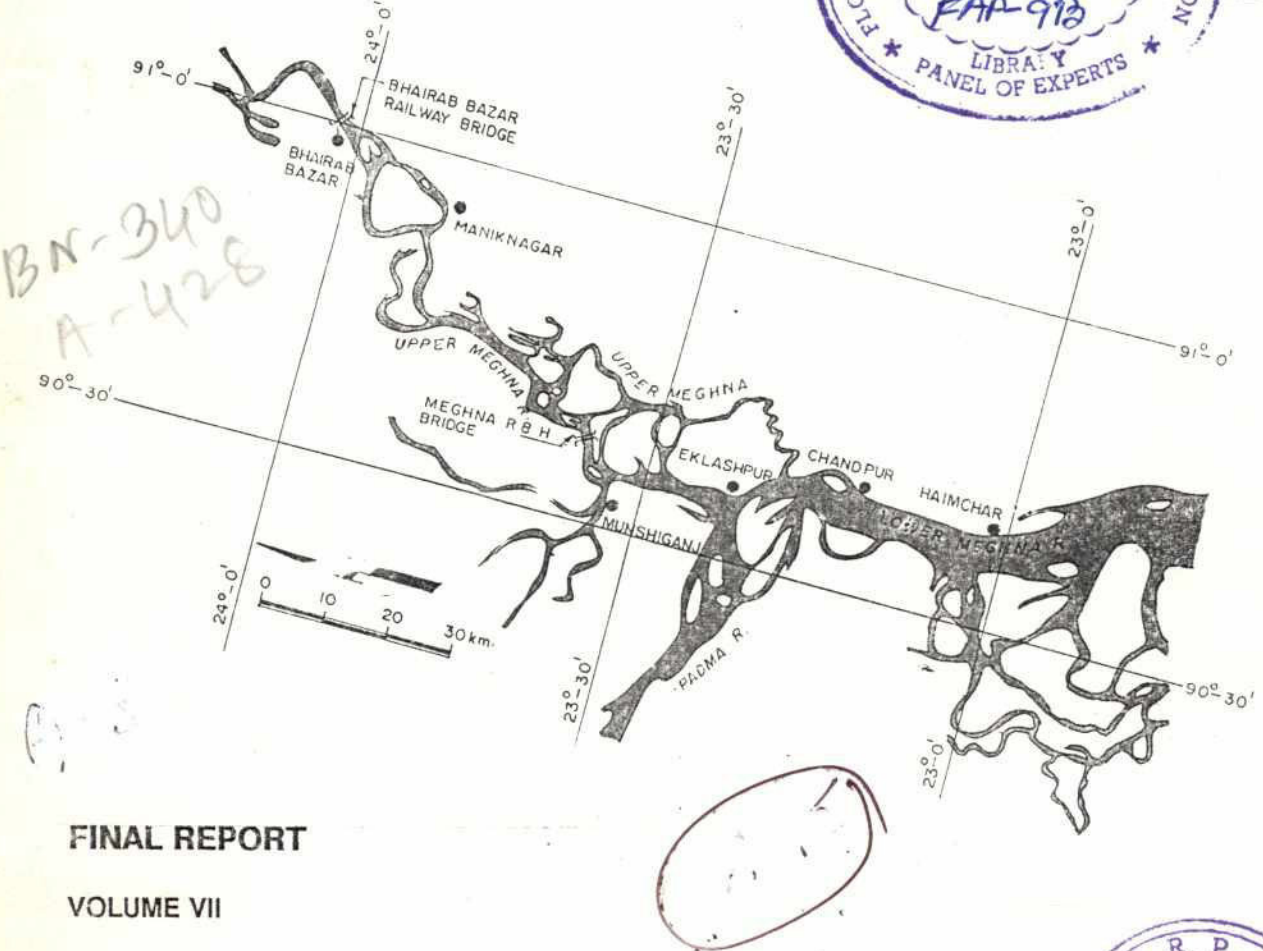
GOVERNMENT OF BANGLADESH

BANGLADESH WATER DEVELOPMENT BOARD

MEGHNA RIVER BANK PROTECTION SHORT TERM STUDY

IDA Credit 1870 BD (Part D), March 1990



FINAL REPORT

VOLUME VII

ANNEX: I ENVIRONMENTAL IMPACT ASSESSMENT

February 1992

HASKONING, Royal Dutch Consulting Engineers and Architects

Delft Hydraulics

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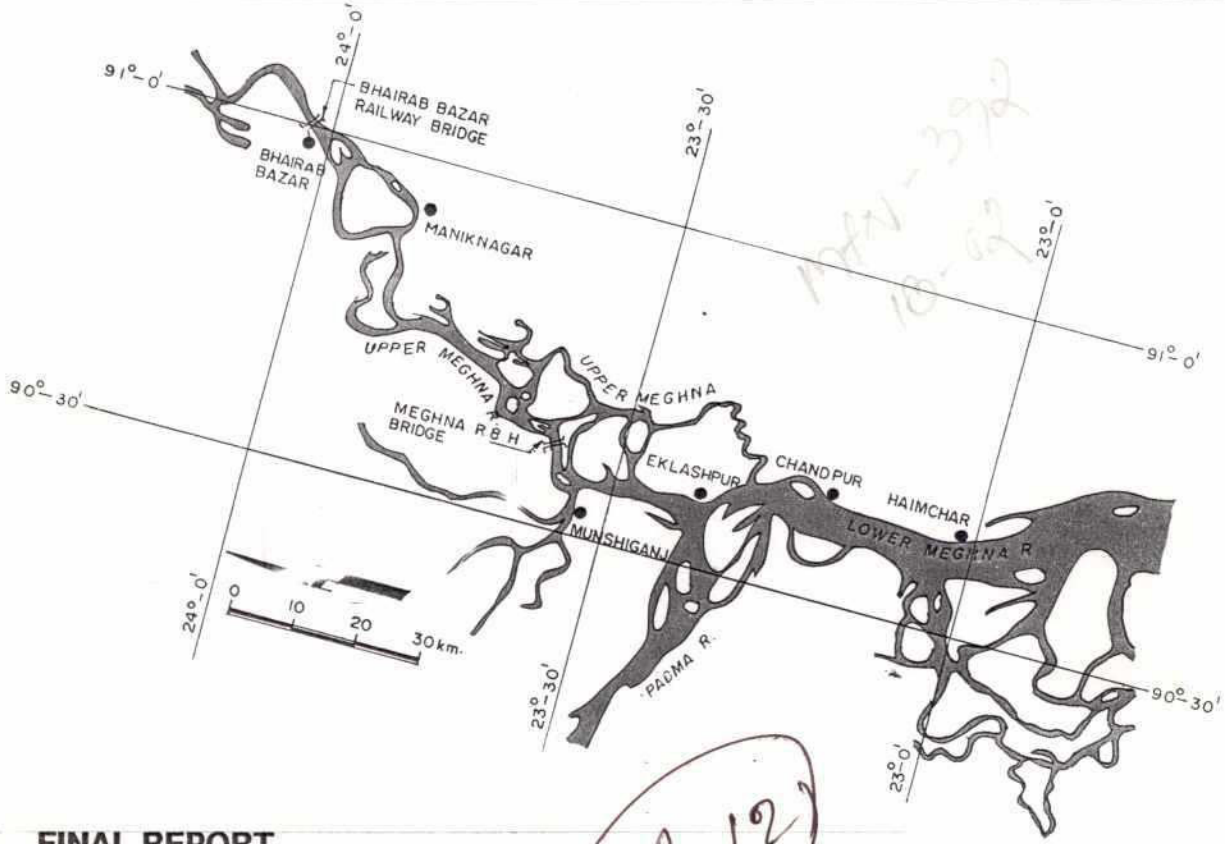

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HASKONING, Royal Dutch Consulting
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in association with:

DELFT HYDRAULICS
BANGLADESH ENGINEERING & TECHNOLOGICAL SERVICES LTD.

PREFACE

The Meghna, one of Bangladesh' major rivers, flows through the eastern part of Bangladesh and discharges into the Bay of Bengal.

Like other rivers in Bangladesh the Meghna erodes it banks in many points and this erosion has assumed an alarming magnitude since the severe floods of 1987 and 1988. Consequently, a number of locations requires prompt attention to prevent further damage or even events of a catastrophic nature.

This Final Report describes the surveys, studies, designs, cost estimating and economic evaluation carried out during 1990-1992 as part of the Short Term Study (FAP-9B) for Meghna Bank Protection.

The Report consists of seven volumes comprising a Main Report and eight Annexes A to G and I. Some Annexes are accompanied by a series of APPENDICES containing detailed information or supporting data relevant to them.

Vol I			Main Report
Vol II	Annex	A :	...ydrology
		B :	River Morphology and Geomorphology
Vol III	Annex	C :	Geotechnical Investigations
Vo. IV	Annex	D :	Scale Model Studies
		E :	Mathematical Model Studies
Vol V	Annex	G :	River Bank Protection
Vol VI	Annex	F :	Economics of Protection Works
Vol VII	Annex	H :	(not used)
		I :	Environmental Impact Assessment.

INTRODUCTION TO THE PROJECT

1. Background

There are three major rivers in Bangladesh; the Ganges, the Brahmaputra and the Meghna. Originating form Assam in India, the Meghna River flows through the eastern part of Bangladesh and discharges into the Bay of Bengal. The Meghna River drains an area of 77,000 km^2, of which about 46,500 km^2 is located in Bangladesh. The major contributors to the river upstream of Bhairab Bazar are the Boulai, the Surma and the Kushiyara rivers, covering an area of 62,960 km^2. The Ganges joins the Brahmaputra near Aricha and thereafter takes the name of the Padma. The Padma joins the Meghna at Chandpur. The Lower Meghna River conveys the melt and rain water form the Ganges and Jamuna basins, combined in the Padma River, and from the Upper Meghna basin to the sea. The total catchment area is about 1,637,000 Km^2. Maximum flows can be as high as 160,000 m^3/s. The major contribution of the discharge originates from the Jamuna River (annual average 19,642 m3/s) and the Ganges River (annual average 10,874 m^3/s).

The reach of the Meghna River from Bhairab Bazar to Haimchar is about 160 km in length. Width of the river varies from 1 km to more than 10 km. The river channel is more or less well defined upstream of its confluence with the Padma and is braided in the reach downstream of Chandpur. The river is considerably deep all along and the depth ranges to 35 m in the bends. The river bed and banks consist mainly of clayey-silt which is often loosely packed and is susceptible to liquefaction at some places. Of the three major rivers, the Meghna carries relatively less sediment. The velocity of flow of the river is high during monsoon. The river banks are also subjected to heavy wave action at some points.

Like other rivers in Bangladesh, the Meghna erodes its banks in many points. Erosion at the Meghna since the severe flood of 1988 has assumed an alarming proportion at the following locations which require prompt attention.

- The Railway bridge at Bhairab Bazar;
- Bhairab Bazar Township along the right bank;
- Maniknagar; along the left bank, falling within the proposed Gumti - Phase II Project;
- Meghna R & H Bridge;
- Eklashpur (near Meghna-Dhonagoda Project);
- Chandpur Town;
- Haimchar (adjacent to Chandpur Irrigation Project);

The Dhaleswari River, a tributary of Meghna, has been eroding its right bank at Munshiganj for quite some time and has threatened the existence of Munshiganj Town.

2. Meghna River Bank Protection -Short term Study

The study of possible bank protection works at critical locations along the Meghna river commenced officially in September 1990 when BWDB, Bangladesh Water Development Board commissioned HASKONING, Royal Dutch Consulting Engineers and Architects in association with DELFT HYDRAULICS and BETS, Bangladesh Engineering and Technological Services, to carry out the Meghna River Protection Short Term Study, financed under Credit IDA BD-1870, Part D.

The objectives of the study are:

- to provide short term measures for protection against erosion for seven locations on the Meghna river and one location on the Dhaleswari;
- to gradually implement a coherent and phased programme of works, aiming at the control of erosion on the defined stretches of the rivers Meghna and Dhaleswari. The protection of the locations indicated above should logically fit in this programme.

The Inception Phase started in November, 1990 with the mobilisation of the Expatriate Consultants. During the Inception Phase, the inter-action between this study and Flood Action Plan (FAP) Components was identified and maintained as far as possible.

The Meghna River Bank Protection Short Term Study, is now one of the **main components** of the Flood Action Plan for Bangladesh (FAP-9B. MEGHNA LB PROTECTION PROJECT), as included in the Review Report FPCO, December, 1990.

It has been recognised that during the Inception Phase, due to the internal and international situation during November 1990 to February 1991, delays were experienced, hampering the normal development of the activities planned. Therefore, activities in the critical path of the study were delayed (i.e, hydrometric surveys, geotechnical investigations, model investigations at RRI).

Furthermore, during the first phase of the project it became more and more clear that the inclusion of the flood season in the survey would considerably improve the designs of the protection works, the Consultants were supposed to submit at the end of the Study. Moreover, strengthening of the relation with the studies of the Bangladesh Action Plan for Flood Control (FAP) would also have a positive contribution to the outcome of this project. Therefore the BWDB instructed the Consultants to review and update the work plan taking note of the flood season of 1991 and the aforementioned studies of FAP.

As part of the Study a priority ranking was established. Accordingly, it was decided:

- to carry out a feasibility study, detailed designs and tender documents for bank protection works at the following locations:
  - Bhairab Bazar Township and Railway Bridge;
  - Munshiganj Town located on the Dhaleswari River;
  - Chandpur Town;
- to carry out a full feasibility study and prepare tender documents for bank protection works in the following locations:
  - Eklashpur;
  - Haimchar;

- and only a pre-feasibility study for

  - Meghna Roads & Highways Bridge;
  - Maniknagar, part of Gumti Phase II Project.

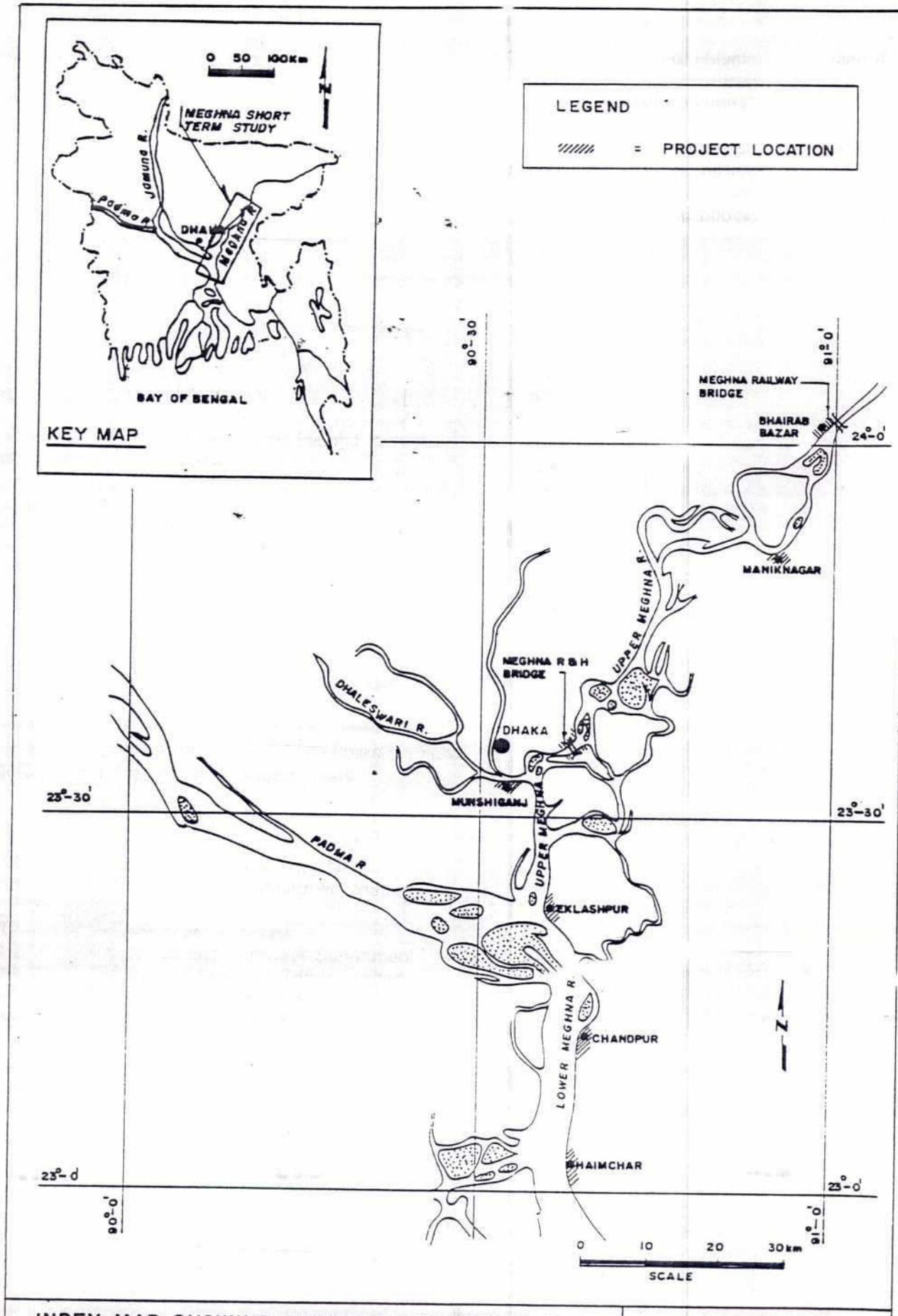
This Final Report submitted in accordance with the (Revised) Terms of Reference comprises all feasibility studies carried out as well as the detailed designs for bank protection works at the three locations mentioned above.

