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

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

KALNI-KUSHIYARA RIVER IMPROVEMENT PROJECT

PRE-FEASIBILITY STUDY
FINAL REPORT
November 1994

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

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

Canadian International Development Agency

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

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ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
AST	Agriculture Sector Team
BBS	Bangladesh Bureau of Statistics
BFDC	Bangladesh Fisheries Development Corporation21
BFRSS	Bangladesh Fisheries Resource System Survey
BIWTA	Bangladesh Inland Water Transport Authority
BIWTMAS	Bangladesh Inland Water Transport Master Plan
BRDB	Bangladesh Rural Development Board
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CEA	Canadian Executing Agency
CO	Community Organizer
DAE	Department of Agricultural Extension
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DSSTW	deep set shallow tube well
DTW	deep tube well
EIA	environmental impact assessment
EIRR	economic internal rate of return
EMP	Environmental Management Plan
EPWAPDA	East Pakistan Water and Power Development Agency
FAP	Flood Action Plan
FCD	flood control, drainage
FEAVDEP	Flood and Erosion-Affected Villages Development Project
FFW	Food for Work
FPCO	Flood Plan Coordination Organization
FW	future with project scenario
FWO	future without project scenario
ha	hectare
HTW	hand tube well
HYV	high yielding variety
IBRD	International Bank for Reconstruction and Development
IEE	Initial Environmental Evaluation
ISPAN	Irrigation Support Project Asia Near East
km	kilometer
LAD	Least Available Depth
LLP	low-lift pump
LT	local transplanted
m	meter
Mm^3	million meter cube
MIWDFC	Ministry of Irrigation, Water Development, and Flood Control
MOEF	Ministry of Environment and Forests
MOL	Ministry of Land
MPO	Master Planning Organization
NERP	Northeast Regional Water Management Project
NGO	non-governmental organization

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NHC	Northwest Hydraulic Consultants
NPV	net present value
O & M	operation and maintenance
PD	person-day
PWD	Public Works Department
RCC	reinforced concrete
RRA	Rapid Rural Appraisal
SLI	SNC-Lavalin International
SPARRSO	Space Research and Remote Sensing Organozation
STW	shallow tube well
SWMC	Surface Water Modelling Centre
WARPO	Water Resources Planning Organization

US $1 = Tk 38

MPO Land Classification Terminology

Class F0	Land inundated to a depth of less than 0.3 m
Class F1	Land inundated to a depth of between 0.3 m - 0.9 m
Class F2	Land inundated to a depth of between 0.9 m - 1.8 m
Class F3	Land inundated to a depth of more than 1.8 m
Class F4	Land inundated to a depth of more than 1.8 m and on which deepwater aman cannot be grown

EXECUTIVE SUMMARY

The purpose of this project is to control the rapid channel instability and aggradation that has been seriously affecting the lower Kushiyara-Kalni River over the last 20 years; to slow or reverse the trends to higher pre-monsoon flood levels that has been occurring throughout the deeply flooded Central Sylhet Basin; to improve navigation along the river; and to develop homestead platforms with the disposed soil for use by the local communities.

During the last 30 years approximately 25 million m^3 of sand and silt has been deposited in the 50 km reach downstream of Markuli, causing bed levels to rise by as much as 5 m. During the same period there has been a trend towards rising pre-monsoon flood levels and poorer drainage due to higher post-monsoon water levels. The changes have been brought about as a result of several factors including upstream channel shifts, impacts of past loop cutting and alterations to the river's discharge regime. These impacts have disrupted water transport, increased channel instability and affected submersible embankment projects in the Sylhet Depression.

A pilot dredging project is proposed as a first step in a long term dredging program. The pilot project is scheduled for two years and would include testing the suitability of using spoil for beneficial uses such as village platforms, marketing centres, landing facilities and other works. The estimated construction cost of the pilot project is US$ 1.5.

Following the pilot project a large scale river improvement program would be undertaken to rehabilitate the lower Kushiyara River. It is proposed to:

- undertake a capital dredging program over a four year period to deepen the main channel by dredging 13.5 million m^3 of material at strategically located shoals, sand bars and loop cuts between Markuli and Madna.

- initiate an annual maintenance dredging program of 0.5 million m^3/year to prevent new aggradation from occurring.

- construct local river training works and channel re-alignments downstream of Ajmiriganj to improve the hydraulic capacity of the channel and to assist in maintaining a self-scouring channel.

The capital dredging program would provide a Class I navigation channel (least available depth of 3.6 m) in the channel reach throughout the year. The combination of dredging and river training would improve the channel conveyance to reduce pre-monsoon flooding, to prevent further spills into the Baulai River system and to improve post-monsoon drainage throughout the Sylhet Depression and as far upstream as Fenchuganj.

The estimated cost of the works including the pilot project is US 43.78 million., based on current FPCO Guidelines.

NERP DOCUMENTS

The Northeast Regional Water Management Plan is comprised of various documents prepared by the NERP study team including specialist studies, the outcome of a series of public seminars held in the region, and pre-feasibility studies of the various initiatives. A complete set of the Northeast Regional Water Management Plan Documents consists of the following:

Northeast Regional Water Management Plan

Main Report
Appendix: Initial Environmental Evaluation

Specialist Studies

Participatory Development and the Role of NGOs
Population Characteristics and the State of Human Development
Fisheries Specialist Study
Wetland Resources Specialist Study
Agriculture in the Northeast Region
Ground Water Resources of the Northeast Region
Surface Water Resources of the Northeast Region
Regional Water Resources Development Status
River Sedimentation and Morphology
Study on Urbanization in the Northeast Region
Local Initiatives and People's Participation in the Management of Water Resources
Water Transport Study

Public Participation Documentation

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

Pre-feasibility Studies

Jadukata/Rakti River Improvement Project
Baulai Dredging
Mrigi River Drainage Improvement Project
Kalni-Kushiyara River Improvement Project
Fisheries Management Programme
Fisheries Engineering Measures
Environmental Management, Research, and Education Project (EMREP)
Habiganj-Khowai Area Development
Development of Rural Settlements
Pond Aquaculture
Applied Research for Improved Farming Systems
Manu River Improvement Project
Narayanganj-Narsingdi Project
Narsingdi District Development Project
Upper Kangsha River Basin Development
Upper Surma-Kushiyara Project
Surma Right Bank Project
Kushiyara-Bijna Inter-Basin Development Project
Dharmapasha-Rui Beel Project
Updakhali River Project
Sarigoyain-Piyain Basin Development

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1. INTRODUCTION

1.1 General Information

BWDB Division:	Sylhet, Sunamganj, Habiganj and Mymensingh
District:	Sylhet, Sunamganj, Habiganj and Kishoreganj
Thana(s):	Baniachong, Ajmiriganj, Nabiganj, Sunamganj, Derai, Sullah, Dowarabazar, Golabganj, Jagannathpur, Sylhet, Chhatak, Fenchuganj, Biswanath, Barlekha, Beanibazar, Kulaura, Itna, Austagram, and Mitamin
MPO Planning Area:	23, 27 and 28
Gross Area:	426,900 ha
Net Area:	361,000 ha
Geographic Extent:	91° 00' E, 24° 10' N 92° 00' E, 25° 00' N

1.2 Scope and Objectives

This report examines concepts for stabilizing and rehabilitating the channel of the lower Kalni-Kushiyara River in order to arrest trends towards rapid siltation, increased pre-monsoon flooding, and drainage congestion that have been plaguing the area for the last 20 years. These ongoing changes, which have occurred as a result of both natural processes as well as impacts from previous developments, are perceived to have widespread impacts throughout the region by contributing to flood damages, by impacting on navigation, and by reducing fisheries habitat.

The need for rehabilitation work along the Kalni-Kushiyara River has been identified previously by BWDB (1992), by BIWTA (1988) and by various local government authorities and residents of the affected region. Comments and opinions from these groups are summarized in a series of public seminars held in Sunamganj, Sylhet and Moulvibazar in 1992-93. However, there has been relatively little previous work done to define specific measures for improving the river.

This pre-feasibility level investigation describes a program of channel improvements by river training and maintenance dredging. The following topics are addressed in the study:

- the nature and causes of past channel changes and siltation;
- impacts of sedimentation and expected future trends;
- concepts for rehabilitating the river by making selective river training improvements and by dredging;

- the need for ongoing channel maintenance to manage future sedimentation;
- order of magnitude benefits from channel improvements and the relation of this work to other project initiatives in the region;
- possible options for disposing of spoil from dredging and potential use of the spoil for homestead and other infrastructure developments;
- unresolved issues and additional information that will need to be provided to demonstrate feasibility of the program; and
- the scope and objectives of a pilot dredging project that could be carried out to address some of the outstanding issues.

The investigation was completed over a period of three months during 1993, followed by an additional three months of work in 1994 to finalize the report. The multi-disciplinary study team included a water resources engineer, river engineering specialist, hydraulic modelling engineer, socio-economist, agronomist, fisheries specialist, environmental specialist, and an economist.

1.3 Data Base

The project analyses presented in this report used secondary data sources, and information obtained during field inspections, and personal interviews. The main data sources used in different specialist analyses are listed below:

- **engineering analysis:** River cross sections surveyed by NERP and SWMC during 1991-93, 1990 SPOT satellite imagery, 1984 LANDSAT imagery, 1983 air photographs, historic navigation sounding charts surveyed by BIWTA, existing topographic maps, MPO developed one square kilometre grid data and historic BWDB hydrological records were used. A two year morphologic monitoring programme was carried out to assess channel stability and sedimentation processes.
- **agricultural analysis:** Land Resources Appraisal for Agricultural Development in Bangladesh (AEZ Reports) for soils and Water Resources Planning Organization (WARPO) for agricultural inputs. Rapid Rural Appraisal (RRA) techniques were used to collect data on cropping patterns, crop damage, and yield.
- **fisheries analysis:** Topographic maps, BFRSS data, NERP Fisheries Specialist Study, field observations and local interviews, information provided by local representatives during a field seminar held in Sylhet in September, 1993.
- **wetland analysis:** Topographic maps, local revenue department records, personal field observations and interviews with local people.

- **socio-economic analysis:** Published BBS data on demographic features, education and agriculture; reports of the Directorate of Public Health and Engineering, and NERP data base on Population and Human Development, personal field observations and field interviews with various cross-sections of local people, opinion and suggestions from local representatives including NGO personnel and the Honourable Members of Parliament. A team of Community Organizers (CO) were placed in villages on the Kalni River to obtain local people's perceptions about problems and to solicit opinions on solutions that are needed.

1.4 Report Layout

The report is organized as follows:

- Chapter 2, *Biophysical Description*, provides a brief description of the region, its hydrology, and the evolution of the river system. Factors affecting siltation are identified.
- Chapter 3, *Settlement, Development, and Resource Management*, characterizes settlement patterns along the river, and land use in the project area.
- Chapter 4, *Without Project Trends*, characterizes conditions in the project area in the future if no mitigation measures are carried out.
- Chapter 5, *Scope of Channel Improvement*, describes the overall scope of a river improvement program.
- Chapter 6, *Proposed Project*, describes the objectives of the project, its components, sustainability and maintenance requirements, costs and phasing.
- Chapter 7, *Pilot Project*, outlines the objectives and scope of a two year pilot dredging project to demonstrate the feasibility of conducting an integrated dredging program on the river.
- Annex A contains supporting engineering data, tables, and detailed information.
- Annex B contains supporting human resources and land-use data.
- Annex C presents the initial environmental evaluation of the project, as required for project studies prepared under the Flood Action Plan. Supporting information, including results of a preliminary sediment/water sampling programme and a literature review of environmental impacts from dredging are also provided.
- Annex D summarizes the fisheries model that was used to assess project impacts
- Annex E summarizes results of the economic analysis

- Annex F describes the field work undertaken by the community organizers

- Annex G contains the report drawings

2. BIOPHYSICAL DESCRIPTION

2.1 Physical Setting

2.1.1 Location

The focus of this investigation is the 90 km reach of the lower Kushiyara and Kalni Rivers, extending from the town of Sherpur to the junction with the Upper Meghna River near Austagram (Figure 1). This river system affects much of the low-lying floodplain and flood basin lands in the Northeast region. The project area is bounded by the Kushiyara-Bijna-Ratna River system on the south, the Surma-Baulai River floodplain on the north and west, and the Upper Surma-Kushiyara River floodplain on the east. The project covers a gross area of 426,900 ha and extends over the districts of Sylhet, Sunamganj, Habiganj and Kisoreganj.

