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MINISTRY OF WATER RESOURCES

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA ESTUARY STUDY

DRAFT MASTER PLAN

EXECUTIVE SUMMARY

November 1998

DHV CONSULTANTS BV

in association with

KAMPSAX INTERNATIONAL
DANISH HYDRAULIC INSTITUTE

DEVELOPMENT DESIGN CONSULTANTS
SURFACE WATER MODELLING CENTRE
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EXECUTIVE SUMMARY

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Terms of Reference and objectives

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 while recognising that bank erosion is also a significant impoverishing factor. There is an overall objective of improving the welfare of the residents through strengthening their economic livelihoods.

The Meghna Estuary Study aims to draw up a planning framework for the area and develop a 25 year outline Master Plan. The main objectives of the Master Plan report are to give the planning framework, criteria for selection and the sequencing for drawing up the 25 year rolling intervention programme for the area. The Master Plan also aims to identify the priority issues in the study area and put forward technically, economically, environmentally and socially feasible ways of addressing them within the framework of sustainable development.

The delineation of the estuary is shown in Figure 1 and covers a gross area of 11,000 km^2.

Output

The Master Plan consists of eight volumes, the Main Report in Volume 1 seven supporting volumes arranged by discipline. The main output of the Master Plan is the 25 year rolling programme for the development of the Meghna Estuary. However in order to get to this output, a planning process has been followed which includes the steps of data collection, 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 26 Technical Notes, 12 Data Volumes and 2 Map Boxes as well as on diskettes and CD ROM. In addition to the Master Plan, a Development Plan for short term development within the Meghna Estuary has been prepared.

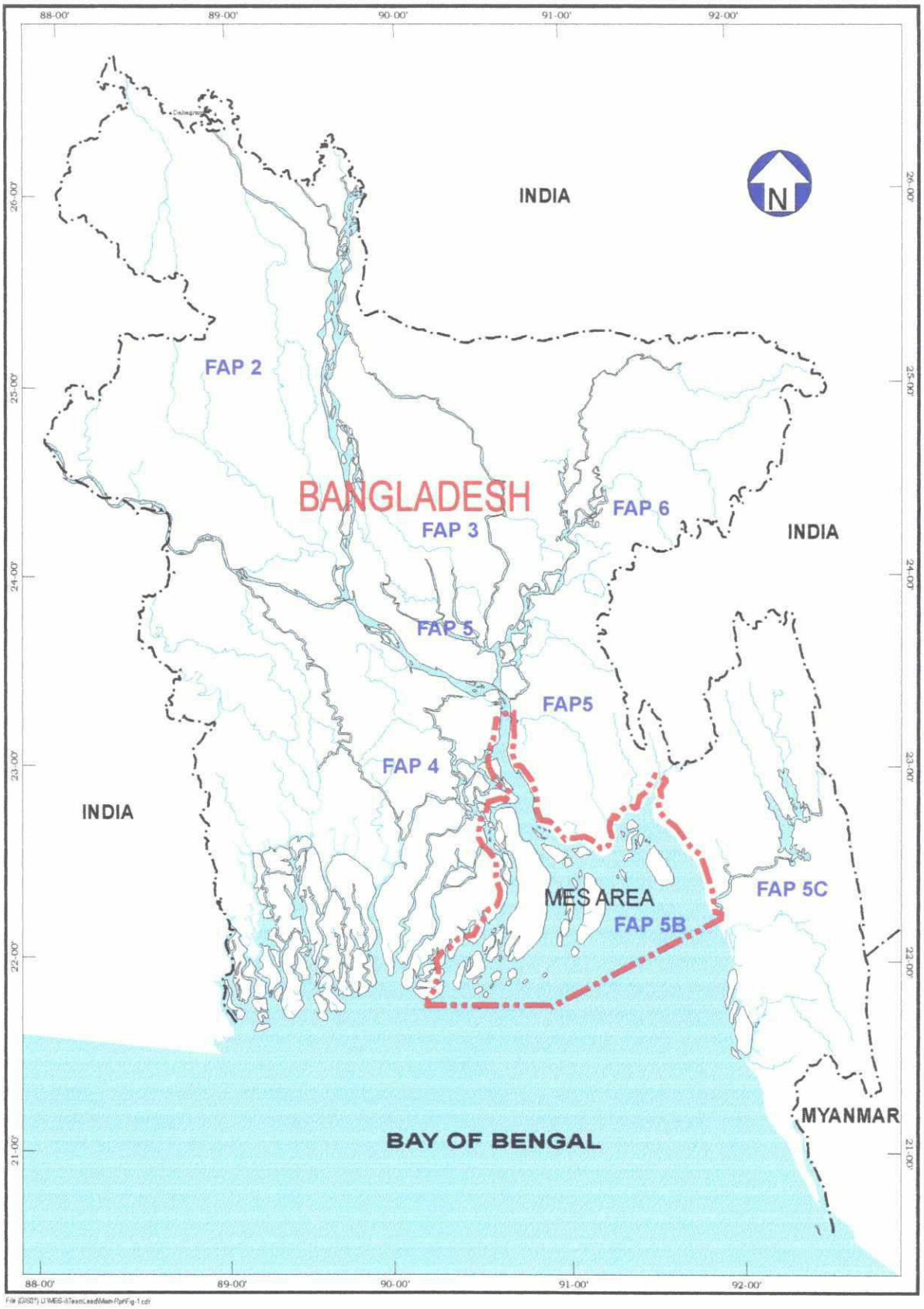
Integrated coastal zone management

Coastal zone management aims at solving present and future problems in the coastal zone, by finding a balance between economic welfare and environmental well-being. This may be achieved by careful analysis, planning and controlling of the natural processes and socio-economic developments. There is a need for controlled development of the Bangladesh coastal zone in an integrated manner because population growth and associated economic development and the erosion of existing valuable agricultural land place demands on coastal areas and resources, posing threats to the sustainability of the areas.