ABBREVIATIONS AND GLOSSARY OF TERMS

ADB	Asian Development Bank
BCSIR	Bangladesh Council for Scientific and Industrial Research
BBS	Bangladesh Bureau of Statistics
B/C	benefit cost ratio
BCL	Bangladesh Consultants Limited
BETS	Bangladesh Engineering and Technological Services Ltd
BH	Bore hole
BIWTA	Bangladesh Inland Water Transport Authority
BIWTC	Bangladesh Inland Water Transport Corporation
BOD	Biological Oxygen Demand
BR	Bangladesh Railway
BS	British Standards
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
°C	degree Celsius
CC blocks	concrete blocks
CIF	Cost, insurance and freight
CPT	Cone Penetration Test
Crore	10,000,000
DH	Delft Hydraulics (Netherlands)
Dollar (US)	taken at an exchange rate of Tk.36 for the Study
EIA	environmental impact assessment
EIRR	economic internal rater of return
FAO	Food and Agricultural Organization (United Nations)
FAP	Flood Action Plan
F/C	foreign currency
Fig(s)	figures(s)
FML	fortnightly mean water level
FPCO	Flood Plan Coordination Organization
g	acceleration due to gravity
GL	ground level
ha	hectare(s)
hr	hour(s)
IBRD	International Bank for Reconstruction and Development
ICB	international competitive bidding
IDA	International Development Association
IRR	internal rate of return
IWTA	Inland Water Transport
JICA	Japan International Cooperation Agency

kg	kilogramme(s)
km	kilometre(s)
Km^2	square kilometre(s)
km/h	kilometre per hour
Kn	kilonewton
Lakh	100.000
L/C	local currency
LCB	local competitive bidding
LWL	Low water level
m	metre(s)
MAT	Manual and automatic tidal gauge
MCA	multi-criteria analysis
m/s	metre(s) per second
m^2	square metre(s)
m^3	cubic metre(s)
m^3/s	cubic metre(s) per second (cumecs)
MG	Metre Gauge
mm	millimetre(s)
MMSS	Mica schist silty sand
MN	meganewton
MPO	Master Plan Organization
MSL	mean sea level
N	Newton
NEDECO	Netherlands Engineering Consultants
NMC	natural moisture content
N-value	standard penetration test value
ODA	Overseas Development Agency
OECF	Overseas Economic Cooperation Fund
OMC	optimum moisture content
p.a	per annum
PDB	Power Development Board
PDF	Probability density function
PWD	Public Works Department (datum)
RC	reinforced concrete
RHD	Roads and Highways Department
RPT	Rendel, Palmer & Tritton Limited
RRI	River Research Institute
RTW	river training works
s.sec	second
SHW(L)	standard high water (level
SLW(L)	standard low water (level)
SOB	Survey of Bangladesh
SPT	standard penetration test
SWMC	Surface Water Modelling Centre
sq.km	square kilometre(s)

t(tons)	metric tons
Tk	taka
TOR	Terms of Reference
US$(or$)	US dollar(s)
USCS	Unified soil classification system
WB	World Bank



INDEX MAP SHOWING PROJECT LOCATIONS FOR THE MEGHNA SHORT TERM STUDY

ANNEX - I

ENVIRONMENTAL IMPACT ASSESSMENT

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I.1 INTRODUCTION

I.1.1 Background

The Meghna, one of Bangladesh's major rivers, flows through the eastern part of the country to the Bay of Bengal. The erosion of it's banks is alarming in many places. Therefore, the Meghna River Bank Protection - Short Term Study was initiated to prevent further damage. The study is one of the main components of the Flood Action Plan for Bangladesh (FAB-9B. Meghna LB Protection Project).

The Meghna River Bank Protection - Short Term Study has two objectives:

- provide short-term measures for protection against erosion for six locations on the Meghna river and one location on the Dhaleswari river;
- gradually implement a coherent and phased programme of works, aimed at controlling erosion at defined stretches of the rivers Meghna and Dhaleswari. The protection of the locations indicated above should fit in logically with this programme.

I.1.2 Environmental assessment

The Government of Bangladesh and the World Bank are concerned about the effects the proposed Meghna river-bank protection works would have on the environment and therefore requested the preparation of an Environmental Impact Assessment. The present environmental assessment was conducted in accordance with the World Bank Operational Directive 4.00, Annex A: Environmental Assessment (1989), and the draft Guidelines for Environmental Impact Assessment of the Bangladesh Flood Action Plan (1991).

Environmental assessment is a flexible procedure which may vary in scope, depth and analytical techniques, depending on the project. The detail and sophistication of the study should be in proportion with the expected impacts. The scope of the present Environmental Impact Assessment is limited. Two objectives were formulated in the Terms of Reference:

- evaluation of potential negative impacts which river-bank protection may have on the environment; and
- proposition of measures which prevent, lessen, or compensate the identified environmental impacts.

I.1.3 Study methodology

In order to obtain a concise report which covers all significant environmental issues, a four-phased work plan has been adopted:

Phase 1: Analysis of the proposed project activities.

Phase 2: Description of the existing environment and autonomous development relevant to the project.

Phase 3: Evaluation of potentially negative environmental impacts.

Phase 4: Recommendation of preventive, mitigative or compensatory measures.

The necessary information was obtained from a number of sources:

- interim report and technical documents on project design;
- site visits to the project locations and other areas which may be affected by the project;
- environmental and socio-economic survey of the project locations;
- consultation of Bangladeshi officials and project experts;
- review of literature on existing environmental conditions, possible environmental impacts of the project activities, and alternatives for mitigation.

I.1.4 Contents of the Annex

The present Annex describes the existing environment and autonomous development in chapter I.2, within the framework of the proposed project activities: in this case the emphasis lies on the aquatic environment.

In chapter I.3, the proposed project activities are elaborated for each of the seven locations, taking into account the different phases of the project.

The combination of information on the existing environment and proposed project leads to the identification of potential environmental impacts in chapter I.4.

Chapter I.5 examines options for mitigation of impacts.

Chapter I.6 presents the executive summary with conclusions and recommendations of environmental assessment.

I.2 EXISTING ENVIRONMENT

I.2.1 General

The description of the existing environment is limited to those aspects which are relevant to the proposed project activities. Therefore, the emphasis lies on the riverine and estuarine environment.

Within the framework of the Meghna River Bank Protection - Short Term Study, detailed reports have been issued in the fields of hydrology and river geomorphology: Annexes A and B. Annex C covers the results of the geotechnical investigations. Information from these reports in summarized in the present Annex.

I.2.2 Study area

Originating in Assam, India, the Meghna flows through the eastern part of Bangladesh to the Bay of Bengal. The confluence of the rivers Ganges, Brahmaputra, and Meghna is known as the Lower Meghna, the third largest river and the largest estuarine delta in the world. The Lower Meghna is six times larger than the Upper Meghna due to the confluence with the Padma, which is the continuation of the Ganges and Jamuna (or Brahmaputra) R.

The study area stretches along the Meghna from Bhairab Bazar to Haimchar, a length of approximately 160 km, and includes one location on the Dhaleswari river near it's confluence with the Meghna. The study area can be divided in two distinct types: a) Upper Meghna and Dhaleswari, and b) Lower Meghna.

The following project locations were identified as urgently requiring river-bank protection:

Upper Meghna and Dhaleswari River

- Bhairab Bazar Township and Railway Bridge
- Maniknagar
- Meghna Road and Highway Bridge
- Munshiganj Town

Lower Meghna

- Eklashpur
- Chandpur Town
- Haimchar

Figure I.2.1 presents an overview of the project locations on the Meghna.

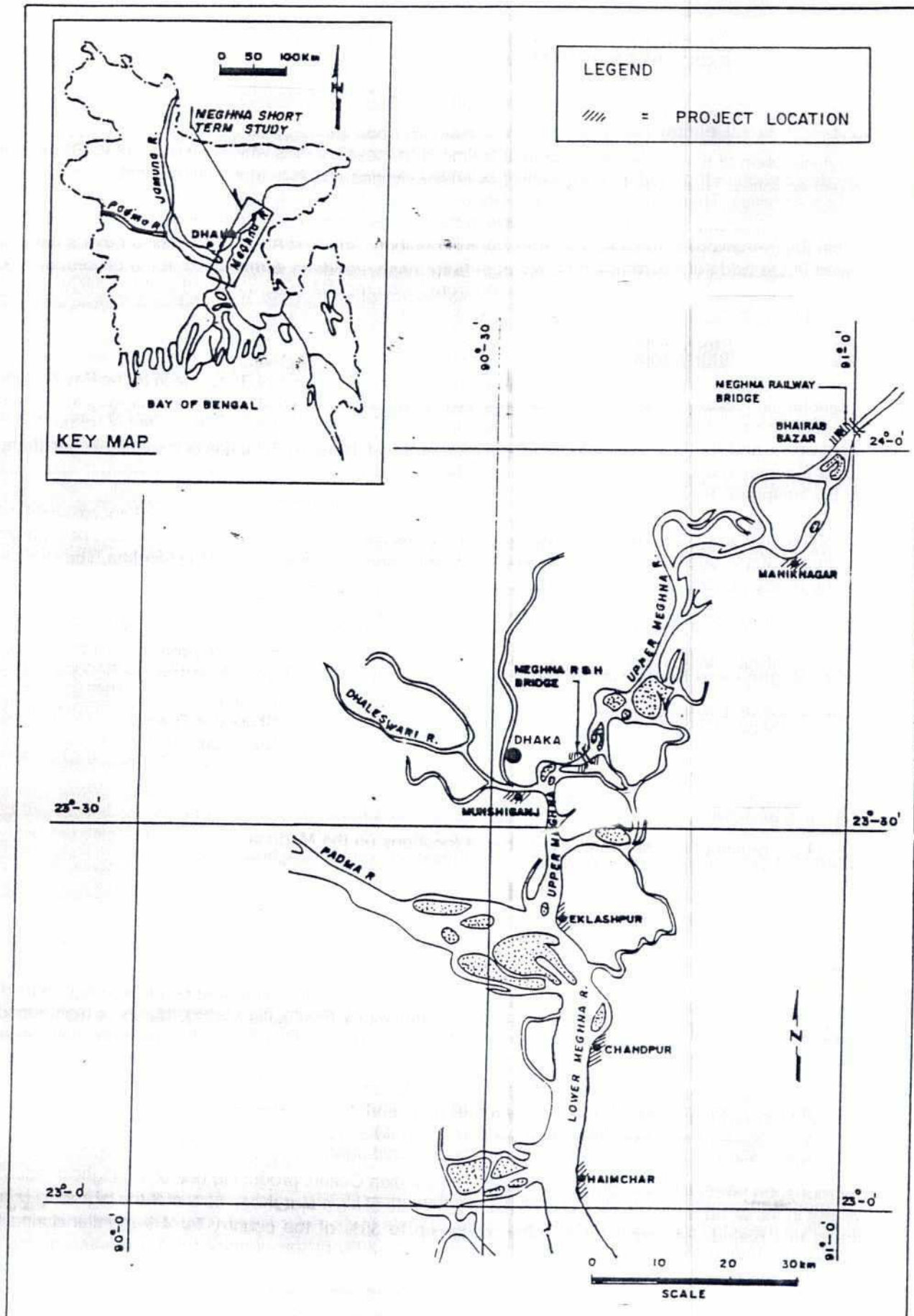
I.2.3 Physical environment

I.2.3.1 Climate

Bangladesh has a tropical monsoon climate characterized by mostly high temperatures, a high humidity, and a heavy rainfall (1,500-5,000 mm a year, about 2,000 mm in the Dhaka region). The three main seasons are:

- monsoon or wet season from mid-June to mid-October,
- cold season from mid-October to end-February, and
- hot season or little rainy season from March to mid-June.

The monsoon sweeps up the Bay of Bengal from the Indian Ocean, producing one of the highest recorded rainfalls in the world over Bangladesh and the catchments of it's major rivers. 80% of the total annual rainfall falls in this period. Recurrent floods often cover up to 30% of the country for 4-5 months during the monsoon season.



INDEX MAP SHOWING PROJECT LOCATIONS FOR THE MEGHNA SHORT TERM STUDY

FIGURE I.2.1

The cold season is mild, with daytime temperatures of about 20°C, but temperatures can fall to 4°C. The winds from the northeast bring no or little rainfall.

In the hot season, before the monsoon begins, the regular Nor'Wester thunderstorm squalls cause high wind speeds and minor rainfall. The daytime temperature is about 35°C.

Cyclones are mostly associated with the retreating monsoon winds in September and October, although they may occur in November-December or in the pre-monsoon season (April-May). They are formed in the Bay of Bengal, and may have wind speeds up to 160 km/h accompanied by torrential rains and wind surges.

I.2.3.2 Topography and geology

Bangladesh lies on the eastern flank of the Indian Platform in the transition zone between the continental shelf and the Bengal Basin. The Dauki fault in the north and the Tripura folded belt in the east have continuing tectonic movements which cause severe earthquakes in the region.

The relief in the alluvial Meghna floodplain is very low: adjoining ridges and basins differ less than 1.5 m in elevation. Often, the relief is artificial: e.g. embankments or mounds constructed to protect infrastructure from flooding.

The top soil layer along the riverbanks consists of fluvial deposits of recent to sub-recent origin. The bulk of the soils is very fine textured, the remainder is moderately fine. Prominent features are a high silt content and a mica admixture. The upper soil layers, 10 - 15 m deep, are relatively silty and the layers at greater depth are sandy.

The river flows on deep sediments over a pre-cambrian basement rock. The river bed and banks consist mainly of often loosely packed, clayey silt.

I.2.3.3 Geomorphology

The Meghna drains ... others the Sylhet depression or Haor Basin, an area which has subsided about 10 m in the last centuries due to compaction and tectonic activity. Drainage from the basin is impeded by lack of sufficient slope, high water levels in the Ganges and Jamuna and a raise in sea level. The flood waters accumulate and create an enormous basin which only gradually drains into the Meghna (Figure I.2.2). This results in major flooding downstream between August and October due to drainage impediment. The floodwater remains between 2 months to maximally 5 months.

The width of the river varies between 1 km to more than 10 km. The river is quite deep along the whole stretch and deepens to 35 m in the bends. The Upper Meghna meanders within a well-defined high waterbed. The Lower Meghna is characterized by a river bed several kilometres wide with a combination of channels and permanent or temporary islands of silt (chars). The channels in the floodplain continuously shift and change in number, eroding and forming chars. Locally, the Lower Meghna is up to 50 m deep due to scour.