2.1.2 Physiography and Topography

The project area lies within the low-lying Central Basin or Sylhet Depression, a large bowl-shaped depression that occupies the middle of the north east region of Bangladesh. The Central Basin is bounded by the Surma River on the north, the Surma/Kushiyara floodplain on the east, the Old Brahmaputra River floodplain on the west, and the Meghna estuarine floodplain on the south. The basin is believed to have evolved as a result of alluvial and shallow lacustrine deposition into a rapidly subsiding trough. Principal landforms in the Central Basin include flood basins and backswamps as well as floodplain features such as channel scars, ox-bow lakes and channel levees. There are several prominent saucer-shaped depressions or *haors* (Dekker Haor, Baram Haor, Chaptir Haor, Naluar Haor, Tangua Haor, Mokar Haor, Puber Haor, Kakailseo Haor) that are bordered by natural levees from the complex maze of ancient and recent distributary channels that cross the basin. Figures 2 and 3 illustrate characteristics of these features.

Figure 4 and Table A.1 summarize the distribution of land elevations in various sub-units of the project. Elevations typically range between El. 3 - 8 m PWD in the project area, with the highest land on the east as it merges with the Surma-Kushiyara River floodplain, and the lowest land in the south-west near the start of the upper Meghna River. As a result, the dominant drainage is from northeast to southwest. In the Central Basin, approximately 25 % of the land lies below elevation 4 m and 50 % is below 5 m PWD.

2.1.3 Soils

The project area is covered by Old and Young Surma-Kushiyara floodplain soils.

The landscape in the Old Surma-Kushiyara floodplain comprises extensive, nearly level to very gently undulating basins, crossed by some narrow high ridges adjoining rivers and creeks. The main ridge soils consist of a grey, massive, puddled topsoil overlying a grey, mottled, silty clay loam to clay subsoil with blocky or prismatic structure and medium to strongly acid reaction. The poorly drained basin soils are grey to dark grey, clay with prismatic or blocky structure and medium to strongly acid reaction. The very poorly drained basin clays which remain saturated throughout the year, have a strongly reduced colour and near neutral reaction. Sometimes this landscape overlie a mucky or peaty layer within 1.2 m of the surface. The depth to the organic

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layer gradually decreases from the periphery to the centre of the basins. Exposed organic layers have not been reported in the project area.

The landscape in the Young Surma-Kushiyara floodplain is dissected by numerous cut-off channels, eroded levee-remnants and broader basins giving an impression of an undulating topography. The major soils on the ridges are grey to olive grey loams to light clays, sometimes stratified from the surface or from below the plough layer. The ridge soils consist of a grey, massive, puddled loamy topsoil with strongly to medium acid reaction overlying a grey, mottled clay subsoil with prismatic or blocky structure. The poorly drained basin soils consist of grey clays having prismatic or blocky structure and medium to strong acid reaction. The poorly drained basin clays which remain saturated throughout the year have a reduced colour, near neutral reaction and massive structure. The entire landscape overlies a buried topsoil (peaty or mucky layer) which generally overlies a more silty deposit.

2.2 Water Bodies

2.2.1 River Channels

The Kushiyara River, Kalni River, Old Surma River, and Darain Rivers are the principal channels of interest in this investigation. The Kushiyara River originates at the International Boundary near Amalshid where the Barak River bifurcates into the northward flowing Surma River and the south flowing Kushiyara. The reach of the Kushiyara downstream of Markuli to its junction with the Dhaleswari River is called the Kalni River. The Dhaleswari River joins the Baulai River to form the upper Meghna River near Bhairab Bazar (Figure 1).

The main tributaries to the Kushiyara-Kalni River system include the Juri River, Manu River, Khowai River, Karangi River and Sonai-Bardal River which drain the Tripura Hills of India to the south. The Ratna River drains the low floodplain land south of Nabiganj and Ajmiriganj and joins the Dhaleswari River near Madna. The Central Basin is traversed by a maze of distributary channels that convey flow from the Surma River as well as locally generated runoff into the Kalni and Baulai River systems. The largest of these channels is the Old Surma River channel which heads south from the Surma River near Sunamganj, bisects the Central Basin at a point near Derai and splits, with the larger channel forming the upper Kalni River and the smaller branch heading south west, eventually entering the main river north of Ajmiriganj. In 1978 the upper Kalni River was closed off just north of Markuli and in 1992 a second closure was constructed north of Ajmiriganj. As a result, other smaller distributaries, such as the Darain River, now serve to inter-connect the Kalni -Old Surma and Baulai River systems.

2.2.2 Open water bodies

About 31,826 ha (7.0%) of the project is under permanent water bodies, of which 18,497 ha are haors and beels, and about 13,329 ha are channels. These open water bodies include 29 haors, 43 beels, and 14 river and khal channels (Figure 5). Most of the haors and beels are interconnected with channels through which water spills into the project from the Surma, Dhanu/Baulai and Kushiyara Rivers during the flood season and drains out at the end of the monsoon season.

2.2.3 Closed water bodies

In addition to the open beels and khals there are about 28,502 ponds and ditches used for fish stocking and other household purposes. The ponds have a total area of about 3,360 ha. Most of the ponds are inundated during the high monsoon floods, particularly in low areas.

2.3 Climate

The project area experiences the sub-tropical monsoon climate typical of Bangladesh, but with variations due to its location and topography. Rainfall is the most significant and variable aspect of the climate, causing severe floods and flooding in summer, and an irrigation requirement in winter.

The variation of annual rainfall over the project area is best represented by data for 1961-90 for the eight BWDB rain gauges in, or around the periphery of, the project area. The locations of these climate stations are given in Table A2, and the data for 1961-90 in Table A3 (Annex A).

Mean annual rainfall increases from an average of 2,898 mm/year in the south to 5539 mm/year in the north, or by 91% across the project area. This latitudinal increase is mainly attributable to the presence of the Shillong Plateau to the north (Figure 6).

A regional analysis of annual rainfalls has shown that mean annual rainfall for 1961-90 was 10% greater than that for 1901-30, and that the variability of annual rainfalls for 1961-90 was 1.95 times that for 1901-30 (NERP Surface Water Resources Specialist Study, 1993).

There are four more or less distinct seasons in the project area relative to the annual cycle of water resource activity which reflects the seasonal distribution of the annual rainfall. The seasons are shown in Table 2.1.

The most distinctive climatic events of the year are the onset and withdrawal of the monsoon. In the project area onset occurs on average on 1 June plus or minus about 4 days, and withdrawal occurs on average on 7 October plus or minus about 14 days. The average duration of the monsoon is 122 days, but it has varied from 112 days to 139 days.

The seasonal distribution of the annual rainfall is shown in Table 2.2.

Table 2.1: Definition of Seasons in the Project Area

Season	Activity	Calendar Period
Dry	Irrigation	December through March
Pre-Monsoon	Flash Floods	April and May
Monsoon	Flooding	June through September
Post-Monsoon	Drainage	October and November

Table 2.2: Seasonal Distribution of Rainfall in the Project Area

Season	Percent of Annual Rainfall in Project Area	
	South (Manumukh)	North (Sunamganj)
Dry	4	2
Pre-Monsoon	25	15
Monsoon	65	78
Post-Monsoon	6	5
Year	100	100

Note: *These tables show that the rainfall is heavily concentrated in the monsoon season, but more so in the north than in the south, and that the dry season is slightly more intense in the north than in the south. Additional information on climatic averages and extremes is summarized in Annex A.*

2.4 Hydrology

2.4.1 Runoff Patterns

Table 2.3: Seasonal Distribution of Runoff

Season	At Sheola		At Sherpur	
	Discharge m^3/s	% of Annual Runoff	Discharge m^3/s	% of Annual Runoff
Pre-monsoon	472	11.5	1,152	17.4
Monsoon	1,415	69.4	1,952	59.0
Post-Monsoon	555	13.6	1,175	17.8
Dry Season	111	5.5	197	5.8
Year	682	100	1,101	100

Discharges on the Kalni-Kushiyara River system are governed by inflows from the Barak River at Amalshid and from tributary streams (Juri, Manu, Khowai, Sonai-Bardal), by inflows or losses that occur through distributaries, spill channels and breaches along the river channel system, and by locally generated runoff from rainfall over the project area. In addition, backwater from the lower Meghna River controls river stages, which affects the distribution of flow carried in the main river channels and as overbank flow on the floodplain.
Annex A summarizes the history of hydrometric measurements in the project area. Daily discharges have been published on the Kushiyara River at Sheola since 1965 and at Sherpur since 1975. No discharges have been measured on the Kalni River due to the large amount of flow carried out of its main channel in the monsoon season.

Figure 7 shows the range in daily discharges that has occurred at these stations as well as hydrographs during a typical year (1989) and an extreme flood year (1991). These hydrographs illustrate the annual pattern of flash flooding during the pre-monsoon season, a longer term flood rise during the monsoon, flood recession and drainage during the post-monsoon, and low water during the dry season.

The seasonal distribution of runoff at Sheola and Sherpur are summarized in Table 2.3. Water balance studies indicate the mean discharge of the Kushiyara-Kalni River at its junction with the

Upper Meghna River amounts to 1,537 m^3/s, or about 40 % higher than the flows recorded at Sherpur.

Table 2.4: Surface Water Availability

River	Location	Decade	Low flow, 80% dependable (m3/sec)		
			January	February	March
Kushiyara	Sheola	I	78.75	62.31	52.74
		II	72.30	55.88	44.08
		III	65.97	56.91	56.57

Source: NERP

2.4.2 Water Availability

Surface Water Availability

Surface water availability for irrigation (80% dependable low flow) for the months of January, February, and March is given in Table 2.4. The table shows available flow of about 44.0 m^3/s in the Kushiyara River during the critical month of March. Although the flows in the Kushiyara River are substantial, its present irrigation use and requirements for navigation restrict further large scale abstractions. However, there is some scope for installation of additional LLPs along both banks of the Kushiyara River.

Ground Water

Based on MPO (WARPO) data the estimated usable ground water recharge within the project area is 543 Mm^3. Of this, about 353 Mm^3 is available within the depth range accessible by force mode technology (DTW). Suction mode STW technologies could withdraw only about 13.0 Mm^3 which indicate STWs probably are not suitable due to aquifer constraints, but about 91 Mm^3 could be withdrawn by deep-set STW (DSSTW)(Table 2.5). The majority of the groundwater resource potential is located in Baniachong, Nabiganj, Biswanath, Jagannathpur, Sunamganj and Chhatak thanas (Table A.18, Annex A).

2.4.3 Flooding

Flood Characteristics

Three types of floods occur in the project area:

- winter floods,
- pre-monsoon flash floods, and
- monsoon season floods.

Table 2.5: Estimated Ground Water Recharge

Mode	Usable Recharge (Mm^3)	Available Recharge (Mm^3)
STW	21.38	12.83
DSSTW	140.11	91.09
DTW	543.01	352.74

Source: MPO (WARPO)

Winter floods, which occur between December and February, are caused by winter storms in the outlying hills as well as by local rainfall. They occur suddenly and are of a relatively short duration and hence are characterized as "flash floods". They rarely overtop the river banks but water readily enters the haors because at this time of the year, there are numerous openings in the river banks including hydraulic structures with opened gates. Because the drainage system generally is inadequate, water remains in the lowlands and submerges crops to

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depths and for durations beyond their tolerance limits. As a result, the crops (usually rabi crops and *boro* rice at various early stages) are damaged. These floods do not occur every year and are very unpredictable.

Pre-monsoon floods, which occur between March and May 15, are a normal feature of the region. Low magnitude pre-monsoon floods usually stay within the channel banks and enter the adjacent flood basins and haor areas through the open spill channels and distributaries. Larger pre-monsoon floods overtop river banks and flood the back basins and floodplain by overland flow as well as through spills. These floods are very flashy and may last from a few days to about two weeks, depending on the time of occurrence. The pre-monsoon flood volume is sufficient to fill the haor depressions, and they are the cause of major crop damages in the region.

Monsoon season floods are large and normally last from July to October. The extent of the 1988 flood over the project area is shown in Figure 8. Flooding in June 1993 was even more severe than the 1988 flood and almost the entire project area was inundated at that time. The monsoon season floods are a combination of flood inflow from external rivers, seasonal rainfall, and a lack of drainage due to backwater effects of the Lower Meghna River. Agricultural damage from these floods tends to be less since farmers either leave their land fallow during this time or they plant low yielding deepwater *aman* rice capable of elongating with the gradual rise of flood levels.