Resource use conflicts are often the primary underlying cause of problems as they result in the unsustainable use and unrestricted development of coastal areas and resources. ICZM provides a framework and practical tools to assist policy makers, planners, and resource managers to meet the challenges of sustainable development in the coastal areas. To be successful, ICZM should include an organisation which is mandated to plan, adopt and implement ICZM programmes or projects within an appropriate and adequate legal and institutional framework. Planning measures and strategies is useless if they cannot be implemented and enforced by laws and regulations and if there is no clear organisational infrastructure to manage the coastal zone system.

ICZM should be developed in a systematic manner which allows time for soliciting financial resources and building local managerial and technical capacities to support the identification and implementation of appropriate technological interventions; promoting interagency and stakeholders co-operation and co-ordination. It is appropriate to apply ICZM on a local level and proceed to more ambitious district and national levels after sufficient expertise has been developed.

Figure 1: Delineation of MES Study Area



The interested and affected parties at all phases and levels of an ICZM programme have to be involved in development and implementation. The public and private stakeholders can contribute to the identification of use conflicts and environmental management problems, determination of their causes and effects and to their resolution. Due to the complex and dynamic nature of the Meghna Estuary, it is important to integrate environmental, economic, and social information at the very start of the coastal development projects and programmes. Information gathering is a continuous process in the ICZM cycle, enriching knowledge as the process progresses.

Integration brings about the harmonisation of policies and legislation between national and local organisations. Co-ordination plays a central role in fostering understanding and co-operation among stakeholders, line agencies, researchers, policy makers, and resource managers. The sources of finance, which can be used to sustain management activities, should be explored before finalising the ICZM project or programme plan. The capacity of stakeholders to contribute effectively to the ICZM programme has to be strengthened. Integration of professional skills of different disciplines is required to support the formulation, design and implementation of a successful ICZM programme. These include ecology, geomorphology, marine biology, economics, sociology, engineering, political science (institutions) and law.

The social, environmental and economic impacts have to be monitored throughout the life of the ICZM programme. Monitoring provides a powerful tool for assessing the performance of projects and gives early warning of adverse effects so that corrective action can be taken to modify the design and management of projects to avoid irreversible impacts.

Planning zones and units

In order to be able to take the diversity systematically into account in the Master Plan as well as future planning the Meghna Estuary has been subdivided into three planning zones and each planning zone covers three to five planning units. The planning zones and units that have been delineated within the framework of the Master Plan are indicated in Figure 2.

The main criteria for delineating these planning units are derived from the type of interventions that have been identified within the planning zones. Other criteria are related to hydro-morphologic and administrative boundaries as well as a reference scenario for the development of the Meghna Estuary beyond the Master Plan period.

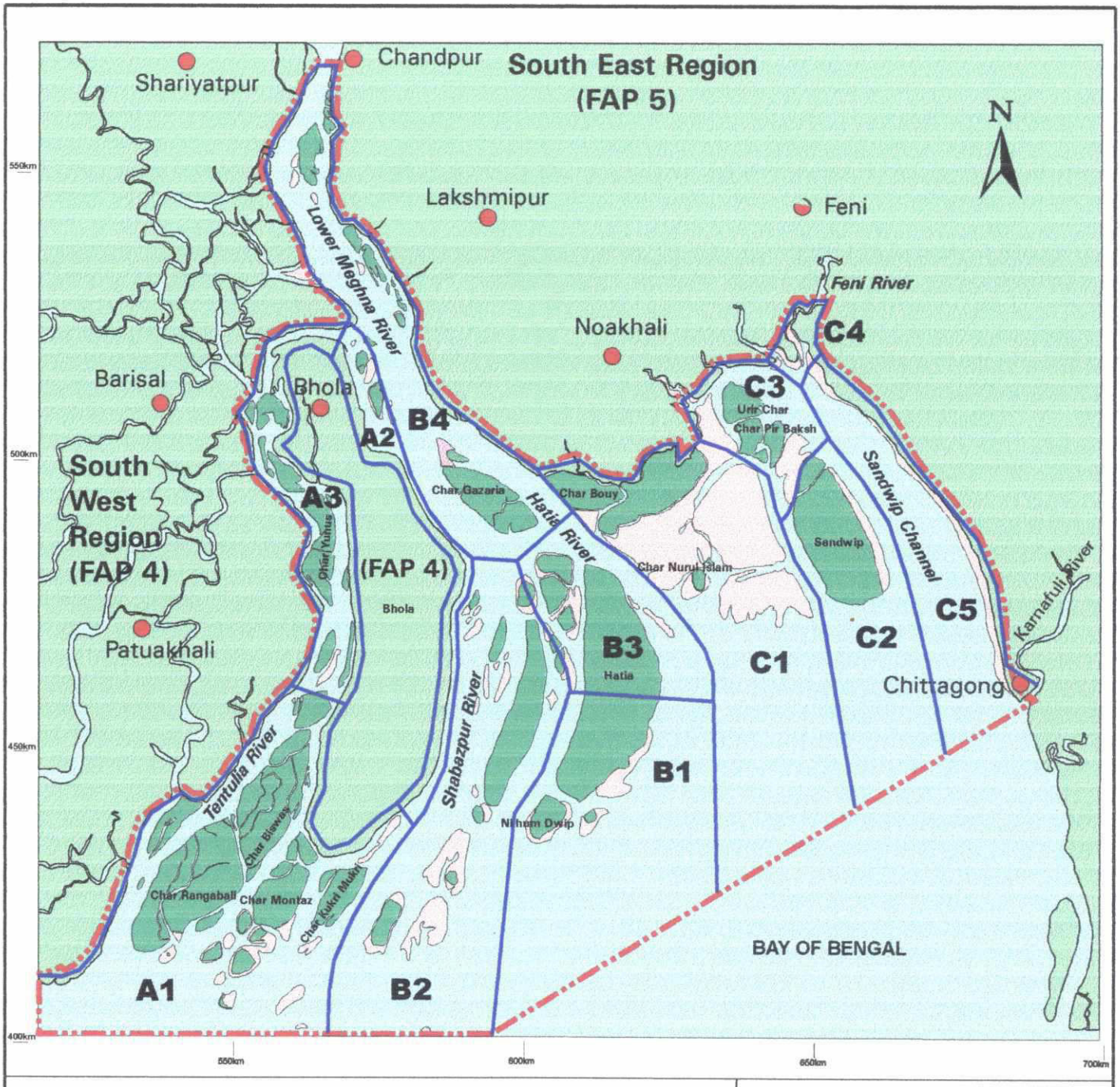
In all there are 20 broad types of intervention ranging from agricultural extension, through non-structural programmes (such as cyclone warning systems), to large scale construction of physical infrastructure. In addition there are environmental mitigation and enhancement programmes which are not interventions in their own right. The potential engineering interventions are indicated in Figure 3, the proposed Master Plan Implementation Schedule is shown in Figure 4.