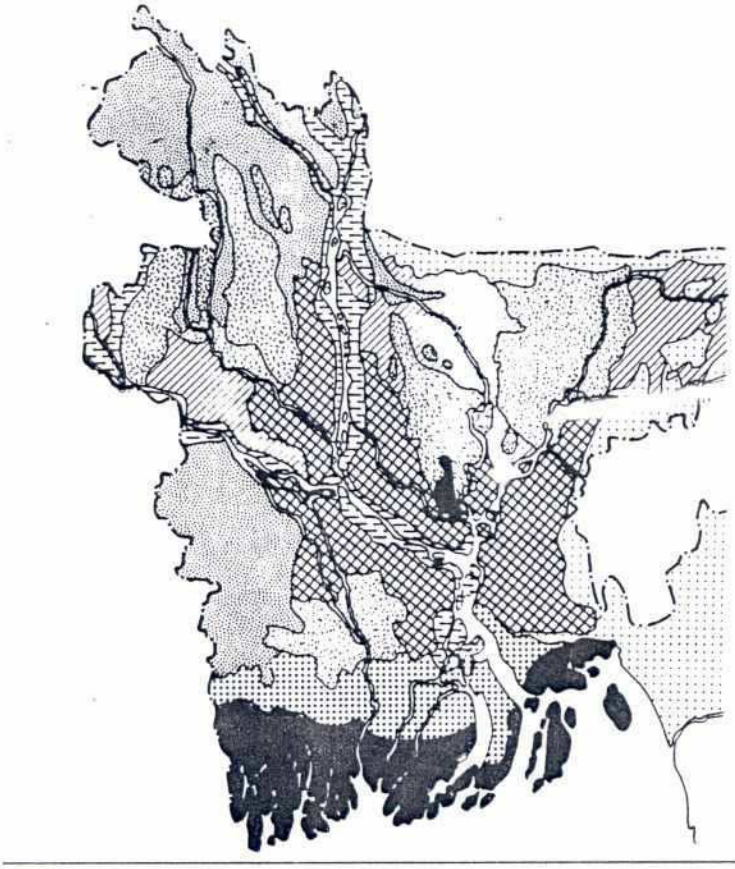
Erosion of river-banks along the Upper Meghna is caused by the continuous shifting of the thalweg. The gradual shift of the Padma to the northeast and eastward shift of the Lower Meghna cause continuous erosion of the latter's left bank. This is aggravated by wave action.

I.2.3.4 Hydrology

The Meghna is formed by the junction of the Kalni River with smaller tributaries, northeast of Bhairab Bazar. Near Bhairab Bazar and Munshiganj the Old Brahmaputra and Dhaleswari Rivers respectively flow into the Meghna, thus interacting with the Jamuna River. At Eklashpur, the Meghna is joined by the Padma, forming the Lower Meghna.

Figure I.2.2 DEPTH AND DURATION OF FLOODING IN BANGLADESH

Source: Wellcome, 1985



Urban area

State limits

Hills and uplands

Permanent river channels

Terrace: occasional floods; flash in valleys

Floodplain, mixed highland and medium land; occasional deep floods on medium land

Floodplain, mixed medium land and lowland; occasional frequent deep floods

Floodplain, mainly lowland ridges and basins; occasional frequent floods

Floodplain, mainly lowland basins; occasional early floods, generally deep

Floodplain, char land, frequent floods, early rapid flow, severe risk of erosion or burial by deposition

Freshwater tidal floodplain, mainly medium land part flooded by ponded rainwater in basins

Saline tidal floodplain, mainly medium land; occasional flood by ponded rainwater in basins; part saline flooding–'sunderbuns'

Highland = above normal flood level. Medium land = normally flooded less than 1m.
Lowland = normally flooded more than 1m

The Upper Meghna drains an area of 77,000 km², over half in Bangladesh. The annual average discharge at Bhairab Bazar is 4,800 m^3/s, but discharge rises up to 20,000 m^3/s in the wet season. Downstream, the flow increases significantly due to the diversions from the Jamuna. The Lower Meghna conveys the water from the Meghna, Ganges and Jamuna basins with a total catchment area of 1,637,000 km². It discharges a peak of about 150,000 m^3/s in the monsoon season. During the monsoon, the large discharges render part of the Bay of Bengal fresh. Dry season discharges are only a fraction of wet season flows. The discharges have decreased due to removal of surface water (mostly for irrigation) which has increased siltation, formation of sand bars, and increased salinity in the estuary during the dry season.

At Bhairab Bazar, the annual average flow velocity is between 0.2 and 0.3 m/s, while the maximum average flow velocity during high floods is almost 2 m/s. The average flow velocity at Chandpur is about 0.6 m/s, but slacks four times daily due to the reversal of the tide. This reversal of the tide can still be noted at Eklashpur. The limit of tidal backwater extends to Sylhet. The tidal variation lessens in the flood period.

The sediment load of the Upper Meghna is very low, mostly less than 100 ppm in samples, and does not vary much per season. In the catchment area of the Upper Meghna, sedimentation prevails over erosion. The Lower Meghna's sediment load increases due to the extremely high load of the Padma, but predicted concentrations are much lower than would be expected. No measurements are available to verify the calculations.

I.2.3.5 Water quality

The water and sediment quality of the Meghna depends on it's pollution load and the fate of the chemicals in the aquatic environment. An overview of these mechanisms is given in Figure I.2.3. Data on the Meghna concerning pollution load and transport and transformation mechanisms are unavailable at present.

Industrial pollution is rather localized: industry is primarily concentrated in five centres, but small-scale industry is found in most towns. Chromium, cadmium and mercury are highly toxic wastes discharged by tanneries and paint factories. Boats and oil terminals cause pollution with oil and oil products. Drainage from irrigated areas may contain residues of agro-chemicals. Vector eradication programmes pollute with pesticides. The Ganges, the most polluted river of India, also contributes to water pollution in Bangladesh.

Organic pollution is expected to be largest near the towns and industrial plants where domestic and agro-industrial wastes are often discharged untreated. The biological oxygen demand (BOD) changes according to site and season: the variation in BOD during the year at Narayanganj is presented in Figure I.2.4. Faecal contamination is widespread (Danida, 1989).

The self-purification capacity of the Meghna is quite large, especially in the monsoon season. Due to the fast flow and large quantity of water discharged, pollutants are quickly transported and diluted. Water quality varies seasonally: as river flows are drastically reduced during the dry season, the concentration of pollutants increases.

Many pollutants bind with the finest fraction of suspended sediments, and are deposited with the sediment further downstream. However, contamination decreases closer to sea due to mobilization and mixing with clean sea sediments. Pollutants are also retained in the interstitial water of the sediment. Through chemical exchange or re-suspension, these pollutants may re-enter the aquatic ecosystem.

Some pollutants are taken up in the food-chain and subsequently broken down to other chemical compounds and/or stored. Storage in aquatic organisms may lead to bioaccumulation, depending on the type of pollutant and organisms. Examples are heavy metal salts and halogenated hydrocarbons (pesticides).

The remaining pollutants decompose, e.g. under influence of light, or are eventually transferred to a sink (e.g. ocean).

Figure I.2.3 TRANSPORT AND TRANSFORMATION OF POLLUTANTS IN AQUATIC SYSTEMS BY PHYSICAL, CHEMICAL AND BIOLOGICAL PATHWAYS

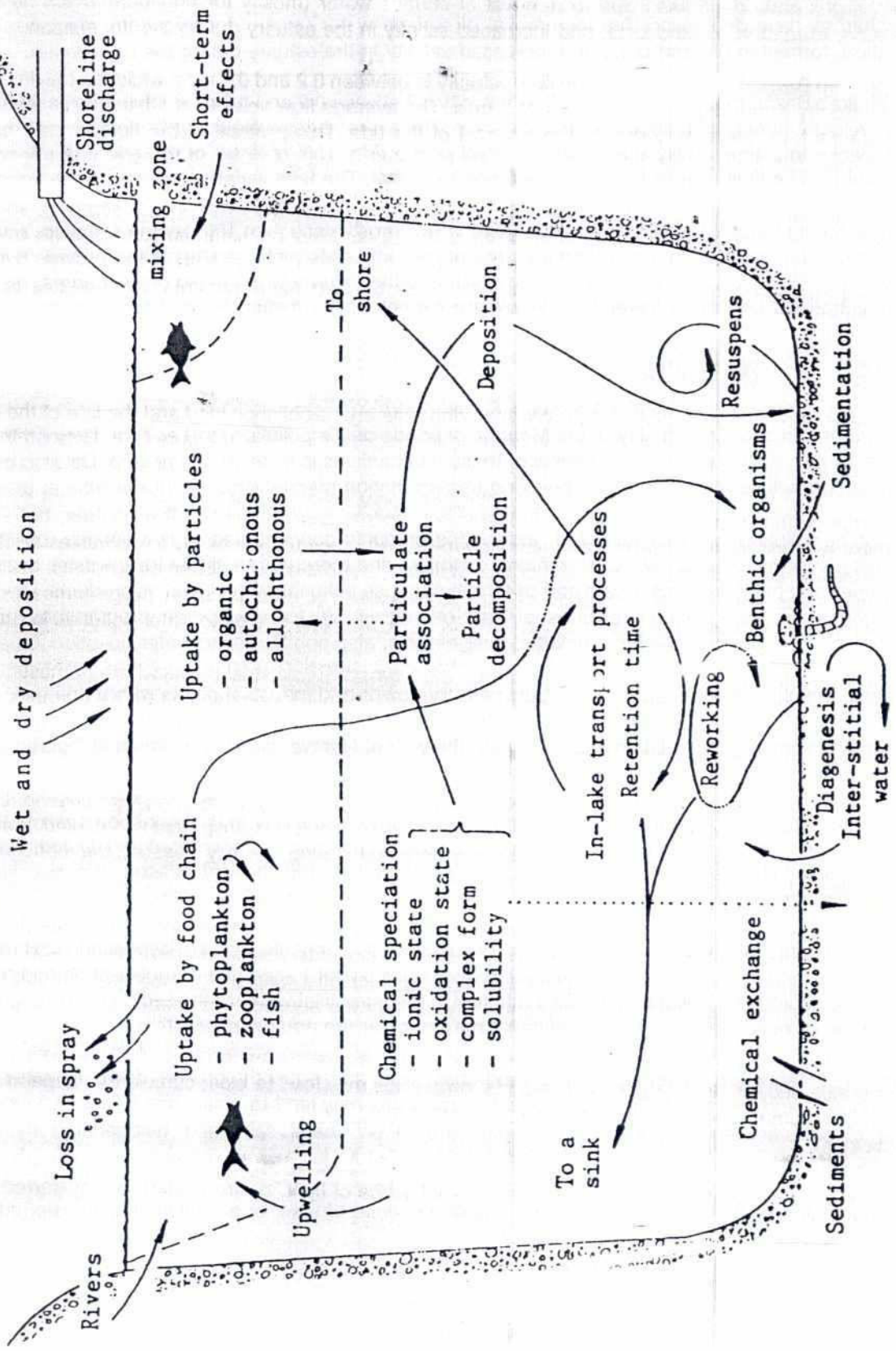
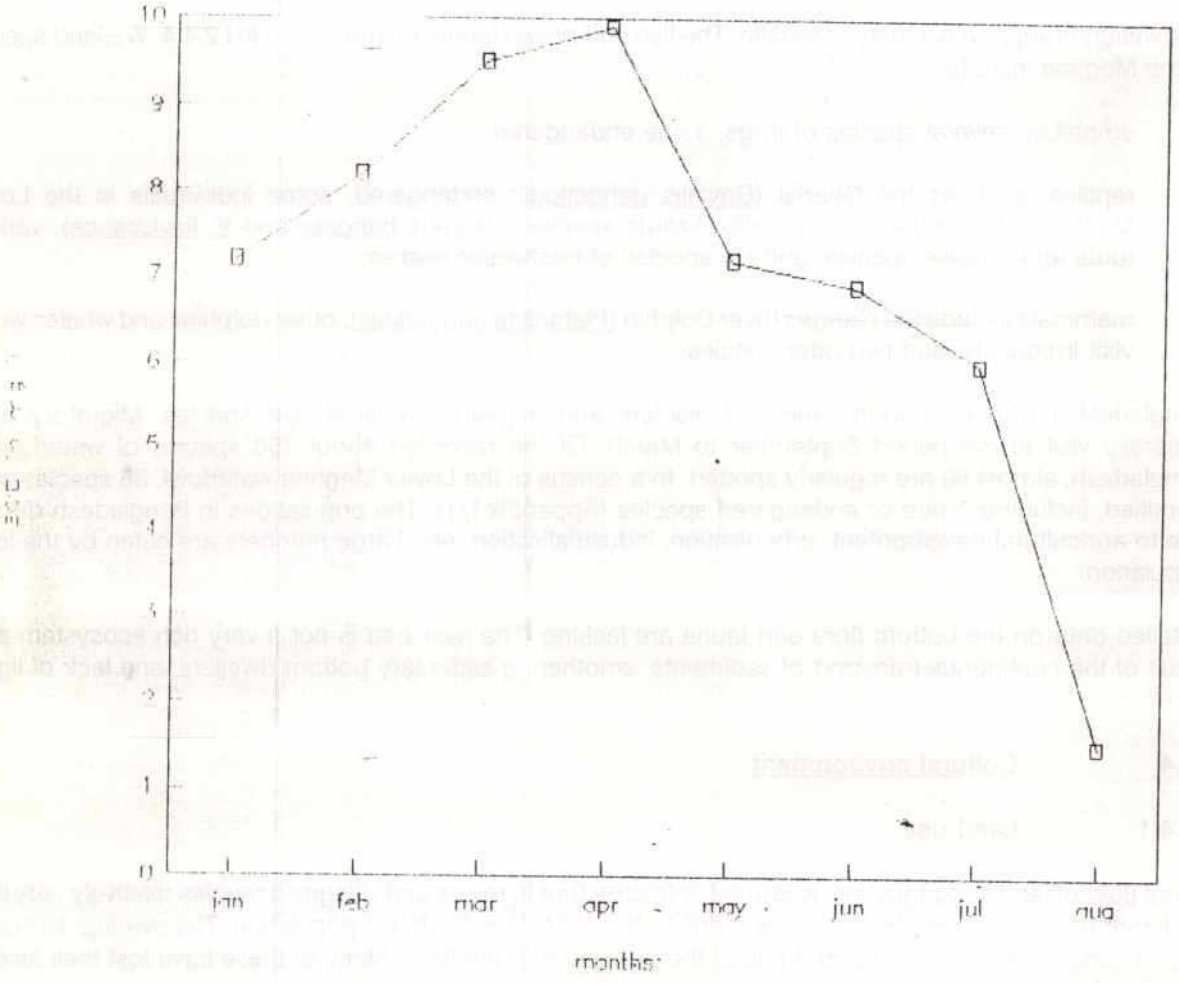


Figure I.2.4 VARIATION IN BOD DURING THE YEAR AT NARAYANGANJ, 1985



Source: Department of Environmental Pollution Control, 1984

I.2.3.6 Flora and Fauna

During the rainy season, half of Bangladesh can be considered a wetland. This includes the Meghna and tributaries, and their cultivated floodplain with shallow freshwater lakes and marshes.

The floral composition of the floodplains bordering the Meghna is relatively uniform, with a seasonal variation in dominant species. The natural aquatic vegetation has for the most part been replaced with cultivated species, as the Meghna is bordered by extensively cultivated floodplains. The former wetland forests have been almost completely destroyed. The Lower Meghna flows between many uninhabited permanent and temporary islands having some remaining swamp vegetation, but in the project area most are cultivated. Detailed data on the composition of the aquatic ecosystem in the Meghna are lacking.

The wetlands support a variety of wildlife. The fish and prawn fauna are discussed in I.2.4.4. Wetland species in the Meghna include:

- amphibia: several species of frogs, some endangered;
- reptiles, such as the Gharial (Gavialis gangeticus: endangered, some individuals in the Lower Meghna), two endangered monitor lizards species (Varanus bengalis and V. flaviscence), various turtle and tortoise species, and six species of freshwater snakes;
- mammals include the Ganges River Dolphin (Platanista gangeticus), other dolphins and whales which visit irregularly, and two otter species.