Magnitude and Frequency

Figure 9 shows trends in the maximum daily discharge during the pre-monsoon and monsoon seasons over the period 1965-1991 at Sheola. The average maximum daily discharge during the pre-monsoon season increased from 737 m^3/s in 1965-75 to 1,008 m^3/s during the period 1980-89. The maximum daily discharge during the monsoon season averaged 1,892 m^3/s in 1965-75 and 2,421 m^3/s in 1980-1989. Additional information on changes in flood discharges are found in Annex A, Table A.6. Explanations for the increased discharges on the Upper Kushiyara River include increased rainfall in the catchment, closure of Kushiyara spill channels which has confined flows to the main channel and reduced distributary flows (such as Sonai Bardal channel), and enlargement of spill channels along the Surma River (Kakura Khal) which has increased inflows to the Kushiyara River during some times of the year.

Previously, it was reported that ongoing channel shifting at the Amalshid bifurcation has caused the Kushiyara channel to capture a greater proportion of the Barak River's flow. However, a comparison of discharge records on the Upper Kushiyara River and Upper Surma River indicated that there has been no noticeable change in the distribution of pre-monsoon and monsoon season discharges at the bifurcation over the last 25 years.

Figure 10 illustrates trends in pre-monsoon and monsoon maximum daily water levels at Sherpur and Markuli on the Kushiyara River over the period 1950-1990. Figure 11 shows similar time series plots at Ajmiriganj and Madna. Madna, Ajmiriganj and Markuli represent respectively, the lower, middle and upper end of the Kalni River.

Maximum daily pre-monsoon flood levels have remained stationary at Austagram and Madna, but show an increasing trend upstream of Ajmiriganj. Pre-monsoon flood levels at Markuli and Ajmiriganj have increased by 1.25 m and about 1.0 m respectively since 1975. At Markuli, the maximum daily pre-monsoon water levels have been increasing in a remarkably consistent fashion since the 1950's, with the rate of increase averaging 8.5 cm/year over the last 25 years. In fact, inspection of Figure 10 shows pre-monsoon levels have risen by over 3 m between 1951 and 1990.

The trend towards increasing pre-monsoon flood levels on the Kalni/Kushiyara River can be attributed to several factors, including:

- increases in discharge
- sediment aggradation causing higher bed levels and reduced channel conveyance
- closure of spill channels which eliminates losses from the main channel

A review of stage-discharge rating curves at Sheola and Sherpur suggests the increased pre-monsoon water levels on the Upper Kushiyara River have been due primarily to changes in the discharge regime. Specific gauge plots at Sherpur and Sheola show no evidence of systematic upward shifts in rating curves over time (Figure 12). In fact, channel enlargement appears to have occurred along much of the Kushiyara River upstream of Manumukh, causing the rating curves to shift gradually downwards at these two sites. The increased pre-monsoon flood levels at Markuli and Ajmiriganj are believed to be related to the cumulative effect of increased discharges, river bed aggradation and channel confinement. The effect of ongoing sediment aggradation on the Kalni River is described in Section 2.5 of this report.

The trend of maximum daily water levels during the monsoon season at Markuli, Ajmiriganj, and Madna displays a very different pattern from those in the pre-monsoon season. Peak water levels during the monsoon season have remained nearly stationary over time, possibly even gradually lowering. A consequence of these trends is that the pre-monsoon flood levels on the Kalni River have been gradually converging to the levels that occur during the monsoon season. This pattern is illustrated at Markuli in Table 2.6 and Figure 10. In 1951-1957, the pre-monsoon flood peaks were lower than the monsoon flood level by an average of 3.6 m. Between 1980-1989, the pre-monsoon flood levels averaged only 1.4 m below the monsoon flood level and in 1991 the annual maximum occurred during the pre-monsoon season. If pre-monsoon flood levels continue to rise at the past rate, it is conceivable that they could approach levels comparable to average monsoon flood conditions in about 15 years. Submersible embankment projects generally are designed to provide a freeboard of 0.6 m above the 1:10 pre-monsoon flood level. If the submersible embankments in the project area continue to be raised to keep up with the rising pre-monsoon water levels on the Kalni River, they will eventually begin to confine monsoon flood flows, which could lead to higher water levels during the monsoon season.

The non-stationarity of the water levels also makes it questionable to estimate the magnitude and frequency of future flood events. Results of a frequency analysis using the historic records between 1964-1991 are summarized in Annex A (Table A9). The analysis showed the difference between an estimated 1:100 year pre-monsoon flood and a 1:5 year pre-monsoon flood amounts to about 0.66 m. This difference is

Table 2.6: Average Maximum Daily Pre-monsoon Water Levels

Station	Water Level (m PWD)		Difference (m)
	1965-75	1980-89	
Austagram	3.00	2.99	-0.01
Madna	3.15	3.39	+0.24
Ajmiriganj	3.56	4.53	+0.97
Markuli	4.89	6.14	+1.25
Sherpur/ Manumukh	6.40	7.20	+0.80

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small compared to the 3 m rise in flood levels that has occurred over the last 40 years (Figure 10). If pre-monsoon water levels continue to rise, it is conceivable that in the next decade or so, a 1:5 year flood level could coincide to a 1:100 year event based on historic water level occurrences.

Floodplain Inundation
Preliminary estimates of the extent of flooding under existing conditions are summarized in Table 2.7. The extent of inundation in the project area was estimated on the basis of a regional hydrodynamic modelling analysis using the MIKE 11 model as well as a review of recorded water level data at various hydrometric stations. The water levels were estimated for a 1:2 year flood condition. The depth of inundation was then calculated using these water levels and ground elevations derived from MPO's 1 km grid data. The project area was sub-divided into four main sub-regions (Figure 4).

Table 2.7 shows that during the pre-monsoon, about 142,000 ha (33%) could be inundated during a 1:2 year flood. During the monsoon season, approximately 370,000 ha (87%) of the total area is inundated, with 129,000 ha flooded in excess of 1.8 m during a 1:2 year flood.

2.4.4 Drainage

Drainage patterns throughout the project area follow the land gradient, sloping from north to south and southwest. Consequently, distributary channels from the Surma River on the northern boundary of the project all behave as spill channels, diverting water out of the Surma system into the Central Basin lowlands. Furthermore, spills from the Upper Kushiyara River drain west through Sadipur Khal near Sherpur. Sadipur Khal, does not have a direct outlet back into the Kushiyara River. Consequently, water accumulates in beels and haors until it overtops the Kushiyara right bank or finds its way into Kamarkhali Khal and the Darain River (Figure 1).

Historically, most of these flows drained into the Kushiyara/Kalni River system between Markuli and Ajmiriganj and thence to the Upper Meghna. However, increasing water levels during the post-monsoon season have reduced the river's drainage capacity (Table 2.8). Drainage has also been adversely affected after a closure dam was constructed across the right bank outlet channel near Markuli in 1978 to eliminate pre-monsoon spills from the Kalni/Kushiyara River into the Central Basin. A similar closure was also constructed near Ajmiriganj in 1993. Consequently, most spills and internal runoff from the basin are intercepted by the channels of the Darain River and Old Surma River which discharges into the Baulai River at Dhanpur (Figure 1). However, since these channels are too small to convey the inflows, the drainage from the entire basin is delayed.

On the left bank (south side), the Bijna-Ratna River system collects most of the accumulated runoff through many collector drains. Previously, water drained towards the Kalni River above Ajmiriganj through the Old Kushiyara River channel. Now, due to increased water levels and siltation in the outlet channel, the water collects in the low depressions north of Baniachung thana until it spills to the Ratna River through the Sutki River and Jhingari Nadi. Local residents report that the cross sections of the Jhingari Nadi and Sutki Rivers are not adequate to carry these flows so that the depth and duration of flooding has increased during the pre-monsoon season and post-monsoon drainage has been delayed.

Table 2.7: Area Flooded During a 1:2 Year Flood

Flood Condition	Non Flooded (ha)	Flooded Area (ha)			
		0.3 to 0.9 m	0.9 m to 1.8 m	> 1.8 m	Total
Pre-monsoon	285,067	66,351	57,410	18,063	141,824
Monsoon	57,334	104,774	136,198	128,594	369,566

Table 2.8: Water Levels at Markuli

Month	Average Level (m PWD)			Maximum Daily Level (m PWD)		
	1965-75	1980-89	Change (m)	1965-75	1979-89	Change (m)
Oct	6.06	6.43	0.37	6.59	6.99	0.40
Nov	4.49	4.82	0.33	5.36	5.66	0.30
Dec	3.01	3.46	0.45	3.53	3.97	0.44
Jan	2.32	2.93	0.61	2.63	3.22	0.59
Feb	1.91	2.65	0.74	2.20	2.91	0.71
Mar	2.13	3.06	0.96	2.69	3.90	1.29
Apr	3.11	4.40	1.29	4.18	5.52	0.34

2.5 River Stability and Sedimentation

Historic information, including Rennells maps of the region in 1768 indicate the Kushiyara River has evolved from a minor distributary channel to the present situation, where it carries two-thirds of the Barak River inflows during the monsoon season. Efforts have been made to develop an understanding of the main factors governing the patterns of channel instability and sediment transport along the river system. The following sections provide a brief description of engineering works and their impact on the river, the general character of the present day river regime and the pattern of sediment deposition and lateral channel shifting that is occurring.

2.5.1 River Regime

The Kushiyara River flows in a single irregularly meandering, high sinuosity sand-bed channel. There are few exposed point bars and no major islands (Figure 2). The Kalni River (downstream of Markuli), has an irregular sinuous channel with occasional long straight reaches as a result of recently constructed loop cuts (Figure 2). The Dhaleswari River (downstream of Madna) is a transitional reach that links the Kalni River with the upper Meghna River. In this backwater controlled reach, the river splits around large permanent islands and displays large bars and sand shoals.

The channel top width ranges from 200 m - 240 m on the Kushiyara River between Manumukh and Markuli, 150 m on the Kalni River below Markuli and up to 500 m below Ajmiriganj.

Figure 13 shows a longitudinal profile of the Kushiyara/Kalni River using cross sections surveyed by SWMC in 1992 and NERP. The channel widens and shoals to an average depth of only four

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metres downstream of Markuli. The channel geometry becomes highly irregular downstream of Markuli, with narrow, deep sections occurring in sections near recent loop cuts and wide, shallow sections immediately downstream from the cuts. The channel is virtually flat throughout this reach, with bars and shoals typically reaching to elevation zero metres PWD.

Water surface slopes vary seasonally and spatially. During pre-monsoon floods, the water surface slope can reach up to 80 mm/km along between Markuli and Ajmiriganj. During the monsoon season, when backwater from the Meghna River system inundates much of the Central Basin, the slope of the Kalni River decreases to less than 8 mm/km. Upstream of Sherpur, water surface profiles are only affected by backwater conditions to a minor degree and water surface slopes typically average 40 mm/km between Fenchuganj and Sherpur.

Bankfull stage coincides closely to a mean annual flood condition along most of the Kushiyara River between Amalshid and Sherpur (Figure 13). The channel's natural bankfull discharge capacity is around 2,100 m^3/s between Amalshid and Manumukh and 2,600 m^3/s at Sherpur. As the river enters the Central Basin lowlands just downstream of Sherpur, the bankfull level becomes lower and flood levels flatten out appreciably so that the channel banks become submerged to a depth of 2 - 3 m during the monsoon season. The bankfull discharge capacity downstream of Markuli averages approximately 1,400 m^3/s. This value is typical of pre-monsoon flood peaks and is less than half of some recent flood discharges. During the height of the monsoon, when water levels are highest and water slopes are lowest, only about 40 per cent of the total discharge will be carried by the main channel, with most flow conveyed overbank on the floodplain or carried by adjacent spill channels.

Channel sediments on the Kushiyara River consist almost entirely of fine sand, with median sizes typically ranging from 0.15 mm to 0.12 mm at Sherpur and 0.11 mm at Markuli. The bed material becomes finer and more variable on the Kalni River downstream of Markuli. Sediment samples from the SWMC at Ajmiriganj showed the bed consisted of fine sand, with a median size of 0.09 mm. Samples collected by NERP in September 1993 showed the reach between Markuli and Madna consisted of sand and silty-sand, with the silt content ranging between 5 % and 40 % in some locations.

2.5.2 Impacts of Past Developments

Flood embankments, spill channel closures and loop cuts have been constructed along the Kushiyara/Kalni River since the 1950's. Between 1952-1963 a major loop cut was constructed downstream of Sherpur (Figure 14). Another series of loop cuts were constructed along the Kalni River between Markuli and Ajmiriganj during the period 1977-1983. It is believed that the original purpose of the loop cuts was to assist navigation. The loop cuts were constructed by excavating a narrow pilot channel through the neck of the meanders, and then letting the new channel widen until it captured the main river flow. Although some widening has occurred along these excavations, the artificial channels are still considerably narrower and experience noticeably higher velocities than natural channel reaches. It appears cohesive bank sediments have prevented the channels from developing a full cross section.