Impacts

There are complexities of social differentiation of impacts (for instance by land holding size groups, income groups or occupations) and also spatial variation of impacts depending on the specific nature and location of the intervention. The likely upstream and downstream constraints and impacts of the broad interventions have also been considered, but these refer to areas outside the designated intervention area. There are also likely to be significant variations in impacts within the intervention area.

The time period over which prediction of impacts can be estimated does not extend beyond 25 to 30 years: predictions beyond this period cannot be considered as realistic. Immediate impacts include those that result from commencement of construction (such as land acquisition) and also those that are apparent soon after operations commence. Medium term impacts are those experienced some five to ten years after commissioning and longer term impacts are in the time period of 10 to 25 years and often include impacts on the natural environment which are slow to be apparent but are often irreversible. A good example of these is induced change to vegetation caused by changes in flooding conditions.

Figure 2: MES Planning Zones and Units



LEGEND

STUDY BOUNDARY

LAND IN STUDY AREA

TIDAL MUD FLATS

AREA OUTSIDE MES STUDY

PLANNING UNIT

DISTRICT HQ

NOTE: BHOLA IS EXCLUDED FROM THE STUDY AREA

MES PLANNING ZONES

A South-West Zone
B Central Zone
C North-East Zone

MEGHNA ESTUARY STUDY

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

10 0 10 20 30 40KM

SCALE

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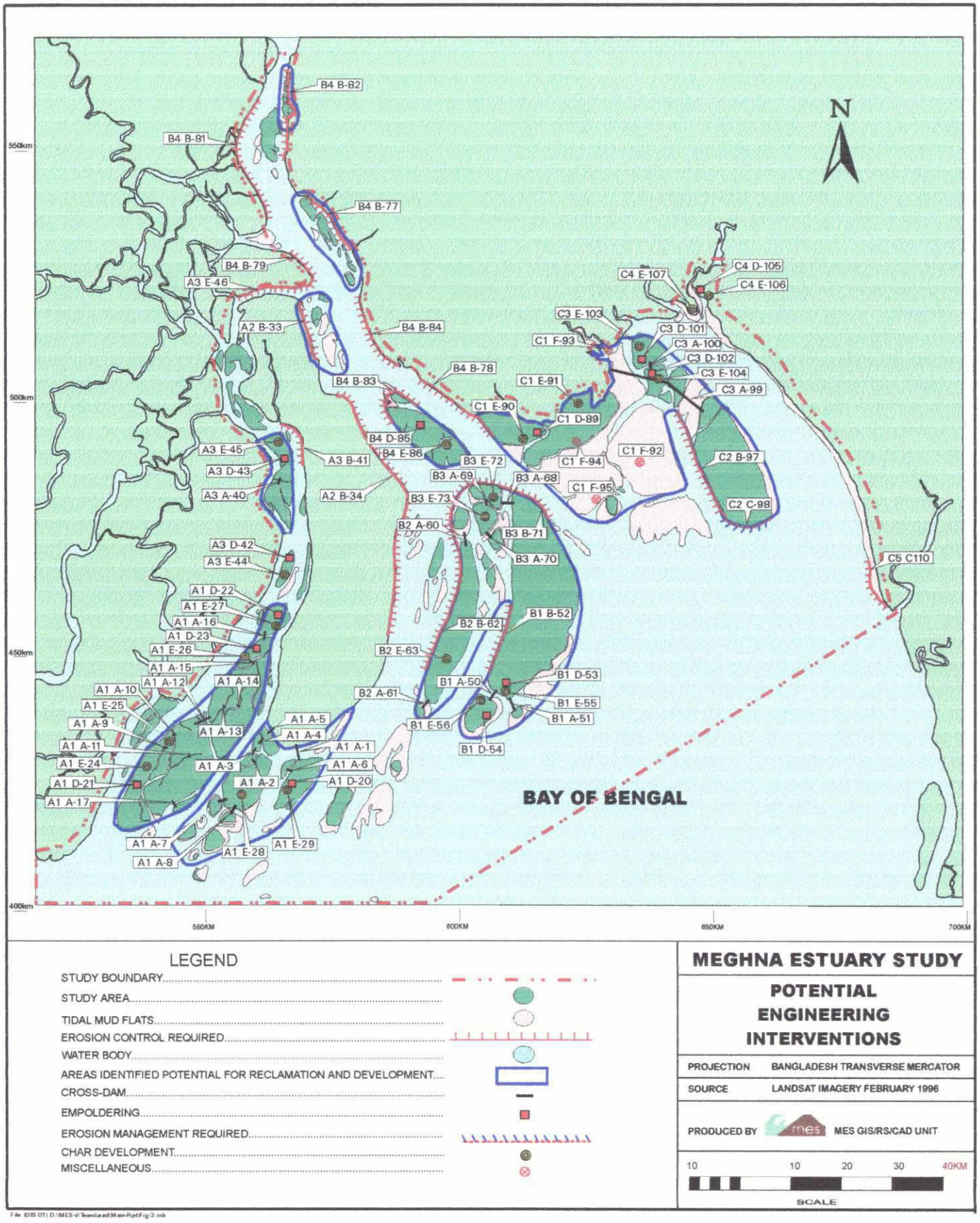
Figure 3: Potential Engineering Interventions