Bangladesh harbours a wide variety of resident and migratory wetland bird species. Migratory birds generally visit in the period September to March. Of the recorded about 150 species of waterfowl in Bangladesh, almost 80 are regularly spotted. In a census of the Lower Meghna waterfowl, 38 species were identified, including 7 rare or endangered species (Appendix I/1). The populations in Bangladesh decline due to agricultural development, urbanisation, industrialisation, etc. Large numbers are eaten by the local population.

Detailed data on the bottom flora and fauna are lacking. The river bed is not a very rich ecosystem as a result of the continuous transport of sediments, smothering sedentary bottom dwellers, and lack of light.

I.2.4 Cultural environment

I.2.4.1 Land-use

About 80% of land in Bangladesh is farmed: infrastructure in towns and villages occupies relatively very little land and the pressure on the land is high due to the exceptionally dense population. The average farm size is quite small, under 1 hectare, and half of the population is landless. Many of these have lost their land in the past due to river-bank erosion.

Optimal use of water resources for agriculture presents a major problem in Bangladesh. Excessive flooding limits agricultural development and damages crops, livestock and infrastructure. In the dry season, the amount of water for irrigation is limited.

Land and large water bodies are often owned by the government. The margins of waters are leased by the government for rice cultivation on an annual basis. Private low-lying areas are almost exclusively used for rice cultivation, while potatoes and other vegetables are grown on the higher lands near the villages.
The main activities in the floodplains are fishing and rice cultivation. Fishing is discussed in Section I.2.4.4, and rice cultivation in I.2.4.2.

I.2.4.2 Agriculture

Agriculture is the backbone of the economy: it provides employment for 60% of the population, accounts for 45% of the Gross National Product and 60% of merchandise exports (World Bank, 1990).

The alluvial soils in the project area are low in nitrogen and phosphate, rich in calcium, magnesium and potassium, and alkaline (pH 7.0-8.5). They are enriched with heavy silt deposits by overbank flooding of the Meghna. Agricultural practices are adapted to flooding: submerged areas become productive land as the floods recede. The principal crops in the floodplains are rice, jute, beans, and lentils. The commonest fruits and vegetables are papaya, pineapple, potatoes, and cabbage.

Rice is the main crop, grown on about 80% of the cropped area. Bangladesh is both the largest producer and one of the largest importers of rice in the world. The yield of rice per ha is relatively low, indicating a limited application of modern technology.

High yielding varieties are grown on the about three million ha of irrigated lands (1987). About 5% of the total area planted is treated with pesticides, mainly on high yielding varieties. This accounts for 90 % of pesticides used, almost all insecticides. The total usage was about 3,700 metric tons per year in 1986-1987 (Hamid, 1991). The project area contains the Meghna-Dhonagoda and Chandpur irrigation projects in which pesticides presumably are used, but detailed data on the type of pesticides used in the project area and it's catchment areas are lacking.

The distribution of fertilizer in Bangladesh was about 2,000,000 metric tons in 1988-89. About three quarters of this is used for rice production, predominantly for high yielding varieties in irrigated rice culture.

Jute and jute-based products supply most of the export earnings. It is a main floodplain crop and accounts for 5% of cropped area. It is predominantly grown during the monsoon season.

Livestock production is relatively unimportant in the project area. Cattle and buffalo play an important role as draft animals. Livestock breeding is hampered by the lack of grassland: they graze in the wetlands during the dry season.

I.2.4.3 Water-use

The elaborate network of rivers and canals provides a major transport and communication system. Steamers and launches are the cheapest, often quickest, and most comfortable means of transport. All project sites are served by water transport means.

Chandpur is an inland river port and a stop on the Dhaka-Chittagong route. Munshiganj is a stop on the Dhaka-Chandpur route. Bhairab Bazar is a main river port connected with Narayanganj. Because a minimum depth is required for year-round navigation these routes are periodically dredged at shoals.

A major use of water is irrigation, as it offers opportunities to increase agricultural production. The extensive wetlands, in particular the rivers, provide a year-round source of water.

The domestic water supply within the municipalities is generally poor. A considerable number of people has access to river water only for bathing, washing, drinking water, etc. The same river is also used for domestic and industrial waste disposal.

I.2.4.4 Fishery

Fish is a staple food in Bangladesh, providing 80% of the per capita animal protein in the daily diet (Ali, 1990). Even though fishery is mostly artisanal, it is the second most important economic activity: Bangladesh exports fish and fish products. Fishery provides full-time employment for an estimated 2 million people. About three-quarters of rural households fishes occasionally.

River fishing is practised under a governmental lease/auction system: the lease holder may sub-lease sections or collect rent from fishermen. Indiscriminate harvesting of fish and prawn is induced by this system, and leads increasingly to overfishing.

260 species of freshwater fish and 20 species of freshwater prawn have been identified, but the catches in the rivers are dominated by hilsa and a variety of major carp and freshwater prawn species. River fishing takes place most of the year but peaks in the cold season, between November and February. Only hilsa catches a peak during the monsoon season.

Hilsa represents about 40% of the total catch. It is sensitive to water quality and only found in relatively clean water. The adult hilsa migrates between the sea and spawning grounds in the estuary. The juveniles disperse upstream from the estuary to the nurseries. The Lower Meghna is a very important nursery ground and accounts for about 70% of the total fish catch, which amounts to 62,000 ton (1988).

Giant freshwater prawn (Macrobrachium rosenbergii) breeds in the estuary, after which the juveniles migrate upstream and into their nursery in the floodplain by crawling. Prawn accounts for 3% of the annual Meghna catch.

The major carps are Rohu (Labeo rohita), Catla (Catla catla), and Mrigal (Cirrhinus mrigala). They breed and spawn in the clear, oxygenated water of the hilly areas (e.g. Sylhet and Assam). Both adults and juveniles then disperse downstream over the floodplain. They present less than 1% of the annual catch of the Meghna.

The timing of reproduction related activities of these major freshwater species is presented in Figure I.2.5.

I.2.4.5 Socio-economic features

The Lower Meghna has one of the highest population pressures in Bangladesh, which is already the most densely populated rural country in the world. The population density was estimated at 576 persons per square kilometre in 1990. The high annual population growth rate (2.4 in 1989) is a major constraint to development.

80% of the population lives below the poverty line. Their socio-economic situation is characterized by a low income, increasing landlessness, illiteracy, malnutrition, vulnerability to natural disasters and dependency on foreign capital, imported food and raw materials.

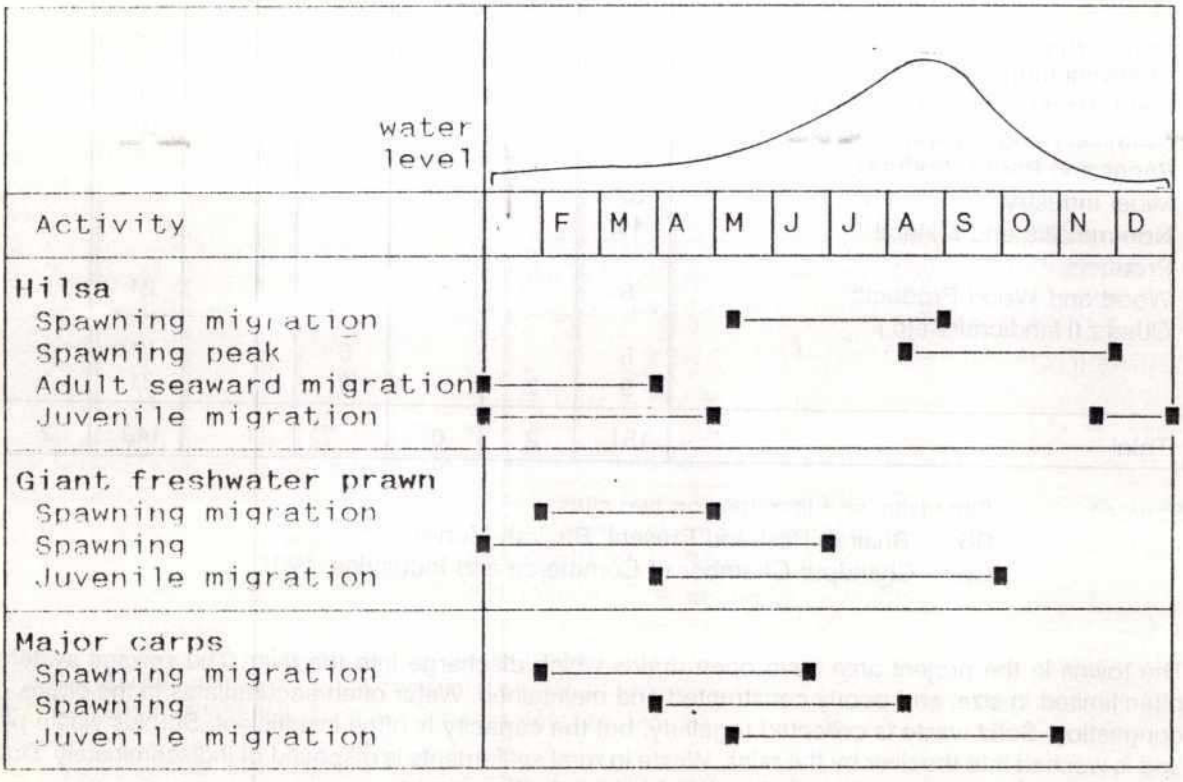
Rural employment is found largely in agriculture and fisheries. In the towns, employment is mostly found as paid worker, followed by unskilled labourer and then entrepreneur. Wages are often supplemented by agricultural and fishery activities.

The mostly small-scale industrial sector in Bangladesh is at a low level of development. Industries are sited preferentially both near the towns and along waterways. In the project area they are concentrated in the Dhaka and Narayanganj area. An overview of industries in the project area is presented in Table I.2.1.

The major industry is jute twine and carpet backing, which produces large quantities of organic waste. Leather tanneries are one of the main sources of pollution, discharging the extremely toxic hexavalent chromium in the Buriganga near Dhaka. Heavy industry is centred mainly around Tongi north of Dhaka. Chemical industries include paper and pulp industries, fertilizer factories, and distilleries.

Intermediate and light manufacturing is scattered across the country. Most industries discharge wastes without treatment into open water: the Zia Fertilizer Factory near Bhairab Bazar is one of the exceptions. Data on the pollution load from industries in the project area are lacking.

Figure I.2.5 TIMING OF FRESHWATER FISH AND PRAWN REPRODUCTION-RELATED ACTIVITIES



Source: MPO, 1985. Technical Report No. 16.

Table I.2.1 **OVERVIEW OF INDUSTRIAL ACTIVITIE , IN THE PROJECT AREAS**

Type of Industry	BB	Mn	RH	Mg	Ep	Cp	Hc
Textile, Apparel and Leather	8			11		3	
Chemical Industry							
Food, Beverages and Tobacco	9					1	
Machinery and Equipment	65			42		91	
Paper and Paper Products							
Metal Industry	37						
Non-metallic and Mineral Products	11						
Wood and Wood Products	8					21	
Others (Handicrafts etc.)							
	6			6		2	1
	9	2		9	1	31	1
Total	151	2	0	?[1]	1	149	2

Sources: Site visits, and literature on two sites:
BB: 'Bhairab Past and Present' Bhairab Municipality, 1990.
Cp: Chandpur Chamber of Commerce and Industries, 1991.

The towns in the project area have open drains which discharge into the river. The sewage systems are often limited in size, and poorly constructed and maintained. Water often accumulates in the drains due to congestion. Solid waste is collected regularly, but the capacity is often insufficient. Surplus waste piles up and is washed into the river by the rains. Waste in rural settlements is disposed of indiscriminately. Drainage is sometimes impeded by the existing river-bank protection works.

The rivers are frequently used for domestic water supply purposes, as access to safer water supplies is often limited. Public health at the project locations is threatened by the habit of washing, bathing and fishing near the discharge sites of municipal waste. The lack of clean drinking water has led to a widespread prevalence of waterborne diarrhoeal diseases.

Housing in the rural project areas often consists of huts constructed with natural materials. After erosion of houses at Eklashpur and Haimchar, large numbers of the local population have taken shelter on the embankments. Municipal housing is mostly constructed by using bricks, but squatters in huts occupy the eroded banks at Chandpur. The market stalls in Bhairab Bazar are also constructed with natural materials.

I.2.5 Autonomous development

This Section on the autonomous development describes the future without project situation, taking into account proposed and anticipated future developments.

I.2.5.1 Environment

The Government has declared 1990 "Year of Environment", and 1991-1999 "Decade of Environment". The presently small Department of Environment will expand considerably in the near future. It's capacity is strengthened for national environmental monitoring, pollution control and environmental management, including Environmental Impact Assessment. A revised law, the Bangladesh Environment Preservation

[1] For Munshiganj, data are available only on industry in the erosion-prone zone. Source: consultant's survey.

Ordinance, National Environmental Quality Standards, and Guidelines for EIA of flood control are in the making.

The number of industries will increase in future, with comparatively more emphasis on non-agro-industrial activities. Environmental degradation from discharge of industrial and domestic wastes will diminish if they are collected and treated adequately. One of the objectives of the Industrial Policy 1991 is to control environmental pollution by forcing industries to take adequate precautionary measures. The Department of Environment is identifying polluting industries in a nation-wide survey. The "National Environmental Monitoring and Pollution Control Project" runs from 1989-1992.

An increase in agricultural production is necessary to make Bangladesh self-sufficient. Intensified use of the existing lands is the main solution. An increase in irrigation, high yielding varieties, pesticide and fertilizer use is expected. The planned monitoring of pesticides and the ban on harmful agro-chemicals will, however, not decrease the impact significantly.

Fisheries production will continue to decrease steadily due to the reduction, modification and degradation of the aquatic environment, and because of overfishing. E.g. the lateral fish migration into the inundated floodplain is hampered by extensive flood control and drainage projects, leading to a decline of floodplain fisheries. Therefore, the Government of Bangladesh plans to enhance aquaculture activities.

I.2.5.2 Project-related activities

At present, various activities are undertaken or planned to protect the river-banks at most sites. In the without project situation these activities will continue, as most do not present a long-term solution to river-bank erosion.

The Bangladesh Railway protects the Railway Bridge at Bhairab Bazar with large quantities of boulders. The township is similarly protected. The proposed embankment at Maniknagar will in due course either be protected or retired. The Meghna Road and Highway Bridge's left bank protection has failed and will have to be repaired and protected. The waterfront and the ferry ghat at Munshiganj will continue to be strengthened regularly by bricks, boulders and other materials. At Eklashpur, the Bangladesh Water Development Board is constructing a revetment with a falling apron consisting of a granular filter and concrete blocks. As this does not influence the gradual shifting of the Meghna, it will have to be strengthened in due course. The protection at Chandpur is regularly renewed with boulders in gabions and concrete blocks, but this offers no long-term solution. As the present embankment near Haimchar is being eroded, the Bangladesh Water Development Board has already constructed a retired embankment. At the present rate of erosion, this also will have to be protected or moved within a few years.

In the long-term, river-bank protection may be followed by river training, which aims to stabilize river morphological patterns. This has significant socio-economic benefits, as the risk of loss of infrastructure, life and property due to river-bank erosion is minimized. River training works will more or less stabilize the main morphological development, but shifting of minor channels and chars will probably not be influenced to a large extent. Therefore, the overall effect on the riverine and estuarine environment is limited.

Plans for flood control, such as the Flood Action Plan, will lead to construction of more embankments and increase the need for river-bank protection and river training. This will have far-reaching effects on the natural environment, due to the interference with natural flooding patterns.

Dredging for navigation purposes will continue, as the sediment load of the rivers will not decrease.