Other developments that have affected flows and sedimentation patterns include:

- A closure was constructed across the Kalni River upstream of its junction with the Kushiyara River in 1978 to prevent pre-monsoon spills from the Kushiyara into the Central Basin haors. Flows now drain westward into the Chamti River, then into the Darain River,

- the outfall of Darain River around Ajmiriganj was closed in 1992; as a result the entire pre-monsoon discharge is now flowing through a small channel of the Old Surma River to the Baulai in the west.

2.5.3 Channel Instability

Lateral Instability

Channel instability and channel shifting have been recurring problems in the project area over the last 40 years (Figures 14 and 15). A major avulsion occurred just downstream of Sherpur between 1952-1963 when the Kushiyara River abandoned its former course (identified as the Bibiyana channel on Figure 14) and shifted northwards into a minor distributary (the Suriya channel). Based on available topographic maps, it appears approximately 60 million m^3 of sediment was eroded from the 30 km long Suriya channel. Furthermore, it appears most of this material was deposited in the Kalni River downstream of Markuli. The shift occurred around the same time as the loop cut just below Sherpur (Figure 14). However, it is not known whether the two events are related, although this appears likely.

In recent years there have been several major breaches along the Kalni River which has diverted flow northwards into the low-lying haors of the Central Basin and eventually into the Baulai River system. These breaches have generally occurred by enlargement of distributary channels and khals which branch from the main channel. In 1992 a breach was closed off opposite from Ajmiriganj by constructing a temporary closure. In 1994 a 200 m wide breach developed about 1 km downstream of Markuli which diverted flow into the Darain River. Another major episode of channel shifting and bank breaching occurred 12 km downstream of Ajmiriganj near the village of Katkhil (near Km 220 on Figure 14). This shift has resulted in a partial abandonment of the main branch of the Kalni channel and additional flow spillage into the Baulai River.

Vertical Instability

Assessments of vertical channel changes were made from a comparison of historic BIWTA sounding charts, from repeated surveys by the Morphology Directorate, BWDB and from repeat surveys by NERP.

Figure 16 shows bed levels along the Kalni River and Suriya River in 1963 and 1988 between Madna and Sherpur, as digitized from BIWTA sounding charts. Figure 17 shows 1 km average bed level changes between 1963-1975, 1975-1988 and 1963-1988. The sounding chart data indicates there has been considerable degradation or lowering of the channel (up to 5 m) along the Suriya River between Sherpur and Markuli. This degradation occurred as a result of the shift from the Bibyana channel into the Suriya channel. The channel responded to this avulsion by first cutting a deep, narrow channel, then gradually widening. Most degradation occurred between 1963 and 1975 when the Suriya channel was still relatively narrow. Most of this widening took place between 1977 and 1988. Degradation has also occurred immediately below Markuli, in the loop cuts that were constructed between 1977-1983. Most of these cuts have remained narrower than the natural channel, which has promoted scour in the constricted channel and deposition immediately downstream in the wider natural channel.

Substantial aggradation or raising of the channel bed has occurred between 1963 and 1988 in the reach downstream of Ajmiriganj. Most of this aggradation has developed since 1975. Figure 17 shows bed levels have risen by up to five metres near Ajmiriganj. Independent estimates of channel siltation were obtained from residents of Ajmiriganj. Their estimates of channel infilling ranged from 15 - 20 feet (4.5 m - 6 m) over the last 15 to 20 years, which are consistent with the values obtained from the BIWTA sounding charts. Aggradation rates declined downstream from Ajmiriganj and bed levels have remained virtually unchanged over the last 30 years at Madna. Therefore, the aggradation has developed in the form of a 50 km long "wedge", reaching its greatest amount near Ajmiriganj and gradually declining to zero near Madna.

A crude estimate of sediment deposition volumes was made from the estimated bed level changes and bed widths shown on the BIWTA sounding charts. This estimate indicated in the order of 25 million m^3 of sediment was deposited below Ajmiriganj in the period between 1963 and 1988. The rate of deposition amounts to roughly one million m^3/year between 1963-1988 and two million m^3/year between 1975-1988. Additional sediment deposition has also occurred outside of the main navigation channel on the floodplain and in adjacent beels and haors.

Repeat cross section surveys between 1989-1991 by the Morphology Directorate, BWDB showed continued aggradation and channel widening downstream of Ajmiriganj and irregular bank erosion, and scour and fill between Markuli and Ajmiriganj. However, it was not possible to estimate sediment deposition volumes from this data.

NERP surveyed nine cross sections between Markuli and Madna on six different occasions in 1993 to assess seasonal deposition and scour patterns along the river. These surveys indicated roughly six million m^3 of predominately silt and fine sand was deposited in the eight month period between May and December. The average bed level rose by about 0.6 m in the vicinity of Markuli and by 1.6 m downstream of Ajmiriganj. Flood conditions during 1993 were unusually severe so the figures are representative of deposition rates during a rare, extreme flood event.

2.5.4 Sediment Transport

Suspended sediment concentrations have been measured periodically at Sheola and Sherpur on the Kushiyara River by the BWDB and SWMC. These data were analyzed to provide a rough estimate of the river's annual suspended sediment load. This involved establishing rating curves between daily sediment concentration (C_i in mg/l) and daily discharge (Q_i) using linear regression:

$$C = aQ^b$$

The annual suspended load (G_a in tonnes/year) was computed from the recorded daily discharges:

$$G_a = k\Sigma aQ_i^{b+1}$$

where k is a constant and a and b are determined from the rating curve regression. Further information on this analysis is contained in Annex A. Given the scatter in the rating curves and biases associated with the measurement techniques, these estimates must be considered preliminary.

The average annual suspended load at Sheola was estimated to be around 5 million tonnes/year between 1964-1979, and 8 million tonnes/year between 1982 - 1991. Since a single composite rating curve was used for the entire period of record, the apparent increase in suspended load between 1982-1991 is due solely to the increased discharges that have occurred since 1980. SWMC determined the size distribution of the suspended sediment in 1991 and 1992 by using pump samplers. The sand fraction of the load (> 0.063 mm) varied between 9% and 35% and averaged 20%.

The average annual suspended sediment load at Sherpur was estimated to be 5 million tonnes/year during the period 1982-1991, or about 61 % of the load at Sheola. The accuracy of the two sets of measurements is probably not sufficient to conclude that there is a real decrease in sediment transport between Sheola and Sherpur.

No measurements of suspended sediment load have been made downstream of Sherpur on the Kalni River.

Sediment routing computations were made using the Ackers-White sediment transport equation (Ackers, White, 1971) to develop a conceptual model of aggradation and degradation along the Kalni-Kushiyara River. The pattern of sediment movement at Sherpur on the Kushiyara River was found to be very different from the pattern on the Kalni River downstream of Markuli. At Sherpur, sediment transport rates increase with discharge throughout the monsoon season and decrease as the discharge decreases during the post-monsoon season. However, on the Kalni River, the water surface slope rises steeply in the pre-monsoon season and then drops to near zero during the monsoon as the backwater from the Meghna River drowns out the channel cross section. The slope increases again during the post-monsoon season when the water levels in the Meghna drop again. As a result, the sediment transport rates in the Kalni River rise very steeply during the pre-monsoon flood, decrease to near zero during the peak of the monsoon, and may rise again somewhat during the post-monsoon season.

The routing calculations indicated sediment is flushed out of the Kalni River during the pre-monsoon season when the slope and channel velocities are highest. Sediment is deposited during the monsoon when velocities and slopes are still high at Sherpur but low along the deeply flooded, backwater controlled reach of the Kalni River. Some sediment can also be scoured from the reach during the post-monsoon season. Future sedimentation patterns on the Kalni River will be very sensitive to any changes to the discharge regime during the pre-monsoon and monsoon seasons. If the magnitude of monsoon discharges increase and pre-monsoon flows decrease or remain approximately the same, then sedimentation rates will accelerate. If pre-monsoon flows increase while monsoon flows remain the same, the river will be able to flush more sediment out of the reach into the Meghna River and the channel may degrade.

2.6 Wetlands and Swamp Forest

2.6.1 Natural Wetlands

The project area includes many important perennial wetlands and at least 40 major haor complexes within the project area. A list of these wetlands with their categories of importance for wildlife is given in Annex B (Table B.2). Most of these haor complexes comprise several beels and are located largely in the south-west portion of the project area (Figure 5). The total area of perennial wetlands is about 18,497 ha, which is about 4.3% of the total project area. Hakaluki Haor, one of the key wetland sites is also situated at the far eastern end of the project area and is discussed separately.

The characteristics of these wetlands depends on their location. The wetlands in the northeastern section such as Morir, Majail, Dubrir and Muktarpur Haors are flat-shallow and have very few perennial water bodies. This situation creates very good habitat for numerous submerged and rooted floating plants. Ongoing siltation due to over bank spills and breaches in the river banks as well as human interference through encroachment of paddy field inside the wetlands makes the area unsuitable for both wild flora and fauna. Moreover, in some areas, utilization of water from the beels for irrigation makes the areas more exposed and unsuitable for natural habitat.

In the northern section, the major wetland is Dekker Haor, which possesses many deep perennial water bodies. These deeper pockets and the vast shallow floodplain makes the wetland a very diversified habitat for wetland flora and fauna. In deeper regions, the deep flooding and high wave action makes it impossible for floating plant communities to survive the monsoon. However, submerged plants grow very well during the time of water recession. In the shallow floodplain, floating plant communities grow profusely with sedge/meadow the most important plant community here. This wetland also suffers from human interference.

Major wetlands in the central portion of the project area (where flooding is more severe), include Chatal, Mokar, Haitola, Tanguar, Baram, Pagnar, Pangasiar, Sanghair, Kaliagota and Madarkandi Haor. All of these haors are extensive and contain many perennial *beels*. The wetlands provide a very diverse habitat for wetland flora and fauna. Floating plant communities can not survive in the monsoon season in the deeper regions because of deep flooding and high wave action. However, submerged plants grow particularly well during the post-monsoon recession. In the shallow floodplains, floating and sedge/meadow as plant communities grow profusely.

The western part of the project area, especially the southwest, is the deepest flooded portion and includes three large and deep haors. The major wetlands include Dabhanga Haor, Abdullahpurer Haor and Matikata Haor. All these haors remain deeply flooded in the monsoon and cannot support much natural vegetation. However, with the recession of water in the post-monsoon season, plant communities start growing and very rapidly spread over almost the entire area. The most important wetland plant community of this area is sedges/meadow, which produces valuable grasses. These grasses are grown on very low land, and at the border of the perennial water bodies where residual moisture remains high throughout the whole dry season. Although interference is lower in this area, encroachment is still a major problem here and most of the land where water is available for irrigation has already gone under rice cultivation.

Habitat degradation makes wildlife rare in almost the entire project area. All of the bigger mammals have already disappeared. Smaller mammals such as otters, rats and fishing cats are the major wildlife constituents. Major concentrations of waterfowl are only restricted to the larger haor complexes and mostly in the western section and in Hakaluki Haor. Hakaluki Haor is designated as a wetland of international significance and is being proposed by NERP and MOEF for declaration as a RAMSAR Site.

Hakaluki Haor

Hakaluki Haor is the largest and most famous haor in Bangladesh. It comprises a complex of more than 80 interconnecting *beels* in a shallow basin with the Patharia and Madhab Hills to the east and the Bhatera Hills to the west. The important *beels* include Chatla, Pinglarkona, Dulla, Sakua, Barajalla, Pioula, Balijuri, Lamba, Tekonia, Haorkhal, Tural, Baghalkuri, and Chinaura beel. The total area of this wetland is about 18,000 ha of which 4,400 ha retains water perennially. During high water, the entire haor is inundated and over 60% of the area is inundated by more than 2.5 m but as the water level falls during the dry season the beels become isolated from one another. Some of the land between the *beels* are cultivated while most of the land remains fallow and serves as pasture lands. The ecological characteristic, especially the vegetation patterns, differ sharply between the permanent water bodies and the seasonal ones. In the permanent water bodies, vegetation is less frequent in the monsoon than during winter. This is because most of the vegetation is submerged and needs light for their growth. Consequently, in the winter season, when the water becomes clear, the vegetation starts to flourish. On the other hand, aquatic vegetation start their germination just after the start of the monsoon season. The dominant species are *Vallisnaria spiralis, Hydrilla verticillata, Ceratophyllum* sp., and *Najas* sp. in the perennial beels and *Nymphoides indicum, Aponogeton* sp. and *Nymphaea* sp.

