration coincides approximately with the zone of salinity intrusion. The lower limit lies at approximately the 10 to 20 metre depth contour, beyond which a vertical gradient in salinity was measured in the water column (Barua, 1990). The upper limit of the sediment concentration appears to be associated with density driven circulation. This means that the zone of the turbidity maximum influences almost the entire estuary during the dry season.

For the long term development of the coastal area it is of utmost importance to know how big a portion of the fluvial and marine inflow of sediment is retained in the Lower Meghna Estuary area. These net quantities are relatively small compared to the total quantities transported.

3.4 Erosion and accretion processes

Important factors that shape the Lower Meghna Estuary area are the hydrodynamic factors, namely tides, river inflow, estuarine circulation, waves and atmospheric forcing. The resulting estuary is primarily a consequence of the interaction of these factors acting all over the estuary or in specific parts of it. Interactions among these factors are complex and mostly non-linear. Evidence of this are the geomorphologic changes that occur in the estuary with the sediment transport processes.
The general sedimentology of the Lower Meghna Estuary is the consequence of many conditions. One of the most important is the sediment source, which may be the river, the adjacent delta or the shelf from which sediment is transported by littoral currents and introduced into the estuary by upland flow tidal action or littoral drift.

Except in the shallow sandy areas of the near shore zone and at the upper part of the delta front (e.g. south and east side of Hatia, the east side of the Sandwip Channel), the importance of littoral drift is negligible compared to tidal action. Furthermore, within the estuary proper, sediment distribution is extremely variable, reflecting the hydrodynamic conditions and the particular transport processes that are dominant in each portion of it.

The circulation patterns, particularly in the lower portions of the Meghna Estuary area are highly affected by river and tidal dynamics, resulting in characteristic morphological patterns. Flow friction and river flow decrease the tidal effect towards the head of the estuary and the river influence becomes progressively larger. The tidal effect reaches about as far as the Ganges-Jamuna confluence and at Baruria there is still some tidal influence felt in winter.

The degree of salt intrusion depends on season and climate. Salt intrusion is an important factor which affects the sediment transport dynamics and hydro-morphological conditions in major portions of the coastal area, in particular during the pre-monsoon and post-monsoon. During the monsoon period the salinity in the Meghna Estuary area drops considerably and the water becomes almost completely fresh in the major part of the area.

The velocities in the Lower Meghna river usually decelerate in a downstream direction as flow expands into the estuarine section of greater cross-sectional area near the river mouth. In the transition zone of the Lower Meghna Estuary area fresh water is encountered and it may mix with salt water; sediment transporting ability diminishes and sediments are deposited. The periodic rise and fall of the tide results in the temporary storage of large volumes of sea water in the estuary during high tide, followed by drainage at low tide. The volume of water exchanged by the tide is known as the tidal prism. Generally, the tidal prism during pre-monsoon and post-monsoon is at least an order of magnitude greater than the river discharge. The tidal prism in the Lower Meghna Estuary system varies significantly over a spring-neap cycle and shows seasonal effects. It is assumed that the Lower Meghna Estuary system displays large variations in mixing and therefore in density circulation.

In the major part of the Lower Meghna Estuary, the effect of the tide produces bi-directional currents and high shear stresses during peak flows. Although residual flow will be downstream, reversals in tide will periodically shift the fluvial-marine interface up and down the distributary channels. Under low tidal energy conditions (neap tide) or high river discharge outflow conditions, the fluvial-marine interface shifts in a seaward direction, while it shifts upstream under high tidal energy conditions (spring tide) and under low river discharge conditions.

In terms of sediment dynamics, one of the most important morphological aspects of the Lower Meghna Estuary is the way in which tide propagates upstream. The speed at which tide moves up the axis of an estuary is governed by the equation for propagation of shallow water waves and is therefore a direct function of water depth. Because of this depth dependence, estuarine tides in the Lower Meghna Estuary are deformed during upstream propagation as flood crests overtake ebb troughs.

The results of this are twofold. Firstly, flood velocities exceed ebb velocities, but are of shorter duration. Secondly, the period of high water slack is longer than that for low water slack. Consequently, the degree of tidal asymmetry increases upstream, thereby magnifying the differences between ebb and flood velocities and slack water duration.

The reversals in tide that produce bi-directional currents also produce patterns of bi-directional bed load and suspended load transport, in particular under spring tide and low river discharge conditions. Typical current speeds of 1 to 3 m/s, which are measured in the East Shahbazpur channel as well as Sandwip channel, are sufficient to keep sediments in motion for much of the tidal cycle, forcing channels to continuously adjust to erosion and deposition. This adjustment often leads to mutually evasive currents and pathways of sediment transport, such that some channels may be dominated by ebb transport and others by flood transport.

Pre-monsoon and post-monsoon measurements in the East Shahbazpur channel indicate a net upstream sediment transport during spring tide. This net upstream sediment transport can be found up to Char Bouy. It is possible that this upstream sediment transport of fine grained sediments might be caused by the response to a time-velocity asymmetry. In the East Hatia channel the flood transport of fine sediment seems to be balanced by ebb transport where flow becomes concentrated during falling tide.

Periods of slack water affect sedimentation by providing an opportunity for the deposition of muds. Longer periods of slack water following flooding tides, as a result of tidal deformation, will favour deposition of sediment in the upstream reaches of the Lower Meghna Estuary. Over numerous tidal cycles processes of infilling are likely to be enhanced.

Sediment concentration measurements under pre-monsoon and post-monsoon conditions in the Shahbazpur channel indicate a high suspended sediment concentration around the north Hatia - Manpura area as well as in the channel around Char Balua - Char Pir Baksh. This high suspended sediment concentration might refer to the so-called turbidity maximum. The turbidity maximum is a zone which contains suspended sediment concentrations higher than both in the river or further seaward in the estuary. It is generally located at, or somewhat to the landward of, the head of the salt intrusion, where salinities are about 0.1 to 0.5 per cent.

The energetic tidal flow is capable of maintaining high concentrations and there are a number of processes that concentrate the suspended sediment and prevent particles from dispersing. The peak concentration of suspended sediment in the turbidity maximum varies within wide limits. Despite the differences due to sediment availability in the Shahbazpur channel and Char Balua and Char Pir Baksh areas, they have maxima with concentrations of the order of 1 to 9 grams per litre.

The turbidity maximum contains a high portion of a narrow size range of mobile fine sediment, and plays a central role in the circulation of fine sediment within the Lower Meghna Estuary area, as well as probably determining the rate of transport of sediment from the river to the sea. The concentrations of sediment in the turbidity maximum appear to remain almost constant when averaged over a reasonable time, so that residence time of grains in the turbidity maximum must be considerable.

The turbidity maximum responds to changes in river flow, with the maximum moving downstream with increasing flow. The mass of sediment in the turbidity maximum also increases. However, a movement of the turbidity maximum down the estuary involves expansion into an increased cross-sectional volume and this could decrease the concentration even though the total mass increases.

Within the Lower Meghna Estuary, the river borne sediments become trapped by the tidal pumping and residual circulation and mix with material brought in from the sea. In this respect, the process of mixing is an important factor which involves continuous erosion, deposition and exchange of sediment within the estuary: the fine sediment cycling through the turbidity maximum and somewhat coarser sediment cycling round the ebb-flood channel systems. Individual particles may spend a considerable time moving within the system before being finally deposited or passing through to the sea.

Some of the particles entering from the river will remain in suspension and pass through the estuary fairly quickly, particularly at times of high river floods (in particular during the monsoon period). However, a significant proportion will undergo many cycles of deposition on the bed followed by resuspension, with the deposition operating for a variety of time scales and occurring at a number of points along the estuary which form temporary sinks for the sediment particles. The trapping efficiency of the estuary is the ratio of the fluvial sediment input to that accumulated in the estuary.

From the literature it is known that for partially mixed estuaries the trapping efficiency can exceed 100 per cent, since the fluvial sediment is only part of that accumulating. The minor part of that drawn in from beyond the estuary mouth is likely to be coastal or marine material, but much will be fluvial material exported at higher river flow stages. Additionally, in well mixed estuaries, tidal pumping becomes significant in transporting sediment up estuary into the turbidity maximum, with the degree of tidal pumping depending on the tidal characteristics, as well as those of the sediment.

Sediment transport measurements indicate that a huge amount of sediment is transported through the estuary rather than being deposited in the estuary. This might be an indication that the overall long term trapping effect of the estuary can be classified as low. Interventions might have a positive effect on the filter efficiency of the estuary. More investigations are needed to enhance the physical knowledge about this trapping effect and its sensitivity to variations in river and sediment discharge in relation to interventions.

In general, the influence of the waves in the Lower Meghna Estuary is limited to the shallow near shore zone and the intertidal areas. The wind induced waves often have an important influence on the erosion and deposition processes. Waves generate an orbital velocity which is superimposed on the normal velocities in an area thus stimulating erosion from the bottom and preventing settling of suspended sediment. Near the coast the waves may break, thus generating a lot of turbulence in the water which is even more effective in generating erosion. Also, a net water movement is induced which can transport the sediment brought into suspension. In the case of a net flood flow the suspended sediment can be transported on to the higher parts of the shallow intertidal area where a major part of the sediment can be trapped. If a net ebb current is dominant the flow becomes concentrated in the gullies and sediment is ejected as plumes into the main channels.

3.5 Bank erosion processes

The bank erosion rate along the Lower Meghna Estuary is mostly related to bank failure. Two types of bank failure generally occur: liquefaction and flowage of material, i.e. the shearing away of bank materials. The former type of bank failure occurs below the low water level or in the zone between low and high water level. Generally, these processes occur during the recession of the flood hydrograph. The recession rates of water level directly influence the rate of failure.

The most common processes of bank failure along the Lower Meghna Estuary are due to shearing, caused by flow attacking the bank or the over-steepening of the bank by an approaching thalweg. In that case, the flow on a river bend attacks the toe of the river bank, removing the sediment from the toe, resulting in an over-steepening of the river bank and causing the bank failure by slumping.

A combined effect of flow attacking the bank and wave activity can increase the bank erosion rate drastically especially during the monsoon period. An important factor is the near bank flow pattern which is determined by the flow and the channel geometry. Bank material properties determine the cohesiveness of the bank, an important parameter for this type of bank erosion, and affect how quickly erosion products are transported by the river and thus determine the time needed for the typical toe-erosion-failure-transport important for mass failures. From the field surveys it seems that in areas along the river where the clay content of the bank material is low the banklines are very sensitive to bank erosion.

Vegetation also plays an important role in bank erosion processes along the Lower Meghna Estuary. Vegetation increases the cohesiveness of the soil. Ground water flow may also have an important effect on the bank erosion, especially during the recession of floods.

The average bank erosion rate on the right and left banks in the area between Chandpur and North Bhola is higher than in other areas due to the migration and widening of the Lower Meghna Estuary channel. In particular, the migration rate was very high in the period 1984 to 1996. The variation of average bank erosion along the channel might be due to the number of higher flood events during this period. Analysis of satellite imageries from recent decades shows that maximum bank erosion can be found on the outer banks of curved channels.

3.6 Future developments

The historical development of the Meghna Estuary appears as a series of periods of continuous development according to some pattern, interrupted by shifts from one pattern to a new one.

Within each pattern, the morphological processes can be mapped empirically, or even by their cause and effect relationships, and the development can be predicted. The morphological development can be predicted as long as a pattern persists, but only until the next shift to a new pattern. The shifts from one pattern to another can be due to some event, an extreme flood, a channel being blocked, a new main channel being formed, or perhaps an earthquake or severe cyclone. The shifts are difficult to predict with any certainty and it is even more difficult to project the development beyond a shift.

Little is known about the shifts from one development pattern to the next - how often they occur, and why. Such knowledge, however, is the key to a medium or long term prediction of the planform development. An improved insight into the processes that can be observed today is only one small step in the right direction.

The morphological trends indicate that the process of erosion and widening of the Lower Meghna River in the area between Chandpur and Bhola will continue in the future. The average channel depth is expected to decrease slightly. The channel and coastline are very mobile and sensitive to changes in hydraulic conditions. New chars may be expected to develop in the braided river and migrate westward. The extrapolation of the position of the coastline in this area can be seen as a potential maximum retreat of the bankline.

In the middle estuary, the coastline of the Noahkali mainland area will extend to the south while the shoreline of the islands around Manpura and Hatia will extend in a southeast direction. The main islands of Manpura and Hatia will also shift to the southeast and without protection measures the heads of these islands will continue to be exposed to erosion.

Without further embankment and erosion protection measures, the erosion process and retreat of the north and east coastlines of Bhola towards the west will continue during the coming decades. The coastline along the Tetulia river is relatively stable and will not change much. The areas around Nijhum Dwip, Rangabali and Kukri Mukri will extend eastward and new islands will develop.

The long term morphological trend around Sandwip-Urir Char indicates net sedimentation. In this highly dynamic environment, zones with strong sedimentation will alternate with zones with strong erosion, both spatially and temporally. The tendency of the Sandwip Channel to silt up will continue but the rate will be relatively slow.

The net natural gain of land within the Meghna Estuary will be in order of 10 km^2 per year. It is noted that the rate of land formation is relatively slow compared with the potentially huge amount of river borne sediment supply, a substantial amount of which is assumed to accrete in the deeper part of the delta and Bay of Bengal.

It is obvious that the overall energetic conditions become higher from west to east. The energetic conditions in the west are low to moderate. The salt content is in general fresh to brackish. The water level and salt content show seasonal variation due to temporal variation in river discharge and the variability decreases with increasing distance from the river through the estuary to the sea. The tidal range increases significantly from west (0 to 2 metres) to east (more than 4 metres). The most easterly chars (Urir Char, Sandwip) are subjected to relative high current velocities and wave heights and higher salt and sediment concentrations. Due to the highly dynamic environment in the east, an unambiguous morphological trend cannot be given.

The chars and flats located on the northern edge of the estuary (North Hatia, south Noahkali area, Urir Char, Sandwip) are younger than the chars located more to the west. This is reflected in a lower actual land level around Sandwip and Urir Char and for this reason it will take longer before the empoldering level, set at MHWL-spring, is reached (in the order of 20 to 40 years). Around Char Montaz and Nijhum Dwip the process of sedimentation dominates and the prospects for new land reclamation are favourable. The expected time period before which reclamation cannot be started is 15 to 30 years.

Developments with interventions

With the execution of the planned interventions the overall energetic conditions will remain more or less the same but local changes, for instance near cross dams, will encourage the potential accretion rate. Negative morphological side effects are expected to be nil close to the chars in the west and around Nijhum Dwip. In the North Hatia - Manpura area the morphological changes may be significant due to the closing of the East Shahbazpur Channel. Model studies indicate that the East Shahbazpur Channel will silt up rapidly and encourage the erosion process on the east side of Bhola. Around Urir Char - Sandwip the negative morphological side effects might also be significant. These morphological side effects should be studied in detail.

When the interventions are implemented, the time that is needed by emerging land area to become suitable for empoldering is speeded up by an order of 2 to 3. The older chars with a higher actual land level (Rangabali-Char Biswas, Char Montaz-Kukri Mukri, Nijhum Dwip) can be reclaimed within 5 to 15 years. The favourable hydrologic conditions, lower energetic conditions and the availability of more fresh water provide the best environment for empoldering. Reclamation of the younger chars with a lower actual land level and higher dynamic conditions (North Hatia - Manpura and Urir Char - Sandwip) can be expected in the order of 10 to 20 years. The Noahkali intertidal area is still in a very early stage of development. Because no intervention measures have been planned here, the time span before empoldering can be started remains long, 20 to 40 years.

Coastal area and sea level rise

The coast of Bangladesh is an area with high ecological values, characterised by a large variability in hydraulic and geomorphological subsystems (channels, shoals and tidal flats), representing a wide range of habitats for different organisms. The intertidal shoals and mudflats, which are highly productive and represent important feeding grounds for bird populations and a nursery for fish and prawns, are expected to be especially vulnerable to changes.

It is expected that the Meghna Estuary system will be most sensitive to accelerated sea level rise. Firstly, a large part of the coastline of Bangladesh consists of loose alluvial and marine deposits. Such a coast will easily adapt itself to changing water levels and waves. Moreover, large deltas and estuaries are found around the world which experience a delicate balance between tidal forcing and estuarine processes. This balance can be easily disrupted by accelerated sea level rise. Secondly, the coast of Bangladesh and the islands are concentrations of socio-economic activities and contain many important (locally) food producing areas. Accelerated sea level rise in combination with an increased frequency of storm surges, cyclones and high waves may be detrimental for many of these areas due to increased risk of flooding. Finally, intertidal areas and marginal seas are valuable ecosystems, vital for biomass production and indispensable for the survival of many species. In those areas where the ecosystem cannot adapt to these changes, loss of low lands and biodiversity will be results.

Prediction of the future sediment patterns in the Lower Meghna Estuary and infilling rates depends on a complex of interacting processes. In order to estimate the effect on the coastal area of an accelerated sea level rise, in combination with changes in river discharge and sediment inflow as well as human interventions, more physical knowledge of the system's behaviour and reliable predictive hydro-morphological models are needed. Because of the influence of time in the sedimentary reactions to the flow, 2D tidal models as developed under MES will only be of restricted use. Consequently, estuary sedimentation and hydrodynamics are a challenging area of interest where direct collaboration among disciplines and combined field, laboratory and modelling work is essential. From a morphological point of view, it is necessary to integrate coastal and river zone management for sustainable development of the delta and coastal area of Bangladesh.

4. POLICY OBJECTIVES

4.1 National development objectives and planning

Bangladesh remains one of the world's poorest countries and poverty is still widespread. Poverty alleviation and sustained economic growth are therefore the principal national development objectives.

The Fifth Five Year Plan (FFYP) is the principal planning document for the years 1997 to 2002. Key objectives of the plan include:

- alleviation of poverty through accelerated economic growth
- development of necessary infrastructure, utilities and other services to promote growth
- establishment of better social justice and creation of effective safety nets for the socially and economically disadvantaged sections of society.

At the local level, the principal objectives of plan implementation are

- improvement in the quality of life of the rural population
- increasing the equity, justice and productivity of the rural socio-economic structure
- improving the effectiveness of local government institutions and increasing the active participation of people belonging to all strata of rural society
- development of the necessary physical and socio-economic infrastructure
- mobilisation of people and resources for sustained growth.