I.3 DESCRIPTION OF PROJECT

I.3.1 Scope of work

Because of an alarming erosion of their river-banks, six points along the Meghna and one point on the Dhaleswari require immediate identification of action necessary to prevent further damage. The priority for each of the locations was studied and the conclusion was that it is necessary:

A) to conduct a pre-feasibility study for bank protection works at:

- Maniknagar
- Meghna Road-and Highway Bridge

B) and a feasibility study for:

- Eklashpur
- Haimchar

C) to conduct a feasibility study, and prepare detailed designs and tender documents for bank protection works at:

- Bhairab Bazar Township and Railway Bridge
- Munshiganj Town
- Chandpur Town

I.3.2 Problem identification

The causes and effects of river-bank erosion were studied in detail for each project location. The following section provides a summary of the extent of the problems as presented in other Annexes to the Main Report.

I.3.2.1 Bhairab Bazar Township and Railway Bridge

Bhairab Bazar plays an important role in transportation: it's railway bridge is the only rail connection with the eastern part of the country. It is a major inland port and a commercial and industrial centre with a busy oil terminal.

Deep scour near the right bank has resulted in steep, unstable underwater slopes and bank slides both up- and downstream of the Railway Bridge. In the past, revetments have been constructed downstream of the bridge. On unprotected stretches, minor to severe erosion has taken place during floods in 1988, 1989 and 1990. In 1990, the river bed upstream and under the Railway Bridge was protected with gunny bags and boulders. At present, the Bangladesh Railway (BR) is active in protection of the embankment with boulders.

The township faces the annual loss of an area of land of about 5 ha, while approximately 2500 people, 200 houses, shops and small industries are affected annually. Furthermore, the stability of the abutment of the Railway Bridge, power transmission towers and the oil terminal on the right bank are endangered.

I.3.2.2 Maniknagar

Maniknagar is a medium-sized bazar and fishing village within the limits of the planned Gumti Pha.. II Irrigation Project. The erosion along 16 km of an outer bend on the left bank threatens the area in which the future flood embankment is planned.

I.3.2.3 Meghna Road and Highway Bridge

The Meghna R & H Bridge facilitates road traffic between the eastern part of the country and the Dhaka region. The left bank protection has failed locally. The left bank infrastructure is located on an eroding bend. The erosion of 40 - 50 m per year is due to the shifting of the main channel to the left bank. Furthermore, a deep scour hole is now approaching piers numbers 8 and 9.

I.3.2.4 Munshiganj Town

Munshiganj is a district headquarters on the Dhaleswari river. It has a number of cold storage facilities for potatoes and numerous industries, mainly rice mills and jute twining and spinning. These are suffering from erosion, together with the river-bank road and the ferry ghat. The right bank, near the launch ghat, is the most seriously affected: the annual erosion rate is between 20 and 30 m. Road embankments have been temporarily protected from wave action with gunny bags, and other stretches with bricks. The most important cause of bank erosion is serious wave attack during high river stages, especially during the monsoon.

I.3.2.5 Eklashpur

Eklashpur is a small village of fishermen and farmers. Most of the town area has already been eroded. The Meghna-Dhonagoda Irrigation Project flood embankment nearby washed away during the 1988 flood. The water level has now reached the toe of the replaced, retired embankment. The site has been subject to erosion from both current and wave action for more than a decade. The Bangladesh Water Development Board is presently constructing a revetment for temporary protection of the embankment.

I.3.2.6 Chandpur

Chandpur Town is an important inland harbour, and a commercial and industrial centre with road, rail and river transport connections. It is divided by the Dakatia River in Puran Bazar and Nutan Bazar. Up- and downstream of the township, the left bank of the Lower Meghna has eroded continuously for the past twenty years. During the 1988 flood, an area of 340 m length and 40 m width was eroded at Nutan Bazar. Annually, a strip of land of about 50 m is eroded, representing 100 ha of arable land. The estimated loss is 500 houses, shops and small industries per year. The strong current has caused scour depths up to 55 m in front of the revetments at Chandpur town. Wave induced erosion takes place during high water stages.

The railway station, ferry ghat and fish market, commercial and industrial properties, and other infrastructure are threatened. Further erosion of Chandpur would affect the embankment of the Chandpur Irrigation Project further downstream. Emergency works with boulders and concrete blocks have been and are being carried out to protect the town.

I.3.2.7 Haimchar

Since 1929, erosion of the left bank has been reported at Haimchar, eroding parts of the embankment of the Chandpur Irrigation Project. The former village Haimchar has been eroded: a new village was constructed further inland. Presently, the erosion rate is about 200 m per annum. The erosion is caused not only by scour, but also by wave attack. A retired embankment has already been constructed.

I.3.3 Project designs

For each of the project locations, various design alternatives were developed. For three priority sites, design alternatives were prepared after which selected alternative designs were elaborated in more detail. Feasibility studies for bank protection works were made for the other project locations.

I.3.3.1 Bhairab Bazar Township and Railway Bridge

Out of seven formulated alternative solutions, the construction of an overall revetment along an advanced right bank and between the bridge piers was selected for further elaboration (Figure I.3.1). The revetment begins near the ferry ghat and extends about 2 km downstream to the second power transmission tower.

The advanced revetment consists of hydraulic fill covered underwater by a fascine mattress of geotextile with a framework of bamboo poles and r ed fascines. Boulders are dumped on top of the mattress. The falling apron section consists of boulders only. Above water, the geotextile is covered by open stone asphalt. At the water-line bitu- grouted boulders cover the geotextile. Figure I.3.2 shows a cross-section of the design alternatives.

I.3.3.2 Maniknagar

Three alternative solutions have been considered:

A. maintenance of bank line by protection works, either a continuous revetment or a series of groynes;
B. deviation of the river flow from the left bank by creating a channel along the right bank;
C. construction of the projected flood embankment at a retired alignment.

I.3.3.3 Meghna Road and Highway Bridge

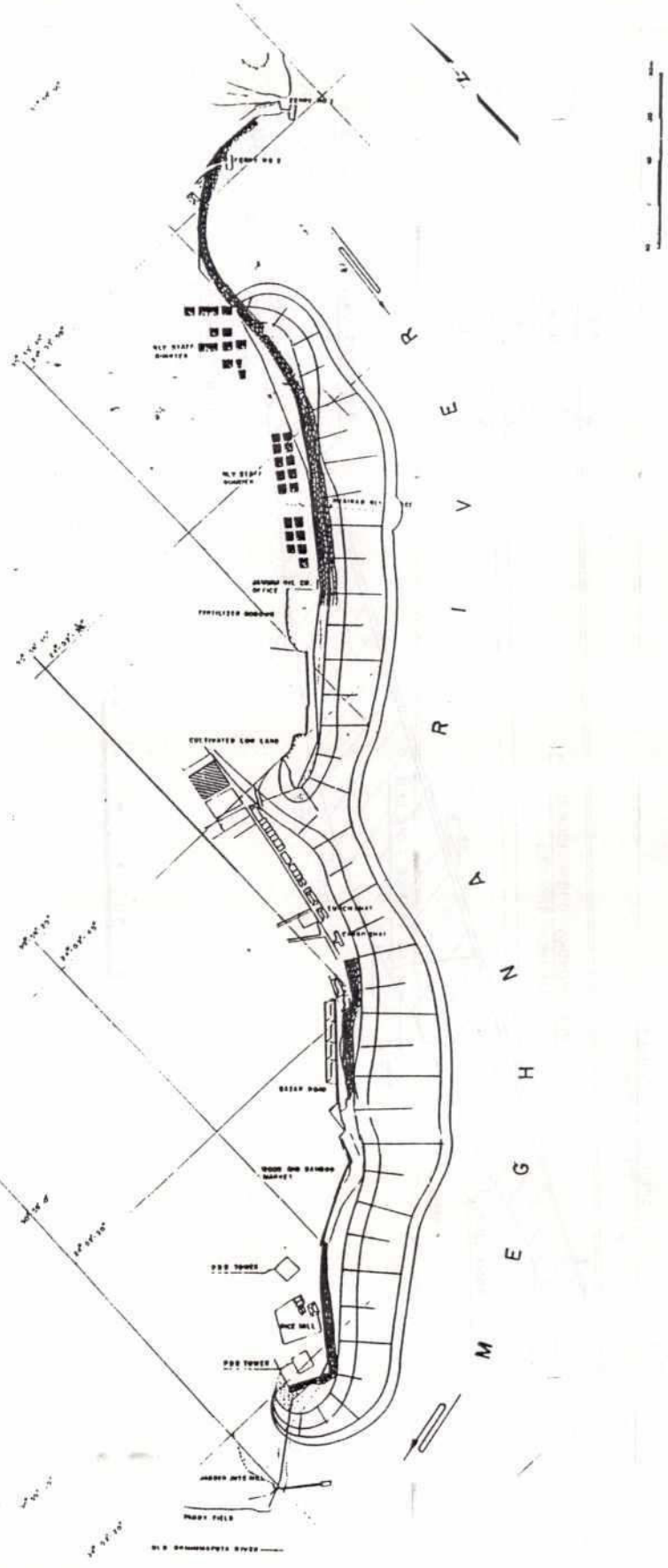
So far only short-term measures were considered by the bridge contractor:

A. bed protection around the piers by means of stone dumping;
B. extended bank protection at left abutment by placing sheetpiles; concrete filled mattresses and gabion dumping.

I.3.3.4 Munshiganj Town

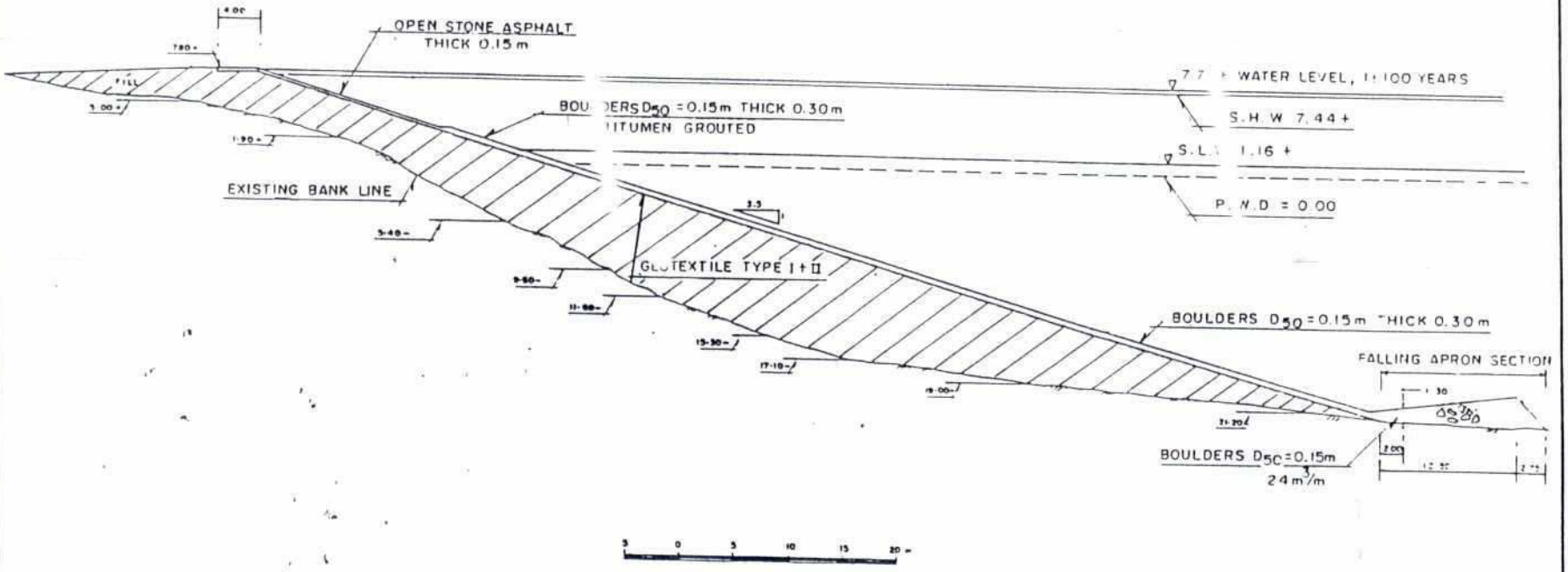
Out of three alternative solutions a combination of two was selected: protection of the foreshore at the existing bank line and on a reconstructed embankment (Figure I.3.3). The protected area stretches about 3 km along the right bank from the ferry ghat to the wharf.

As much as possible of the existing embankment is used. Cut and fill operations at the top create a suitable slope for the revetment. To prevent drainage congestion, the river-bank protection is discontinued locally for drainage canals. The revetment design is similar to Bhairab Bazar, as presented in Figure I.3.4.



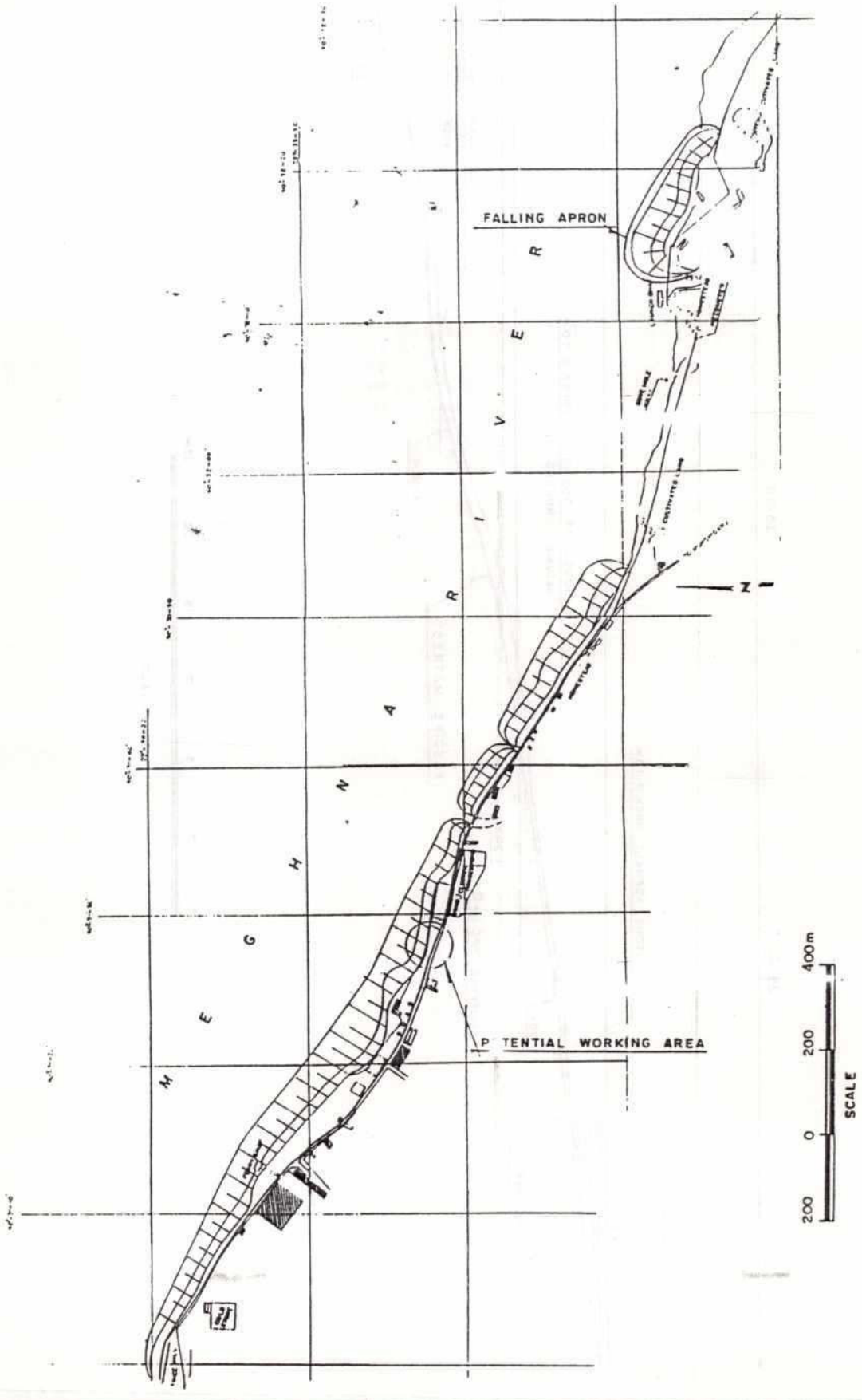
LAYOUT PLAN BHAIRAB BAZAR
ADVANCED PROTECTION