This wetland is very important for the migratory waterfowl. In January 1993, 64,000 and 15,000 waterfowl were counted from Haorkhal and Chatla beel respectively. Barheaded Geese, which are now very rare in the freshwater wetlands of Bangladesh were observed during these counts. Adjutant Stork, Bear's Pochard, Falcated Teal, Broadbill Sandpiper, Nordmann's Greenshank, Spotted Redshank, Temminck's Stint, Pallas's fish Eagle, Steppe Eagle and Osprey are other important species in this area. During winter, Hakaluki Haor becomes an important area for duck shooting and commercial trapping. At least 20,000 ducks are harvested from this haor alone.

Human interference, mostly due to fishing practices and poaching has affected the area. Wildlife is not very common in the haor proper, except for some frogs, tree rats, and resident waterfowl, particularly pheasant-tailed jacana. The practice of de-watering for fishing and irrigation purposes has rapidly depleted the turtle population from the wetlands.

2.6.2 Swamp Forest Trees

Many small swamp forest plots ranging in area from 5 to 10 ha still exist in the project area. The major ones include Islampur, Bhatidhal, Udaypur and Kartikpur in Sunamganj district and Delhir Akhra, Choto Abda, Bitangol, Khorotir jungle in Kishoreganj district. All these forest patches are more or less similar in characteristics and consist mostly of *Barringtonia racemosa* (hizal) and *Pongamia pinnata* (koroch) trees. These forests are not very dense and undergrowth are not at all prominent except for some grasses.

3. SETTLEMENT, DEVELOPMENT, AND RESOURCE MANAGEMENT

3.1 Human Resources

The following section provides a summary of settlement patterns and land use. Additional information,including quality of life indicators is contained in Annex B.

3.1.1 Land Use and Settlement Pattern

Land Use
Current land use is summarized in Table 3.1.

Table 3.1: Current Land Use

Use	Area (ha)
Cultivated (F0+F1+F2+F3)	361,000
Homesteads	9,500
Beels	18,497
Ponds	3,360
Channels	13,329
Hills	4,200
Fallow[1]	9,924
Infrastructure[2]	7,090
Total	**426,900**

[1] Multi-use land, wetlands, reedlands, grazing lands, village grounds. Includes F4 land.
[2] Government-owned land not appearing elsewhere.

Settlements
Settlements within the project area are mainly found in the form of villages along the levees of the rivers and along road sides. Where land levels are higher, especially in Sylhet, Bishwanath and Golapganj thanas, homesteads are constructed in the fields. Settlements are extremely sparse in the low-lying haor areas where land elevation is low.

Flood Damage to Housing
Generally, homesteads located on higher lands are not damaged by floods. Homesteads situated in the north-eastern part of the project area are damaged by pre- monsoon and early monsoon flash floods. Damage to homesteads as a result of monsoon flooding is common in the haor areas where homesteads are frequently eroded as a result of wave action. Homesteads constructed along the river banks are threatened by bank erosion, especially along the Kalni-Kushiyara River banks.

Coping Strategies
Homestead platforms are typically raised above natural ground levels by one meter or more to avoid monsoon flooding. Within villages situated in low-lying haor areas, homesteads are raised by three to five meters to avoid flooding. Measures are taken to protect the homesteads against wave action during the monsoon season. For example, protective walls are made around the homesteads with soil, bamboo, and locally available grasses. Flood waters from pre-monsoon flash floods usually recede from homesteads within a week or so. By comparison, monsoon flood waters stay in the haor areas for five to six months, starting in late May or early June. If there is severe flooding, villagers generally make platforms inside their houses and shift their belongings to safer places, if available. In such situations the poor suffer the most. Villagers shift their homesteads to other places when their homesteads are eroded as a result of bank erosion. In such situation, the landless generally migrate to the cities for survival.

Table 3.2: Population Distribution by Age Group (%)

Sex	Population Age Group (Years)						Total
	0-4	5-9	10-14	15-54	55-59	>60	
Male	16.6	15.8	13.6	45.7	2.0	6.3	100.0
Female	17.4	16.6	12.3	47.0	1.6	5.1	100.0
Total	17.0	16.1	12.9	46.5	1.8	5.7	100.0

Source: BBS, 1981 Population Census

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 2,410,605 (1991) of whom 1,183,409 are female. The gender ratio is calculated to be 103.7 (males to 100 females). The total households, are estimated to be 388,874 within 3,766 villages. The population increased by 1.87 % per year between 1981 and 1991.

The cohort distribution for males is as follows: 32.4 % are below 10 years of age, 45.7% are between 15 and 54 years of age, and 6.3% are above 60 years of age. The corresponding distribution for females is 34.0%, 47.0%, and 5.1% (Table 3.2).

The average population density is 565 persons per km^2, with densities ranging from a maximum of 1,071 persons per km^2 in Sylhet Sadar thana to 331 persons per km^2 in Itna thana. The average household size in the area is estimated to be six persons.

3.1.3 Land Ownership Pattern

More than 55% of the households are functionally landless (with less than 0.2 ha of cultivable land). Among the landless, about 2.5% have no homesteads of their own. If the definition of landless includes land holdings up to 0.4 ha, the proportion of households increases by 13%. Among the others, the small (0.21 - 1.00 ha), medium (1.01 - 3.00 ha) and large farmers (more than 3.00 ha) are 19.7%, 18.5%, and 6.6% respectively.

The project area has a substantial amount of land not available for cultivation. These include deeper wetlands, reed lands and community pastures. The price of agricultural land varies from Tk 5,000 to Tk 100,000 per ker (0.12 ha), depending on the quality of the land and the intensity with which it can be cropped.

3.1.4 Land Tenure

Owner operation is common in the area. The large land owners of the area generally share out their lands to tenants for operation. In this share cropping system, land owners provide no inputs but can retain one-half of the produce. For HYV rice, the land owners share 50% of the input costs. The leasing out of land in kind (chukti) is declining in the area. However, leasing out of land with advance cash (rangjama) is widely practised in the project area, especially in the haor areas. The usual rate for such arrangements varies from Tk 500 to Tk 1,200 per ker (0.12 ha) and this is paid in advance to the land owner for one season.

3.2 Water Resources Development

3.2.1 Flood Control & Drainage

There are 13 existing major FCD projects in the study area including seven completed projects and six ongoing projects (Figure 1). The total gross area of these projects is about 72,000 ha, and the net cultivable area is 56,000 ha. (Table 3.3). These projects are described in the NERP report entitled *Regional Water Resources Development Status*.

Projects on Kushiyara Left Bank

There are four existing projects on the left bank with a gross area of about 25,000 ha. Two of the projects, Sutki River Embankment Project and Sutki River FCD Project include about 92 km of submersible embankments and are designed to protect boro crops from pre-monsoon flooding. The remaining two projects, Jhingari Nadi Scheme and Bashira River Re-excavation, were designed to improve drainage and increase winter season irrigation and include about 26 km of re-excavated drainage channels. All these projects are located around Baniachong thana.

Projects on Kushiyara Right Bank

There are nine projects on the right bank of the Kushiyara River with a total gross area of about 47,000 ha. The Kushiyara right bank schemes are all submersible embankment projects which provide pre-monsoon flood protection to boro crops. Four of the projects are completed (Shanghair Haor, Baram Haor, Bhanda Beel, and Tangua Haor); work is ongoing on five of the projects. Two of the ongoing projects have only embankments (Naluar II and Chaptir Haors) and the remaining three have completed embankments but the structures are still under construction. The total length of embankments for the nine projects is about 250 km.

Boro cultivation has increased following completion of some of the projects, and it appears that there have been some agricultural benefits. However, pre-monsoon flooding still occurs and crops are damaged almost every year in parts of the schemes. Local people of the Bhanda Beel project stated that in recent years Kushiyara River water levels have increased substantially. Now the banks of the Kushiyara are frequently overtopped, submersible embankments are breached, and *boro* crops damaged. Local information suggests that the design crest level of submersible embankments was in the range 6.6 to 6.9 m PWD. Due to recurring overtopping, EIP reviewed the pre-monsoon water levels and has revised the submersible embankment design crest levels to 7.4 m PWD. The new crest level for submersible embankments is now approaching the level of monsoon floods.

Table 3.3: Completed and Ongoing Projects

Name of Project	Area (ha)		Embankment/ Re-excavation (km)	Structures (nos)	Remarks
	Gross	Net			
Kushiyara Left Bank					
Sutki River Embankment	12146	9710	33.8(E)	-	Completed
Sutki River FCD	1417	810	58(E)	2 Reg.	Completed
Jhingari Nadi Drainage and Irrigation	7150	1900	15 Re-excavation	2 Reg.	Under SRP
Basira River Re-excavation	4260	3600	11 Re-excavation	-	Completed
Sub-Total:	24,973	16,020	91.8(E); 26 (D)		
Kushiyara Right Bank					
Shanghair Haor	5000	4200	25	3 Reg.; 30 inlets	Completed
Naluar Haor I	9840	8800	52	6 Reg.	Reg. under completed
Naluar Haor II	2300	1924	26	under construct.	Ongoing
Chaptir Haor	4453	3624	35	under construct	under SRP
Udgal Beel	5900	4700	34	1 Reg; 3 Pipe sl.	Ongoing
Baram Haor	5500	4800	26	3 Reg.; 3 Pipe sl.; 34 inlets	Completed
Tangua Haor	5000	4500	20	2 Reg.; 6 Pipe sl.; 20 inlets	Completed
Bhanda Beel	4000	3600	32	1 Reg.; 5 Pipe sl; 20 inlets	Completed
Khai Haor	4940	4200	17.3	2 Reg.; 5 Pipe sl; 10 inlets	Ongoing
Sub-Total:	46,933	40,348	250 (E)		
Total:	**71,906**	**56,368**	**341.8(E); 26 (D)**		

Note: E - Embankment
D - Re-excavation for Drainage Improvement

3.2.2 Embankments along the Kushiyara Banks

Left Bank

Local information indicates that by 1966 the left bank of the Kushiyara River was embanked continuously along the Indian border downstream of Amalshid to Bairagir Bazar connecting high ridges and homesteads. Subsequently, during the 1980's submersible embankments were constructed from Bairagir Bazar to Bagla under the Kushiyara Bardal project. There are no embankments between Kushiyara Bardal and Manu River projects. Full flood embankments exist along the left bank from Nalua Gang to Manumukh as a part of the Manu River Irrigation Project which was constructed in the early 1960's.

Right Bank

The right bank of the Kushiyara River is embanked from Amalshid to Sheola and downstream of Balagnaj (opposite Manu River Irrigation Project). These embankments were originally constructed as submersible embankments, but have been gradually raised so that they are occasionally overtopped during the monsoon season

3.2.3 Irrigation

Surface Water

Present surface water irrigation coverage is about 138,122 ha by LLP's and traditional modes (AST, 1991). There are 2772 LLP's of various discharge capacities (1943 equivalent to 57 litres/sec) operating, which irrigate an area of 43,509 ha. The majority of the surface water irrigated area is concentrated in Ajmiriganj, Nabiganj, Baniachong, Derai, Sullah, Jagannathpur, Sunamganj, Kulaura and Beanibazar (Table A.19).

Ground Water

Present groundwater abstraction for irrigation is not significant. According to AST (1991), there are 89 shallow tube wells and 63 deep tube wells in the project area. The reported groundwater irrigated area is 3862 ha, of which 2075 ha is by shallow tube well and 1787 ha is from deep tube wells. Groundwater abstraction is about 23.5 million m^3 based on MPO's (currently WARPO) estimated groundwater irrigation duty. According to AST, groundwater irrigation is mainly concentrated in Baniachong, Nabiganj, Austagram, Itna and Chattak thana (Table A.20).

3.3 Agriculture

Crop production practices in the project are guided by agro-climatic conditions, especially the hydrologic regime. Present cropping patterns indicate the outcome of farmer's efforts to adjust crop production practices with the hydrologic regime. The area flooded in excess of 1.8 m (F3 land type) constitutes 30 percent of the cultivated area, another 32 percent of which is under F2 land type. Most of these areas are flooded early in the pre-monsoon season and continue to remain wet for a part of the *rabi* season. The dominant semi-aquatic environment during most part of the year has led to the emergence of rice as the single most important crop on these land types. Local *boro* is the only crop grown in most of the F3 land type initially on static water after the recession of flood water from these areas. Irrigation water is provided at the later stage wherever available. Elsewhere, farmers have to depend on pre-monsoon rains. Local varieties of broadcast *aman* are the dominant crop in F2 land type. Most of this is grown as a single crop except for minor areas where timely recession of the flood water in the post-monsoon season permits growing of *rabi* crops in the winter. Depending on irrigation facilities and the time of initiation of flooding, high yielding varieties of *boro* rice are grown mostly as a single crop and partly in sequence with transplanted deep water *aman* rice. Local varieties of *aus* rice are grown in sequence with *rabi* crops on about 5 percent of the cultivated area in F2 land type.