4.2 Sector policies and objectives

Key policies and objectives for important development sectors are outlined in the following paragraphs.

4.2.1 Water

Important water sector objectives relevant for the MES study area include:

- protecting agricultural land from erosion
- promoting water conservation for irrigation and other uses
- promoting optimal use of available flows in the rivers among the various sectors
- preventing saline intrusion
- ensuring people's participation in the planning, implementation and maintenance of water sector projects.

Flood control and water management measures to protect lives and property and promote the development of agriculture and aquaculture are a major strategy for achieving sector objectives. In the context of MES, this implies the development and maintenance of polders to protect newly accreted land (once the appropriate level for embankment has been reached) and the upgrading of water management, infrastructure and O&M.

The overall objective of water management in polders is to ensure sustainable development and management of a polder. Water management in a polder can be seen as the sum of human interventions to control water levels (quantity) and water salinity (quality), using all the available hydraulic infrastructure.

These interventions are the result of social and institutional interactions among stakeholders and organisations with different interests and strategies for water control inside a polder. Government policy is to increase participation of people in local institutions and polders should be managed in accordance with the forthcoming revised Guidelines on People's Participation.

4.2.2 Agriculture

At the national level, objectives for the agricultural sector focus on increasing productivity and the real incomes of farming families, achieving self-sufficiency in foodgrain production and increasing production of other food crops. In the FFYP, agricultural development is still identified as being synonymous with economic development in Bangladesh. Agriculture is estimated to contribute almost 30 per cent of GDP in 1996-97, with a target growth rate for the sector of between five and six per cent. Development of agriculture in the coastal area has not been given high priority in the past and while this is still the case, several of the sector policies and strategies are directly relevant to the area.

The strategy for achieving crop production targets at national level, as in the past, focuses largely on the use and development of HYV rice and wheat, the application and further development of irrigation and the optimisation of fertiliser use. However, for the MES area where irrigation cannot be developed much because of the lack of fresh water, this strategy is not relevant.

In the MES area, especially on the chars and islands, agriculture is characterised by low yields, low cropping intensities and a limited range of cropping options. The FFYP recognises these constraints and the importance of developing the agricultural extension service. Policy and strategy for coastal farming focus on location specific research, extension and other programmes that will be developed and provided for the purpose of exploiting the potential of the area. Improvement of saline tolerant varieties of rice is mentioned as one option. Under the New Agricultural Extension Policy, a farming systems research and development approach is adopted to facilitate the development of farming technology for each area and its transfer to farmers.

4.2.3 Livestock

The Government has identified development of the livestock sector as an important means for reducing the protein gap as well as for the generation of employment and income for the more disadvantaged sections of the population, including the landless, unemployed youths and destitute women. No particular livestock policy for the coastal region is mentioned in the FFYP, but the general policies and strategies adopted for other parts of the country are valid for the estuary area in this case.

At national level the Government envisages the increase of milk, meat and egg production and quality draft power availability. In the FFYP there is an increased financial allocation for livestock development to be achieved through peoples' participation, the involvement of NGOs, privatisation of input supply and commercialisation of veterinary vaccine production. The major programmes should include fodder development; animal health and disease control; genetic improvement of local chicken, ducks, goats, cattle and buffaloes; and training of DLS staff, NGO workers and participating farmers.

4.2.4 Fisheries

The major thrust of government's fisheries policy, as stated in the FFYP, is on culture and capture fisheries, promotion of rice-fish farming in the flood plains, conservation and management and the equitable distribution of the benefits from common property water resources. Specific objectives include:

- generating additional employment opportunities in fisheries and ancillary industries
- increasing fish production to improve nutritional levels
- improving the socio-economic conditions of fishermen, fish farmers and others in the subsector
- improving biological and institutional mechanisms for judicious use of fisheries resources
- strengthening research, extension and management.

The focus of Government policy and strategies for the sector is on increasing production and income from fishing. As far as fisheries in the estuary area are concerned, this contains a contradiction, given the existing high levels of exploitation.
At present there is a high risk that marine fisheries will collapse in the near future due to over-exploitation of the stocks. From a fisheries management point of view, only a reduction in fishing effort or the use of large mesh sizes will address this critical issue. Fisheries management demands an integrated approach within the context of integrated coastal area management and an overall rural enterprise development policy.

The promotion of aquaculture is an important strategy for meeting fisheries production objectives. In the MES area, there is potential for improving the production of both carp and shrimp in ponds.

4.2.5 Forestry

The forestry policy, revised in 1994, now places greater emphasis than previously on people-oriented forestry programmes to manage the environment, to preserve existing forests, to conserve plants and animals and to maximise benefits to the local people.
The new forest policy emphasises that in order to safeguard the future of the national forest, protected areas and plantations, the genuine and legitimate needs of the local people must be accommodated through appropriate participatory arrangements. Three major programmes have been formulated: people-oriented programmes, production directed programmes and institutional strengthening programmes. _The current FFYP continues these objectives and programmes and a goal has been set to double the forest cover and to ensure a sustained yield in the state forests.

The more people oriented programme is in line with the recommendations of the Forestry Sector Master Plan and will promote programmes such as community forestry and socially oriented forestry from which people will benefit directly by participating actively in tree growing and forest management. The policy document is a major step forward from the past, but still seems too general in its statements and recommendations.

After realising that mangrove plantations have a positive effect in reducing damage caused by cyclones, a policy for coastal afforestation was initiated. This programme expanded during the seventies and continues today under various projects, targeting coastal afforestation either as a main activity or as a component in wider ranging forestry programmes. The objective is firstly to provide initial protection to coastal communities against cyclone damage. A secondary objective is the role of mangrove plantations in stabilising newly formed lands.
Emerging land is state land and falls under the jurisdiction of the Ministry of Land. It was decided in 1976 that this land should be afforested and managed by the Forest Department for a period of 10 years after which it would be returned to the Ministry for subsequent conversion for agricultural development. This period has since been extended to twenty years and no land has so far been converted. Current thought in the FD is that these lands should remain permanently under mangrove plantation.

4.2.6 Environment and coastal zone management

The Bangladesh coastal ecology is one of the most fragile in the country and the interactions of terrestrial, aquatic and human components are complex and dynamic. Since 1986, steps have been taken to draw up a long term integrated coastal management plan, with an appropriate institutional structure for its implementation, to ensure environmentally sound and sustainable development.

These steps have included the development of a Coastal Environmental Management Plan which identified constraints to and made recommendations for the environmentally sound development of coastal areas and the Bangladesh National Conservation Strategy, completed in 1987, which identified the coastal zone and the Sundarbans as one of the four ecosystems of greatest ecological importance in the country.

The Ministry of Environment and Forest, and within it the Department of Environment, are responsible for environmental management. Under the National Environmental Management Action Plan (NEMAP), which sets the policy framework of an action plan for environmentally sound development, there is a specific Coastal and Marine Resources Management component. The DOE is now drawing up the framework for a programme to develop a coastal management plan, which should be formulated together with all concerned parties.

A significant issue for the coastal areas are the implications for predicted sea level rise. Currently the DOE has put forward documentation for a study on National Climate Change proposed to lead to a National Climate Change Action Plan. The main objectives of the proposed study are:

- to prepare a National Climate Change Action Plan and an associated communication system
- to identify priority mitigation and adaptation technologies and assess their implementation
- to identify and prepare priority project profiles for mitigation and adaptation to climate change
- to undertake activities to increase public support for implementation of the National Climate Change Action Plan.

For the MES area, an inter-disciplinary Coastal Zone Management Plan is required, along with a suitable institutional framework for planning and implementation. The consideration of the environmental impact of all proposed interventions in the estuary area, such as the construction of cross dams and embankments, is an intrinsic part of the planning process. The environmental assessment process aims to achieve this by identifying impacts and then reducing the negative one and promoting those that are positive. The legal framework and requirement for this process in Bangladesh has been in place since August 1997.

4.2.7 Health

Government is committed to the objective to expanding the provision of primary health care services to all parts of the country, in particular through the Thana Health Complexes and Union Health and Family Welfare Centres.

Access to these facilities in remote parts of the MES area, on the islands and chars, is still difficult or limited and services in these areas should be expanded together with other development activities.

4.2.8 Education

In education, policies focus on rapidly increasing literacy rates through the extension of primary education, with the principal objective of bringing uniform, compulsory education to all villages in the country. At the secondary level, the policy is to emphasise technical and vocational education. If these policies are to be successfully implemented, a number of identified problems will need to be overcome, including:

- a shortage of schools within easy access of villages
- a shortage of class rooms and overcrowding
- a lack of equipment, furniture, books and supplies
- a lack of professional skills among teachers
- weak community involvement and a lack of interest and awareness among parents
- unattractive teaching and learning environments
- a shortage of teachers.

Many of these problems are particularly acute in the more remote parts of the MES area. Special efforts will need to be made to overcome them since the success of many development efforts for the area will depend on increasing levels of education among the local population.

4.2.9 Transport and communications

The objective of policy in the transport and communications sector is to improve road, rail and boat links throughout the country. Major investment projects planned for the FFYP period do not include any that will directly affect the MES area. In the water transport subsector, policy objectives that may affect the MES area include:

- establishing rural launch landing facilities and ensuring safety in navigation
- increasing operational efficiency and institutional capability and maintaining links with offshore islands
- providing passenger services to the offshore islands

Many parts of the MES area are still poorly served by communications networks. Increasing the links of these areas to the outside, facilitating access to markets and services, is in line with policy objectives for this and other sectors.

4.2.10 Disaster relief

Disaster preparedness and relief is the responsibility of Disaster Management Committees at national, district, thana and union level. A National Disaster Management Plan is also being prepared.

The guiding concept is that people need to be prepared in advance to face disasters through information and motivation and through the implementation of adequate structural and non-structural measures. Particular measures include:

- non-structural measures including warning dissemination systems, training, community mobilisation, etc.
- structural measures such as embankment construction and related activities, forestry planting, construction of raised shelters, upgrading road and transport systems and protecting water supplies.

Measures are being implemented by various government agencies and NGOs.

4.2.11 Land and settlement

Newly accreted land in the estuary area is khas land and comes under the control of the Ministry of Land, which is also responsible for the distribution of land for various uses. The Ministry is also responsible for land titling.
On the islands and chars in the estuary, the initiation of any sustainable development of the farming systems depends on the establishment of institutional structures that support farmers in relation to:

- land titling, to secure the long term interest in improvements of the farm resources
- protection of land and land use rights to break the power of big land owners and "land grabbers".

Previously, some groups have been settled in the MES area under the Adarsha Gram programme, but under current policy this programme has been suspended.

4.2.12 Local government

Present government policy is to strengthen the role of local government in development activities and to increase the participation of local people in local government institutions at the village, union, thana and district levels.

4.3 MES objectives

The principal development objectives of the MES are:

- to increase the physical safety of the population living in the coastal areas of the estuary
- to promote sustainable development in these areas
- to increase the social security for the population in the coastal areas and on the islands.

In order to achieve these objectives, the study also has a number of important intermediate objectives:

- to enhance the operational knowledge of hydraulic and morphological processes in the Meghna Estuary and to strengthen the institutional capacity for maintaining and updating this knowledge
- to identify suitable land reclamation and bank protection methods and increase the capacity of BWDB to reclaim new land and install bank protection works
- to prepare a development plan with priority projects and programmes for flood protection, agricultural and socio-economic development prepared for implementation.

4.3.1 Physical safety

There is a clear need to enhance the levels of physical protection for people living in the MES area against the floods and cyclones that characterise the coastal zone. Physical security can be enhanced by the construction of embankments, bank protection works, cyclone shelters and also by establishing and maintaining mangrove plantations along all coastlines.

4.3.2 Social security and integrated rural development

Rural development interventions will benefit both present communities and settlers on newly accreted land. Under the conditions existing on the islands, an integrated approach to rural development and improving the social security of the population is necessary. Such an approach will address issues of production (agriculture, livestock, fisheries), security of land tenure, water supply, sanitation and health and other social services.

4.4 People's participation

In the FFYP a prominent role is given to strengthening local government institutions and to participatory development and the role of the people in the planning and implementation of development activities at the local government level. In the water sector, the FAP eleven guiding principles include "encouraging maximum possible popular participation by beneficiaries in the planning, implementation, operation and maintenance of flood protection infrastructure and facilities". By extension, it may be inferred that the participation of local people in the development and operation of all water control structures is an important policy objective for MES related activities.

Consultation with local people for the planning of activities arising from MES should be through needs assessments carried out in all affected locations and among all the social groups at each location. The purpose of these needs assessments is to ascertain the development priorities and aspirations of local people, which should then be used to guide project planning. At a later stage, local people representing farmers, fishermen and other groups should be directly involved in the operation and maintenance of infrastructure. This should be in accordance with the new Guidelines for People's Participation that are currently being prepared.

5. STRATEGY AND INTERVENTIONS

5.1 Strategy

The objectives for the development of the estuary and coastal zone focus on two priorities:

- the physical safety of present and future populations and communities resident within the estuary and coastal zone
- enhancing the social security of local communities through an integrated approach to rural development for both land and other resources.

The MES area is characterized by continuous hydro-dynamic activities. Erosion and accretion rates are high and the area is periodically subject to severe storms and cyclones, the latter accompanied by tidal bores and storm surges. The safety of the lives and property of people living in the coastal areas and islands is of permanent concern.

5.1.1 Physical safety

The strategy adopted for enhancing the physical safety of the population focuses on:

- the construction of engineering works, including embankments, bank protection works and cyclone shelters
- establishing and maintaining mangrove plantations along the coasts of he mainland and all islands and chars in the area, especially where there are human settlements
- further improvements to cyclone warning and evacuation measures at present practised in cyclone prone areas.

From necessity, physical interventions will be phased. For example, newly accreting land will be suitable for mangrove plantation only when suitable levels are reached, perhaps after as many as five years. The same land may be suitable for embankment protection only after a further fifteen to twenty years, or perhaps even more.

Establishing priorities for potential project areas will also result in phasing for physical and development interventions. The priority ordering of project areas and interventions will take account of the relative levels of exposure to natural disasters, the potential for accretion, the potential for socio-economic development of each area and the potential benefits for communities occupying existing land or land accreted as a result of other project interventions.

5.1.2 Social security

Socio-economic development in the study area, as elsewhere, is a continuous process of change. Specific project interventions, however, will be phased over the planning period. The strategy for enhancing the social security of local communities focuses on:

- enhancing existing settlements through the provision of services such as schools and clinics, and upgrading access through improved road and water transport networks
- establishing new settlements where necessary
- providing secure land tenure for resident households through the issuing of certificates of land tenure
- development of agricultural, livestock and aquaculture activities to improve household incomes
- fostering other employment opportunities for the local population wherever possible
- providing a favourable environment for the development of private sector activities in the area
- the participation of households and communities in the planning and implementation of development activities in their areas.

Secure access to land is a sensitive and important rural development issue. Secure land title provides a basis for security of livelihood for households and fosters investment by households in land improvements. Several reports produced in connection with development projects of the coastal char lands have emphasised that rivalries between gangs representing and supporting influential and powerful elites present a significant problem to both settlement and subsequent development of these areas.

Yields from agriculture on the chars are generally low there is a constant danger of crop destruction from cyclones and salt water intrusion. Given these low yields, the small areas usually allocated to households when land is distributed and the limited potential in many areas for irrigated dry season cropping, household self-sufficiency in food grain is unlikely to be achieved in the short or medium term. It is unlikely agricultural production alone will provide levels of income sufficient to alleviate poverty and thereby promote rural development. Integrated development for the area must therefore seek ways to maximise crop production under local constraints and to develop the potential for increasing livestock production, tree crops and aquaculture and fish products. Current policies favour a farming systems approach and strategy.

The FFYP acknowledges the need for productive employment generation in the rural areas and the development of rural infrastructure provision, including development of a marketing system to boost economic growth. Employment opportunities in the MES area will likely be based on the processing of agricultural, livestock, tree or fish products. The potential for such post-harvest processing should be considered when identifying appropriate land management strategies and farming systems. Post-harvest processing in various forms is also the most likely basis for private sector investment in the area, either on a small scale by area households or on a larger scale by individuals or enterprises from outside the area. Local households and communities should be encouraged and supported in initiating their own strategies for economic development, often with support from NGOs.

5.2 Range of possible interventions

The possible interventions in the study area fall into 20 broad categories in three groups, together as non-engineering sector programmes, non-structural interventions and structural interventions. The categories of intervention are:

Non-engineering sector programmes

- farming
- fisheries
- forestry
- navigation

Non-structural interventions

- flood and cyclone warning
- disaster preparedness and management
- flood proofing
- social infrastructure

Structural interventions

- coastal flood protection embankments
- foreshore conservation
- secondary embankment construction
- water management systems
- settlement programmes
- rural physical infrastructure
- cyclone shelters and platforms

- bank protection and river training
- erosion management
- mangrove planting
- settling basin construction
- cross dam construction

These interventions are described in the following section and are some aspects are further elaborated in section 5.4 below.

5.3 Intervention formulation and selection

5.3.1 Framework for formulation and selection

In Section 5.2 above a full range of 20 broad possible interventions has been outlined, split into three categories from the "softest" approach to the more structural. Many of these types of projects and programmes are already the remit of designated institutions. While one of the outputs of the Meghna Estuary Study is to draw up a 25 year phased Master Plan for the area, implementation of components of the plan will be the responsibility of existing institutions. Co-operation among institutions, working together in an inter-disciplinary manner, will be needed for some types of MES related intervention. The greatest requirement for an inter-disciplinary approach is likely to be for integrated area based development programmes, particularly those located in areas of newly accreted land. For each of the 20 possible intervention types, the institution presently responsible for such work is identified. Some suggestions are made regarding implementation in the context of the Master Plan for the estuary area.

5.3.2 Farming

A farming systems development approach, at household level, emphasising production from crops, livestock and possibly aquaculture has been suggested for the MES area (see Volume 5). The Ministry of Agriculture, through the Department of Agricultural Extension, is the agency responsible for implementation of such an approach. Such an approach is especially relevant for newly accreted land where crop yield potential is low; it is therefore an integral part of the proposals for land development (see section 5.4.4 below). This approach is also incorporated into the feasibility studies prepared as part of the Development Plan.