Figure I.3.1

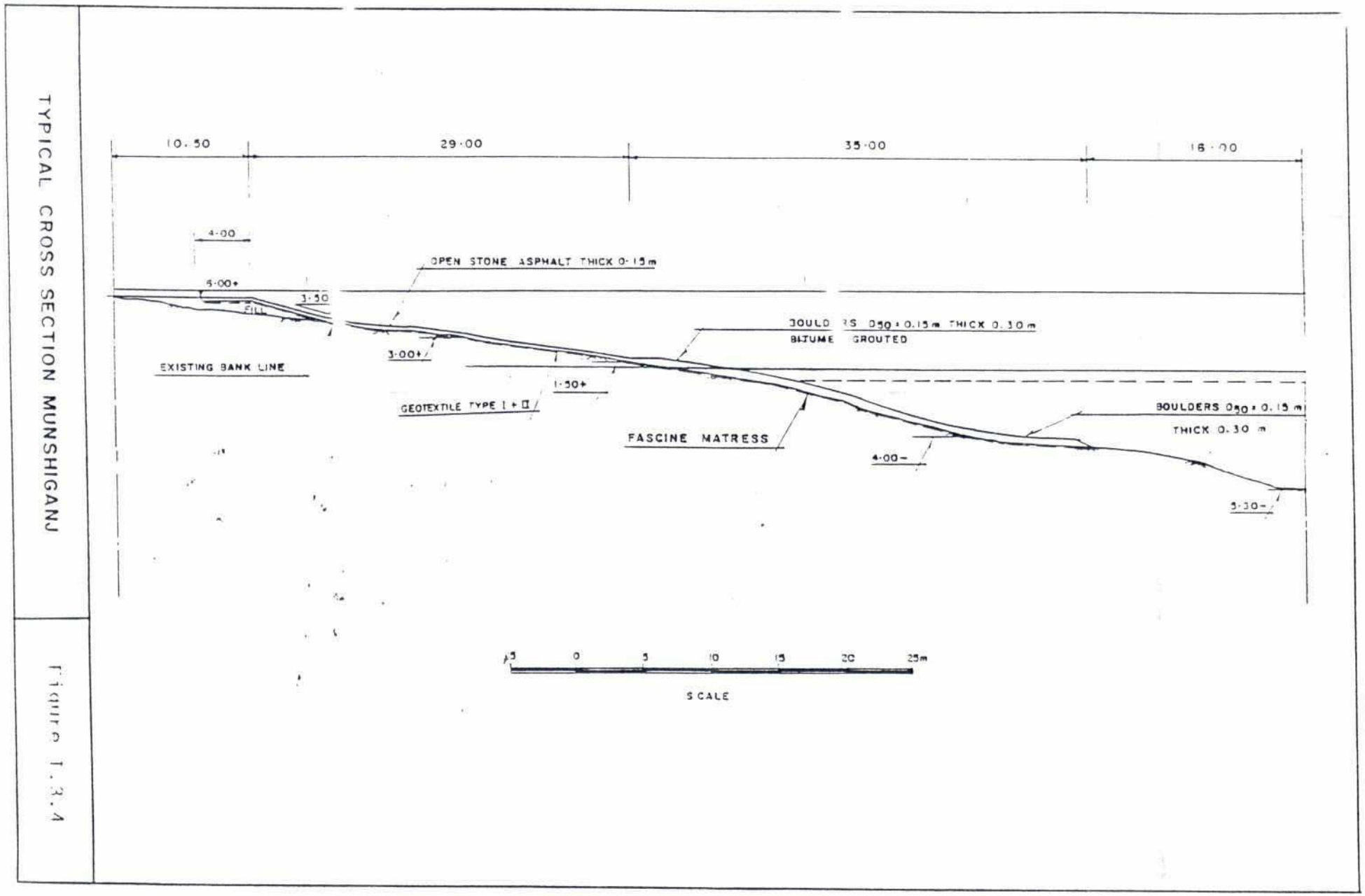


TYPICAL CROSS SECTION BHAIRAB BAZAR
(ADVANCED PROTECTION)

Figure I.3.2



LAYOUT PLAN MUNSHIGANJ PROTECTION | Figure I.3.3


TYPICAL CROSS SECTION MUNSHIGANJ
Figure 1.3.4
10.50
29.00
35.00
16.00
4.00
5.00+
3.50
FILL
OPEN STONE ASPHALT THICK 0.15m
BOULDERS D50 = 0.15m THICK 0.30m
BITUME GROUTED
3.00+
EXISTING BANK LINE
1.50+
GEOTEXTILE TYPE I + II
FASCINE MATRESS
BOULDERS D50 = 0.15 m
THICK 0.30 m
4.00-
5.30-
5 0 5 10 15 20 25m
SCALE

I.3.3.5 Eklashpur

The following four alternative solutions are proposed:

A. protection of existing embankment by means of a deeply founded revetment;
B. construction of a retired embankment, for the time being without revetment;
C. a banana shaped guide bund protecting a bank line stretch in addition to the stretch of river defended according to BWDB design;
D. a groyne placed under an angle with the embankment's axis (length ... upstream from Eklashpur).

I.3.3.6 Chandpur Town

Five alternatives were considered but an advanced protection at Nutan Bazar was selected, because Chandpur benefits most from a quick solution. This also protects Puran Bazar against scour, to a lesser extent. In addition, measures against wave attack will be necessary at Puran Bazar.

The protection at Nutan Bazar consists of a curved bank protection having a 25 m wide berm (Figure I.3.5). Containment bunds will prevent the hydraulic fill from flowing out to a too gentle gradient. The embankment consists of stone asphalt on geotextile above water, and rock on a fascine mattress underwater. The falling apron is formed by rock only. A cross-section of the design is presented in Figure I.3.6.

I.3.3.7 Haimchar

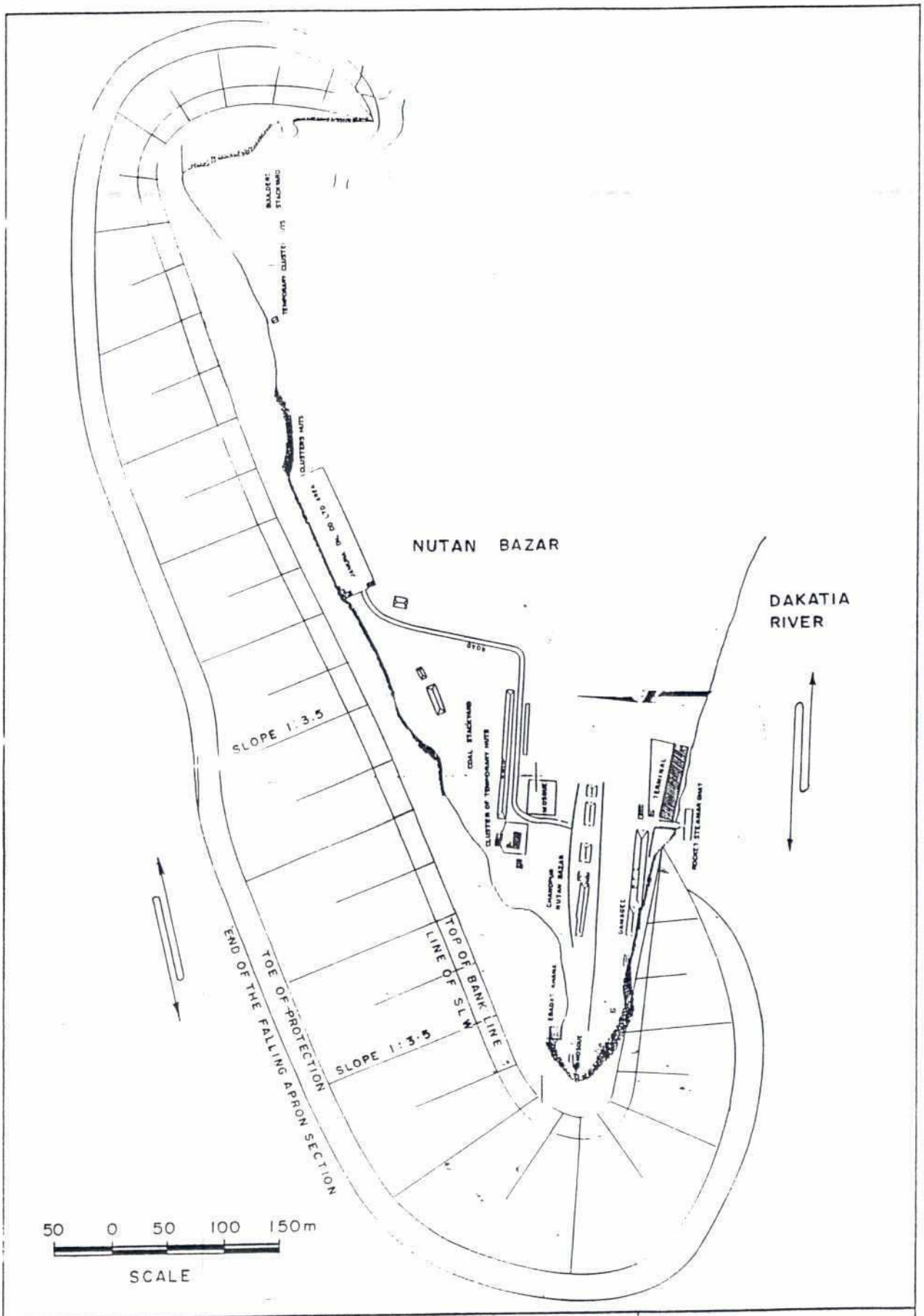
Three alternative solutions were proposed:

A. revetment protecting the existing bank;
B. retired embankment protected by a deeply founded revetment;
C. groynes upstream of Haimchar to deviate the flow away from the town.

I.3.4 Construction methods

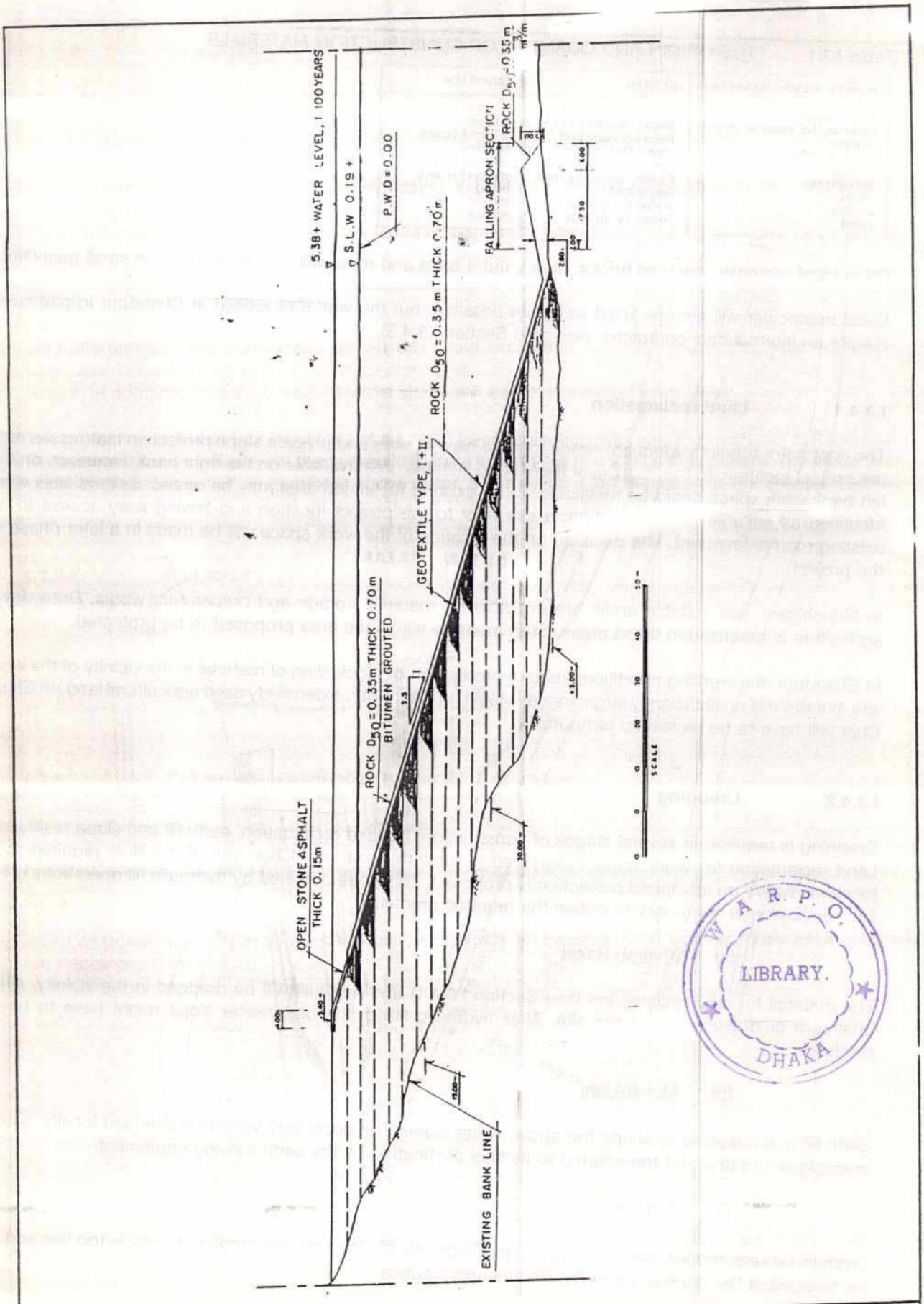
The two vital elements of river-bank protection are interrelated: hydraulic fill should be followed immediately by the installation of protection mattresses. This should be done preferably when current velocities are low: in the dry season, mid-November to mid-May. A construction schedule is presented in Volume I of the Final Report.

As far as possible, locally available construction materials will be used. The following construction materials are necessary (Table I.3.1):



LAYOUT ADVANCED PROTECTION CHANDPUR

Figure I.3.5



TYPICAL CROSS SECTION CHANDPUR

Figure I.3.6

Table I.3.1 THE ORIGIN AND QUANTITY OF CONSTRUCTION MATERIALS

construction material	origin	quantity
fine sand	dredged locally	significant
medium to coarse sand	local material	minor
cement	local/imported	significant
geotextile	imported	minor
bitumen	local material	significant
boulders	river beds Sylhet	significant
rock	imported	minor
bamboo	locally grown	minor
reed	locally grown	minor

Other local materials, such as bricks, gunny (jute) bags and rope, will also be required in small quantities.

Local manpower will also be used as far as possible, but the works proposed at Chandpur in particular require an international contractor (see also Section I.3.4.3).

I.3.4.1 Land reclamation

The contractor requires adequate space to store his materials and prepare slope protection mattresses near the project location. In Bhairab Bazar there is no suitable area available on the right bank. However, on the left bank work space could be reclaimed, or an existing reclaimed area may be rented. Several sites were identified as suitable for reclamation: a site near to the project location and having easy access to an existing road is favoured. The decision on the location of the work space will be made in a later phase of the project.

In Munshiganj, two suitable areas are available for material storage and preparatory works. Draw-down agriculture is practised in these areas. Both areas lie within the area proposed to be protected.

In Chandpur, the working conditions require production or stockpiling of material in the vicinity of the work site, but there is no sufficiently large area available. In Chandpur, extensively used agricultural land on Chirar Char will have to be reclaimed temporarily.

I.3.4.2 Dredging

Dredging is required in several stages of construction: for land reclamation, earth fill and slope reshaping. Land reclamation for work space is required in Bhairab Bazar and Chandpur. Earth fill is required at all locations where an advanced protection is proposed. The slope obtained by hydraulic fill operations is too flat: re-shaping is necessary to obtain the required gradient.