Rice-based multiple cropping is practised in F0 and F1 land types where high yielding varieties concentrate on higher elevation. These include local and high yielding varieties of *aus* in the 1st *kharif* season and local and high yielding varieties of transplanted *aman* rice in the 2nd *kharif* season. *Rabi* crops grown in the winter with residual soil moisture, in sequence with rice in the *kharif* season, include different types of pulses, oilseeds, spices and vegetables.

Cropping patterns, presently practised on different land types in the project, are presented in Table 3.4. Crop production data have been generated separately for damage-free and damaged area using information on yields obtained under damaged and damage-free conditions. These are presented in Table 3.5.

Storage and marketing facilities are very limited and most farmers are compelled to sell their produce in the village market immediately after harvest when prices are normally low. Later on in the year, they have to buy back the same produce for family consumption at higher prices. It is estimated that only 10 to 20 percent of the production actually enters commercial markets. Private traders handle most of this amount.

Homesteads are an integral part of the farming system. Homestead agriculture production varies with the size of the homestead. On higher homesteads in the eastern part of the project area, trees (mango, betel nut, bamboo, banana etc.) are common, providing fruit, fuel, and building material. Lower homestead in the western part of the project have fewer trees.

Crops are damaged by floods, drainage congestion, hailstorm, cyclones and pests. Data on damage due to floods, especially flash floods and drainage congestion were collected from the field and then cross checked with the results of the hydrologic analyses.

Overbank spills and bank breaching between Markuli and Madna occurs during flash floods in the pre-monsoon season when local and high yielding varieties of *boro* rice are in the reproductive phase. The crops are submerged with the sudden rise in water level following rains in the catchment. The extent of damage depends on the growth stage of the crop and the duration of submergence. Farmers manage to collect the partially matured panicles of local and high yielding varieties of *boro* rice from underneath water in the flooded fields. This bring downs the yield level of these crops in the damaged area.

Local varieties of *aus* rice are frequently submerged and damaged at the early vegetative growth stage, bringing down its yield level. Local varieties of broadcast *aman* seedlings are damaged when submerged before the plants are able to acquire the ability to elongate with a gradual rise of flood levels. The loss is partially covered up by rapid elongation of the internodes for short periods but a part of the production is lost in the process.

Local and high yielding varieties of transplanted *aman* rice are occasionally damaged by monsoon floods and drainage congestion. The damage from flooding takes place at the vegetative growth stage that hampers tillering and brings down the yield level of the crops. Drainage congestion in the post-monsoon season affects the reproductive phase of the crops.

Table 3.4: Present Cropping Patterns

Cropping Pattern	F0		F1		F2		F3		Total Area (ha)
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
b aman-fallow					80780	70	0	0	80780
fallow-l boro					0	0	105840	98	105840
fallow-hyv boro	0	0	0	0	5770	5	2160	2	7930
b aus-fallow-rabi	0	0	8870	10	5770	5	0	0	14640
b aus-lt aman	9780	20	31045	35	0	0	0	0	40825
b aus-lt aman-potato	2445	5	0	0	0	0	0	0	2445
b aus-lt aman-rabi	4890	10	13305	15	0	0	0	0	18195
b aus-hyv aman	6357	13	0	0	0	0	0	0	6357
b aus-hyv aman-rabi	1467	3	0	0	0	0	0	0	1467
hyv aus-rabi	4890	10	4435	5	0	0	0	0	9325
hyv aus-lt aman	1956	4	6209	7	0	0	0	0	8165
hyv aus-hyv aman	4401	9	1774	2	0	0	0	0	6175
lt aman-fallow	3912	8	3548	4	0	0	0	0	7460
lt aman-rabi	4401	9	13305	15	0	0	0	0	17706
hyv aman-wheat	1956	4	0	0	0	0	0	0	1956
hyv aman-potato	0	0	2661	3	0	0	0	0	2661
hyv aman-rabi	2445	5	3548	4	0	0	0	0	5993
b aman-rabi	0	0	0	0	17310	15	0	0	17310
b aman-hyv boro	0	0	0	0	5770	5	0	0	5770
Total	**48900**		**88700**		**115400**		**108000**		**361000**

Table 3.5: Present Crop Production

Crop	Damage free area			Damaged Area			Total Prod. (Tonnes)
	Area (ha)	Yield (t/ha)	Prod. (tonnes)	Area (ha)	Yield (t/ha)	Prod. (tonnes)	
b aus	76929	1.25	96161	7000	1.05	7350	103511
hyv aus	23665	3.75	88744	0	0	0	88744
b aman	88860	1.75	155505	15000	1.45	21750	177255
lt aman	86296	2.15	185536	8500	1.75	14875	200411
hyv aman	23109	3.95	91280	1500	3.55	5325	96605
l boro	70340	2.25	158265	35500	1.45	51475	209740
hyv boro	9200	4.55	41860	4500	2.75	12375	54235
Paddy	378399		817352	72000		113150	930502
wheat	1956	2.05	4010				
potato	5106	12	61272				
pulses	12695	0.85	10791				
oilseeds	42318	0.75	31738				
spices	4231	2.25	9521				
vegetables	25391	9.25	234865				

3.4 Fisheries

3.4.1 Floodplain Fisheries

Fishing is an important activity in the project area and competition over the fish resource is increasing. There are two types of fishermen: traditional and non-traditional. Traditional fishermen make fishing their main livelihood and have been engaged in the profession for generations. There are an estimated 12,000 to 15,000 traditional fisherman households in the project area.

Non-traditional fishermen are mainly an emerging group from the landless and poor agriculturists. They fish in open water especially during monsoon months and sell their catch. Such non-traditional fishermen are increasing and nearly 35-40% of the households, especially from the deeply flooded haor area, are reportedly engaged in catching fish.

Floodplain fisheries is the main source of living for the poor people living in the project area particularly in the late monsoon period when there are no other sources of income.

Most of the open permanent water bodies are leased out through open auction. For beels, most of the fish are harvested during the dry season, whereas fish are harvested throughout the year from the rivers and channels.

Table 3.6. Major Fish in the Kalni-Kushiyara Area

Large fish	Small fish
Catla, Rui, Mrigel, Air, Gonia, Boal, Rita, Pangas Chital, Gazar K.Baush, Shoal Ilish etc.	Pabda, Koi, Punti, Baim Singhi, Magur, Tengra, Gulsha, Chapila, Laso, Bheda, Lati, Bacha, Poa Keski, Chela, Jhainja Foli, Mola, Gutum, Icha Bajori, Shilon, Chanda, Kaikkya, Kholisha, Gharua etc.

3.4.2 Species Present in the Area

It is estimated that about 90 fish species inhabit the area. The main species are listed in the Table 3.6.

3.4.3 Duar Fishery

During the dry season young fish overwinter in the river *duars* and in the deeper *beels*. The role of river *duars* is becoming increasingly more important as many of the beels are gradually silting-up. At present, there are more than 100 *duars* in the project area; 10 are located between Markuli and Madna (Figure 5). A number of these *duars* have been partially infilled with sediment. For example, BIWTA's navigation charts show there were at least 18 deep scour holes that extended to El. -10 m in 1963 and only four scour holes in 1988.

3.4.4 Sources of Fish and Breeding

In general, floodplain/open water fish production in a particular area depends on the number of fish successfully breeding and their rate of survival. Natural brood fishes start their spawning migration towards suitable shallower areas during the early monsoon, when the early flash floods or rain water inundate new areas possessing higher nutrients and a favourable environment (temperature, gradually shallow region, suitable water velocity, water transparency, soil texture, and so on). Migration is generally opposite to the direction of flow at the time. Most of the small fish including *Pabda*, *Foli*, *Koi*, *Magur*, and *Lati* are usually localized breeders who swim only a short distance for spawning.

Perennial water bodies including shallow floodplains and reeds are the potential breeding environment for most of the floodplain species. Early flash floods with less turbidity help successful breeding.

Fish composition of the project area is dominated by miscellaneous species (55-65%) followed by carps (25-30%) and catfish (5-10%).

Some long distance migratory fish such as the giant fresh water prawn (M. rosenbergii) and Ilish (Hilsa ilisha) are also widespread in the rivers and floodplains of the western part of the project area. Prawn fry migrate towards the floodplain from the sea for grazing, while Ilish migrate primarily for spawning.

3.4.5 Production Trends

Fish production in the project area has reportedly declined by 25-30% over the last five years. Present fish production for the project area is estimated at 26,337 tonnes (Table 3.7).

Siltation of the rivers in the project area is one cause for the decline in fish production. Other causes for the decline include:

- gradual conversion of permanent beels to seasonal beels.
- juvenile fishing/overfishing by illegal gears/nets.
- increased fish disease.
- construction of embankments and regulators on fish migratory routes.
- increased agricultural area encroaching into water bodies and use of insecticide.

3.4.6 Fishing Practices

Open water fisheries resources are important; they contribute 90% of the total catch (floodplain 52%, beel 29%, river 9%), while closed water fisheries contributed only 10%. Subsistence fishing occurs mainly during the monsoon season and large scale beel fishing occurs from December to March.

Installation of *katha* along river banks is common to attract fish; usually *hizal*, *koroch*, *jarul*, *jam*, *shewra* are used. Various types of nets and gear (Ber jal, Kona jal, Phash jal, Bhesal jal, Thela Jal, Uther jal) as well as hooks and lines are commonly used for fishing in the area.

3.4.7 Present Fisheries Resource Development

A small portion of the fish catch is processed and exported. There are two processing plants situated in and around the area.

Ajmiriganj Fish Industries Ltd, Ajmiriganj
The plant started operation in 1972. It is a large fish processing plant with a daily freezing capacity of four mt/day. The ice plant has a capacity of 10 mt/day. The plant exported 262 mt of fish during 1992. About 70% of the supply of fish to the plant is harvested from the project area.

BFDC Fish Marketing Centre, Dabor
The centre was opened in May 1991 and has a capacity of 50 tons/day for cold storage and 20 ton/day for ice. The centre is not operating at its capacity.

Table 3.7: Present Estimated Fish Production

Water body type	Area (ha)	Prod Rate (kg)	Total prod (mt)
Beel	18497	410	7584
F. plain	312100	44	13732
Pond	3360	800	2688
River	13329	175	2333
Total			**26337**

Eight ice plants are also present in the project area for fish preservation and marketing.

Sun-dried (*Sutki*) and fermented fish (*Sidal*) are the most common form of processed fish product. Kaliajuri, Jamalganj, Derai, and Sunamganj are important dried fish marketing centres. Both the products are marketed to other parts of the country from November to May.

3.5 Wetland Resources Utilization and Management

Wetlands have played a significant part in the development of human society. The civilizations in Asia and the Far East developed in floodplain environments. The major river systems of the world have supported the development of rich and sophisticated civilizations, and many diverse societies have evolved systems for deriving benefits from the rich natural productivity of the wetland ecosystems. While the importance of wetlands for biodiversity has long provided the driving force for wetland conservation, the economic benefits have been realized by people and governments only recently and major investments are being made.

Wetlands are probably the most dynamic of all ecosystems. They support an array of faunal and floral diversity, many of which are of great commercial importance and intensively utilized for varied purposes. One of the most important use of natural wetlands products in this area is thatching material. Various types of grasses are used. Utilization can be divided into two forms; 1) for making structures to protect homesteads from wave action and 2) for making roof and panels of houses and mats. The species used for protecting homesteads is *Hemarthria protensa* (chilla) and the species mostly used for other purposes are *Vetiveria zizanioides* (binna), *Sclerostachya fusca* and some *Phragmites karka* (nol khagra). These species generally grow at the border of the perennial beels, so it is very difficult to estimate their growing area. The area is not less than 10,000 ha and the estimated yield is about Tk. 200/ha/year. As a result, the gross total value could reach Tk. 2.0 million/year. The estimated employment in gathering for this usage is about 18,000 pd/ year, assuming 2 pd/ ha.