It should be recognised that secure title to agricultural land is an important component of sound agricultural development in area of many uncertainties and where investment by households in land improvement is important for long term security of production and livelihood. The Ministry of Land therefore has a crucial role to play in the development of agriculture in the MES area.

5.3.3 Fisheries

The need for major interventions to avert a potentially severe decline in fisheries resources in the MES area due to over-fishing has been outlined in Volume 6 of the Master Plan. The aim of a fisheries programme would be to reform the fishing system to try and make it more sustainable and would include provision of extension services, credit, replacement of fishing gear and storage and processing facilities. Proposals for studies to increase knowledge of critical aspects of the fisheries in the estuary are also made in Volume 6. The Department of Fisheries is the primary institution for addressing these issues and implementing measures to conserve fisheries resources.

The main type of intervention within which fisheries should be an active component is integrated development based upon an area approach, for either newly accreted or newly embanked land. The feasibility studies have thus assumed that fisheries development (aquaculture) would be an intrinsic part of such types of intervention. For specific interventions, the expected impacts on fisheries would be studied during the environmental assessment process and the need for any mitigation measures would be identified together with relevant institutions to implement them.

5.3.4 Forestry

The main emphasis of a forestry component would be planting on newly accreted land. The Forest Department has already been very active in the MES area and there is no doubt that planting of appropriate tree species at the correct time has a highly beneficial effect across many sectors. The engineering, economic, ecological and social benefits of such measures have been clearly demonstrated and include dissipating wave energy and assisting land accretion, stabilisation and improvement of soil quality. In addition there are benefits to flora and fauna habitats and common good resources which help the rural energy balance and also improve landscape aesthetics.

The planting of forest is an intervention in its own right, either on the foreshore, as part of integrated development (including accretion promotion) or land development and also as part of embankment construction in the form of social forestry. Ideally an arrangement should be in place where the Forest Department plants virtually all newly accreted land as part of a rolling sustainable and self-funding programme. Such an arrangement would also assist in preventing illicit land grabbing. There is thus a major role to be played by the Forest Department in the MES area, in both integrated programmes at project level and also in its own right with a sector programme across the whole area.

5.3.5 Navigation

The main intervention for the navigation sector would be provision of more and improved ghats. In many parts of the study area, all households depend on shipping for communications with other parts of the country. Benefits would also accrue to boat owners and crew as well as all fishing households and those depending upon the trading of goods and services.

The BIWTA is the institution responsible for navigation with the LGED actually constructing local infrastructure for navigation. These two institutions are well placed to continue this work, in co-operation with other development activities, where appropriate. In particular, some MES related projects proposed for the area (e.g. the construction of cross dams) may have local effects on navigation, mitigation of which may be addressed through co-operation among the concerned agencies.

5.3.6 Flood and cyclone warning

Flood and cyclone warning programmes are essential for the saving of human life and reduction of loss of assets. The flood forecasting project (FAP 10) has been designated and is best placed to carry out this work. The results of FAP10 and possible requirements for future progress in this sector should be fed into the planning process at each subsequent revision of the Master Plan for the estuary area.

5.3.7 Disaster preparedness and management

Like flood and cyclone warning programmes, disaster preparedness and management programmes are essential for saving human life and allowing households to re-establish their economy more quickly after a cyclone. The Disaster Management Bureau, to which the Cyclone Shelter Preparedness Study reported, is responsible for disaster preparedness and management. There are no proposals for new projects in this sector, but the results of the CSPS have been considered when drawing up the MES Master Plan.

5.3.8 Flood proofing

Flood proofing for inland areas has been studied under FAP 14 and FAP 23 and implemented under a trial basis at Jamalpur for FAP 3.1. Flood proofing is not suitable for the coastal areas affected by tidal surges but is an appropriate intervention for specific situations and locations in the MES area as part of a flood protection strategy. Such locations include places where flood protection embankments have to be retired due to the threat of erosion and areas formerly protected from river floods are no longer protected.

The main problem with these types of situation is they are likely to be eroded away in the near future and it is thus questionable if the estimated cost of Tk 23,000 per household for flood proofing can be justified. Areas appropriate for such flood proofing interventions are more commonly found further upstream in the MES area, such as Haimchar just south of Chandpur. It is considered unwise to encourage settlement outside coastal embankments in the downstream areas and thus areas outside the coastal embankments should not be considered for flood proofing. The best option in these cases is for the development of flood proofed homesteads on the coastal embankments which have been specifically designed for multi-purpose use.

5.3.9 Social infrastructure

The main requirements for social infrastructure are provision of health and education services. Bangladesh has made significant strides in these areas in the last 10 years, including in the MES area. It is assumed that continuing provision of these services will be made by the designated institutions using the guidelines for sizing and location that are already established. The Ministries of Health and Education provide these services, with LGED constructing the buildings required. Needs for these services have been identified during the MES, especially in the context of the feasibility studies and Development Plan. It is hoped that the Ministries' existing programmes will address these needs. In particular, the MES needs assessment surveys showed that health service provision is a high priority demand in the offshore islands. There is also a strong need for secondary education.

5.3.10 Coastal embankment construction

Coastal flood protection embankments prevent inundation of the lands under cyclone conditions and are essential to ensure the physical safety of the population living in the coastal areas. There is considerable scope to maximise the benefits of flood protection embankment construction by following a multipurpose use strategy, with planned use of embankments for formalised settlement, tree planting and roads.

Rehabilitation, retirement and revetment of coastal embankments is the responsibility of BWDB and is being carried out by CERP and, in the recent past, also by the SRP. As part of an area based development approach, the MES has proposed the construction of new coastal embankments in areas of newly accreted land when they have reached an appropriate level. These proposals refer to proposed interventions during the first 10 years of the Master Plan period. Future revisions of the Master Plan would identify other locations requiring new embankments or rehabilitation of existing ones.

Retiring coastal embankments threatened by erosion may also be considered as also part of the programme of erosion control measures in the Master Plan, as at Haimchar. In such cases of retirement, consideration needs to be given to flood proofing measures (see section 5.3.8.)

5.3.11 Foreshore conservation

The main intervention proposed is mangrove planting on the foreshore, which has clear engineering, economic, ecological and social benefits. As noted in section 5.3.4, the Forest Department is responsible for afforestation programmes. The most significant engineering benefit of foreshore afforestation is wave dissipation, but in some locations there can also be some accretion enhancement. Once established, a 1 km forested strip should be maintained permanently along the coasts of all islands, chars and mainland areas in the estuary.

5.3.12 Secondary embankment construction

The main aim of providing secondary embankments is to contain flooding in the case of a breach in a primary flood protection embankment. In the context of the MES Master Plan, construction of new secondary embankments would be limited and part of a land development strategy. A more common occurrence is likely to be that the construction of new coastal embankments will give previously constructed coastal embankments a new role as secondary embankments. Like coastal embankments, it is imperative that adequate drainage is provided and the embankments are designed for multi-purpose use.

5.3.13 Water management

Effective water management within empoldered areas is essential. The provision of new drainage, re-excavation of existing drainage, the rehabilitation and new provision of water control structures plus their operation and maintenance is an intervention in its own right. Such measures may also form part of embankment rehabilitation, retirement and new provision, as well as being an intrinsic part of land development.

5.3.14 Settlement schemes

One of the major benefits of promoting land accretion in the coastal areas is that it allows landless people, including erosion displacees, to be re-settled. A rational settlement programme should include appropriate infrastructure provision (raised house building, agricultural land allocation, water supply and sanitation, schools, health centres, aquaculture ponds, access roads and, if necessary, cyclone shelters) as well as a systematic and transparent system of land and house plot allocation that is fair, equitable and timely.

Formal settlement schemes have been part of previous policy in the MES area, with notable examples at Nijhum Dwip and in the CDSP project area. Settlement schemes form part of an integrated development strategy for newly accreted land, but they raise fundamental policy issues. In the feasibility studies for the MES Development Plan settlement schemes have been restricted to providing homestead plots and agricultural land to people from outside the area only once the existing residents have been allocated a minimum agricultural landholding. It is questionable if settlement should be encouraged at all in the peripheral parts of the study area due to the cyclone risk and the marginal nature of economic livelihoods. A guiding principle that has been used is that all new settlement schemes must be constructed inside embankments, with homesteads designed to be flood proofed against local rainfall flooding, and with provision of adequate cyclone shelters and killas.

5.3.15 Rural physical infrastructure

The main components of rural infrastructure include water supply and sanitation, road construction and upgrading of markets. The provision of these services (although the level of provision is low) is normally carried out by LGED. The main requirement for the planning of such infrastructure is for the rational use of the available resources, along with inter-department co-operation, to avoid wastage. As part of the development strategy for newly accreted land, provision of these services should be incorporated into an integrated development planning framework, using existing but possibly strengthened institutions.

5.3.16 Cyclone shelters and raised platforms

The provision of cyclone shelters and raised platforms for livestock (killas) is essential to save human life and livestock in areas that have not been sufficiently protected against storm surges and high waves caused by cyclones. The shelter buildings may have a second function, for example as schools, since their use as shelter will be infrequent.

The Disaster Management Bureau is the delegated institution to oversee the planning of cyclone shelters and killas, although construction has been carried out by many different organisations, including LGED. As for other rural infrastructure, the MES Master Plan proposes an integrated planning approach with co-operation and co-ordination among concerned agencies, particularly for development of newly accreted land.

5.3.17 Bank protection and river training works

The construction of bank protection works is part of the erosion response strategy to reduce the loss of valuable existing land and infrastructure. As the loss of land due to erosion is a significant reason for household economic destitution in Bangladesh, these works contribute to the combating of poverty in the estuary.

Under MES trials and pilot schemes are being implemented to test new methods and designs for bank protection. BWDB is responsibility for bank protection and river training works in the estuary, including with the new methods once they are proven. These measures must be placed within the context of integrated area planning and development, not just carried out in isolation, if the full benefits of such measures are to be realised. It is also important that the likelihood of success of such measures is assessed cautiously, as for the foreseeable future it is likely that embankments will still need to be retired from time to time.

5.3.18 Erosion management

Erosion management is a planned response to an acceptance of the reality that main river bank erosion will occur and it is either technically impossible or uneconomic to prevent it. This allows for a rational strategy to be drawn up for the removal and replacement of infrastructure and the relocation of people. Such a planned strategy should reduce the loss of movable assets and allow recovery to proceed more quickly. The steps to be followed include a phased withdrawal of movable assets, both private and public, and the planning of replacement provision. LGED is already a key player in this as its own programmes address the need to upgrade and realign roads, the retirement of flood embankments being an intrinsic part of this process.

5.3.19 Mangrove planting for enhancement of accretion

The forestry sector programme discussed in section 5.3.4 includes the planting of mangroves on all newly accreted land. There is increasing evidence that this also acts in enhancing rates of accretion, although this is not a clear cut situation for all locations. Such measures therefore form part of the accretion promotion strategy.

5.3.20 Settling basin construction

The construction of settling basins is part of the accretion promotion strategy but the places that are appropriate are highly site specific and complex. The aim is to accrete more land, but detailed sedimentation and erosion modelling is required to ensure that this can be achieved and economic analysis is necessary to test the viability of the intervention.

5.3.21 Cross dam construction

Installation of cross dams in channels between coastal islands aims to accelerate accretion and gain new land. The locations for cross dams are highly site specific and the erosion and accretion patterns need careful study using simulation modelling, so that the positive and negative effects of an intervention can be predicted with sufficient accuracy.

Cross dam construction is a central part of the accretion promotion strategy. However, it is not a "technical fix" to be carried out in isolation of other measures. The benefits of land accretion can only be realised through a long term integrated land development programme on the newly accreted areas. Even so, the benefits are likely to be long term. In order to provide security it is also vital that coastal protection embankments are built, but only once land levels have accreted to the appropriate level for the area (usually MHWL-spring).

5.4 Selected interventions

5.4.1 Flood protection

Main river system

Many stretches of the river bank on both sides of the Meghna Estuary are permanently at risk from erosion damage. Rates of erosion can be spectacular (see sections 3.1, 3.4 and 3.5 above). The lands at either side of the river are susceptible to regular flooding and the volume and power of these flood waters inflict high levels of damage and in places may endanger the livelihood of large numbers of people.

In response to these circumstances, the Government has repeatedly emphasized the need for high embankments to be constructed along river banks. These high embankments involve high levels of capital investment. What is more, in such a dynamic environment there is considerable risk that these costly embankments will, themselves, be eroded away before their normal economic life is reached. Not only does this expose both land and people to flooding once more, it places responsibility on Government to commit further large sums of money to retiring the damaged embankments.

Current thinking is that it might be better to accept the fact of erosion and to construct high embankments at a distance from the present river bank. The distance from the existing bank would be an estimate of the extent of bank erosion over a pre-determined number of years. An indicative period might be from ten to twenty years.

Constructing high embankments at a distance of perhaps two kilometers from the existing river bank will, of course, expose large numbers of people to regular flooding and associated risks. Measures to provide protection from these risks include flood proofing such as the construction of low level flood barriers in place of riverside embankments and the construction of raised platforms, or killas, which will provide some shelter for both people and livestock during floods. Both flood barriers and killas can be constructed with low level technology, labour intensive methods, thereby offering local people a supplementary cash income.

Coastal islands

Flood protection for coastal lands opens the way for economic development, in particular agricultural development since the intrusion of saline water through tidal floods can be stopped. The main objective of empoldering coastal lands is to provide safety and security of life and property for the inhabitants.

Unprotected land permanently inhabited by fishermen and landless farmers can be found throughout the estuary. Not all lands that emerge and where people start to settle can be empoldered immediately. Land which has not yet attained the mean HWL shall not be considered for empolderment. Such land will face two main problems:

- lower land levels result in less efficiency of drainage by gravity; drainage gradients will be smaller and the periods in which no drainage is possible (higher outside water levels) will increase
- natural desalinisation will be slow and empolderment of lands with high initial salinity levels will delay the future benefits of empoldering.

The hydraulic infrastructure of the old land has to be taken into account. Empolderment of the foreshore accreted land of an existing polder should not affect the drainage condition of the already protected land.
From an economic point of view, an empolderment with a minimum embankment length and a minimum number of sluices for efficient drainage of a maximum number of hectares will probably be the most attractive solution. Security and safety inside a polder can further be improved through compartmentalization into several sub-polders with hydrological boundaries where this is technically and economically viable.

5.4.2 Erosion responses

Bank protection

Erosion reponses include installation of protective measures to prevent river banks eroding due to high velocity flow, wave action striking the river bank, rapid draw down of water levels, non-cohesive soils and human interference.
Protection can be attained directly by means of revetment construction in which a properly designed layer of filter material is covered with graded stones or concrete blocks sufficiently heavy to remain stable in the current and under wave attack.

Indirect methods of protection aim to stop or to slow down the erosion of embankments and river banks by the deflection or diversion of the flow away from the bank. This can be achieved by the construction of groynes or spurs and other low cost flow diversion devices like bottom or surface vanes.

The most direct and effective way to combat erosion of river banks or sea facing coasts is the installation of revetment works. This sort of protection covers the slope of the river bank as well as part of the river bed or the coast line over its full length. Planning and design considerations for this type of protection works should be such that:

- the soil is protected from being washed away by the action of flowing water and the dynamic action of waves;
- the work remains stable under the most unfavourable conditions i.e. combination of strong current, heavy wave attack, rapid pressure fluctuations, settlement and liquefaction of the materials under the revetment;
- it resists destructive action of men, animals, vegetation, etc.

River bank protection and coastal defence can also be achieved by construction of groynes or spurs. Groynes are dams more or less perpendicular, or at a chosen angle, to the bank and protruding into the channel at selected intervals. Groynes do not provide direct protection to the bank under erosion but keep the erosive flow at a distance from the bank and thus prevent erosion.

The cost of protection by groynes is less expensive than that of revetments but it may not be as effective. Moreover, groynes should be designed and implemented with caution. Planning and design considerations for bank protection by constructing groynes are indicated below:

- selection of types of groynes and the materials used should be determined: submersible or non-submersible, permeable or impermeable, attracting, repelling or deflecting, single or in a series
- hydraulic and hydrological factors such as water level, discharge, flow velocity, current pattern and velocity, wave heights and other wave characteristics and the anticipated scour bed level of the channel have to be established
- orientation, length and spacing of the groynes should be determined in respect of the channel section and extent of protection required
- shape of the groyne heads, whether bell-head, T-head, L-head and hockey stick-head should be determined.

There are other types of protection works such as bamboo spurs and porcupines which are of limited application and are suitable for use in bank protection and river training in small and interior rivers. These are not considered sufficiently durable for the Meghna Estuary.
The continuous revetment and spur type bank protection works mentioned above are very expensive and from an economic point of view usually not feasible for preventing loss of agricultural land or even rural settlements.

During the Meghna Estuary Study, low cost flow diversion devices have been installed within the frame work of pilot schemes. These devices, permeable spurs and bottom screens, are intended to check or reduce erosion by diverting the aggressive flow away from the river bank and to initiate or enhance the settlement of sediment by deflecting the bed load materials towards the river bank.
The technology and equipment, required for installation of the spurs and bottom screens have been successfully tested, including the under water installation by divers. The effectiveness of the devices has been observed, at both Haimchar and Khorki test sites, during the very severe flood season of 1998. The durability of the devices has to be improved by using more durable materials as well as by some adjustment in the design. An issue of concern is the firmness of the anchoring of the bottom screens in the movable bed of the river channels. After recession of the flood, under water inspection is planned to check the position of the screens.

As a component of MES II, another pilot scheme for erosion control will be installed at Hanarchar, located about 10 km south of Chandpur, so that more extensive experience can be gained with this type of bank protection.

Provided that the pilot schemes are successful and the cost of the installation does not have to be increased substantially as a result of design changes or adjustment in the installation technology, this type of erosion control works appears to be economically justifiable for rural areas like Haimchar.

The strategy to be followed for future implementation of this innovative type of intervention would be initially to select locations where the river attacks it banks moderately to severely and then monitor the performance and durability of the works installed before considering sections of the river bank where the attack is severe to very severe. The impact of tidal movement on the effectiveness of the installations also has to be taken into account as well as the erosive force of waves.

Erosion management

Erosion management comes into consideration as a temporary measure in case of emergency or due to time constraints, lack of funds or for any other reason where erosion protection measures become not feasible and at the same time the need to protect agriculture land and the lives and property of the people from erosion becomes imminent.