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 GIS/RS/CAD UNIT

10 10 20 30 40KM

SCALE

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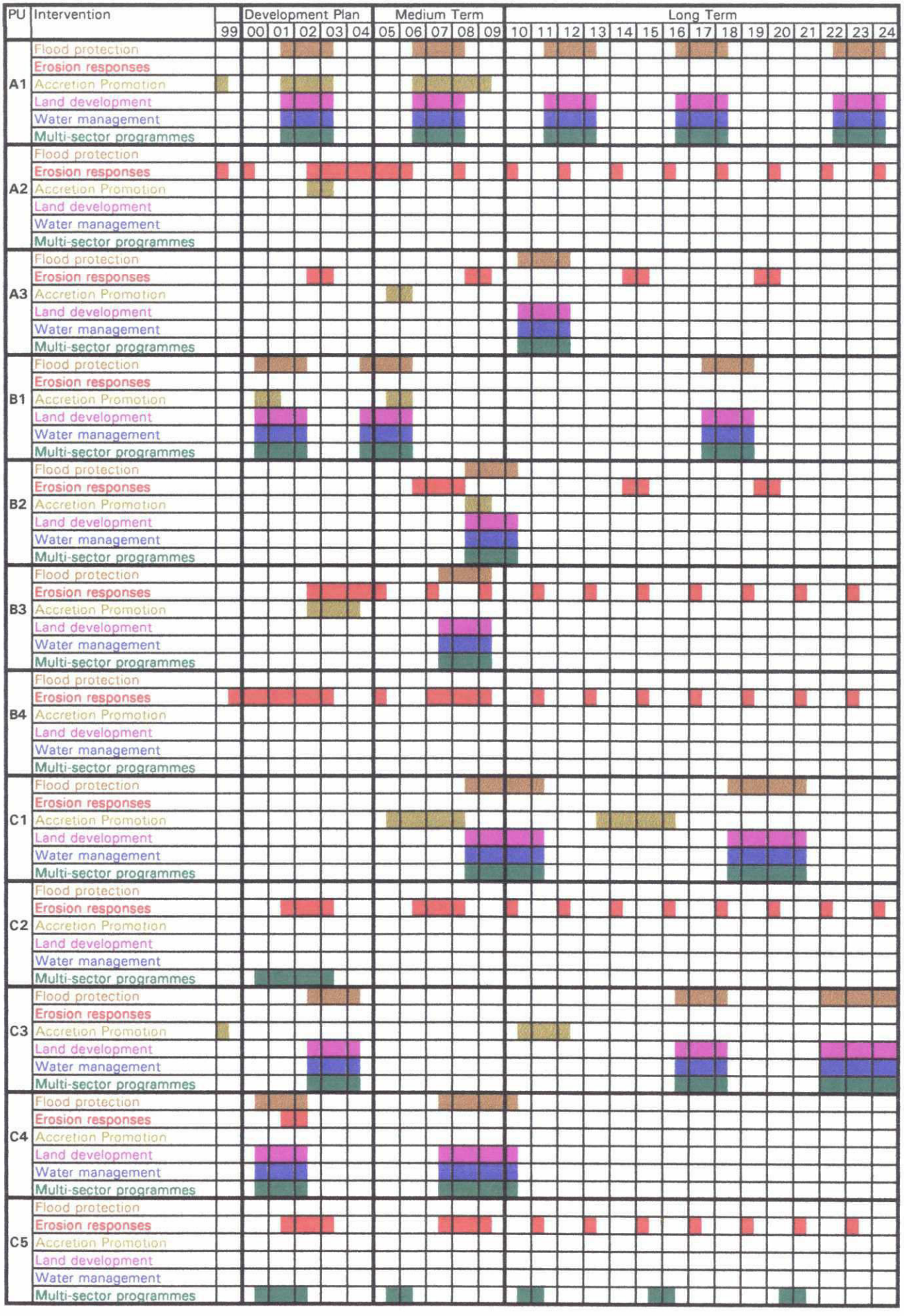
Figure 4: Master Plan Implementation Schedule



Most non-engineering sector programmes and non-structural interventions give positive impacts to the human environment, although some of these may not be particularly large. The engineering structural interventions are far more complex, giving larger impacts, both positive and negative, but often at a greater intervention cost.

Benefits and risks

The benefits to agriculture of many of the possible interventions may not be large, particularly in the newly accreted lands where saline intrusion and drainage remain significant problems. Production is also low where land levels are still too low to build embankments.

The present Guidelines for Project Assessment (GPA) emphasise economic returns to cultivation as a justification for interventions. However, in marginal areas such as most of the MES area, it is necessary to incorporate the benefits of livestock, forestry and fisheries into the analysis. A multi-criteria analysis is also needed to include into the overall assessment of a project those aspects which cannot easily be quantified.

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 criteria for phasing of the development are derived from the strategy formulated for the development of the Meghna Estuary. On the one hand new land has to be created and developed so that people who have become landless due to erosion of their homestead and land by the river can be settled again while, on the other hand, erosion has to be controlled to reduce the loss of valuable existing homesteads and land.