(a) Bhairab Bazar

The material for land reclamation (see Section I.3.4.1) and earth fill will be dredged in the vicinity, either upstream or downstream of the site. After hydraulic filling, the underwater slope might have to be re-dredged.

(b) Munshiganj

Earth fill is required to re-shape the above water slope. The necessary volume is dredged locally, placed in stockpiles to dry, and transported to its final destination by dry earth moving equipment.

(c) Chandpur

Dredging is required for land reclamation and hydraulic fill. The material dredged locally is too fine and will be dredged at the confluence of the Padma and Meghna.

I.3.4.3 Containment bunds

At Chandpur, containment bunds will prevent the hydraulic fill from flowing out to a too gentle gradient. Re-dredging is not viable because of the large depths prevailing at Chandpur. The containment bunds should be made of coarse granular material, e.g. sand cement blocks. These can be made by mixing dredged sand with cement.

The use of underwater containment bunds requires highly sophisticated floating equipment to place hydraulic fill to the required accuracy and to minimize the use of granular material.

I.3.4.4 Geotextile

A geotextile layer is placed over the hydraulic-fill. The layer consists of a polypropylene fabric and a non-woven mat. The geotextile is combined with different materials above water, at the water-line, and underwater: open stone asphalt, bitumen grouted boulders and fascine mattresses respectively. Water can permeate through all layers: the outflow of groundwater will not be hampered.

The construction of steps above the water-line, as included in the tender documents, facilitates loading of boats, washing and bathing.

(a) Open stone asphalt

Open stone asphalt can be produced by an asphalt production plant with almost exclusively local materials. It requires stone or brick chips, and bitumen.

(b) Bitumen grouted boulders

At the water-line, boulders coated with bitumen enable the landing of small cargo boats, as the protection is shock-resistant.

(c) Slope protection mattresses

Slope protection mattresses consist of a geotextile fabric with affixed bamboo fascines with reed, covered by boulders or rock. Construction of the mattress takes place on a launching ramp. At Chandpur, mattress sinking operations require sophisticated equipment and positioning methods, e.g. computer controlled stone dumping barges.

I.3.4.5 Falling apron

The falling apron consists of dumped boulders in Bhairab Bazar and Munshiganj, and of rock in Chandpur.

I.4. ENVIRONMENTAL IMPACTS

I.4.1 General

The emphasis of an environmental impact assessment lies on the identification of negative effects of a project because unprecedented adverse impacts decrease the success of a project in economic, social and environmental terms. Therefore, EIA identifies negative impacts at an early stage to enable incorporation of mitigative measures in the project design, and evaluation of environmental costs and overall project benefits by decision-makers.

Beneficial impacts are usually not assessed in detail as they are often the objective of a project and do not require mitigation. In this case, the aim of protection of eroding river-banks at the selected sites is to safeguard municipal infrastructure and agricultural lands. This has significant socio-economic benefits: among others, employment opportunities are secured and created; transport is assured; risk of loss of life and property is decreased; and erosion of agricultural lands is reduced, preventing increased landlessness.

A major constraint for the present environmental impact assessment is the general lack of quantitative or qualitative data on the environment of the Meghna, in particular of the aquatic ecosystem. This forces a qualitative assessment of the proposed project.

A second constraint is that in the present environmental study for two sites pre-feasibility and for two others only feasibility studies were conducted. No final decision has been made for these four sites as to which alternative will be ultimately constructed. Thus, the description of environmental impacts concentrates on the proposed protection works at Bhairab Bazar, Munshiganj and Chandpur.

I.4.2 Possible impacts

The possible impacts are discussed in chronological order for all project sites. Only where necessary are impacts specified per location. Table I.4.1 presents an overview of possible environmental impacts and potentially significant effects.

I.4.2.1 General impacts

The use of mechanized equipment in all phases of the project will temporarily have some negative effects: air pollution from exhaust fumes, soil and water pollution from oil spills, noise and vibration, and accident risks. The impact is short-term, but the extent depends on the equipment used and its physical condition.

Table I.4.1 **OVERVIEW OF MAIN EFFECTS OF PROPOSED PROJECTS ACTIVITIES**

Activities	Possible effects	Significant effects
General		
1 equipment	1 pollution, accidents	1 -
2 labour force	2 pollution, social impacts	2 socioeconomic benefit
Pre-construction		
1 land clearing	1 loss of land	1 -
2 infrastructure displacement	2 social impacts	2 potential adverse social impact if unplanned
3 dredging	3 ecosystem change, pollution, transport disruption	3 potential adverse impact if the dredged sand is heavily polluted
	4 loss of land, impeded drainage, pollution	4 -
4 work areas	5 pollution	5 -
5 construction material		
Construction		
1 hydraulic fill	1 pollution, transport disruption	1 -
	2 pollution, transport disruption	
2 slope re-dredging		2 -
Post-construction		
1 river-bank protection	1 ecosystem change, loss of land	1 socioeconomic benefits
2 wrap-up	2 pollution	2 -

Most of the labour force (up to an estimated 500 - 1000 people per site) will be recruited locally, presenting an economic benefit. Import of labourers requires the establishment of labour camps, which may have short-term adverse environmental and socio-economic impacts. Labour camps may cause water and soil pollution with domestic wastes, an increase in infectious disease incidence, and disruption of social, cultural and economic patterns. The impact is short-term, the extent of the impact depends largely on the planning and management of the camps.

I.4.2.2 Pre-construction phase

(a) Site preparation

Land must be cleared for labour camps, work areas and project sites. In Bhairab Bazar, Munshiganj and Chandpur this leads to a loss of land used for draw-down agriculture. In the rural areas, land clearing may lead to a loss of agricultural lands or natural vegetation and thus fauna habitat. The effect is negligible due to the relatively small area needed for working space.

To enable earth filling, the landing facilities for the oil terminal, launch and cargo ghats in Bhairab Bazar will temporarily have to be shifted. Of the about 70 market stalls along the waterfront, some may have to be relocated temporarily. The ferry ghat at Munshiganj and loading/unloading operations at the cold stores and industries must be moved temporarily. At Chandpur, unloading at the fish market and use of the launch ghat may be hampered. These temporary relocations may cause resistance by the local population and are potentially significant impacts (see Section I.4.3.1).

(b) Dredging

Dredging will temporarily alter the river bed but, due to sediment transport, the dredged material is quickly replaced. The dredging also destroys the sedentary aquatic life at the site, but the bottom flora and fauna is relatively poor. The effect is short-term: the chemical and physical characteristics of the dredged site remain the same and it will rapidly be recolonized after the operations are finished.

The increased turbidity due to dredging in the Lower Meghna has negligible environmental impacts, as the natural sediment load of the river is relatively high. The Dhaleswari at Munshiganj receives water from the Jamuna River, and therefore presumably has rather high sediment loads, which minimizes the effect of increased turbidity. Indigenous aquatic life is adapted to these conditions. The Upper Meghna, however, has a low sediment load. Increased turbidity will have short-term effects on aquatic life as the penetration of light is reduced locally.

Spawning and migration of the major fish and shrimps species will not be affected by increased sedimentation (Figure I.2.4). Dredging will mostly take place in the dry season, when most species do not spawn. The giant freshwater prawn does spawn, but is not affected as it spawns in brackish water in the estuary. Hilsa and giant freshwater prawn migrate in the dry season, but only in the Lower Meghna where dredging is relatively insignificant. Dredging in the wet season will be limited: some is necessary to reclaim land at Chandpur and Bhairab Bazar. This may theoretically affect fish migration, e.g. at Bhairab Bazar, spawning and juvenile migration of major carps. However, migration of fish species will in general not be hampered as the rivers are very wide, especially in the monsoon season.

As dredged material is predominantly anaerobic, suspension of these sediments may temporarily lower dissolved oxygen levels at the dredging site. The dissolved oxygen content varies during the year and differs from site to site. It will especially be low near drainage sites of agro-industries. If areas with a low dissolved oxygen content are dredged, the dissolved oxygen levels may fall to a level which is lethal to fish. The respiration of sedentary organisms near the dredging site may temporarily be affected, but mobile organisms such as fish can avoid the disturbed area. Detailed data on the conditions of the soil and the dissolved oxygen levels of the water are not available at present, but the information available indicates that the decrease in water quality might significantly affect fish (see Section I.4.3.2).

Dredging releases pollutants from sediment and interstitial water into the already polluted water. Much will be deposited downstream by (re)suspended sediments. High levels of industrial or agro-chemical wastes do probably not occur in the project area. The effect of re-suspension of pollutants depends largely on the selected site, as industrial pollution is rather localized. The impact may be significant if the dredged material is heavily polluted (see Section I.4.3.2).

Dredging activities may hinder navigation depending on the selected site and the planning of activities.

(c) Work areas

If land is reclaimed in Bhairab Bazar and Chandpur, this leads to a loss of land used for draw-down agriculture. The area, however, is of little importance as a seasonal bird and fisheries habitat because larger and undisturbed areas are available in the vicinity. The effect is negligible because the amount of land needed is very small.

Reclaimed land, storage facilities and access roads may impede surface water drainage if not properly planned and executed.

Disposal of discarded construction materials may cause some pollution. The extent of the effect depends largely on the execution of the activities, but should be minor under normal circumstances.

(d) Construction materials

The quantity of construction materials required, such as boulders, is quite large. The transport of material by boat may cause water and air pollution, and hindrance to navigation. The transport of soil by road at Munshiganj may cause air pollution. The transfer and storage of material at the work space may cause pollution due to dust. However, the necessary quantity of material and related transport and transfer activities do probably not significantly differ from the without project scenario when river-bank protection activities must be conducted regularly.

The use of open stone asphalt and bitumen has only very limited environmental impacts. Preparation of asphalt and bitumen causes some short-term air pollution. After incorporation into the works, asphalt and bitumen wear very slightly from daily use, but the effect is insignificant as it is a very long-term decomposition process in a large volume of water. Open stone asphalt is widely used elsewhere where stringent environmental regulations are maintained.

The slow decomposition of bamboo and reed will not detectably deoxygenate the water. The use of geotextile is not anticipated to have adverse effects: the material has passed the stringent Dutch environmental regulations and is widely used. Construction of containment bunds with cement, sand, gravel and water will temporarily cause some air pollution with dust.

I.4.2.3 Construction phase

(a) Hydraulic fill

The existing flora and fauna is disturbed and sedentary organisms are smothered by hydraulic fill. The effect is negligible as the extent of habitat destroyed is very small. Moreover, the existing flora and fauna is relatively poor, and is already locally affected by water pollution near the towns.

A temporary decrease in water quality may occur if the hydraulic fill is polluted. The effect depends on the pollution load of the dredged material. The present river-bank soils near the towns are likely to be more contaminated than the dredged material due to local drainage of domestic and industrial water. Theoretically, clean hydraulic fill may adsorb/absorb more pollutants than the former river-bank material, thus decreasing water pollution temporarily.

Hydraulic fill transported by truck may temporarily hinder road transport at Munshiganj, if not adequately planned.

(b) Slope re-dredging

At Bhairab Bazar, a temporary decrease in water quality may occur if the hydraulic fill is polluted. The effect depends on the pollution load of the re-dredged material.

Re-dredging activities may hinder navigation, depending on the selected site and the planning of activities.

I.4.2.4 Post-construction phase

(a) River-bank protection

In Maniknagar and Haimchar, the river-bank material is changed from fine sand to boulders, bamboo, and reed. The river-banks of the other sites have already been strengthened with boulders, bricks, or cement blocks. The stones covered with algae and some aquatic vegetation attract certain types of fish and discourage others. As the area to be protected is quite small in comparison to the total length of river-bank, the overall effect will be insignificant.

River-bank protection with revetments does not change erosion patterns downstream. The advanced revetments decrease the width of the river, and increase the flow velocities in the outer bend up to about 5% of high discharges. The constriction may theoretically cause a limited backwater effect upstream and a diminished overbank flow downstream. The effects of constriction are marginal as the rivers are very wide.

(b) Wrap

Demolition of storage facilities, labour camps and reclaimed areas may temporarily cause some air, water and soil pollution.

I.4.3 Potentially significant effects

In the following section background information is presented for a further assessment of the extent of the impacts identified as potentially significant.

I.4.3.1 Infrastructure displacement

River-bank protection will provide significant socio-economic benefits to the population of Bhairab Bazar, Munshiganj and Chandpur. However, it will also give some temporary inconvenience to activities along the waterfront:

- In Bhairab Bazar, landing facilities for the oil terminal, launch and cargo ghats will have to shift temporarily. Several market stalls may have to be re-located temporarily to enable earth filling.
- The ferry ghat at Munshiganj will be moved temporarily; loading/unloading operations at the cold store and industries will temporarily have to be shifted.
- At Chandpur, unloading at the fish market near the railway station will have to be shifted.

The provision of alternative landing facilities will modify the effect to a great extent.

These displacements may cause resistance by the local population. Cooperation of the local population is necessary: vandalism or other forms of resistance may damage the newly constructed protection or delay the construction schedule.

The risk of public resistance is at present not clear. The affected population faces short-term costs versus long term benefits, such as protection from river-bank erosion, and extension of the market on the advanced revetment. Therefore, if the inconveniences are limited due to proper re-location planning, the project will probably be perceived as beneficial to the local population's interests and the socio-economic effect will be minimal.

I.4.3.2 Water quality deterioration

The extent of the impact of dredging depends on the pollution load of the dredged material. Two types of pollution may be involved: organic pollution and toxic chemicals. The soil and water quality of the Meghna has not been quantified, but some assumptions can be made:

- Upstream of Bhairab Bazar there are a few pollution sources (pulp and paper industry, agro-chemicals used for tea), but the concentration of their pollutants will be insignificant when they reach the town. The waste water of the Zia fertilizer factory is treated before discharge. Organic pollution from agro-industries and domestic wastes is likely along the waterfront, but hydraulic fill will not be dredged nearby. Further downstream, the dissolved oxygen content will be higher, as

the discharge from the Old Brahmaputra dilutes the pollution.

Pollution by toxic chemicals is not considerable. Only pollution from the Jamuna Oil Terminal poses a small risk if material is dredged downstream, above the confluence with the Old Brahmaputra.

- Munshiganj accommodates a considerable number of agro-industries. Furthermore, the Dhaleswari receives water from the Dhaka and Narayanganj industrial areas, and the Dhaka sewerage system. Organic pollution lowers the dissolved oxygen content. A very low dissolved oxygen content, combined with dredging of anaerobic sediments, may locally affect respiration of aquatic life, leading to fish kill in extreme cases. The extent of the impact depends on the water and soil quality at the dredging site.

  The Dhaleswari receives the waters of the Buriganga, which is polluted with chromium from the tanneries near Dhaka. The concentration of pollutants will have decreased considerably when it reaches Munshiganj due to the mechanisms elaborated upon in Section I.2.3.5. The town itself contributes mostly organic effluent from domestic and agro-industrial wastes. Therefore, the soil of the Dhaleswari is not expected to be heavily polluted with toxic chemicals.

- At Chandpur, some sand will be dredged locally to reclaim land on Chirar Char, north of the town. The major part will be dredged elsewhere. The three main sources of pollution in the area are discharges from the Ganges and the Dhaleswari, and industrial and municipal waste discharged by Chandpur. Pollution from the Ganges and Dhaleswari are diluted by the large flows of the Meghna and Brahmaputra (Jamuna). As Chandpur has mainly small-scale agro-industry the soils in the vicinity will not be heavily polluted.

Concluding, there is a small risk of dredging material being polluted with toxic chemicals at Munshiganj. The pollution is not expected to be significant.

As dredged material is predominantly anaerobic, suspension of these sediments may temporarily lower dissolved oxygen levels at the dredging site. The dissolved oxygen content of the Meghna is unknown, but might especially be low near drainage sites of agro-industries. There is a small risk of fish kill if anaerobic material is dredged in water with a low dissolved oxygen content. Detailed data on the conditions of the soil and the dissolved oxygen levels of the water are not available at present, but the information available indicates that only dredging downstream of the agro-industry in Munshiganj poses a risk. The effect is estimated to be minor as it is localized and short-term.