This can be done by means of constructing a retired embankment at a safe distance from the erosion point just to safeguard the lives and property of the people and to contain the erosion within the retired embankment until some other alternative measures can be taken up.

This category of projects also includes the shifting of people and their property to safety where lives are at stake. Such movements are generally the responsibility of zila and upazila authorities.

A strategy for erosion management cannot be precisely defined as it will generally depend on type, extent, environment and behaviour of erosion and at what speed and ferocity the erosion takes place.

5.4.3 Accretion promotion

Cross dams

Physical intervention by constructing cross dams will constitute a very effective method of accelerating accretion in the estuary area. A prime reason for constructing cross dams is that they will lead to a unification of chars into a single land mass by closing the intervening channels and creeks. Closure of channels will promote and accelerate accretion (land formation) on both sides of a cross dam by reducing flow velocity in the closed channel section. In the longer term this process promises an increase in the area of land for agriculture and improved communications.

The conventional methods of closure of channels consist of dumping gunny bags filled with clayey soil on top of bed protection that prevents scour during construction of the cross dam body. After the closure of the channel has been achieved with gunny bags, earth fill is used to complete the section of the cross dam. In case of waves, a revetment consisting of concrete slabs on top of a filter layer is required to protect the earthen cross dam from erosion in the first years after construction.

In order to construct such a cross dam, the following requirements need to be met:

- a site should be selected away from exposure to the erosive force of waves, on a straight part of the channel with uniform bottom depth across the width

- data should be collected on water levels and tides, current velocities along the width of the channel to be closed, discharges during both spring and neap tides, meteorological conditions, soil conditions and a semi-detailed hydrographic survey

- availability of sufficient borrow areas with good quality of filling material for gunny bags (earth having clay contents of approximately 25 per cent or more)

- availability of other construction materials and labour for placing gunny bags on top of the bottom mattresses (Detailed descriptions are provided in various reports on closure dams in tidal channels)

- determination of crest height, crest width, side slopes, selection of bed protection material, final closure gap and computation of velocities at different stages of closure operation - most importantly during final closure - and the choice of closure method to be used, whether the horizontal, vertical or combined method.

This conventional type of cross dams is relatively costly and since the investment in the works is required many years before any benefits accrue, it is usually difficult to justify this type of project from an economic point of view..

New cross dam design

During the Meghna Estuary Study an innovative cross dam design has been developed that requires fewer construction materials although some components have to be imported and others are to be manufactured elsewhere in Bangladesh. The cost of this type of cross dam is much less than the conventional cross dam.

At the end of MES, a pilot scheme including this type of cross dam at Char Montaz was under preparation, with implementation expected in the first quarter of 1999. The findings during installation and monitoring of bank protection pilot schemes at Khorki and Haimchar have been incorporated in the proposed design for the Char Montaz cross dam.

The results of the Khorki and Haimchar pilot schemes, using similar technology, are very encouraging and although this innovative cross dam design and the associated implementation methods have not yet been proven under field conditions, the preliminary designs of future cross dams to be implemented in the Meghna Estuary have been based on the same design features. For future cross dams some adjustments of the design and installation technology may be required, but it is not expected that this will increase the cost of design drastically. On the other hand, some savings on current cost estimates may also be possible.

Sedimentation fields

Another method for accelerating accretion is the construction of sedimentation fields. Several trial fields were implemented along the Chittagong coast without achieving the desired results, partly because erosion occurred naturally at the test sites. It appears that more attractive sites for such trials are available within the Meghna Estuary.

Three locations were selected for further study: near Char Lakshmi, southeast of Hatia and southeast of Bhola. A preliminary design and cost estimate were prepared but for all three sites it appeared that, from an economic view, this method of accelerating accretion cannot be justified. Moreover since the sedimentation fields will be heavily exposed to waves during cyclones, the risk of severe damage would be considerable.

Therefore acceleration of accretion by constructing sedimentation fields has not been further considered in the Master Plan.

5.4.4 Land development

Newly emerged char land and land which is still below the level for embankment, remains unprotected. Unprotected land already permanently inhabited by fishermen and landless farmers, can be found throughout the estuary. There is a need for development programmes for both this unprotected land and for land already protected by embankments.

There are a number of considerations to take into account such as land level, primary protection, secondary protection. A strategy is proposed to guide preparation and implementation of development initiatives throughout the MES area. The strategy comprises provisional criteria to be consulted in their evaluation of proposed development initiatives in the area:

- interventions must be associated with an identified potential for economic development, which in most cases will be the potential for improving farm production through an integrated farming systems approach, but in many areas fishing will also be important

- where interventions are targeted on protection measures a land and resource management strategy that reflects the characteristic successional ecology of these coastal areas has to be identified before settlement takes place

- a rural development component must be introduced and described during project identification and preparation and a suitably financed and staffed project for this component must be included to enable the potential for economic development to be realised.

For low lying unprotected areas, interventions such as the excavation of khals, placement of culverts and eventually the construction of minor seasonal embankments (creation of compartments) can improve the scope for agriculture. The latter is mainly to protect a standing crop (late rabi crop, aus or recently planted aman) in the months of March till June when the highest tide levels are still relatively low, but open water salinity levels are in most cases too high.

The selection of chars for development activities should be made using a procedure for selection that is transparent and based upon a set of objective criteria. A series of selection criteria must be discussed and decided upon by all agencies and residents involved in char development. Selection for development intervention implies the investment of considerable amounts of financial aid and other assistance and for this reason there will likely be lobbying by those with interests in particular chars that 'their' char be chosen as a focus of development activities.

Key issues and aspects of development activities on chars include:

- for development initiatives to succeed, appropriate infrastructural support will have to be provided by the responsible agencies to ensure adequate levels of physical and social security for the resident population and shortfalls in physical and social infrastructure necessary to support and sustain the proposed economic development must be identified and provided for
- any proposed intervention must be environmentally sound and sustainable, exploiting as diverse a natural resource base as possible and with adequate provision for environmental inquiry and mitigation
- farming systems and household economies should reflect a multi-sectoral management strategy as the potential of resources in particular sectors is limited and would be easily over-exploited and so they can respond to changes in local ecological circumstances
- land tenure is a most important issue that must be addressed in any intervention that includes rural development: security of tenure is a prerequisite for ensuring settler household commitment to the development of the land farmed.

Land is the prime and most valued resource. To avoid corruption and misappropriation of land rights the household selection process must be clear and comprehensible to all. It must be totally transparent and made with reference to a non-controversial list of objective criteria.

Where land settlement is considered, poverty alleviation will be a prime objective with hitherto landless households being the first priority settlers. Households displaced, either directly or indirectly, by project activities must be compensated for this loss. The offer of re-settlement and associated benefits will constitute part of this compensation.

Many of the projects will include land accretion as an important feature. Areas accreted are unsuitable for occupation for some years, but will be brought under some form of management, usually being planted in mangroves, at the earliest opportunity. Nevertheless, land accretion may result in an increase in local population. Where this happens provision must be made for corresponding increases in cyclone shelter provision. This issue must be given priority as, for some years, these char areas will remain outside any embankment.

For effective implementation of land and char development activities, it is necessary to ensure that local institutions have the capability to implement activities and interventions independently of any project. Strengthening these local institutions will also help to ensure consistent levels and qualities of services and inputs. During project appraisal, an institutional needs analysis should assess the capabilities of sector thana offices and their associated extension services. Any resulting project should then include a component aimed at providing sufficient numbers of trained field officers and material support.

The success of development initiatives will, to a large extent, reflect the level of infrastructural support provided by the responsible government departments. Support should be co-ordinated among agencies and managed by the Estuary and Coastal Zone Planning Section in WARPO. Furthermore, the enhanced monitoring and evaluation capability to be established in WARPO must be geared to the identification of needs for infrastructural provision throughout project implementation and beyond.

Support services are conveniently categorised as either physical or social infrastructure. The provision of both physical and social infrastructural support services will be phased over the duration of respective project area development programmes.

Rural infrastructure is expensive to provide and before implementation adequate provision must be made for its maintenance after commissioning. The provision of rural infrastructure must be targeted at facilitating exploitation of a pre-identified economic development potential. Schools, health centres and drinking water provision will be given high priority and should be included in the initial preparation of projects. For social infrastructure, timely provision of physical facilities, such as school buildings and medical centres, is necessary though not sufficient. Essential human resources, such as teachers and trained medical staff, must be engaged. In these remote areas special incentives may be needed to ensure adequate staffing levels.

5.4.5 Water management

Accretion and land formation processes in the estuary differ considerably from place to place. These differences influence opportunities for water management at a macro level.

Levels of agricultural production in coastal areas are generally lower than in other parts of Bangladesh. Drainage congestion, water logging accompanied by salinity and poor water management are the main obstacles to agricultural development in flood protected areas in the Meghna Estuary.

Drainage

Consideration must be given to the possibility of using compartment embankments to reduce drainage congestion inside a poldered area. These secondary embankments, together with appropriately sized drains and sluices, facilitate water management by improving control over water entering the main drainage system during periods of high rainfall. Compartment embankments can also be used for road communications inside the polder, thus minimising the distortion of sluice catchment areas by LGED and other roads and footpaths. Appropriate planning will also minimize the expense of bridge and culvert construction.

Salinity control

Soil salinity is a major constraint to agricultural production in the study area. The salinity levels of open water surrounding polders, which show both regional and seasonal variations, will play an important role in defining the scope of water management. The opportunities for using (fresh) irrigation water and annual monsoon rains for accelerating reductions in soil salinity by leaching out surface salt deposits have to be considered.

Soils exhibit little variation throughout the estuary and the scope for desalinisation should be widespread throughout the estuary and coastal zone. However, desalinisation of polders is hampered by breaches in the flood protection embankment or damage to sluice gates which result in saline tidal flooding and the resalination of soil moisture. Desalinisation is also obstructed if drainage khals are not regularly maintained and re-excavated. All efforts must be made to prevent resalinisation of soils through flooding with sea water. Such flooding will damage standing and succeeding crops and delay the cultivation of Rabi and pre-monsoon (Aus) crops.

O&M

Improving drainage and salinity control will only be effective with adequate levels of competent institutional and technical support, for the O&M of infrastructure. For O&M of structures and other applied elements a two tier water users' organization should be considered:

- in the first tier, the Water Users Association (WUA) will participate in water management affairs for the entire polder and the Polder Council (PC) will co-ordinate between the water users, the various government departments (DAE, DOF, Forestry, BWDB) and NGOs

- in the second tier, compartment committees or sluice committees will be responsible for the day to day operation of sluices and control of water levels in main and secondary drains.

Participation of water users should result in better identification of maintenance needs, planning, implementation and better operation. Current practice is that sluices are often operated by influential persons or fishermen who take the lease of khals for fisheries. The interests of these and other stakeholders are in most cases conflicting. Transparent rules need to be formulated with the users to describe the primary and secondary functions and the use of infrastructure. Public supported enforcement of these rules will be required for their implementation.

At present, O&M operations are hampered by inadequate levels and poor quality of field level information and an inefficient planning procedure. Administrative procedures are too centralised, resulting in a lack of transparency and accountability.

The most important role of beneficiary participation is in planning water management and maintenance, monitoring and implementation (feed back from the field, supervision of works). Beneficiary participation will also include cost recovery (financial accountability of BWDB) and participation in the O&M of small canals and structures. The Water Users Committee (WUC) of the WUA will also be the body that approves the water management plan prepared by BWDB in co-operation with all other water users.

For future projects, the planning of preventive, periodic and emergency maintenance should follow the concept of SRP. Effective maintenance is necessary to keep the system functional. Realistic and appropriate planning and budgeting procedures should be designed and introduced to ensure that available funds most effectively take care of the most urgent need. Appropriate procedures should be designed and implemented to ensure the monitoring of all activities to meet the specific requirements of O&M.

5.4.6 Multi-Sector Programmes

Agriculture and farm systems

Most farms in the Meghna estuary are complex systems where the integrated production of food crops, livestock, trees and other plants all contribute to the survival of the farm household. When planning farming systems development in the area, the institutional structures, technical constraints to coastal farming as well as the viability and sustainability of farm households should be considered.

The development of farming systems and improvement of the individual components will depend on the establishment of institutional structures that are able to secure the farmers interests and support sustainable development and have a mandate to:

- secure land titling for the long term interest in improvements of the farm resources
- protect the land and user rights and reduce the power of big land owners and "land grabbers"
- secure the supply of credit to facilitate farmers' production activities
- provide extension services to support farmers in developing production and the farming system.

The estuary area provides quite different farming conditions than what are found in the inland areas of Bangladesh. The constraints to production make it one of the more marginal agricultural areas and it has been given low priority for development in the past. The main constraints are:

- limited fresh water supply for irrigation during the dry season
- high soil salinity
- soils that are generally of low fertility but especially deficient in organic matter.

These physical constraints are the main reasons for low yields and low cropping intensities. Farmers also cannot profit from the three cropping seasons observed in many other parts of Bangladesh. The high risk of damage from storm surges, flooding, pests and animal diseases, combined with the remoteness of the area, further constrains the potential for development.

The limited market access in some parts of the study area restricts the supply of inputs as well as the marketing of production. Dependency of local tradesmen limits the farmers' possibilities for securing supply and sale of products as well as influencing timing and prices.

Under these conditions, the potential for self-sufficiency and sustainability of the farming becomes an issue. Most farmers cannot survive from the output of their farms with the present farming system and many depend highly on fishing to maintain their livelihood. If farm households are to be self-sufficient and sustain a living based on the output of the land, the development of farming must be founded on a holistic farming systems approach, based on a needs assessments of the farm households.

Priority should also be given to a higher degree of integration among forestry, farming and development of the livestock sector combined with a larger focus on farm forestry or agroforestry to secure fodder and fuelwood supply.

Spatial conflicts may arise between forestry, livestock production, agricultural cropping and fish and shrimp cultivation as well as conflicts related to how different activities affect each other.

- Forestry versus farming: although most people in the coastal chars respect the existence of the mangrove forests for their own protection, an early integration of the settlers in the management and the use of the forest is needed to decrease the number of forestry/farming conflicts.

- Livestock versus agriculture: secure title to the land and allocation of community grassland according to assessment of the village needs might solve the problem to a certain extent.
- Shrimp cultivation in the same polders as agricultural cropping creates conflicts because the salt water intake needed for shrimps is damaging for agricultural cropping and slows the desalinisation of the protected areas. This conflict has to be resolved before allocating land.

Fisheries and aquaculture

Fisheries play a major role in nutrition, employment, exports and other aspects of the economy of Bangladesh and the Meghna Estuary in particular.

Biologically, the estuary provides spawning and nursery areas for a large number of fish and crustaceans which spend the remainder of their life cycles at sea or in fresh water. The estuary also provide avenues of entry and exit for the migration of anadromous and catadromous fishes. Within the Meghna estuary, species such as hilsha, shrimps and fresh water prawn are known as estuarine dependent, that is, passing a stage of their respective life cycles in the estuary is obligatory for the completion of their life cycles.

Fisheries in the Meghna estuary is a interactive process between ecological (the fish), socio-economic (the fishermen) and physical (the estuary) factors. Any intervention or development in the MES area should encompass these three inter-related elements:

- the different species of fish in the estuary, with their respective ecologies and behaviours, is a given biological fact and will not change over time
- the total biomass of fish for each species in the estuary (the stock) is directly influenced by fishing activities; over-exploitation of stocks will occur when the number of gears or fishermen is higher than the stocks can support
- between 60 and 80 per cent of all fish and shrimp in the Bay of Bengal are estuarine dependent and alteration of the habitat, for example the estuary or intertidal area, will be to risk directly influencing fish stocks and consequently the catch of the fishermen.

It is emphasized that a reduction of the estuarine area through land reclamation will have a direct linear impact on fisheries production. Any reduction in the spawning or nursery areas of fish, however, will most likely have an exponential impact. This concern must be taken into account when identifying or preparing engineering and other physical components of proposed interventions.

The last decade in Bangladesh has seen a rapid increase in aquaculture production. This has been primarily due to the introduction of improved husbandry techniques and the execution of large scale extension projects. The potential for such an aquaculture development within the MES area has not yet been realized though there is clear scope for further development in fresh or brackish water aquaculture.

The main elements in a strategy for long term development of fisheries in the estuary should include:

- a focus on improvement in the socio-economic conditions of the fisherfolk households, who are the poorest of the poor in the estuary, and all interventions should be screened for their impact upon this community
- sustainable management of fisheries resources in the estuary, based on catch and effort data and stock assessment analyses
- regulation of fishing effort through the creation of alternative income generating activities
- maintaining the recruitment of the economic important fish species such as hilsha, bagda, golda and pangash, which must be achieved through fisheries regulations and co-operation with the fishing communities and through protection of the actual spawning and nursery areas
- taking advantage of opportunities to improve fresh water aquaculture such as, for example, the introduction of Indian carps and fresh water prawns

- the introduction of the culture of brackish water marine aquaculture, other then shrimp farming since, in light of the recent disease outbreaks and developments regarding the environmental impacts of shrimp farming, the sustainability of further development in this sector must be carefully studied.

Forestry

Forestry issues should be addressed in a wider context of environment and development, taking into consideration the multiple functions and uses of forests, including the objectives of wood and fuelwood production and the potential for development offered by sustainable forest management, community and social forestry.

Land use classification and allocation of forest types are fundamental for development planning and forest management. Categories to be considered are protection forests, production forest, forest for conversion to agriculture, and forest for nature conservation.

A distinction should be made between the already established *existing resource* and the *newly created* plantations, with respect to forest management options for protection (including stabilization of mudflats and accretion enhancement) and socio-economic issues (satisfying the needs of people for forest goods and services and providing additional income and employment, agroforestry, cottage industry);

Land tenure issues and implications for developing newly accreted lands, including handover procedures and a practical division of responsibilities among the involved institutions, have to be considered as well as overall resource assessment with current data on stand parameters like mangrove plantation area, stocking, growth and plantation quality.

A resource management strategy, which contemplates the successional nature of the mangrove vegetation as well as development based on conversion of plantation land for integrated farming systems has to be developed and implemented in the future.

Navigation

The primary navigation route in the Meghna Estuary is the bay crossing passage connecting Chittagong sea port with Dhaka and other inland river ports, as well as Mongla sea port. This passage is subject to constant change in response to changes in the coastal and estuarine morphology. The route from Ilsa and Gazipur towards Barisal and Khulna or Patuakhali, also forms a part of primary waterways of the country.