Acceleration of 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. However, 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 has to 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 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 relation 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 preliminary results of computer simulations indicate that velocities may increase in the main channels which will 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 will be required to offset the negative impacts of Sandwip cross dam.

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 its potential for developing new land. Before considering the implementation of Sandwip cross dam again, these changes and the requirements for mitigating measures, which appear to be considerable, must be studied in detail.

The planning of the development of Urir Char and Char Pir Baksh, must be based on a more detailed analysis of future 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 deferred until more certainty about the future morphological development has been obtained.

Unit C4 is situated in a relatively stable area form 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, B3 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 to nature. 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, for example Char Gazaria. Otherwise, the chars within the course of the Lower Meghna and Tetulia rivers should be left without erosion control measures and embankments.

As erosion control is one of the main components of integrated coastal zone management, it will be indispensable to develop adequate and economic measures to control erosion of the bank lines and coast line and to start implementing such measures 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.

Unit A2 includes the northeast and east coast of Bhola island between Ilsha in the northeast and Betua in the southeast of this island. In the past 25 years the coast line 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 may occur during the master plan period of 25 years. In planning unit A2 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 before about halfway through the development plan period. 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. The river also serves as the main navigation route to Barisal, Patuakhali and areas beyond. Several sections of the river bank have been severely eroded over time and this process is still continuing.

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 they protect long term stable land. In the long term Char Yunus may be empoldered and developed. However, a pre-requisite for this is adequate bank protection in place along the left bank of the Tetulia river opposite Char Yunus.

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. 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 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 B4 includes the main course of the lower Meghna river between Chandpur and Gazaria island, except the coast of Bhola. 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 again, as happened around 1970.

Meanwhile, the erosion along the eastern bank line will continue and may even accelerate later when the western branch channel loses more and more of its conveyance capacity. The severe 1998 flooding may already have initiated shifting of the main river channel from west to east. 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 chars will develop and disappear again as the river continuously reworks its bed.

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 was widened by siltation, the opposite banks of the branch channels continued and will continue to be eroded. The effect of tidal currents is very strong in this section of the Lower Meghna River.

As for 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.

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. 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. Piecemeal protection 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 C2 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.

Priority interventions

The following interventions (see Figure 5) will be given priority and be 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

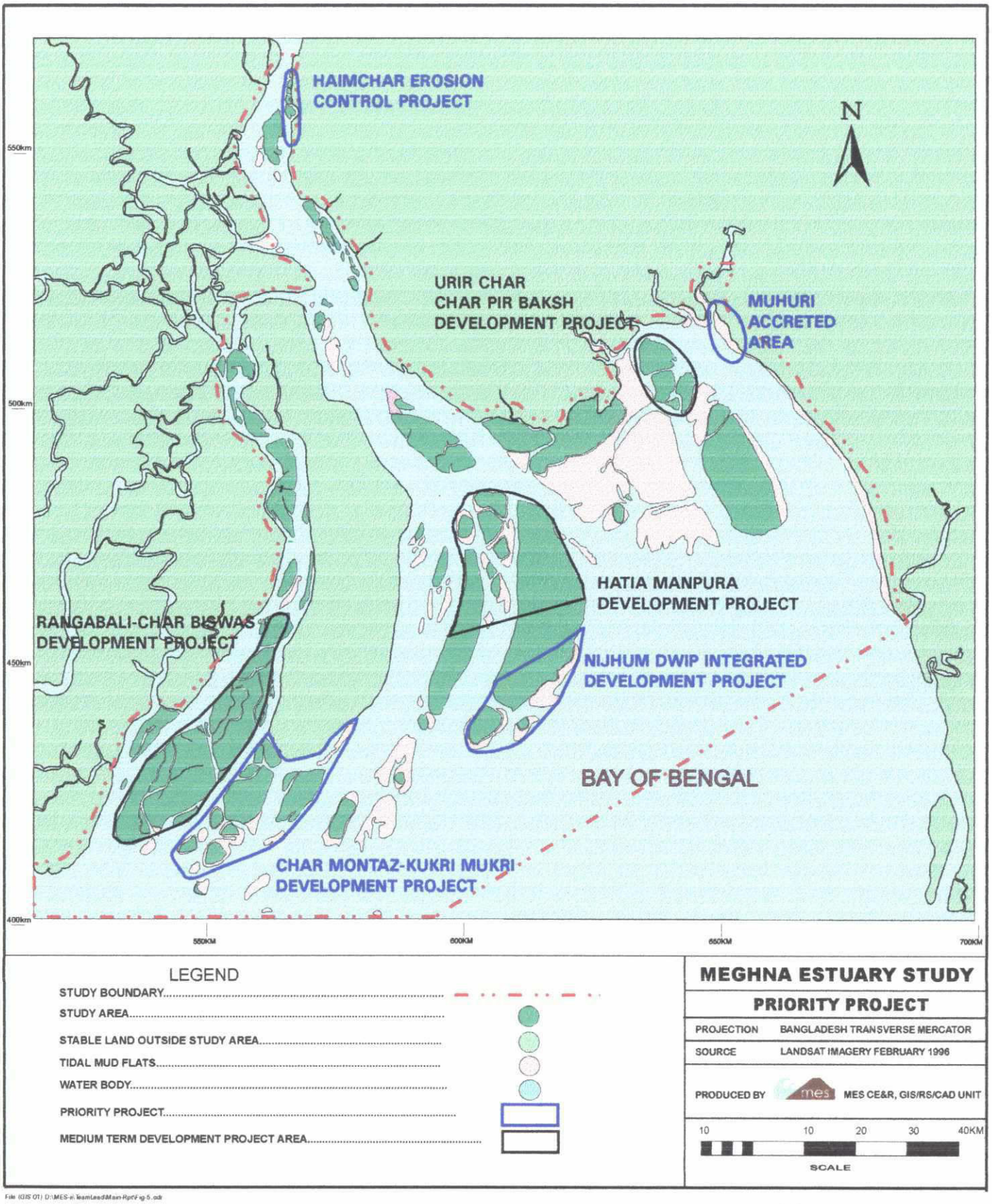
Rural development

The physical and climatic conditions that characterise the study area offer little by way of opportunities for economic development. Even with optimum engineering and extension inputs opportunities for improvements in land use strategies and incomes will remain poor, with only limited prospects for improvements in either standard of living or quality of life.