The second important use of wetland products is for fodder. People of the southwestern part of the project area are fully dependent on these materials, particularly during the monsoon season because at that time, flood waters cover almost the entire grazing land. Plants such as *Nymphaea* sp. (shapla), *Nymphoides* sp. (chandmela) and other grasses are commonly used. Quantification of their real economic value is very difficult since most people collect their own requirements. Consequently, estimates of its value are based on their replacement value and from data collected in other projects. Land areas which produce this material are mostly F3 land, which remains fallow in the summer. The estimated area is about 155,000 ha, so the estimated gross total value could reach up to Tk. 6.2 million/year, assuming a unit yield of Tk. 40/ha. The estimated employment in gathering for this is about 155,000 pd/year, assuming 1 pd/ ha.

Another important use of these resources is fuel wood. Due to the high scarcity of fuel wood around the homesteads, people are becoming increasingly dependent on this fuel. Swamp forest trees other than hizal are the most demanded fuel wood in these wetlands. However, all the other woody shrubs as well as grasses are used for this purpose. The naturally regenerated saplings of swamp forest trees are suffering badly due to this scarcity, which makes it difficult to re-establish swamp forests. The estimated gross total value of this material could be Taka 3.0 million/ year. The estimated employment involved in this is about 100,000 pd/year.

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Among the wetland faunal resources, fish are the most important. Other than fishes, wetlands in the project area support many ecologically and economically important faunal species. Noteworthy species include:

Skipper Frog (*Rana cyanophlyctis*): This species is widely distributed and very common in the wetlands. It is collected intensively by the local people and used as bait to catch carnivorous fishes and piscivorous birds. It is estimated that 10,000 - 20,000 individuals are captured everyday from the wetlands within the project area. Since these are used by the collectors, they are not traded and it is difficult to put a value on its head. An estimated value for each individual comes to Tk 1/frog, which represents Tk 10,000/day and an annual utilized value of Taka 1.2 million (assuming four months harvest in a year).

Indian Bull Frog (*Rana tigerina*): This widely distributed species is threatened by commercial exploitation due to the great demand in the West for froglegs. The Government has banned the export of this species, but still it is exported clandestinely. The Government exported froglegs worth Tk 111.0 million in fiscal year 1991-92 (Export Promotion Bureau, 1994), of which an estimated 5% (Tk 5.54 million) came from activities within the project area (Fugler & Ahsan 1983, Rashid & Swingland 1989). These frogs are of great importance for the role they play in controlling rice insect pests. They also hold an important position in the ecological food chain by being a prey species for other predator such as snakes and birds.

Freshwater Turtles: Wetlands are the abode of many species of turtles. Ecologically, turtles play an important role in keeping the aquatic environment clean by devouring dead animals, snails, some fish, and aquatic weeds. Habitat destruction, conversion of wetlands to cultivable land, and commercial exploitation are some of the factors for the decline in the turtle population. In 1992-93, the government exported live turtles worth Taka 67.6 million (EPB, 1994) An estimated 5% of the total quantity exported (valued Tk.3.4 million) came from within the project area (Rashid & Swingland 1989, Das 1989). The main species for export was the Peacock Softshell (*Aspideretes hurum*). Other commercially exploited species for local utilization are *Hardella thurjii*, *Morenia petersi*, *Kachuga tecta*, and *Lissemys punctata*. Turtles are exploited mostly for consumption as food. Hindus and tribal people (mostly tea garden labourers) are the main consumers within the project area.

Monitor Lizards (*Varanus bengalensis* and *V. flavescens*). These two economically important species occur in and around the wetlands of the project area. Ecologically, these animals provide services in controlling the rodent and snake population and scavenging dead animal matter and household wastes. The skin of these lizards are in great demand for making leather bags, shoes, etc., and the animals are constantly sought after. Export of their skins are banned by the Government because of the commercial threat to extinction. In 1988-89, the Government exported skins worth Taka 8.66 million (EPB, 1994) of which 2% (valued at Taka 0.18 million) came from the northeast region (Khan & Rashid 1988).

Waterfowl: During winter season, the project area is visited by thousands of migratory waterfowl. These waterfowl are hunted and commercially trapped and sold in the market. The average price for an individual duck is Tk. 60. Each year an estimated 20,000 ducks are commercially exploited, which amounts to Taka 1.2 million. Being wild ducks, they are in great demand by city dwellers and some people take it as a way to earn extra money. An estimated two thousand people are professionally involved in this trade (WSS 1993), while almost everybody in the area takes advantage if the opportunity arises.

Other direct uses of the wetlands and wetland products are:

- **Food material**. Mostly from *Nymphaea* (shapla), *Ottelia* (panikola), *Trapa* (singra) and *Aponogeton* (ghechu). The total value for food could be as much as Taka 2.5 million and requires about 50,000 pd /year.

- **Industrial/Cottage industry raw material**. eg. *Phragmites kankra* (nol khagra), *Ratan* (bet), *Clinogyne* (murta bet).

- **Duckery/Duck feed**. Several species of snails are collected from the wetlands, crushed and fed to domestic ducks. Usually a duck needs 150 gms of food a day on average. The commercial costs involved in feeding and maintaining 100 ducks a year come to Taka 40,000. The price of the commercially produced duck feed costs Taka 10/kg, while in the low-lying wetland areas there is virtually no expense for feeding domestic ducks. The ducks graze in the wetlands all through the day. This indicates that the wetlands provide sufficient food for the domestic ducks. An estimated 20,000 domestic ducks within the project area are dependent on the wetlands for food. The value of the food utilized to maintain these ducks is equivalent to Taka 8 million /year.

- **Pink Pearl and Oyster**: Pearls are being sold in Dhaka city for Taka 150 each on average, although the price paid to the collectors is only one fifth to one sixth of this amount. A great deal of potential lies in any future attempt to improve and commercialize pearl farming.

- **Edible lime from molluscs**: Edible lime is prepared by grinding mollusc shells collected from the wetlands. Efforts need to be made to quantify the volume of edible lime produced. The present market price is Taka 15 per kilogram. The total production, and quantity of mollusc shells used for this purpose are not known.

- **Green manure**: Aquatic weeds are used as green fertilizer by some farmers while preparing land for cultivation. These weeds are either collected or arranged free excepting the labour costs involved in collection. Some studies are needed to focus on this aspect of resource utilization.

These common property resources are of great importance to the poor, who are most likely to engage in wetland product gathering, depend on wetland food sources at times of scarcity and depend on income from wetland products. Fodder and building materials tend to be collected by men, and food and medicinal materials tend to be collected by women. Information on resource management practices is not available, and studies need to be carried out on the traditional methodologies for managing wetland products.

3.6 Water Transport

The river channels of the Meghna-Kalni-Kushiyara system provide a key transport route for the Northeast Region. Many thana headquarters depend solely on water transport, particularly during the monsoon months. Most of the villages in Ajmiriganj, Sullah, Baniachong, Itna, Mitamain and Derai thana, particularly in the central part of the project area, depend entirely on water transport throughout the year. This is because road transport is almost non-existent in these villages while there are usually internal canals and khals that connect the lowest levels of the haors to the main river systems. These canals are used for transportation of goods and passengers to and from the haors.

Figure 18 shows the major navigation routes in the project area. The various routes have been classified by IWTA according to their "Least Available Depth" (LAD) using the criteria listed in Table 3.8 (BIWTMAS, 1988).

Table 3.8: BIWTA Route Classification

Route	LAD (m)	Season
I	2.6-3.9	Perennial
II	2.1-2.4	Perennial
III	1.5-1.8	Perennial
IV	< 1.5	Seasonal

Note: LAD - Least Available Depth

The Kushiyara River carries over 60% of the navigation traffic to the greater Sylhet district. It is classified by the BIWTA as a Class I route. However, due to channel siltation in the reach between Madna and Markuli, the river drops to a class II route during the flood recession period from October to December, and is a Class III route from January to the end of March. Furthermore, river traffic is reported to be decreasing due to the deteriorating conditions in the main channel.

The important landing facilities along the Kushiyara River are at Madna, Austagram, Ajmiriganj, Markuli, Raniganj, Fateganj, Sherpur, and Zakiganj. The inflow and outflow of major commodities is over 210,000 tonnes for five of the markets along the Kushiyara River (Table 3.9).

The major commodities transported on the river are paddy, rice, wheat, salt, jute, fertilizer, cement, molasses, wood, sand, and boulders. The Kushiyara River also provides for the movement of traffic and trade between Bangladesh and India under a trade agreement, entitled "Protocol on Inland Water Transport and Trade". One of the important routes between India and Bangladesh is along the Kushiyara River between Calcutta and Karimganj as follows:

- Calcutta-Raimongal-Mongla-Kaukhali-Barisal-Nandirbazar-Chandpur-Narayanganj-Bhairab Bazar-Ajmiriganj-Markuli-Sherpur-Fenchuganj-Zakiganj-Karimganj.

Inter-country cargo movement has ranged from 2,000 - 46,000 tonnes (Table 3.10) over the periods 1981-82 to 1990-91. In-transit cargo movement is also significant, ranging from 50,000-100,000 tonnes over the period 1981-82 to 1990-91 (Table 3.11). Reportedly, in-transit and inter-country cargo movements have decreased sharply in recent years due to inadequate depths even during the monsoon season.

Recent studies show that during the dry season, from December to April, no barges, ships, or big launches can operate in the river due to inadequate channel depths. Between Astagram and Ajmiriganj the available depths are now so shallow that even smaller launches have difficulties. The lowest recorded depth is about 0.8 m at Ikardia and Katakhali from December to March (Water Transport Study, NERP, September 1993).

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Table 3.9: Inflow and Outflow of Major Commodities in Tons

Name of the Market	Total Volume	Mode of Transport			
		Mode - 1	Mode - 2	Mode - 3	Mode - 4
Inflow of Major Commodities					
Ajmiriganj	51845	48953	248	2365	277
Habiganj	127719	80279	16	47376	47
Markuli	32297	31621		676	
Zakiganj	14884	7724		7159	
Sherpur	1086	111		975	
Total	**227,840**	**168,688**	**264**	**58,551**	**324**
Outflow of Major Commodities					
Ajmiriganj	51845	49817		2028	
Habiganj	111821	3202		108619	
Markuli	32275	30516	721	1037	
Zakiganj	14884	200	633	14050	
Sherpur	1386	33		1353	
Total	**212,211**	**83,768**	**1,354**	**127,087**	

Source: Water Transport Study, NERP, September 1993. *Note:* *Mode 1 - Private Sector vessels*
Mode 2 - Mechanized BIWTA vessels
Mode 3 - Road Transport
Mode 4 - Rail Transport

Table 3.10: Inter-Country Cargo Movement in Tons (Between Bangladesh and India)

Year	Total Cargo Moved	Carried by Indian Vessels	Carried by Bangladeshi Vessels
1981-82	5573	4573	1000
1982-83	13078	5359	7719
1983-84	25407	11065	14342
1984-85	9792	3400	6392
1985-86	1250	1250	-
1986-87	12209	10860	1349
1987-88	1500	1500	-
1988-89	19136	7800	11336
1989-90	45767	25435	20332
1990-91	2169	1121	1048

Source: Annual Ports and Traffic Reports, 1990-91, BIWTA.

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Table 3.11: In-transit Cargo Movement in Tons
(All movement by Indian Vessels)

Year	From Calcutta	To Karimganj	Total
1981-82	27372	22237	49610
1982-83	38325	26427	59660
1983-84	40060	19600	77950
1984-85	51950	26000	96849
1985-86	67160	29689	96849
1986-87	60806	36819	97625
1987-88	72770	27239	100009
1988-89	67750	26935	94685
1989-90	32200	23010	55210
1990-91	43350	28029	71379

Source: Annual Ports and Traffic Reports, 1990-91, BIWTA.

Disruption of navigation along the Kalni-Kushiyara River has impacted adversely on trading both nationally and internationally. Historically, Ajmiriganj and Markuli have been famous trading centres in the Greater Sylhet district. These trading centres have already started loosing their importance which has impacted adversely on the socio-economic condition of the haor people. The cost of commodities has also increased significantly in recent years because transportation of commodities to these centres from Bhairab Bazar - Dhaka currently requires using several different modes.

Siltation in the internal distributary channels and khals has also hampered water transport. For example, the Shakha Barak, a distributary of the Kushiyara River, was previously navigable from its mouth near Sherpur to its outfall near Madna. Now the channel has silted-up in many sections and carries insufficient water for navigation during the winter months. Construction of embankments and the closure of many distributaries has also hampered navigation.