Other navigational routes in the estuary, which are not secondary or tertiary waterways are the channels in the Shahbazpur river, routes on the east and west sides of Hatia and channels around Sandwip.

The unstable nature of the navigational route for the bay crossing requires the shifting of its location and direction from time to time. It is not possible to maintain the route artificially, specially by dredging, which is simply ineffective in the area. Therefore, regular surveying to locate the position of the deeper channels is required for the marking of shipping lanes.

The requirements for navigation in the estuary must be an integral part of strategic planning. In particular, erosion control measures will have to be planned in such a way that navigation along the primary and secondary routes is not hampered. This applies in particular to the construction of cross dams and in certain cases also to bank erosion protection.

Channels that are used for local communications may only be closed after close consultation with the stakeholders and beneficiaries. The provision of small navigation locks will not help in maintaining the local navigation routes since the connecting channels will rapidly silt up as a result of cross dam construction.
The proposed Hatia-Damar Char and Hatia-Nijhum Dwip cross dams are likely to develop a leeward seaboard on the eastern side of the islands making for easier navigation in this part of bay-crossing. These dams are not expected to influence any other part of this trunk route but can reasonably be expected to result in a better bay-crossing route.

Integrated coastal planning and environmental management

The need for an integrated approach to coastal area management has been outlined in section 4.2.6 above. While it is possible to have environmentally based programmes and projects in their own right, the recent emphasis in Bangladesh has understandably been on setting up environmental components to existing programmes and projects so that environmental impacts can be identified, quantified and valued.

The aim of the EIA process is to ensure that no person is worse off as a result of the proposed intervention, with all negative impacts being avoided or mitigated for, with the cost of mitigation programmes included in the intervention economic and financial analysis. In addition, steps to increase positive impacts are also investigated. Under the MES, the primary objective of the environmental component is to provide a mechanism to ensure that proposed interventions are environmentally sound and sustainable.

It is not justifiable or valuable to draw up special environmentally based programmes. There is, however, one major issue, induced sea level rise as a result of global warming, which requires consideration and discussion when identifying components for intervention programmes.

6 MASTER PLAN

6.1 Master Planning process

6.1.1 Introduction

The aim of the Master Plan (and the Development Plan) for the Meghna Estuary Study is to draw up a phased management and intervention strategy for the long term development of the area. The Master Plan is to be a 25 year rolling programme, whilst the Development Plan has a five to ten year time horizon. The Terms of Reference for the Study specifically require three priority projects to be identified and carried through to feasibility study. In addition a further three projects are to be identified for pre-feasibility study.

The methodology for assessing such proposed interventions in Bangladesh has been drawn up and is given in the Guidelines for Project Assessment (GPA), (Ref: FPCO, 1994). These Guidelines include the methodology for economic and financial analysis, but also recognise that there are many benefits of interventions which cannot be judged purely in economic terms. This is particularly true of social impacts which can be difficult to quantify and value. In order to allow a relative assessment to be carried out, a multi-criteria analysis can be used which assists the prioritisation of expected benefits in relation to policy objectives. The GPA also gives methodologies for assessment of agricultural and fisheries benefits.

For regional studies it is first necessary to build up a baseline assessment of the area and identify future trends. These trends include those that are naturally on-going and also those that are due to existing and already proposed human interventions. Once the overall policy objectives for development in the area have been established and constraints to development identified then a phased management and intervention programme can be drawn up.

The Meghna Estuary is a large and diversified territory with area specific characteristics as far as hydro-morphology, population, land use, socio-economic and other aspects are concerned. In order to be able to take this diversity systematically into account in the Master Plan, the Meghna estuary has been subdivided into three planning zones and each planning zone covers three to five planning units.

6.1.2 Planning zones

The planning zones that have been delineated within the framework of the Master Plan are indicated in Figure 6.1.

Southwest Zone A includes:
Bhola island, the islands and chars south of Bhola as well as the Tetulia River west of Bhola and the chars northeast of Bhola.

Central Zone B includes:
the main river system between the Bay of Bengal and Chandpur, including Hatia and Manpura islands and newly emerged chars.

Northeast Zone C includes:
the tidal channels to the west and east of Sandwip, Sandwip island, Urirchar, Char Pir Baksh as well as the tidal mudflats that have developed recently southeast of the Noakhali mainland. The coastal strip between Patenga/Chittagong and Feni cross dam and the newly accreted areas of Muhuri and Little Feni are also included in this zone. The new chars that have been developed south of the Noakhali mainland are considered part of the CDSP study area and as such are not included in the Meghna Estuary Study area.

The three planning zones have not been delineated in accordance with strict zoning criteria as it is not deemed necessary at this stage to prepare detailed zoning criteria. Instead, the reference scenarios developed in the Inception Report have been used as the starting point for zoning of the estuary.

Zone A encompasses the future land mass (including Bhola island) that will be formed in the western part of the estuary and may be protected by coastal and river embankments with a drainage outlet to the Tetulia River.

Zone B is the present and future course of the Lower Meghna River, that has to be kept open indefinitely. The banks of the river need to be stabilised in order to prevent or reduce the loss of valuable existing land. Within zone B, Hatia, Manpura and Gazaria may eventually be combined into one island protected by coastal embankments.

Zone C may eventually include a land mass consisting of new chars and mudflats south of Noakhali as well as Sandwip, Urir Char and Char Pir Baksh. These islands may be connected to the mainland south of Noakhali in the medium term .
In the very distant future the closing of the Sandwip channel to the southeast of Sandwip may be considered in order to protect the coastal areas surrounding this channel from the vagaries of cyclones, improve the drainage in the area and create a large fresh water body that may be used for irrigation.

6.1.3 Planning units

The three planning zones have been sub-divided into planning units, see Figure 6.1. The main criteria for delineating these planning units are derived from the types of interventions that have been identified within the planning zones. Other criteria relate to hydro-morphologic and administrative boundaries as well as a reference scenario for the development of the Meghna estuary beyond the Master Plan period.

Planning Zone A has been sub-divided into three Planning Units.

Unit A1 includes the islands and chars south and southwest of Bhola island. Within this unit two long term integrated development projects have been identified. These include measures to accelerate accretion by construction of a large number of cross dams, empoldering of areas that have been raised by siltation to the required level in relation to tide levels and char development and settlement of people in areas that will be empoldered or have been already empoldered but are in need of full scale development.
Unit A2 includes the northeast and east coasts of Bhola island and the chars that have developed northeast of Bhola in areas that were once part of Bhola island but have been eroded by the river in recent years. This planning unit could also have been included in the central zone B, but existing administrative boundaries made its inclusion in Zone B preferable.

Within this unit the most urgently needed intervention is erosion control. Along the east coast of Bhola between Ilsha, Tazumuddin and Betua thousands of ha have been lost in the past 25 years and within the Master Plan period again thousands more will be eroded by the river if nature is left to shape the coastline. A combination of bank protection and river training works should gradually be implemented to fix the coastline.

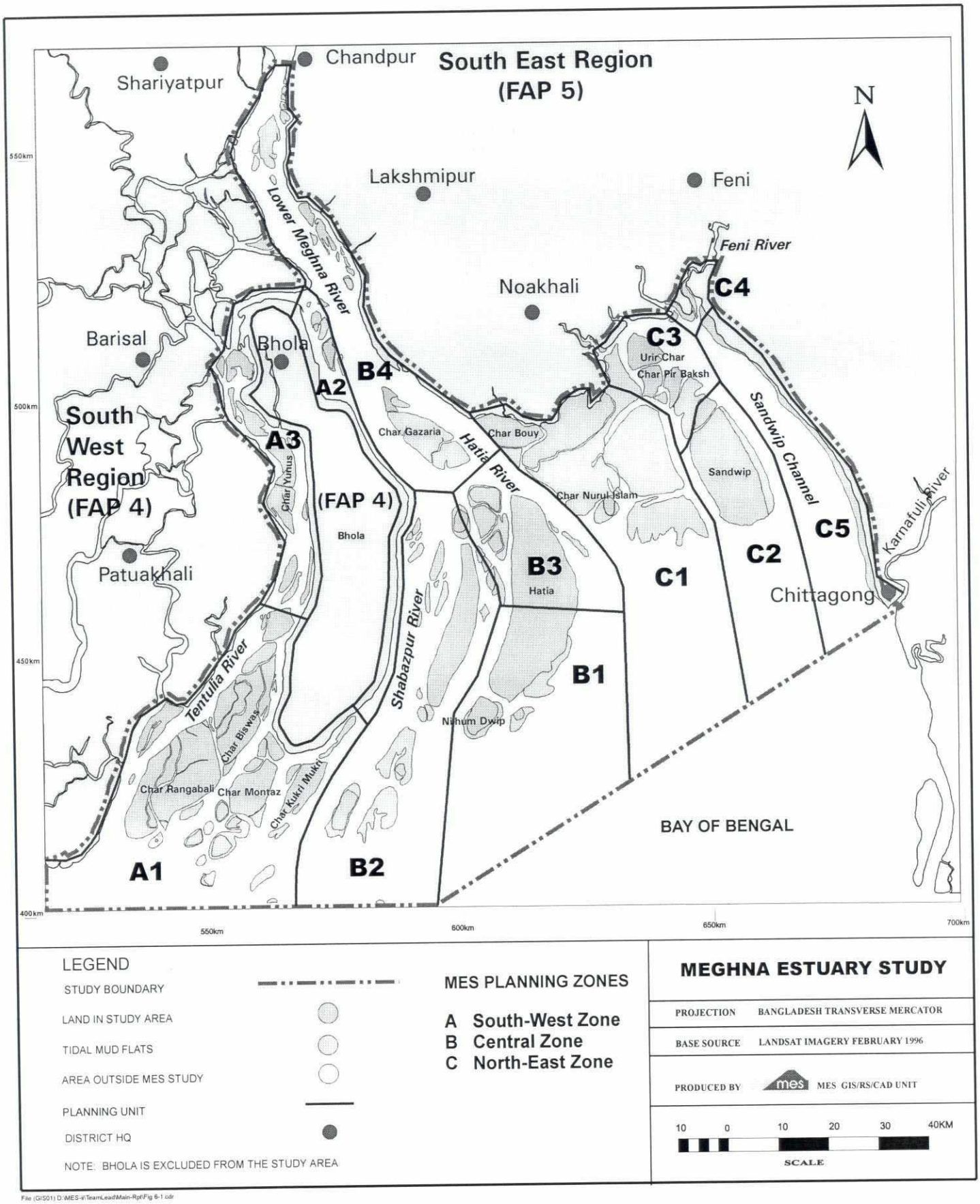
Unit A3 includes the Tetulia River between Dasmonida and Ilsha. Within this unit, cross dam construction and bank protection as well as empoldering and char development will be required in the long term. In order to prevent substantial loss of existing land, bank protection would be required over a distance of about 10 km along the west coast of Bhola in the second five years of the Master Plan.

Planning Zone B has been sub-divided into four Planning Units.

Unit B1 includes South Hatia, Nijhum Dwip and Damar Char. The channels in between South Hatia - Nijhum Dwip and South Hatia - Damar Char are gradually silting up, but available bathymetric data indicates that these channels will not completely silt up in the foreseeable future without intervention. It is proposed to close the two channels with cross dams to enhance and speed up accretion in the area.
On the West Hatia coast bank protection works have been proposed for an embankment under threat of erosion.

Land has also been accreting along the south and southeast coasts of Hatia. This land, which is partly being used for agriculture and partly for afforestation by the Forestry Department, together with Nijhum Dwip, Damar Char and the land expected to accrete due to construction of the two cross dams will form a single land mass which will be empoldered after it reaches a height above +2.00 m PWD. Char development activities are also proposed for the area.

Figure 6.1: MES Planning Zones and Units



Unit B2 includes Manpura island. In the future, cross dams may be constructed to promote accretion and connect the island to Char Bakshi Majhir in the north and Char Nizam in the south creating a single land mass. Parts of the west coast of Manpura are threatened by erosion and will need bank protection measures. These have included in the Master Plan for eventual implementation.

Unit B3 includes the northern part of Hatia island. There are a number of islands in between north Hatia and north Manpura which may be interconnected with cross dams. Cross dams might be constructed between Moulvir Char and Dhal Char and between Dhal Char and Char Parvez. The resulting area might eventually be connected to north Hatia with another cross dam. The end result would, in this case, be to make north Manpura, north Hatia and the intervening chars into a single land mass. Char development activities could then be implemented in the area.

North Hatia has long been subject to severe erosion and the implementation of bank protection works is required.

Unit B4 includes the left bank of the Meghna from Chandpur down to Char Alexander in Noakhali as well as Char Gazaria. There is tendency to erosion along the whole of this coast, but especially in the Hanachar and Haimchar areas and around Ramgati. Bank protection in the Hanarchar and Haimchar area is a priority included for early implementation in the first phase of the Development Plan. Erosion management will also be required for Ramgati.

Char Gazaria situated in the midstream of Meghna may be empoldered in due course, with char development activities implemented subsequently.

Planning Zone C has been sub-divided into five Planning Units.

Unit C1 includes the islands and accreted mudflats south of Noakhali Sadar Thana. Within the framework of the Master Plan empoldering, char development and measures to enhance accretion may be considered. This area will be studied in detail by a CDSP study team and their conclusions and recommendations ultimately included in the Master Plan.

Unit C2 includes Sandwip island. Along the west and southwest coasts of Sandwip island coastal defence works will be required to stop continued loss of valuable land and infrastructure. As long as adequate protection has not been provided, erosion management is proposed.

Unit C3 includes the Urir Char complex as well as the proposed Sandwip cross dam between Char Lakhi, Urir Char and Sandwip. The Sandwip cross dam is expected to accelerate accretion in this area helping to develop a land mass extending westward up to south of Char Clark. However, the most recent model simulations suggest that the negative consequences of the Sandwip cross dam would be severe, at least under present conditions. One small cross dam between north and south Urir Char has already been constructed by LGED and another cross dam is planned further to the south.

Char Buoya, Urir Char and Char Pir Baksh may be empoldered after they attain the appropriate height for this part of the estuary. Char development activities could then be implemented. There are mud flats at south of Char Clark which are slightly above or below low water level. If found feasible, appropriate measures may be taken to raise these mudflats by enhancing accretion.

Unit C4 includes the Muhuri and Little Feni accreted areas. The Muhuri accreted area has been studied at feasibility level under CDSP and may be empoldered and further developed in the near future. Similarly, the char development process may also be continued in the Little Feni accreted area.

Unit C5 includes the east coast of the Sandwip channel between Patenga/Chittagong and the Muhuri Accreted area. From an analysis of satellite imagery it appears that in the period 1973 to 1998 accretion has been predominant with only limited coastal erosion, both in terms of area and time. Only at Patenga beach has severe erosion occurred recently. However, this erosion has been stopped by adequate coastal defence works. Where possible the accreted foreshore should be planted with mangroves to reduce the wave height at the protective embankments along the coast.

6.2 Intervention selection

The table below summarises the 20 types of intervention outlined and discussed in chapter 5:

Sl. No.	Type of intervention	Sub-category	Category
1	agriculture: secure land title, extension, credit, marketing, co-ops, storage, processing livestock: diversification, improved breeding stock, fodder homestead production: diversification, tree crops and fuelwood	farming systems	non-engineering sector programmes
2	sustainable management, training, credit, gear changes, landing stations, hatcheries, storage and processing, marketing	fisheries	
3	sustainable planting and management	forestry	
4	no specific interventions proposed	navigation	
5	flood and cyclone warning	warning systems	non-structural interventions
6	disaster preparedness and management	disaster management	
7	raise existing houses, consider new settlement design	flood proofing	
8	health education	social infrastructure	
9	coastal embankment construction	primary flood protection	engineering structural components
10	foreshore conservation - forest planting		
11	secondary embankment construction	secondary flood protection	
12	water management systems (including drainage)		
13	settlement schemes	char development	
14	water supply, sanitation, roads, upgrading markets	rural physical infrastructure	
15	cyclone shelters and raised platforms	cyclone protection	
16	bank protection and river training works	erosion strategy	
17	erosion management		
18	mangrove planting	enhancement of accretion	
19	settling basins		
20	cross dams		
	mitigation and enhancement programmes	environmental management	environment

The 20 broad types of intervention range from agricultural extension, through non-structural programmes (such as cyclone warning systems), to large scale construction of physical infrastructure. In addition there are environmental mitigation and enhancement programmes which are not interventions in their own right, but are aimed at avoiding, minimising or mitigating potential negative impacts and maximising positive ones.

In drawing up the list of possible interventions it is important to identify clearly both the types of intervention themselves as well as their expected impacts, both positive and negative, and their associated costs, benefits and risks. The impacts identified must be those of the specific intervention proposed and should not include the on-going impacts of interventions already in place.

Impacts of interventions

The process of selecting interventions for implementation must include an assessment of their various possible impacts on the population and on socio-economic and physical environments. Impacts may be either direct or indirect and caused by complex linkages among components.

In general, potential impacts expected during the 25 to 30 years after implementation are considered; predictions beyond this period will not be realistic. Impacts may be divided into short term impacts which include those that result from construction or that are apparent soon after operation commences, medium term impacts that are experienced some five to ten years after commissioning and longer term impacts, which often include impacts on the natural environment which are slow to be apparent but are often irreversible (e.g. the effects of changed flood conditions on natural vegetation).

Interventions may have complex impacts on the population and socio-economy, affecting various sectors of population differently, depending on social differentiation (for instance landholding size, household income level, occupation), on the spatial variation of impacts (i.e. depending on the specific nature and location of the intervention) or many other factors. Impacts on the natural and physical environments will vary in a similar way. To obtain an overall assessment of the proposed intervention, these varying impacts need to be balanced against each other. The effect of interventions outside their immediate area of operation - their likely upstream and downstream constraints and impacts - must also be taken into consideration in this assessment.

Most impacts on the natural environment (both positive and negative) are from major structural interventions and many of these are highly complex. The one notable exception is forest planting which has significant positive impacts on the natural environment and very few negative ones.

The intensification of farming systems is often at the expense of the natural environment and may compete with other land uses and common resource uses such as grazing, forestry and fisheries. However, the degree to which displacement occurs depends upon the age of the land, particularly its topographic level, and hence risk of saline intrusion, and soil quality. The establishment of rice monoculture often results in losses of fauna and particularly fish habitats. However, the indirect result of homestead development is normally an improvement of flora bio-diversity.