Social infrastructure provision, primarily health and education services, is very poor throughout the study area. Infant and maternal mortality is generally not recorded but the incidence of both is known to be high. Levels of literacy are low, even by national standards and children's school attendance levels are unsatisfactory. Cash incomes are low.

The results from the socio-economic survey suggest that, in the absence of in-migration, the number of people living on these off-shore chars is growing at a rate lower than national average for Bangladesh. In-migration is occurring, however, and there is reason to expect that activities projected and undertaken under the aegis of the proposed Master Plan and Development Plan process will result in more people migrating to the targeted areas.

Figure 5: Priority Projects



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Understandably, it can be anticipated that Government may not be able to provide basic education and health provision throughout the estuary within the foreseeable future. The high costs and difficulties of providing adequate levels of service to these remote regions surely cannot be justified given the relatively low total numbers of residents and the low levels of overall population density.

The study area can thus be characterised by an absence of opportunities for economic development. Similarly communities resident in the area are characteristically suffering the consequences and limitations associated with high levels of human deprivation.

Agriculture and farming systems

The natural resources of the MES area do not provide potential for a highly intensive farming system. The poor soil, the lack of water for irrigation and the capillary rise of saline water from the ground during the dry season indicate that there will always be limitations for the farm production. However. with the present situation where damage and losses are frequent there is a potential for reasonable improvements. A less risk prone environment might enable the subsistence level farming to develop into a system where income generation and accumulation of resources take place.

The initiation of any sustainable development of the farming systems in the offshore islands depends on the establishment of institutional structures, that support farmers in relation to land titling and to protect them against the power of big land owners and "land grabbers". Such structures are fundamental for the protection of farmers' interests and to ensure that farmers are able to benefit from their investments and various project interventions.

The overall strategy for development of the farming system of the offshore islands should be based on the expected potential of the different development activities, the inter-dependency of interventions and development activities, the evaluation of impacts and people's participation. The highest potential for development lies with the elimination and minimisation of damage and losses. As the losses resulting from crop and animal diseases and pests are somewhat increased by flooding and poor health status of animals, the improved environment for farming created by empoldering the land might mitigate the severity of these constraints. A general reassessment of constraints during implementation should be built into the development strategy.

An integrated whole farm approach based on assessments of farmer's needs and resources as well as an assessment of the communal resources in the area is more likely to result in sustainable development than implementation of individual components where conflicts in the use of resources are not taken into consideration. However, an integrated approach requires more effort and resources as well as planning and organisation.

Therefore, if selection is necessary, priority should be given to individual components with high potential such as improving animal health or a pest management. Physical development should have a strong emphasis on the institutional set-up for the operation and the maintenance of the polder system. Establishment of procedures through people's participation are essential for continued protection of the land and sustainable improvement of the environment for farming. Farmers are often capable of obtaining benefits from such improvements without further assistance.

Livestock and poultry programmes with a primary focus on animal health, participatory integrated pest management programmes at farm level and women focused homestead production programmes should be implemented immediately. The potential results are relatively minor compared to the potential of land protection systems, but the results are likely to be of a permanent character and the development sustainable.

Marine fisheries

At present there is a tremendous risk that the 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 of the fishing effort or the use of large mesh sizes can be recommended. Such a recommendation fits well in the traditional sectoral basis of fisheries management, mainly concerned with issues and impacts within the fisheries sector. Traditional fisheries management presupposes that corrective action would be taken by other sectors to eliminate or modify externally generated impacts on the fisheries sector. However, this is an illusion and fisheries management demands a more integrated approach within the context of integrated coastal area management and an overall rural enterprise development policy

Fisheries in the coastal areas of Bangladesh is "poverty driven". The Bay of Bengal is one of the few "open common resources" left in Bangladesh, still attracting numerous labourers from the poorest segment of the population. This trend will continue till the moment the system collapses. Reversing this trend can only be tackled with integrated development projects creating investment opportunities and employment outside the fisheries sector and channelling surplus labour to other sectors of the economy. This will be a long term and difficult task and there will still be a high risk that the system will collapse before it can be achieved.

The long term strategies should be implemented at the national level and improvement will be a long term, gradual development process. However, in order to try to slow down the process of degradation several actions should be undertaken immediately, including the setting up of a credit programme, an estuarine set bagnet replacement programme, a programme for the reduction of post-harvest losses, improved monitoring and a major research programme on the spawning and nursery of estuarine dependent fish and shrimp species. All fisheries related activities should be a part of an integrated coastal management strategy.

Aquaculture

It is now generally recognised that shrimp farming must enter a new era. Compared to poultry, cattle or even fish production, shrimp farming is primitive. In order to compete in the future and become a more sustainable activity, a long term strategy for shrimp farming should be adopted based on proper coastal management plans, domestication and genetic improvement of stocking material, sustainable rearing techniques, disease diagnostics and treatment methods, advanced feeding strategies and implementation of sound environmental management plans.

Replanning and zoning of the shrimp farming industry within the context of a Coastal Area Management and Development Plan can be undertaken at an early stage as past experience has made policy makers and shrimp farmers aware of the problems. A major bottleneck, however, is the continuing existence of the China virus in the environment. In the long run it will most likely disappear, but without changing the roots of the industry a new disease will certainly appear with similar impacts to the China virus. A major change would be the development of pathogen free, certified, hatchery reared post-larvae, which is a long term process.