I.5 MITIGATION OPTIONS

I.5.1 Introduction

Mitigation may include avoiding, minimizing, rectifying, reducing, eliminating or compensating impacts. In the EIA, the emphasis lies on significant and easily mitigatable negative impacts.

Several mitigative measures have already been incorporated in the project design: the permeable river-bank protection works do not impede drainage; the tender documents specify that outlets for municipal drains will be constructed to prevent congestion; and dredging will mostly take place during the low flow period. After land reclamation, erosion control measures will be taken. The nature of the contract is such that the contractor will limit dredging or reclamation activities as far as possible. After completion of the project, the contractor will be required to convert the work space to it's original state, as far as possible.

I.5.2 Mitigation

Two river-bank protection activities were identified with potentially significant adverse impacts, namely infrastructure displacement and dredging of polluted soil, but the extent of their impact can not be quantified at present (see Section I.4.3). A major component of their mitigation is the more detailed study of the extent of the impact.

Care must be taken that execution of the mitigative measures proposed is proportional to the impact. For example, if pollution levels are low at dredging sites, it is not required to monitor them.

Table I.5.1 presents an overview of the proposed mitigation options.

I.5.2.1 General

(a) Equipment

The air pollution from exhaust fumes, soil and water pollution from oil spills, and noise and vibration can be minimized with 'clean technology': this implies a minimal pollution generation or end-of-pipe pollution control measures. The contractor may be required to incorporate these measures to comply with Bangladeshi pollution standards. Accident risks can be reduced by enforcing safety regulations during construction.

(b) Labour force

Provision of adequate housing, waste disposal facilities, and medical care will minimize the environmental and social impacts.

Table I.5.1 **OVERVIEW OF MITIGATION OPTIONS**

Activities	Mitigation options
General	
1 equipment	1 pollution control measures
2 labour force	2 adequate housing and sanitary facilities, safety measures
Pre-construction	
1 land clearing	1 site selection
2 infrastructure displacement	2 temporary relocation, pontoons, planning
3 dredging	3 site selection, water and sediment quality assessment, pollution control measures, coordination
	4 site selection, drainage planning, pollution control measures
4 work areas	5 none
5 construction materials	
Construction	
1 hydraulic fill	1 pollution control measures, coordination
2 slope re-dredging	2 water and sediment quality analysis, pollution control measures, coordination
Post-construction	
1 river-bank protection	1 planning
2 wrap-up	2 pollution control measures, planning

I.5.2.2 Pre-construction phase

(a) Land clearing

The loss of land and wildlife habitat can be minimized by careful site selection, avoiding environmentally sensitive areas, and by limiting the extent of area to be cleared

(b) Infrastructure displacement

The provision of pontoons as temporary landing facilities, and the reorganization of market facilities in the vicinity will compensate the temporary loss of landing and market facilities at Bhairab Bazar, Munshiganj and Chandpur. It is recommended to develop a re-location scenario in cooperation with the local authorities.

(c) Dredging

The effect on flora and fauna at dredging sites can be minimized by avoiding polluted sites. An assessment of the environmental quality and composition of the soil at the dredging sites is recommended. If it is heavily polluted, dredging can take place at a less polluted site. If this is not possible, the effects on aquatic life should be monitored.

Interference with navigation, and road transport at Munshiganj, can be minimized by developing transport scenarios in cooperation with transport authorities.

(d) Work areas

At Bhairab Bazar, the effect of loss of land and fauna habitat can be minimized by using already reclaimed land in the vicinity. Drainage impediment can be avoided by constructing outlets.

Pollution during construction and operation can be minimized by the correct disposal of waste and pollution control measures.

(e) Construction materials

Both the quantity of materials used and the need for transport and transfer to work space and project sites can not be mitigated easily.

I.5.2.3 Construction phase

(a) Hydraulic fill

An assessment of the environmental quality and composition of the sediment at the project site is recommended.

Interference with navigation, and road transport at Munshiganj, can be minimized by developing transport scenarios in cooperation with transport authorities.

(b) Slope re-dredging

Interference with water and road transport can be minimized by developing transport scenarios in cooperation with transport authorities.

I.5.2.4 Post-construction phase

(a) River-bank protection

After completion of construction activities, the effects of river-bank protection are insignificant, and mitigation is not required.

(b) Wrap-up

Pollution can be minimized by adequate planning of demolition activities and incorporation of pollution control measures.

Fish is a staple food in Bangladesh, providing most of per capita animal protein in the daily diet. Even though fisheries are mostly artisanal, it is the second most important economic activity.

The main pollution sources are localized: municipal and industrial pollution is concentrated around the towns. Agro-chemicals are predominantly used in irrigated areas. The self-purification capacity of the Meghna is quite large, especially in the monsoon season. Due to the fast flow and large quantity of water discharged, pollutants are quickly transported and diluted. Water quality varies seasonally: as river flows are drastically reduced during the dry season, the concentration of pollutants increases.

I.6.3 Main environmental impacts

For each phase of the project, all possible negative environmental impacts have been identified for the various project activities. Most activities associated with river-bank protection have only temporary, short-term or small-scale impacts. This is due to the relatively limited area concerned. Furthermore, most impacts are associated with construction activities and not with the constructed works. The effects are therefore also limited in time. River-bank protection does not have a very intrusive nature: it strives to maintain a steady state at a certain location but does not significantly alter the riverine and estuarine ecosystems.

Only two activities were identified which may have a significant impact on the environment.

Firstly, displacement of infrastructure to enable hydraulic filling may have a socio-economic impact: resistance by the affected population, but the impression is that the local population is in favour of protection as it will protect infrastructure from erosion. Therefore, there is only a small chance that the impact will be significant for instance when short-term inconveniences shifts its attitude. At all sites, landing facilities, e.g. for launches, ferries or country boats, will have to be shifted temporarily.

Secondly, dredging may have significant environmental impacts under certain environmental conditions. If the dredged material is anaerobic and dissolved oxygen levels are low, respiration of aquatic life will be affected. In extreme cases, this may lead to fish kill. Moreover, the dredged material may be heavily polluted with toxic chemicals, leading to resuspension of pollutants and high levels of toxic pollutants downstream. Data on the water and sediment quality of the Meghna and Dhaleswari near the proposed dredging sites are, however, not available. Pollution is quickly diluted by high flow velocities and very large discharges. The sediment is therefore not anticipated to be significantly polluted.

I.6.4 Main mitigation options

Several mitigative measures have already been incorporated in the project design, such as the provision of drainage outlets.

The socio-economic impact of infrastructure displacement depends on the attitude of the affected population. Information on this issue is not available, but it is expected that minimization of the inconvenience is advisable. The provision of pontoons as temporary landing facilities, and the reorganization of market facilities in the vicinity, will compensate the temporary loss of landing and market facilities at Bhairab Bazar, Munshiganj and Chandpur. It is recommended to develop a relocation scenario in cooperation with the local authorities.

A major component of the mitigation of dredging activities is the more detailed study of the extent of the impact. Therefore, an analysis of sediment and water quality at project sites and proposed dredging sites is recommended before dredging. Appendix I/2 provides an overview of parameters for water and sediment quality surveys, and Bangladesh water quality standards.

I.6 EXECUTIVE SUMMARY

I.6.1 Scope of study

The Meghna flows through the eastern part of Bangladesh to the Bay of Bengal. The confluence of the rivers Ganges, Brahmaputra, and Meghna is known as the Lower Meghna, the third largest river and the largest estuarine delta in the world. The Lower Meghna has a river bed several kilometres wide, with channels and permanent or temporary islands of silt (chars) which continuously shift and change in number.

Erosion of the Meghna's banks is alarming at many places. Erosion of river-banks along the Upper Meghna is caused by the continuous shifting of the thalweg, meandering within a well-defined high waterbed. A gradual shift of the Padma to the northeast and eastward shift of the Lower Meghna cause continuous erosion of the latter's left bank. This is aggravated by wave action.

The Meghna River Bank Protection - Short Term Study was initiated to prevent further damage from river-bank erosion at seven sites and river-bank protection works are now in fact proposed at these sites along the Meghna including one location on the Dhaleswari river near its confluence with the Meghna. The study area can be divided in two distinct types: a) Upper Meghna and Dhaleswari, and b) Lower Meghna.

Upper Meghna and Dhaleswari River

- Bhairab Bazar Township and Railway Bridge
- Maniknagar
- Meghna Road and Highway Bridge
- Munshiganj Town

Lower Meghna

- Eklashpur
- Chandpur Town
- Haimchar

At present, detailed designs have been prepared for three priority sites. Feasibility or pre-feasibility studies were conducted for the four other sites.

Advanced revetments are proposed at Bhairab Bazar, Munshiganj and Chandpur. The existing river-banks are trimmed to acceptable slopes with dredged sand, and covered by a geotextile. At Chandpur, containment bunds prevent hydraulic fill from flowing out to a too gentle gradient. Underwater, boulders are dumped on top of a framework of bamboo poles and reed fascines (fascine mattress), and at the foot of the mattress to form a falling apron. Above water, the geotextile is covered by open stone asphalt. At the water-line, bitumen grouted boulders cover the geotextile.

I.6.2 Existing environment

The monsoon winds from the Bay of Bengal produce one of the highest recorded rainfalls in the world over Bangladesh and the catchments of its major rivers. The river discharges are very high. Recurrent floods often cover up to 30% of the country for 4-5 months during the monsoon season.

The Lower Meghna has one of the highest rural population densities in the world, and nearly all cultivable land in Bangladesh is farmed.

The Meghna and its tributaries, as well as their floodplains with shallow freshwater lakes and marshes, can be considered a wetland during the rainy season. The natural aquatic vegetation has for the most part been replaced with cultivated species. The wetlands support a variety of wildlife, but their numbers have decreased due to the high population pressure.

Agriculture is the backbone of the economy. Agricultural practices are adapted to flooding: as the floods recede, submerged areas become productive land, especially for rice.

The nature of the contract is such, that the contractor will minimize dredging activities. The effect on flora and fauna at the dredging site can further be reduced by avoiding heavily polluted sites. If dredging elsewhere is too costly, the effects on water quality and aquatic life should be monitored.

Ideally, a monitoring programme should study the changes in water and soil quality, including the effect on aquatic organisms and fish, before the proposed works are carried out (assessment of existing situation), directly after project implementation (assessment of short-term impact), and after one year (assessment of long-term impact). The monitoring programme should run for at least a year to detect seasonal variations, and preferably several years to detect annual changes.

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Appendix I/1

ASIAN WATERFOWL CENSUS OF THE LOWER MEGHNA, JANUARY-FEBRUARY 1990

APPENDIX I/1 ASIAN WATERFOWL CENSUS OF THE LOWER MEGHNA, JANUARY-FEBRUARY 1990

	English name of species	Latin name of species	No.
Cormorants and Darters	Little Cormorant	Phalacrocorax niger	35
Herons and Egrets	Indian Pond Heron	Ardeola grayii	172
	Cattle Egret	Bubulcus ibis	94
	Great Egret	Egretta alba	629
	Purple Heron	Ardea purpurea	7
	Grey Heron	Ardea cinerea	32
	Unidentified		238
Storks	Unidentified		2
Ibises and Spoonbills	White spoonbill	Platalea leucorodia	5
Geese and Ducks	Lesser Whistling Duck	Dendrocygna javanica	125
	Bar-headed Goose	Anser indicus	16
	Ruddy Shelduck	Tadorna ferruginea	239
	Common Shelduck	Tadorna tadorna	71
	Eurasian Wigeon	Anas penelope	173
	Common Teal	Anas crecca	5
	Garganey	Anas querquedula	3
	Northern Shoveler	Anas clypeata	59
	Unidentified Ducks		396
Shorebirds and Waders	Avocet	Recuvirostra avosetta	22
	Oriental Pratincole	Glareola maldivarum	4
	River Lapwing	Vanellus duvaucelii	8
	Grey-headed Lapwing	Vanellus cinereus	20
	Red-wattled Lapwing	Vanellus indicus	31
	Asiatic Golden Plover	Pluvialis fulva	70
	Kentish Plover	Charadrius alexandrinus	52
	Mongolian plover	Charadrius mongolus	473
	Black-tailed Godwit	Limosa limosa	40
	Bar-tailed Godwit	Limosa lapponica	6
	Whimbrel	Numenius phaeopus	101
	Eurasian Curlew	Numenius arquata	75
	Redshank	Tringa totanus	34
	Greenshank	Tringa nebularia	29
	Terek Sandpiper	Xenus cinereus	36
	Ruddy turnstone	Arenaria interpres	4
	Little Stint	Calidris minuta	2
	Curlew Sandpiper	Calidris ferruginea	12
	Unidentified Shorebirds		392
Gulls, Terns and Skimmers	Great Black-headed Gull	Larus ichtyaetus	138
	Brown-headed Gull	Larus brunnicephalus	93
	Unidentified Gulls		17
	Whiskered Tern	Chlidonias hybrida	39
	Indian River Tern	Sterna aurantia	18
	Little Tern	Sterna albifrons	7
	Unidentified Terns		25

Rare or endangered species

Appendix I/2

SELECTED PARAMETERS FOR WATER AND SEDIMENT QUALITY SURVEYS

APPENDIX I/2 SELECTED PARAMETERS FOR WATER AND SEDIMENT QUALITY SURVEYS

Type of Survey	Physical Parameters	Chemical parameters			Biological parameters	
		Inorganic	Organic	Nutrients	Microbiological	Hydrobiological
All surveys	Colour pH Conductance Suspended solids Total solids		Chemical Oxygen Demand (COD) Total Organic Carbon (TOC)			
Collection of base-line data	Odour	Acidity Alkalinity Calcium (Ca) Chloride (Cl) Dissolved Oxygen Hardness Iron (Fe) Magnesium (Mg) Manganese (Mn) Potassium (K) Selenium (Se) Silver (Ag) Sodium (Na)	Immediate, 5 day, and ultimate Biological Oxygen Demand (BOD)	Nitrate (NO_3)	Total plate count	
Municipal or industrial pollution	Floating solids	Arsenic (As) Barium (Ba) Beryllium (Be) Boron (Bo) Cadmium (Cd) Chromium (Cr) Copper (Cu) Dissolved carbon dioxide (CO_2) Fluoride (F) Hydrogen sulphide (H_2S) Lead (Pb) Mercury (Hg) Nickel (Ni) Vanadium (V) Zinc (Zn)	Cyanide (CN) Dissolved organic carbon Methylene blue active substances (MBAS) Oil and grease Pesticides Phenolics	Ammonia (NH_3) Nitrite (NO_3) Organic nitrogen Soluble phosphorous Total phosphorous	Faecal streptococci Salmonella	Benthos Plankton counts
Special surveys	Bed load Light penetration Particle size Sediment concentration Settleable solids	Aluminium (Al) Sulphates	Carbon alcohol extract (CAE) Carbon chloroform extract (CCE) Chlorine demand	Organic phosphorous Orthosulphates Polysulphates Reactive silica	Shigella viruses - Coxsackie A&B - Polio - Adenoviruses - Echovirus	Chlorophylls Fish Periphyton Taxonomic composition

Source: IHD-WHO Working Group on the Quality of Water, 1978

TENTATIVE WATER QUALITY STANDARDS FOR BANGLADESH

Parameters	Maximum allowable limits
Physical	
Turbidity	25 units
Colour	30 units
Threshold odour	unobjectionable
Chemical	
Total Dissolved Solids	1500 ppm
Chloride	600 ppm (max. 1000)
Iron	1 ppm (max. 5)
Manganese	0.5 ppm
Zinc	15 ppm
Copper	1.5 ppm
Sulphate	400 ppm
Total hardness	250 - 450 ppm
Fluoride	1 - 2 ppm
Nitrate	45 - 50 ppm
Phenolic substances	0.002 ppm
pH	6.5 - 9.2
Bacteriological	No detection of coliform bacteria in 90% of samples
Toxic substances	
Cyanide	0.2 ppm
Hexavalent Chromium	0.05 ppm
Lead	0.05 ppm

Source: **Department of Environment**