In the context of the MES area, water management interventions usually involve the development or improvement of drainage systems, including provision of water control structures which allow outflow of rainfall run off at low tide and prevent inflow of saline water at high tide or during storm surges and the construction or upgrading of drains. Effective operation of these systems will reduce flood plain areas and hence fisheries habitats. However, if well designed and managed it is possible to improve internal river fish habitats by maintaining all year water in the deepened drainage system.
An analysis of the impact of construction of cross dams and settling basins is difficult, as they are such site specific interventions. There are likely to be complex, induced impacts on sedimentation as a result of these two types of intervention which could alter aquatic and marine habitats but increase terrestrial ones.

In general, most non-engineering sector programmes and non-structural interventions have relatively low costs and have, overall, positive impacts on the human environment, although some of these may not be particularly large.

The engineering structural interventions generally have higher costs and are far more complex in their impacts, both positive and negative. The most significant negative impacts are likely to result from new embankment construction which may increase rainfall run-off flooding yet reduce fisheries resources. The need for land acquisition, compensation and resettlement may also be a significant cost and create a major constraint to large scale infrastructure construction.

Benefits and risks

All interventions create the potential for benefits to the human population and the natural and physical environment, but carry at the same time, risks of negative consequences that will leave some people or some aspects of the environment worse off. In most cases, the potential for positive benefits will have to be balanced against the potential for negative consequences.

Effective implementation of interventions that maximises benefits and minimises the risk of negative outcomes requires an appropriate institutional management structure. Institutional aspects therefore need to be specifically included in any project intervention for the MES area arising from the Master Plan.

Similarly, proper O&M of infrastructure is essential for maximising the benefits of an intervention. It is therefore necessary to make adequate provision in any future project for O&M, with appropriate participation by project beneficiaries.

The indirect consequences of changes in flood regime on human health (particularly the risk of increased water borne disease) and reduced nutritional level due to cuts in available protein intake from fish can be considerable but will vary greatly depending upon the location of the intervention.

The agricultural benefits of many of the possible interventions may not be large, particularly in the newly accreted lands where saline intrusion remains a significant problem or where land levels are still too low for embanking.

The level of risk attached to economic activity may also increase greatly as a result of constructing flood protection embankments and erosion protection works. The consequences of failure of either of these two types of intervention can often be far more serious than if they were not built in the first place, as increased investments based upon the assumed protection offered by these interventions could be lost.

The aim of carrying out a broad impact assessment of possible intervention types in the MES area is to identify major impacts, both positive and negative, to be borne in mind during the selection of intervention types and phasing of the development programme. For specific interventions, the need for carrying out social, economic and environmental assessments at pre-feasibility and then feasibility level is also emphasised. It is necessary to ensure that sufficient time and resources are available for baseline data collection and analysis relating to all potential project impacts.

6.3 Phasing of planning unit development

Within the Meghna Estuary three planning zones and 12 planning units have been delineated, as described in sections 6.1.2 and 6.1.3. Since it will be neither feasible nor desirable to start development in all planning units immediately, the development of the units will have to be phased. The criteria for phasing of the development are derived from the strategy formulated for the development of the Meghna Estuary.

So that implementation is manageable, the phasing of development activities in the planning units is as follows: three planning units for years 0 to 5, three more planning units years 5 to 10 and then eight to follow after year 10.

The guiding principle for estuary development is that, on the one hand, new land has to be created and developed so that people who have been made landless by the erosion of their homesteads and land by the river can be resettled while, on the other hand, erosion has to be controlled to reduce the future loss of valuable existing homesteads, land and infrastructure.

Accretion

The broad areas where accretion occurs naturally and erosion under present conditions is mostly limited are within planning units A1, B1, B2, B3, C1, C3 and C4.

In planning units A1 and B1 some reworking by erosion of newly accreted land may occur, but the area involved will be relatively small and through regular monitoring it will be possible to identify these vulnerable areas and plan the development accordingly. Since the hydro-morphological developments are relatively stable and predictable, these planning units should be considered for early development

Units B2 and B3 include areas with accretion as well as moderate to severe erosion. Since the channels within these units form a part of the Lower Meghna river system, the future hydro-morphological development is less stable and predictable. In the near future the development within these planning units must be monitored and studied in more detail. In the medium term interventions like erosion control and cross dams may be considered and land development and settlement may be taken up.

Unit B3 includes the north and northeast coast of Hatia island. Since 1970 this coast has been eroded over large distances by the strong tidal currents in the channel. At present, cost effective protective measures for the Hatia coast are not available. However, within the framework of integrated coastal zone management the search for such effective measures should be pursued with vigour. Innovative designs as well as the development of sustainable maintenance systems may pave the way to protection of this vulnerable coast in the medium to long term, within the master plan period.

Unit C1 will be vulnerable to erosion in particular along the southwest bankline because of the shifting of the Lower Meghna in an easterly direction. The eastern part of C1 is subject to the erosive forces generated by shifting tidal channels. The middle part of the new char land complex will not be affected by shifting river channels and may be considered for gradual development as soon as the general levels of the land have risen sufficiently in respect to the high water levels.

Unit C3 is situated in an area that is still unstable and vulnerable to erosion along its southwest and southeast boundaries. The planned Sandwip cross dam is located within this planning unit. The possible impact of this dam has been studied with the help of the hydro-dynamic model of the estuary. The model has been calibrated with inaccurate data of the inter-tidal zones and mudflats and therefore the results have a limited accuracy only. The results of the simulations indicate that velocities may increase in the main channels which would result in an acceleration of erosion that may, in the long term, even threaten the cross dam itself. Moreover, the highest tidal water levels in planning unit C3, as well as in units C2, C4 and C5, may rise substantially due to construction of the Sandwip cross dam. It appears that costly mitigating measures would be required to offset the negative impacts of this cross dam.

The planning of the development of Urir Char and Char Pir Baksh must be based on a more detailed analysis of future morphological changes and therefore should be considered for the medium term or later. The construction of small cross dams by LGED to connect the islands may be continued, but costly empoldering and provision of a water management system and rural infrastructure should be deferred until there is more certainty about the future morphological development.

The implementation of the Sandwip cross dam shall not be considered in the short and medium term. Within the framework of integrated coastal zone management, the hydro-morphological changes in the area have to be monitored intensively in order to establish a reliable data base for the study and planning of this cross dam and the assessment of its potential for developing new land.

Previous assumptions with regard to the potential for land development, both time-wise and area-wise, appear to be quite optimistic. The risk of accelerated erosion of newly accreted land has not been assessed with adequate accuracy. Before considering the implementation of Sandwip cross dam again, these issues must be studied in detail as must the requirements for mitigating measures, which appear to be considerable.

Unit C4 is situated in a relatively stable area from morphological point of view. The development of Muhuri Accreted Area and Little Feni area may proceed during the Development Plan period and in the medium term, depending mostly on the availability of the necessary funding.

Erosion control

Erosion of river banks is the predominant morphological feature in planning units A2, A3 and B4 that cover the main river system within the Meghna Estuary.
However, at the same time existing chars in the river course will migrate and change in shape while new chars will emerge continuously. None of these chars can be considered as long term stable land if left under natural conditions.

The emphasis of erosion control shall be on stabilising the banks of the river adjacent to long term stable land. In case river training works appear attractive to help stabilise a certain river section such measures could also be considered. These river training works could include stabilisation of chars; as an example Char Gazaria may be mentioned. Otherwise the chars within the course of the Lower Meghna and Tetulia rivers shall be left without erosion control measures and embankments.
Unit A2 includes the northeast and east coast of Bhola island between Ilsha in the northeast and Betua in the southeast. In the past 25 years the coastline has been eroded in a westerly direction over distances of up to 4,000 metres. Without interventions, the erosion will continue and similar losses of existing stable land will occur during the Master Plan period of 25 years.

As erosion control is one of the main components of integrated coastal zone management, it is indispensable to develop adequate technical and economic measures to control erosion of the bank and coastline and to start implementing them as soon as it has been proven that these measures are effective and durable. Since the river courses will remain very unstable between the protected banks and as a result the attack of strong tidal currents will shift continuously, large scale maintenance will be permanently needed to control erosion of the banks.

In this planning unit, erosion control works should be implemented as soon as possible. However, since at present proven technology for such control works is not available, large scale implementation will not be justified until about halfway the Development Plan period (by which time it is hoped that proven technology will be available). Bearing in mind the importance of erosion control within the Meghna Estuary, it is obvious that the search for effective and durable measures has to be continued vigorously.

Unit A3 covers the course of the Tetulia River between Ilsha and Dalmonida. This river discharges about 10 per cent of the total flow at Chandpur into the Bay of Bengal. Several sections of the river bank have been severely eroded over time and this process is still continuing. The river also serves as the main navigation route to Barisal, Patuakhali and areas beyond.

Based on experience with the performance of erosion control pilot schemes, it appears possible to provide erosion control at relatively low cost along those sections of the river that are under more or less severe attack. As with the Lower Meghna River, the chars in the Tetulia river should be left without control works unless such works are beneficial for the protection of long term stable land.

In the long term, Char Yunus may be empoldered and developed. However, before this could be undertaken, adequate bank protection has to be in place along the left bank of the Tetulia river opposite of Char Yunus.

Unit B4 includes the main course of the lower Meghna river between Chandpur and Gazaria island. As mentioned before, erosion of the river banks is the main issue within this unit. Between about 10 and 30 km south of Chandpur, the main course of the Lower Meghna is shifting in a westward direction at a rate of several hundred metres per year. This process is expected to continue for a number of years until the length of this river channel has increased so much that the present secondary, eastern channel, which will start conveying an ever increasing part of the river discharge, becomes the main river channel once again, as happened around 1970.

Meanwhile the erosion along the eastern bank line will continue and may even accelerate later on when the western branch channel loses more and more of its conveyance capacity. The present rapid western shift of the main river channel will have a destabilising effect on the eastern bank off Lakshmipur and further downstream. The expected shift of the main channel to the east will then accelerate erosion of the west bank further downstream. All in all, the river is expected to widen in both westerly and easterly directions while between the banks char will develop and disappear again as the river reworks its bed continuously.

Further to the south Char Gazaria started to emerge around 1970. This char divided the single river course into two channels and while the char has widened by siltation, the opposite banks of the branch channels have continued and will continue to be eroded. The effect of tidal currents is very strong in this section of the Lower Meghna River.

In view of the magnitude of the erosive forces acting in the Lower Meghna, piecemeal implementation of erosion control works will be totally ineffective. A comprehensive programme for the implementation of erosion control works and maintenance thereafter will have to be prepared and executed.

As in the case of Unit A2, it is proposed to start implementing river control works as soon as possible after proven measures for erosion control have been developed. It is recommended to start by stabilising the river banks south of Chandpur.

For the time being the attack on the east bank between Chandpur and Haimchar is moderate to severe. Low cost erosion control works developed during MES and MES II are expected to be suitable for protection of this bank line. In order to prevent further loss of valuable land and infrastructure, protection should be provided as soon as possible.

The west bank of the river is rapidly eroding and this process is expected to continue. Although the value of the land and its infrastructure is considerably less than that of the east bank, from the point of view of overall stabilisation of the Lower Meghna early implementation of erosion control works is deemed highly desirable, as it is expected to reduce the attack on the banks further downstream.

The east bank off Char Alexander and Ramgati is in urgent need of erosion control works. As mentioned already, piecemeal protective works will not be effective since the sections where the river attack is most severe shift continuously. The implementation of erosion control works should only be considered after effective and durable measures have been developed for protection of banks attacked by strong tidal currents.

Coastal erosion and accretion

Coastal erosion and accretion are the predominant features of planning units C2 and C5.

Unit C4 includes Sandwip island. Comparison of Rennell's map and the change maps prepared from Landsat satellite images clearly shows a movement of Sandwip island in an easterly direction and a gradual reduction of the land area.

The erosion along the west coast of Sandwip island could be controlled by protective measures similar to the coastal protection that has been installed on the Patenga/Chittagong coast. However, the implementation of such costly works to protect agricultural land and rural infrastructure cannot be justified from an economic point of view. The west and south coasts of Sandwip are under attack by strong tidal currents while the erosive action of waves under normal conditions, as well as under extreme (cyclone) conditions, is also (very) severe. In the long term (beyond the Master Plan period), the natural development of the shallow areas towards the south may reduce the rate of erosion. The effects of implementing the Sandwip cross dam could also have a mitigating effect in this respect; this will require further detailed study. Without intervention, the coastal erosion of western Sandwip will continue at least in the short and medium term.

At present, proven low cost measures to control coastal erosion at Sandwip are not available. It may be possible to adjust the innovative designs for bank protection, developed during MES and MES II, to withstand the currents and waves attacking Sandwip island. However, additional testing under field conditions such as those prevailing at Sandwip is required to ensure that the works will function as envisaged and withstand the vagaries of the Bay of Bengal.

Unit C5 covers the mainland coast between the Muhuri Accreted area and Patenga. During the past 25 years accretion was predominant along this coast, with short periods of coastal erosion over limited lengths of the coastline. This situation is expected to continue during the Master Plan period, with the exception of the coastline north and south of the mouth of the Karnafuli river where erosion is expected to predominate. In this part of the mainland coast, additional coastal protection may be required to protect the infrastructure of Chittagong harbour.

6.4 Phasing of interventions within planning units

The potential engineering interventions are indicated in Figure 6.2; the time schedule for implementing the interventions proposed in the Master Plan is shown in Figure 6.3.

Planning Unit A1

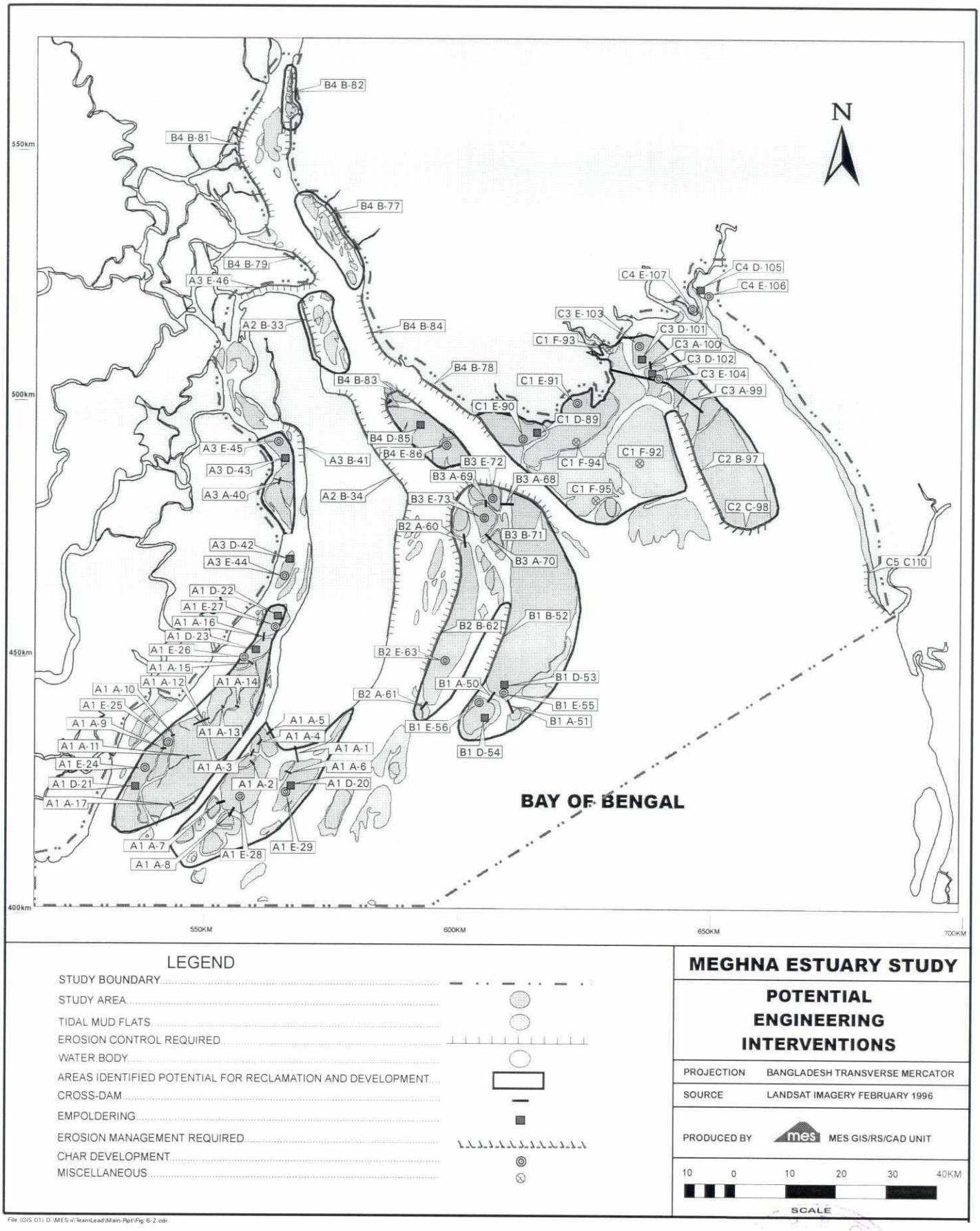
This unit covers the islands and chars south and southwest of Bhola. Two groups of islands and chars have been clustered: the Char Montaz - Kukri Mukri complex and the Char Biswas - Rangabali - Chota Baishdia - Bara Baishdia complex.

The Char Montaz - Kukri Mukri complex has been given the highest priority for development because of the potential for accelerating accretion by constructing cross dams in the channels between the chars. Secondly, although Kukri Mukri has been an inhabited char for quite a long time already, it has not so far been protected by an embankment. The population of the island feels an urgent need for this protection. Thirdly, the cross dams will eventually connect these remote chars with the Bhola mainland and thus facilitate communication with other parts of Bangladesh.

The other complex within the planning unit has similar requirements but the scope for accelerating accretion is less. Parts of the chars have been empoldered already and access to the mainland to the west is much easier.