Forestry

Any kind of forest development planning in the estuary must take into account the extremely dynamic nature of the rapidly changing coastal environment caused by the continuous erosion and accretion phenomena, with special focus on the areas outside the embankments.

The overall effect of sedimentation is the expansion of the land area in the estuary. This implies a continuous outward movement of the habitable areas as land rises. The effect of this on the mangrove plantations is a change in the bio-physical conditions for the plantations leading to a succession towards other species. From a forestry perspective, the development of dynamic management schemes capable of responding to the successional nature of the bio-physical environment and ecological conditions with special focus on the areas outside the embankments is clearly needed. Classification and allocation of land use categories must also respond to the successional nature of the estuary development. Criteria for the land use categories should be developed.

Resource assessments must be frequent and utilise modern information processing methods to ensure timely information, as an integral part of the resource management strategy. Developing training programmes for the participants on land use planning and project preparation, including the strengthening local organisations in support and implementation of social forestry projects is a prerequisite. The traditional functions of the Forestry Department focused on enforcement, must change to one of extension and participation, in view of the past experience of the management of state forests. Any programme must include strengthening of the national institutions, calling for investment in human resources. At the local level, development of proper institutional and organisational arrangements to involve the people in the execution of such programmes, with the focus on devising and implementing integrated land use systems with forestry playing a major role must be emphasised.

Environmental impact analysis

The results of the three feasibility studies carried out for the MES indicate that if an inter-disciplinary and flexible planning approach is followed then most predicted negative impacts can be avoided or minimised and benefits can be increased. The overall cumulative negative impacts on in-shore marine fisheries could be serious although the predicted decline irrespective of any MES intervention is so severe that the differential impact is probably not large.

For all of these proposed interventions, the predicted value of the economic benefits is low and long term. While social benefits are an additional justification, they need to be carefully targeted to be in line with government and potential donor policies and priorities. Feedback is required from government to give its priorities and to see what type of project it is prepared to fund and under what conditions. In addition, the estimated intervention costs per beneficiary household are high, especially compared to other alternative uses of the resources and other water sector projects in Bangladesh. Priorities need to be set at national level, as part of the National Water Master Plan, based upon likely economic resources that could be made available for development.

There are no environmental grounds that seriously negate the benefits of the proposed interventions, however care is needed in implementation. For the two integrated development projects a long term and phased approach is favoured, with continuous monitoring.

Morphological processes

The Meghna Estuary system is a very dynamic estuarine and coastal system, this system forms the northern end of the Bay of Bengal where some of the world's largest rivers, the Ganges, Brahmaputra and Meghna join and flow via the Lower Meghna river into the sea. 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 sediment discharge from the Lower Meghna river is the highest and the water discharge the third highest, of all river systems in the world. The river borne sediment load of the Lower Meghna river amounts to more than a billion tons annually and is dominated by silt to fine sand. The river discharge varies between approximately 20,000 m^3/s during the dry season to more than 100,000 m^3/s during the monsoon.

The changes in tidal flow direction and channel topography, the occurrence of new channels and newly accreted land and abandonment of old ones are the rapid building and destroying processes that exist in the estuary. These processes trigger changes in sedimentation and erosion rates which are directly related to the change in discharge and sediment content. The knowledge about the physical processes and morpho-dynamic behaviour of the Lower Meghna Estuary system is still fairly limited. A complicated interplay between the forces of the river, tide and the waves creates a complex pattern of sediment displacement in the estuary.

Large quantities of sediment are transferred continuously towards the shallow coastal region of Bengal, the overall sediment budget is determined by the continuous redistribution process of the sediment in the river system upstream.

The displacement of sediment is one part of a continuous process of the estuarine landscape striving to achieve dynamic equilibrium between the physical shape (morphology) and the constantly changing river discharge conditions and the continuously changing tide flows.

The Meghna Estuary system exhibits a funnel shape. The river influence becomes progressively larger in an upstream direction as friction drains tidal energy. Tidal influence extends substantially farther upstream than salt intrusion and deltaic sedimentation occurs only in the subaqueous environment. There is appreciable upstream transport of bed load and suspended load sediment as a result of deformation of tide propagation. Sediment is received from both the river and Bay of Bengal, yet most of the sediment received by the river ends up being transported and deposited by tidal currents.

Salinity data indicate an enormous seasonal effect on salinity in the coastal area due to the influence of the huge fresh water discharge from the Lower Meghna river. Approximately during the period from mid-August to mid-October the salinity in the MES area drops considerably and the water becomes almost completely fresh. After the monsoon the salinities rise again and the sea water intrudes into the study area. However, even during the period with low river discharges the salinities in the area never approach normal sea water salinity but always remain distinctly lower.

A time series of satellite images for the period 1973 to 1998 were used to examine the extent of land and intertidal area (i.e., mudflats) and to assess the changes in the project area. The net change of mudflats for this period is 76,300 ha or about 3,000 ha per year. The net change by period shows an overall land gain in the Meghna estuary system as a whole, for the period 1973-1998 of about 19,900 ha. However observed changes show periods of gains (maximum 20,000 ha/year) interspersed with periods of severe land loss (up to 8,900 ha/year). The average natural gain of land for the entire study period is about 800 ha per year.

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 6. It is predicated that the Lower Meghna will widen its channels substantially while new chars will be formed in this widened river channel.

The sediment supply from the catchment to the estuary is much less in the dry season than during the monsoon. In the northern part of the estuary, where the flow is jointly influenced by the river flow and by the tide, the transport capacity decreases in the dry season, thereby further reducing the supply of sediments to the southern parts.