It is proposed to implement an integrated development project for Char Montaz - Kukri Mukri in five phases during the master plan period, with phases at intervals of about five years. The first two phases will include the construction of a large number of cross dams that will accelerate accretion in the channels between chars and the channels criss-crossing chars. The phases planned for the second half of the master plan period will provide flood protection, land development and settlement, water management systems for the newly accreted areas as well as multi-sector programmes, as required. The Forestry Department shall manage the mangrove plantations throughout the planning period by planting mangroves on the mudflats, thinning the forest as required and ensuring the clearance of the mangroves once the land has reached the required levels and been empoldered.

Figure 6.2: Potential Engineering Interventions



LEGEND

- STUDY BOUNDARY
- STUDY AREA
- TIDAL MUD FLATS
- EROSION CONTROL REQUIRED
- WATER BODY
- AREAS IDENTIFIED POTENTIAL FOR RECLAMATION AND DEVELOPMENT
- CROSS-DAM
- EMPOLDERING
- EROSION MANAGEMENT REQUIRED
- CHAR DEVELOPMENT
- MISCELLANEOUS

MEGHNA ESTUARY STUDY

POTENTIAL ENGINEERING INTERVENTIONS

PROJECTION	BANGLADESH TRANSVERSE MERCATOR
SOURCE	LANDSAT IMAGERY FEBRUARY 1996
PRODUCED BY	mes MES GIS/RS/CAD UNIT

10 0 10 20 30 40KM

SCALE

File (GIS 01) D:\MES-II\TeamLead\Main-Rpt\Fig 6-2.cdr

Planning Unit A2

The main activity in this planning unit is the installation of erosion control measures. In addition, a small cross dam may be constructed to connect a newly developed char to the west of Chowkighat with mainland Bhola.

Before large scale protective works are implemented, the innovative designs developed during MES and MES II must have been proven under field conditions. Since a few years of monitoring the performance of the installations is required and more pilot schemes may be needed to produce adequate design criteria, large scale interventions have only been planned in the middle of the development plan period. After installation of the works, regular substantial maintenance works will be required.

The small cross dam may be installed at any time. However, if no erosion control works are installed, the char will disappear gradually as a result of the general westward shifting of the Bhola coast in the future. In that case it does not make sense to close the secondary channel to promote accretion.

Planning Unit A3

The interventions required in this unit are erosion control at several locations along the banks of Tetulia river as well as development of Char Yunus, including the installation of some cross dams to accelerate accretion. Since development of Char Yunus will have an effect on the flow pattern in this section of Tetulia river, the Bhola bank opposite Char Yunus, that has been eroding for quite some time, has to be protected first.

Planning Unit B1

The development of this planning unit will start in the first years of the master and development plan periods. An integrated development project with three phases has been planned for this unit. The first phase includes Nijhum Dwip cross dam and the empoldering and development of an area of South Hatia as well as a small area on Nijhum Dwip to provide a protected area for the people already living on that island. The second phase, to be implemented five years after the first, will include Damar Char cross dam and additional empoldering of land newly accreted as a result of Nijhum Dwip cross dam. In the long term a third phase will be executed to develop newly accreted land that has attained the required level, has been under mangroves for a sufficient length of time and is inside the 1 km coastal forest margin.

Planning Unit B2

In this planning unit interventions have been envisaged for the medium and long term. The west coast of Manpura island will have to be protected against erosion. Two cross dams may be installed depending on morphological developments in this unit. In the long term an integrated development project is foreseen.

Planning Unit B3

During the development plan period erosion control works have been planned to stabilise the river banks around the area west of Hatia that has accreted in recent years. Simultaneously, several cross dams may be installed to accelerate accretion and connect existing chars. In the medium term, an integrated development project may be considered to consolidate the newly accreted land and, provided that proven designs are available by that time, protective works may also be considered to control the severe erosion along the north coast of Hatia.

Planning Unit B4

In this unit erosion control works are the sole type of intervention foreseen. Since erosion control along the east bank of the Lower Meghna between Sakhua and Haimchar is urgently required to halt the loss of valuable land and infrastructure, as well as to protect the embankment of the Chandpur Irrigation Project against breaching, this project has been given a high priority in planning the interventions within this unit. Actual timing of implementation of the works depends on the outcome of ongoing pilot schemes.

It should be clear that before a final decision to go ahead with the erosion control measures, the results of the pilot schemes must show that the designs are adequate. Since the long term durability of the measures will not be known at the time of decision, a substantial budget allocation will be required for maintenance of the works.

Preparations for protection of areas other than Haimchar must be postponed until proven technology for cost effective measures has been developed. It is envisaged that during the development plan period erosion control works will be implemented along the west bank of the Lower Meghna river to halt further shifting in a westward direction that would have a destabilising effect further downstream.

Further downstream, additional erosion control works are foreseen in the medium term. Maintenance of the protective works will have to be continued throughout the master plan period.

Planning Unit C1

The proposed interventions in unit C1 are measures to promote accretion together with integrated development of newly accreted land that has reached the required level for empoldering.

MES has investigated the effectiveness of settling basins as a measure to promote rapid accretion. A desk study clearly indicated that based on realistic assumptions settling basins would not be feasible from an economic point of view. However, it may be investigated whether or not cross dams at a spacing of several km and with a length of several km would be cost effective as a means of accelerating accretion. The design could be based on cross dam designs developed under MES and MES II.

The results of an ongoing reconnaissance study of the chars and mudflats south of the Noakhali mainland may indicate that sufficient land has accreted already to start empoldering in the near future. For the time being it is assumed that measures to promote accretion will be taken during the development plan period and an integrated development project could start at the end of this period. In the long term, one or more development projects are foreseen in the planning unit.

Planning Unit C2

Interventions along the coast of Sandwip island are covered in this unit. In particular, erosion of the west coast of the island should be arrested for the benefit of the population living on Sandwip. Moreover, coastal embankments under construction by CERP may be lost after a limited number of years when the coastline shifts eastwards again.

Since the traditional coastal protection designs are very expensive and not usually economically feasible for protecting basically rural areas, only cheaper measures for coastal protection would be attractive. It is advisable to study the performance of the permeable spurs in combination with bottom screens under field conditions. Installation of three spurs is expected to yield sufficient information about the effectiveness and durability of the these erosion control measures in coastal areas. Provided that the outcome of the tests is positive, protective measures could already be installed during the development plan period. A second project may be required in the medium term and maintenance of the installations will have to be provided in the long term.

A fisheries project may be set up in the eastern coastal zone of Sandwip during the development plan period. This will require the design and implementation of the required infrastructure as well as other facilities for the development of shrimp farming.

Planning Unit C3

This unit includes the development of the Urir Char - Char Pir Baksh complex as well as the Sandwip cross dam. Recently one cross dam was constructed by LGED under the Food for Work programme; another dam is planned for the 1998/1999 winter season. After the newly accreted land has reached the required level, an integrated development project should be implemented to empolder the reclaimed area and provide additional rural infrastructure and other facilities to the people of these chars.

A note of caution is added here: from the available satellite imagery it appears that the south-eastern and south-western coasts have been eroded severely in recent years. This tendency will continue at least in the short and medium term and has to be taken into account in the planning of the development of this area.

Implementation of the Sandwip cross dam shall be considered only in the long term. The environmental impacts, including increases in tidal water levels, appear to be substantial. Under the present conditions erosion prevails along the western boundary of the mudflats between Sandwip and the Urir Char-Char Pir Baksh complex. Additional surveys and studies will be needed to ascertain future morphological development in the area. In particular, the development of the inter-tidal zones in the alignment of the cross dams will have to be monitored in the coming years. The proper timing for implementation of the works should be based on the changes in the bathymetry. It is quite possible that nature is already building a connection between Sandwip and the mainland. Human intervention should be timed in such a way that both the cost and the environmental impact are minimised.

Planning Unit C4

Unit C4 covers the Muhuri Accreted Area and the Little Feni Area. A feasibility study for the Muhuri Accreted Area has been completed already while Little Feni has been studied at pre-feasibility level. Empoldering and char development of the Muhuri Accreted Area is planned within the development plan period. The project also includes multi-sector programmes as well as some erosion control works. The Little Feni Area may be developed in the medium term or earlier.

Planning Unit C5

The coastal zone between the Muhuri Accreted Area and Patenga/Chittagong are included in this unit. Generally the coast appears to be stable, but additional works may be required near Patenga to protect this industrial and harbour area.

6.5 Priority projects for development plan

The following projects will be given priority and included in the Draft Development Plan:

Planning Unit A1	Char Montaz - Kukri Mukri Integrated Development Project
Planning Unit B1	Nijhum Dwip Integrated Development Project
Planning Unit B4	Haimchar Erosion Control Project
Planning Unit C4	Muhuri Accreted Area Integrated Development Project

The location of the priority projects and programmes as well as medium term projects is indicated in Figure 6.4.

Figure 6.3: Master Plan Implementation Schedule

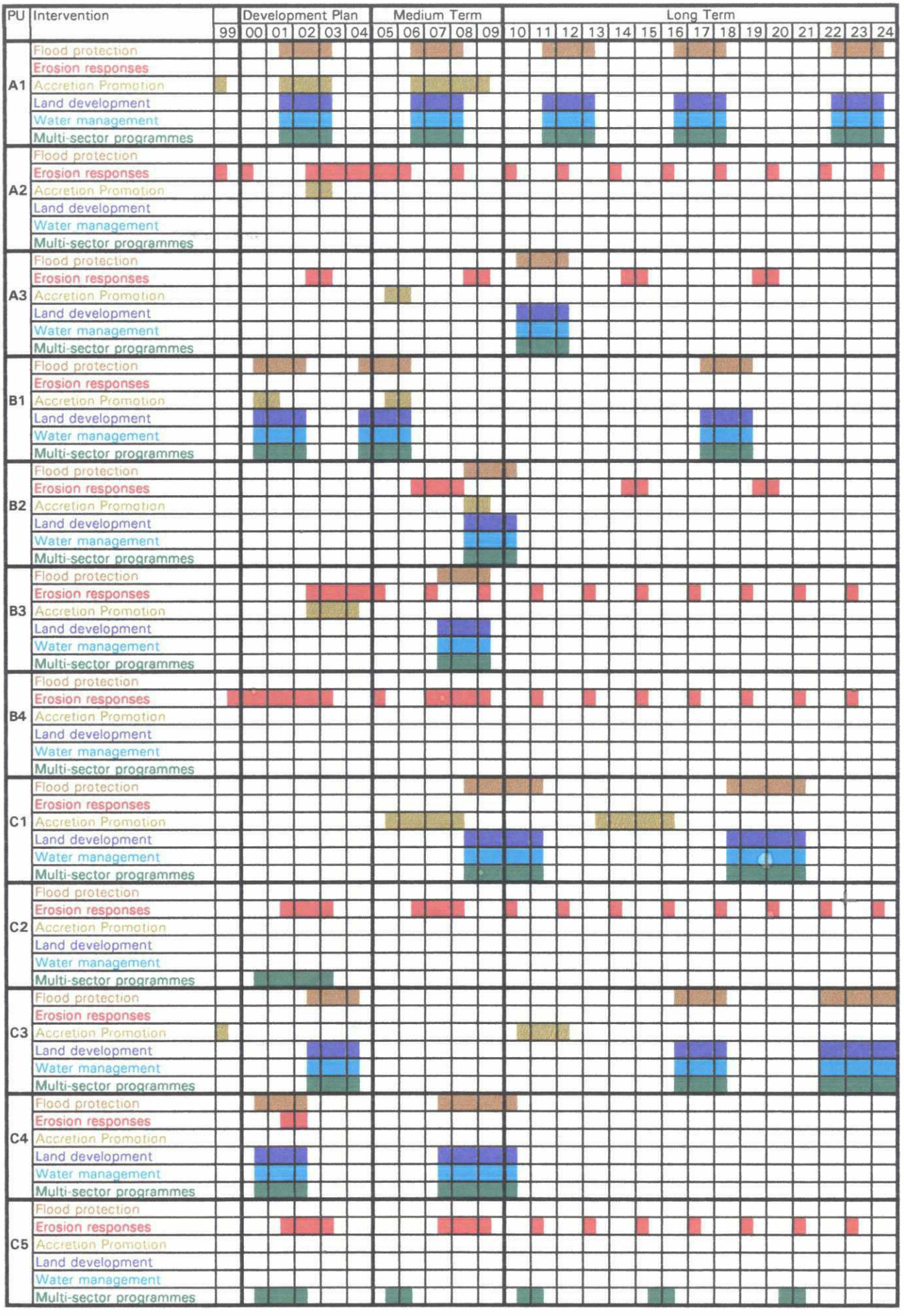
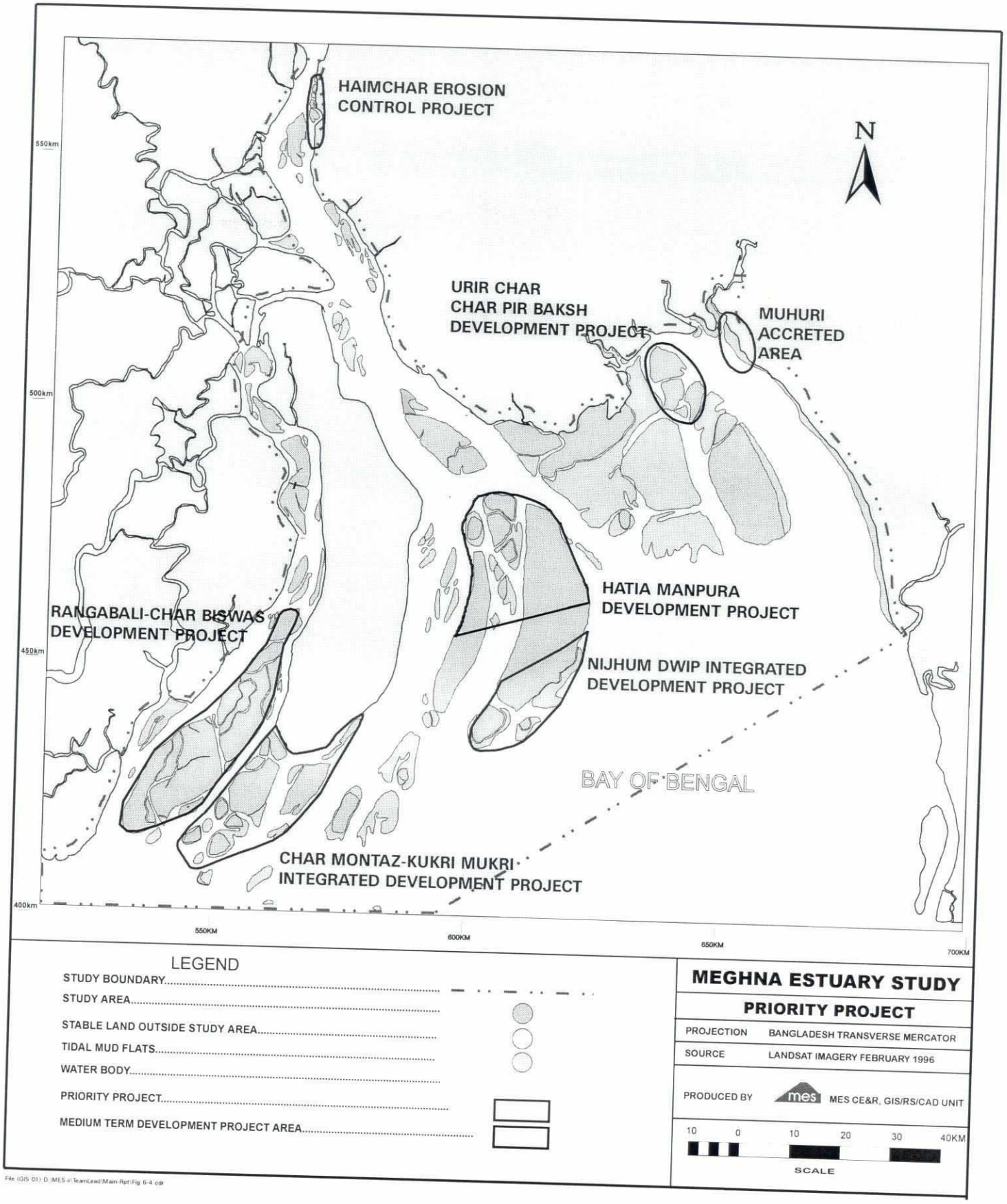


Figure 6.4: Priority Projects



7. STRATEGY FOR MASTER PLAN IMPLEMENTATION

7.1 Continuation of the Master Planning Process

7.1.1 Data collection and modelling

During the Meghna Estuary Study two technologies of recent origin have been introduced. One was RTK based bathymetric surveys and the other was flow measurements by ADCP.

RTK positioning was developed shortly before the start of the project and was applied for the first time in Bangladesh. The expectations were fulfilled with respect to survey capacity and data quality, both of which are considered superior to traditional surveying, notably with respect to datum reduction. The technique is better than any alternative with respect to detection of sea bed level variations over large areas.

Flow measurements by ADCP have been made once before in Bangladesh (by the River Survey Project, FAP24, between 1992 and 1996), but was implemented within BWDB for the first time in connection with MES.

The key quality of the technique is its recording capacity, which makes it possible to cover a cross-section while sailing at a cruising speed of 4 knots (compared with 30 minutes or more per vertical for traditional flow measurements). This quality is decisive when operating in a tidal-influenced environment such as the Meghna Estuary, where the current speed changes continuously and the current direction in many cases shifts 4 times per day.

The point has been made that such advanced technology incurs a dependency on foreign, expensive expertise, because repairs can only be made by the manufacturer. This is correct; but the same argument relates to so many other types of modern technology which are now indispensable for a variety of purposes, in Bangladesh as well as worldwide.

A further development of the routines, possibly a simplification, may be considered in connection with a continuation of the monitoring.

As a subject for future development, the flow and sediment transport data quality may be enhanced by a data assimilation technique, whereby the complex time and space variations during the measurements are jointly referred to a numerical model of the cross-section. Today, such a technique is not available as a routine tool, but needs to be developed, possibly as a research project. The data produced by MES can serve as part of the basis for such development.

There remains a need for implementation of the off-line data processing routines somewhere outside of the temporary MES project organisation. This is a prerequisite for utilising the acquired field techniques and skills after completion of the project.

The network of reference benchmarks established by MES is believed to be the best one available in the area today. Furthermore, the co-ordinates are publicly available. The benchmarks are highly valuable in connection with any monitoring or construction activities in the estuary (for example embankments and irrigation and drainage schemes). It is strongly recommended that the network be retained for future applications. This will require merely an annual inspection, freshening up the painting etc., and an occasional re-establishment of lost benchmarks, as required.

Today, the national geodetic network of Survey of Bangladesh covers almost the entire country, except the estuary. Presumably, at some time in the future that network will be extended to include the estuary as well. In this connection, suitable links should be established to the MES network, in order to facilitate conversion of reference levels for the purpose of historical analyses of land and sea bed elevations and water levels.

Therefore, provision should be made for building a permanent data processing expertise within the Survey Unit Anwesha, which would in this way become self-contained with respect to the final product of the survey operation.

The present applied data management routines were tailored for the specific needs of MES, and for that particular project organisation, and should be reviewed prior to implementation in a different setting. The detailed individual routines may be well suited for many purposes, but the general organisation of the data flow must be adapted, particularly with respect to organisation and allocation of competence. The framework should be well defined, so that it is clear who is doing what. The entire data flow should be stored on CD ROMs, from the sensors on the vessel to the post-processing and the final storage.

For the sake of long term data consistency, routines should be changed only with due consideration. Measuring locations and reference stations should be retained as far as practicable. In general, minor improvements should be implemented with caution. Whenever field or data processing routines are modified, the documentation should be revised. The transparency of the methodology is a cornerstone of the quality of survey data.

The numerical modelling of the Meghna Estuary has been an on-going learning process throughout the study period. One example is the realisation during the early phases of the study that a bathymeric survey of the entire study area was required in order to be able to describe the existing hydrodynamic conditions properly. During the later stages of the numerical modelling a number of other possible improvements to the basic modelling data and modelling procedures have been identified.

Coastlines and river banks are changing rapidly in certain areas of the estuary. The coastlines in the present models are based on satellite mapping in February 1996 supplemented with a few data around Nijhum Dwip from November 1997. In connection with future use of the models, it is recommended that coastlines and river banks are updated regularly. Due to erosion and accretion, the depths in the estuary are also changing. Regular updates of the model bathymetry are therefore also required in order to keep the model up to date.

Interpolation from bathymeric survey lines to a square model grid in rivers and areas with channels in the sea bed is not well performed by standard interpolation routines. Often the depth in between survey lines will be underestimated leading to an unrealistically small flow in the area. During the set-up of the bathymetry this problem was identified, but only tedious ad hoc solutions to the problem were found. It is therefore recommended that alternative interpolation routines are checked and, if necessary, developed or acquired. In this way the bathymetric survey data will be better utilised.

During the course of MES, water level measurements and ADCP measurements have been collected and utilised in the calibration of the hydro-dynamic models. When the model bathymetry is updated with new survey data in the future, and if his update introduces significant changes in the bathymetry, a recalibration of the model with new water levels and new ADCP measurements is recommended.

If the hydro-dynamic model is going to be used for the modelling of cyclonic surges, a nested model approach as used in the Cyclone Shelter Preparatory Study will be required, because a larger area must be covered be the model.

If general salinity simulations are to be made and especially if simulations during the monsoon season are to be carried out, it is also recommended that a nested grid approach be adopted. It is also recommended that more salinity measurements be carried out for the calibration of the salinity model.

A sediment transport model of the Meghna Estuary would be a valuable tool for impact assessments but it requires an extensive and detailed calibration effort with correspondingly extensive data requirements as the estuary is a very dynamic area from a morphological point of view. It is recommended that the sediment transport model for the estuary be further developed, supported by a targeted field programme as an integral component of the estuary and coastal zone management efforts.

7.1.2 Integration with NWMP and Coastal Zone Management Plan

The outputs of the Meghna Estuary Study constitute the most recent example of an integrated approach to planning. The planning process started during MES should be continued to ensure that plans at all levels are based on up-to-date information on field conditions and results of studies including numerical modelling of the hydro-morphological phenomena that are of interest for the planning process.

There is a strong linkage between the Meghna Estuary and the upstream rivers. All upstream interventions can be reflected in the delta with negative consequences. Moreover, interventions within one part of the estuary can have implications, both positive and negative, for other parts. This leads to the conclusion that the Master Plan for the Meghna Estuary is of national importance and that it should be closely linked to the national planning for water resources.

The integration of the Master Plan with the National Water Management Plan is a task of WARPO. Whenever the MES Master Plan is updated, the results of subsequent planning activities shall also be incorporated in the revised NWMP by WARPO.

Because of its dynamic nature, the planning efforts for the estuary will be more intensive and continuous than for other regions of Bangladesh. There is a clear need for an integrated management and planning effort for the Meghna Estuary. Such an effort can best be regarded as a continuous governmental activity directed at the sustainable development of this dynamic and vulnerable estuarine and coastal area.

Activities include the evaluation and revision of the Master Plan for the Meghna Estuary as well as the preparation of an Integrated Coastal Zone Management Programme (ICZMP). This programme should be closely linked to the Government's five year plans.

As long as a separate organisation is not charged with the planning for the development of the estuary, WARPO will be the leading organisation for maintaining the Master Plan for the Meghna Estuary and for developing and maintaining the ICZMP. This has implications for the WARPO as an organisation that is currently undergoing a process of transformation towards a multi-disciplinary organisation, able to negotiate and co-operate with all other departments and agencies involved in water related issues.

Overall supervision of the inter-sectoral and inter-departmental co-ordination and the planning processes needed for developing and revising the Master Plan for the Meghna Estuary is the responsibility of the National Water Council, which may form a sub-committee for the development of the Meghna Estuary.

7.1.3 Sustainable development of the estuary

In the Master Plan for the Meghna Estuary, the need for integrated development projects has been identified, including both large scale interventions and more sector oriented projects (e.g. fisheries, forestry).

The planning for the development of the Meghna Estuary as well as the implementation of projects and programmes can only be sustainable if the institutions responsible for the planning, implementation and maintenance have been established and long term commitments to funding of the estuary development have been made.

The components that have to be considered for sustainable continuation of the development of the estuary can be divided into the following groups.

Master plan updating

WARPO, under the general supervision of the National Water Council, must take the lead in the planning processes that are required for developing and maintaining the Master Plan and also take responsibility for the inter-sectoral and inter-departmental co-ordination that will be needed for its development and revision.

The Master Plan shall be updated every five years in line with the time frame of the five year planning process of Government.

Integrated coastal zone management

An Estuary and Coastal Zone Management Centre as well as an Estuary and Coastal Zone Development Consortium should be established in order to ensure that the development of the Meghna Estuary will be taken up and continued in a sustainable manner. The Centre would be responsible for the planning and co-ordination of the development efforts while the Consortium would be committed to providing the financing for the implementation of the approved projects and programmes.

Until such an Estuary and Coastal Zone Management Centre is operational, a new section should be established within WARPO under the title "Estuary and Coastal Zone Planning". This is in addition to the four discipline oriented sections already within the organisation. As a consequence, a redistribution of the Engineering Section of WARPO would be required.

The Estuary and Coastal Zone Planning section shall be in charge of the evaluation and revision process that is required to keep the Integrated Coastal Zone Management Programme up-to-date. The section shall also continue to enforce co-operation with all other departments involved in the development of the Meghna Estuary to ensure in integrated approach. The section will have to contract survey and data processing and modelling studies as well as acquiring satellite imagery to support the evaluation and revision process of the Master Plan.

Design and implementation of interventions

The design and implementation of interventions like cross dams, embankments and shore protection measures, should be undertaken by BWDB which will have to contract survey and data processing and modelling studies to support the design and evaluation process.
Undoubtedly, the reform of the BWDB should continue with the aim of transforming the organisation into a transparent, efficient and professional organisation, able to conduct open planning procedures and equipped with multi-disciplinary skills in order to better meet the needs of society and to become a more attractive negotiating partner for all other governmental and non- governmental organisations involved.

Other non-engineering sector programmes and non-structural interventions may be organised through local government and specialised governmental organisations e.g. the Ministries of Land, Fisheries and Forest, as well as through NGOs.

Numerical modelling and evaluation

Since WARPO and BWDB are to provide their core processes with data and information from the SWMC, SWMC shall be developed into a contracting partner, able to provide the WARPO and BWDB with adequate information. The contracts with the SWMC shall comprise items such as products, budgets, time frames and quality control.

Similarly contracts with EGIS will concern the provision of satellite imagery and related GIS analysis. This information will be an important source for the planning processes undertaken by WARPO and BWDB.

A contract on a year by year basis between the departments of the Ministry and the SWMC and EGIS seems to be an adequate basis for revision and adaptation to developments. In order to reduce the costs for providing their services to WARPO and BWDB, SWMC and EGIS should be allowed, with the approval of the Ministry, to provide services to other public or private organisations that need information on the physical situation and development of the Meghna Estuary.

In order to ensure that the use of hydro-morphologic modelling techniques by local specialists will be sustainable, it is recommended that formal training in connection with further development and application of the models be conducted at regular intervals e.g. at least every two years. This would apply to staff of the proposed Estuary and Coastal Zone Management Unit of WARPO as well as to the specialists of SWMC who will be in charge of updating and refining of the hydro-dynamic model and its appurtenant sub-modules for simulation of sediment transport, waves and salinity distribution.

Data collection and processing

In order to ensure the sustainability of data collection and processing, it is necessary that:

- the Survey Unit Anwesha will be engaged in data collection and processing on a commercial basis with a separate accounting system to ensure that sufficient incentives can be provided to the survey staff and crew for efficient and accurate outputs and that the vessels and survey equipment will be kept in tip-top condition

- the Survey Unit Anwesha shall, with the approval of the Ministry, be allowed to provide services to other public or private organisations that need hydrographic data on the Meghna Estuary in order to reduce the costs for providing its services to WARPO and BWDB

- the quality procedures that were implemented during MES should be continuously revised and further developed, so that a suitable concordance is maintained between nominal and actual procedures for field work and data processing. This requires a regular updating of the survey and data processing guidelines (while the need to update the sediment analysis guidelines seems less urgent)

- the continued estuarine monitoring programme is extended with a small pilot programme of water quality monitoring, comprising collection of some water samples and some fish samples for subsequent analysis of, for example, pesticides and heavy metals.

- the liaison between the field staff and the data processing staff is consolidated, in order to develop an understanding of the context of the field work and enhance the overall data quality.

7.1.4 Monitoring and evaluation

Continued bathymetric, hydraulic and morphological monitoring is a necessity for any prudent management of the Meghna Estuary. This is because of the highly dynamic morphology of the area, which renders information about bathymetry and coast contours uncertain or even obsolete within the space of a few years.

The information is required for a variety of important purposes, such as general water resources management, rehabilitation of embankments, design and maintenance of drainage and irrigation systems, navigation and any coastal management in the area. Such monitoring would serve as an important supplement to the routine monitoring of river flow, sediment transport and morphology which has being carried out by BWDB for decades, but which has so far not been extended to cover the downstream, tidal reaches of the main river system.

The monitoring can provide data for a variety of purposes of high national importance, as indicated below:

- river basin management: data from the downstream reaches is important for basin-wide water balances of flow and sediment transport, which in turn are a fundamental part of national water management
- flood forecasting: data from the downstream reaches are important for set-up calculations, as carried out on a routine basis by BWDB's Flood Forecasting and Warning Centre
- engineering design: valid, updated design water levels and morphological stability data for coastal flood protection embankments, cyclone shelters, irrigation and drainage schemes, waterways, marine pipelines, harbours, power plants, offshore structures and any coastal structures and physical development schemes
- navigation: feasibility and impact studies and non-routine monitoring of waterways
- water quality monitoring: salinity and salinity intrusion through the lower part of the river system into agricultural areas and mangrove areas, and the management of fish farming.

Continuous monitoring could be based on regular, say bi-annual, satellite mappings and a programme of vessel surveys, for example a monsoon campaign and a dry season campaign. The monsoon campaign could comprise flow and sediment transport measurements during one cruise, and the dry season campaign could comprise bathymetry during two cruises, flow and sediment transport during one additional cruise, and salinity during one cruise. If more practical, the salinity cruise could be made from a small separate launch, doing one tour around Bhola. The programme would leave ample time for non-routine allocation of survey capacity for dedicated purposes.

The hydraulic monitoring can conveniently be combined with some suitable programme of extended water quality monitoring with a scope beyond salinity. Initially, provision should be made for collecting a limited number of water samples for analysis of pesticides and heavy metals. Fish samples should also be collected for the same purpose.

The programme should cover the dry season and should distinguish between the fresh water body and the saline water body. Depending on the outcome, a suitable level of continued effort can be established. Furthermore, it is recommended that the scope of needed systematic biological monitoring of fish and fisheries and possibly other biological characteristics and indicators be considered.

In addition the installation and performance of newly installed erosion control works and cross dams shall be monitored and evaluated in order to establish and improve the design criteria and installation methodology for this type of works.

7.2 Implementation of the Development Plan

7.2.1 Institutional structure needed

The institutional structure required for the implementation of the Development Plan will have to follow a decentralised approach as much as possible in order to ensure maximum participation of the stakeholders in the detailed planning and implementation of the projects.

The executing agencies will set up their office within the Planning Unit of the concerned project; since the development effort will be long term, the facilities should be at least of a semi-permanent nature. All disciplines involved in the implementation of a project will appoint staff and make available facilities to the project organisation based within the planning unit to ensure that maximum interaction among disciplines is achieved during the implementation of the projects.

For erosion control works, which do not require an integrated approach, the existing structure of BWDB would suffice for their implementation.
Self-standing non-engineering projects may be implemented through existing institutes that may set up their facilities within the estuary area to ensure efficient project execution.

7.2.2 Organisation and implementation procedures

The responsibility for design and implementation of physical interventions such as erosion control works, cross dams, embankments and shore protection measures, as follow up activities of MES, should be within the BWDB. To support these activities, BWDB should contract survey and data processing and modelling studies to support the design and evaluation process.

As has already been noted in the context of the Master Plan, the present reform of the BWDB should continue with the aim of transforming the organisation into a transparent, efficient and professional organisation, able to conduct open planning procedures and equipped with multi-disciplinary skills in order to better meet the needs of society and to become a more attractive negotiating partner for all other organisations involved.

Other non-engineering sector programmes and non-structural interventions may be organised through the local government and specialised governmental organisations e.g. the Ministries of Land, Fisheries and Forest.

7.2.3 Participation

A distinction is drawn between public participation in the planning and decisions regarding proposed engineering intervention and the facilitating of householders involvement in economic development activities or programmes.

As to the former, the proposed approach will be based on the strategy and activities in the forthcoming revision of the *1994 Guidelines for People's Participation in the Water Sector in Bangladesh* This original Guidelines proposed that participation can be achieved by disseminating information about the proposed project "in a timely and accurate manner" and then recording people's reaction to it in a systematic fashion so that the planning can be appropriately revised to reflect these opinions.

The recently established Study Monitoring Unit (SMU) will be engaged to undertake this opinion and attitudinal survey, though responsibility for it's management and completion will rest with the Land Accretion and Estuary Development Division (LAED) of BWDB. SMU is a government institution with a multi-disciplinary structure and function. The use of this Unit is regarded as important to give authenticity to both the survey and to project implementation.

Regarding participation of households and local government officers in the economic development programmes and initiatives, the objective will be to install conditions and capacity for community development sustainable beyond the duration of the project. It will be a principle of project implementation, therefore, that the communities and government field staff, not the plantations, infrastructural works, vehicles or offices, are the focus of project efforts and activities. To reorient these communities and field staff and to develop the capacity and motivation for initiating development activities, is time consuming and will require skilled workshop facilitators and trainers.

NGOs will encourage and initiate groups of households involved in the same development activities to meet at regular intervals to discuss common problems and opportunities. Appropriate support agencies, for example agricultural extension officers might be invited to participate in these group meetings. A spirit of 'working together' would be encouraged.

Work programmes would be developed in a participatory manner, that is, in full consultation with respective government department personnel, communities and any concerned NGO. The NGO's role would be to ensure a spirit of mutual learning through an analysis, involving all parties, of a community's 'felt' problems. The NGO will act as facilitator: supporting, stimulating and encouraging whilst not allowing the imposition of technical fixes.

7.2.4 Technical assistance

Although several pilot schemes have recently been constructed in the estuary, the experience of BWDB staff will still have to be enhanced through transfer of technology. Moreover, the design and installation technology proposed for the closure of channels with cross dams, based on an innovative design, have only been used for the Char Montaz Cross Dam Pilot Scheme and as such have not yet been thoroughly tested. The same applies for the design and implementation of erosion control works. Moreover, the workable period is very limited compared to the magnitude of the works and strict adherence to a very tight time schedule will be required to ensure timely completion of the closure works.

Therefore, the involvement of foreign experts in the planning and supervision of the implementation of erosion control works and cross dams in the early stages of the Development Plan period is recommended. Later on, when more experience has been gained by the Government authorities and local consultants, implementation of these works should be possible without foreign experts.

Foreign consultancy services may also be required for special studies or projects related to environmental impact assessment, char development and settlement programmes, forestry and fisheries. In the medium term, this expertise should be made available through WARPO (Estuary and Coastal Zone Management Section) and in the long run through the Integrated Coastal Zone Management Programme.

7.2.5 Monitoring and evaluation

The performance and impact of engineering works like erosion control measures and cross dams will have to be closely monitored on a long term basis. This monitoring will not only provide valuable data for establishing design criteria for these innovative works but is also essential for the planning of maintenance works that will be required to ensure proper functioning of the works and prevent further damage to them during subsequent periods of high current velocities or attack by waves.

Accurate measurement of the currents and bed levels in the areas effected by the interventions (e.g. spurs, cross dams) will be required. In order to achieve the required accuracy, the positioning system and hydrographic equipment of the Survey Unit Anwesha is indispensable.

Detailed underwater inspections will be part of the monitoring activities. These inspections shall be planned concurrently with the hydrographic surveys so that the diver of the Survey Unit Anwesha can be assigned to perform this job.

As a supplement to more formal project benefit monitoring of integrated development projects, project monitoring and evaluation will be undertaken as an iterative process, most likely in a facilitated meeting, in which all stakeholders will be encouraged to participate. In this way, monitoring and evaluation becomes a process of learning. It remains likely, however, that stakeholders will each have their own agenda and target achievements. It is proposed that M&E of the project should oblige NGOs to monitor these participatory meetings to ensure that the self- interests of poorer householders and women are to the fore and that through the process these latter become less dependent and more self reliant.

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