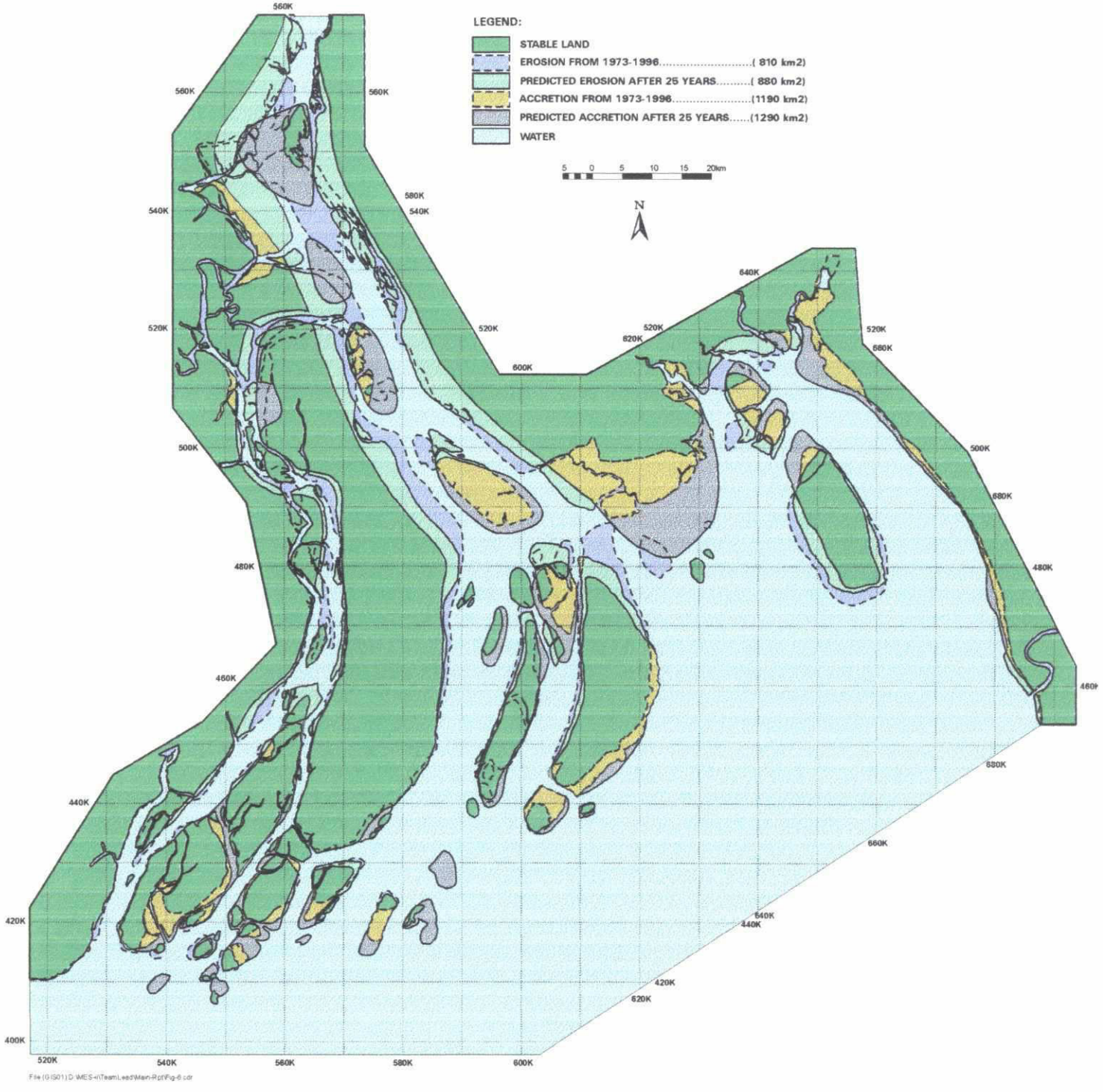
In the southern part, where the flow is predominantly determined by the tide all the year round, the transport capacity decrease is small, so a gross loss of material from this area will occur (as the supply is reduced while the loss is unchanged).

During the monsoon, the supply of sediments and the transport capacity of the main net flow channels are at their highest (while, in the purely tidal channels, the transport capacity is more or less the same all year). In this season, the major erosion and accretion takes place.

As is the case all year, the loss of material from the estuary is related to the transport capacity in its southern part, through which the material must pass before it is eventually lost to the Bay of Bengal. This area is tide dominated, so the seasonal transport capacity variation is small. Therefore, since the supply of material is high, material will accumulate within the estuary during the monsoon.

The seasonal changes in river flow suggest that sediment can accumulate in the upper estuary during the pre-monsoon and post-monsoon and be redistributed down the estuary during monsoon. 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.

Figure 6: Past and Future Accretion and Erosion Patterns



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. However, a significant proportion will undergo many cycles of deposition on the bed followed by re-suspension, with the deposition occurring at a number of points along the estuary which form temporary sinks for the sediment particles operating for a variety of time scales.

Preliminary results of the studies indicate an overall tendency of silting up of the Sandwip Channel and levelling up of the shallow areas between Hatia and Sandwip.

An overall sedimentation trend can also be seen near the edge of the delta front where new islands and intertidal areas are formed and silted up. The results show a dominant erosion trend around north Hatia and north Bhola. The morphology of the Upper Tetulia river is relatively stable compared to the Lower Meghna Estuary. Alternate erosion and sedimentation patterns along the Lower Meghna River, in particular in the area between Chandpur and north Bhola, might indicate that the channel is very mobile and sensitive to river discharge and tidal conditions. The East Shahbazpur channel is, compared to the West Shahbazpur channel, relatively stable and tends to silt up only slowly. The southeast and south sides of Bhola and Hatia also tend to silt up.