3.7 Summary of Problems and People's Perceptions

General

Local people's perceptions of their problems were solicited. These were related mainly to water and its impact on their livelihood and their suggestions as to the nature of interventions which could solve these problems. These were collected through personal interviews, group discussions and meetings with various cross-sections of people during the relatively short period of field work in the project area. Also opinions and suggestions were sought in one-day seminars held at the district headquarters of Sylhet, Habiganj, Sunamganj, and Kishoreganj in 1992-93 with the Honourable Members of the Parliament, District and Thana level officials, Union Parishad Chairmen, representatives from village level organizations, and NGOs. Intensive consultation with the communities have taken place in the villages close to the proposed river improvement works. NERP's multi-disciplinary team participated in these consultation processes when discussions were held on the communities 1) perceived problems and suggested solutions 2) dredging spoil disposal vis-a-vis development of settlements and infrastructure with dredged material.

Problems

The major problems of the project area are flooding, drainage congestion and river bank erosion. Pre-monsoon flash flooding is said to be the most serious problem and is widespread in the project area. The flooding mainly damages rice crops. *Boro* is affected almost every year and is either damaged fully or partly in many haors and beels. Flash floods generally enter into the project from over bank spill, breaches in the river banks and through channels and distributaries from the Kushiyara River. The situation is further aggravated in the lower pockets by intensive rainfall which can take place during the same period. Damage is reported to be worse in recent years. In 1994, about 90-95% of the *boro* crop was damaged in the project area due to breaches in the river banks and over bank spill. In March 1994, the right bank of the Kalni River was breached near Faizullahpur village downstream of Markuli and spilled into the haors on the right bank through the Bhanda Beel Project. Pre-monsoon back flows of the Kalni river through the Ratna River and frequent breaches around Kaiyer Dhala on the left bank were reported as also causing damage.

Aus and the seed beds of *T aman* are damaged by pre- and early monsoon floods in the upper lands of the project area. *T aman* is sometimes affected in these areas by monsoon floods during June to September by overbank spill from the Kushiyara and Bijna-Ratna Rivers. The flood waters generally last for seven to ten days in the upper areas and there are three or four such occurrences reported each monsoon period.

Drainage congestion is reported to be the second most important problem of the basin. Water can not be drained out in time to start the *boro* cultivation due to sand/silt deposition along both banks of the Kushiyara River, and the silting up of the Kushiyara, Bibiyana, and Bijna-Ratna River systems, and internal smaller rivers and channels, This delays the transplanting of *boro* (local and HYV).

Damage to homesteads by monsoon wave action was reported as a serious problem, especially in villages of the south-west part of the project area in Baniyachong, Ajmiriganj, Derai, Sullah, Itna, Mitamain, and Austagram thanas. Many villages are rapidly being eroded.

Bank erosion of the Kalni-Kushiyara River was also reported to be a serious problem. Many villages, such as Shantipur, Char Katkhal, Dighalbag and Markuli-Omarpur are threatened due to ongoing, rapid bank erosion. For example, in 1994 a sudden channel shift occurred around Shahebnagar village, a few kilometres downstream of Ajmiriganj. The village, which had over 120 homesteads, was completely eroded. Shantipur village is likely to be completely eroded within one to two years if remedial works are not carried out.

Fishermen considered that fishing by de-watering jalmohals was a major cause for the decline in fish production in the project area. Concerns were also expressed about the leasing system of the jalmohal, where an outsider/non-fisherman is entitled to be a lessee. Fishermen also stated that roads and embankments on the floodplain obstructed the movement of fish and reduced fish production. Concern was expressed about fish migration in the project area from the Kushiyara and Ratna Rivers. They were also concerned about the loss of fish habitat and large scale deforestation on the floodplains.

Finally, navigation along the Kalni-Kushiyara River has been disrupted, particularly during the three to five month long dry season due to siltation and draft limitations. The situation is particularly apparent at ports such as Ajmiriganj which are virtually unusable during the dry season.

Suggestions
A near universal enthusiasm has been found among the residents of the area for re-excavating portions of the Kalni River. There is a strong perception that this would reduce damages to crops from flooding, reduce hazards from bank erosion and improve water transport.

Interviews with local residents has also demonstrated there is a strong interest in using dredge spoil to improve their villages by constructing new village platforms (or extending existing ones), as well as for providing landing facilities, and marketing centres. Villagers have also indicated interest in re-locating to newly created platforms that can be located in safer areas that are not threatened by channel instability and bank erosion. An example of this local interest can be illustrated at the village of Kalimpur (Km 225, Figure 22). In 1994 BIWTA dredged about 1.5 km of the river directly in front of the village, as part of their occasional maintenance dredging programme. The villagers contacted the dredger crew and asked that the spoil be pumped onto the village lands. Temporary embankments were constructed to contain the spoil. Two separate disposal sites were used, one in the middle of the village and the other at its end to provide an extension. Unfortunately, the volume of spoil was not sufficient to raise the land above the level of the monsoon. Consequently, they would like to repeat the operation next year. However, the villagers reported it is unlikely that BIWTA will return to this area in the near future.

Other suggestions that were received include:

- Re-excavate Shakha Barak-Bijna-Ratna River system from its offtake up to the outfall near Madna for improved pre-monsoon and post-monsoon drainage. Re-excavation was also suggested for the Sutki, Jhingari, Mohasingh, Darain, and Old Surma Rivers;

- Improve the banks of the Kushiyara-Kalni, Bijna, Darain, and Sutki Rivers to stop over bank spill during the pre-monsoon season;

- Protect villages from wave actions during the pre-monsoon and monsoon seasons. The most affected villages are in Baniachong, Ajmiriganj, Itna, Mitamain, Austagram, Derai, Sullah, Nabiganj, and Jagannathpur thanas;

- Control bank erosion of the Kalni-Kushiyara River to save the vulnerable homesteads of the bank erosion- prone villages, such as Shantipur, Char Katkhal, Dighalbag and Markuli-Omarpur;

- Ensure dredging in one location will not affect other locations by increasing bank erosion, and damaging other village homesteads;

- Stop leasing out sections of the rivers. This would prevent katha being installed and avoid siltation;

- Conserve enough fish habitat for normal production of fish. Plant water resistant trees such as hizol and koroch on the higher flood plains and river banks;
- Identify the duars in the area and protect them as fish shelters;
- Select a few suitable jalmohals as fish sanctuaries;
- Lease the jalmohals to the fishermen;
- Keep enough provisions for easy movement of fish from rivers to haor;
- Provide adequate provisions for navigation so that embankment construction does not impede the waterways. Provisions for early monsoon navigation should be provided to reduce the need to cut embankments;
- Disposed dredged spoil should be reused for the following purposes:

  - village homesteads including development of new village homestead platforms;
  - play grounds, school grounds, bazar, mosque grounds, and landing platforms;
  - filling up of doba, canals and low-lying areas;
  - filling up of agricultural fields;
  - roads/embankment connecting several villages;
  - thana complex/infrastructure development.

4. WITHOUT-PROJECT TRENDS (NULL OPTION)

The purpose of this chapter is to characterize the future conditions in the project area, assuming no new interventions are carried out. This provides a "Future Without Project" (FWO) scenario. The time frame considered in this analysis extends to the year 2015. The main trends and changes that can be identified are summarized below.

4.1 Human Resources and Settlements

4.1.1 Net population growth

Net population will increase by about 1.8% per year, which is below the National average. The future population growth rate will be down from the yearly growth of 2.43% experienced over the past 10 years. By the year 2000, the population is expected to be 2,669,700 and by the year 2015 the population will be 3,482,580.

4.1.2 Settlements

The rate of landlessness will increase in the project area, particularly for the small-marginal farmers and poorer people due to continuous crop failures and erosion to villages and homesteads. This process has already started and reportedly, many families have migrated to the different urban centres such as Dhaka for their livelihood. Villages such as Shantipur, Char Katkhal, Dighalbag are severely threatened by river erosion and within a span of three to five years these villages will be completely eroded.

4.2 Flooding, Channel Instability and Morphologic Change

Future patterns of flooding and sediment transport will depend on the magnitude of discharges and sediment inflows from the Kushiyara River. These patterns could be affected by three external factors:

- climatic changes, particularly variations in rainfall and storm intensity during the pre-monsoon and monsoon season;
- future changes in the division of Barak River flows at the Amalshid bifurcation;
- flow regulation due to construction of Tipaimukh dam or other projects in India.

For the purposes of this report, the "future without" condition was made assuming no change in these factors and without the implementation of Tipaimukh dam. However, some general comments on potential impacts are included in Section 4.8.

4.2.1 Channel Aggradation and Flood Levels

Trends of increasing bed levels and water levels at Ajmiriganj and Markuli are expected to continue in the future, but at a gradually diminishing rate. A crude estimate of potential impacts was made by assuming an additional 15 million m^3 of sediment would be deposited in the reach between Madna and Markuli. Hydrodynamic model simulations of the 1991 water year were then made with the revised channel geometry and compared with earlier runs of the existing situation. It was found that water levels at Markuli would be raised by 0.6 m during the peak pre-monsoon flood.

4.2.2 Lateral Channel Instability

The pattern of channel instability and abrupt channel shifting that has occurred downstream of Markuli will continue to occur in the future. Tendencies for bank breaching and spills into low-lying areas, particularly into the Central Basin will also continue even more frequently than in the past due to the projected higher flood levels. Ongoing bank erosion upstream of Markuli could lead to the river re-occupying the lower part of the Bibyana channel, which would divert water southwards into the Ratna River system. However, there is also a strong possibility that the Kalni River could develop an avulsion near Ajmiriganj and permanently shift flow northwards into the Baulai River system. This avulsion would cause severe impacts to the existing drainage patterns of the Kushiyara-Kalni, Baulai Basin:

- rates of channel siltation downstream of the avulsion site will be increased due to decreased flows. As a result, the intensity of pre-monsoon floods will be increased and post-monsoon drainage will be delayed in the entire area upstream of the avulsion point;
- water levels in the Baulai River system will also be increased during the pre-monsoon and post-monsoon seasons.

4.3 Water Resources Development

Around Markuli, there are nine completed and ongoing projects (Figure 1 and Table 3.3) on the right bank of the Kushiyara River. These projects include submersible embankments and provide pre-monsoon flood protection to a gross area of about 47,000 ha. To protect *boro* crops under the FWO condition, it is conceivable that the embankment heights would have to be raised by approximately one metre in the future. Total earthwork cost for raising embankment heights by one metre is about Tk 120 million, based on 1991 prices. Moreover, this could require acquiring an additional 150 ha land for the embankments which would cost an additional Taka 18 million (assuming land costs of Tk 120,000/ha). These lands would mostly be taken from the existing cultivable areas. With this additional one metre height and a provision for freeboard, the submersible embankment crest level at some locations would begin to approach the annual monsoon flood level. As a result, these embankments could begin to affect monsoon flood levels in the Central Basin.

The left bank of the Kushiyara River has a net cultivable area of about 84,000 ha of which only 16,000 ha (refer Figure 1 and Table 3.3) is provided with pre-monsoon flood protection. To protect *boro* crops in the remaining unprotected areas, would require constructing about 35 km of submersible embankments with associated drainage cum regulating structures from Markuli to the downstream reach. This will create a number of social problems particularly to navigation and fish migration.

If the Kalni River developed an avulsion in the Central Basin, the resulting disruption of drainage patterns and increased pre-monsoon flood levels would threaten the viability of the 17 submersible embankment projects in the Baulai Basin. At the least, the height of the embankments (totalling 650 km in length) would have to be increased to protect the *boro* crop. The Baulai Basin already suffers from post-monsoon drainage congestion. Therefore, further increases in post-monsoon water levels would delay plantation. Later plantation would make the crops more vulnerable to pre-monsoon floods and rainfall inundation. This suggests that the net cultivable area could decrease substantially from its present level (refer Jadukata-Rakti River Improvement Project, Draft Final, 1993 and Draft Thematic Study, July 1992, NERP).

Table 4.1: Pre-Monsoon Depth of Flooding (by 1:2 Year Flood before 15 May)

Flood Depth (m)	Gross Area (ha)	
	Present	Future Without[a]
0.00-0.30	285,076	248,956
0.30-0.90	66,351	72,166
0.90-1.80	57,410	66,951
>1.80	18,063	38,827
Total	426,900	426,900

[a] These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in Section 6.8.

4.4 Agriculture

Current trends in agricultural production will continue. An additional area of about 36,000 ha (25% of the gross area) will be inundated during the pre-monsoon season under the Future Without (FWO) condition (Table 4.1).

Drainage congestion will be aggravated further and about 4,000 ha will be subjected to late plantation in the post-monsoon season. Late plantation of crops makes them more vulnerable to damage by the pre-monsoon flash floods and accumulated rainfall inundation. This suggests that it will not be possible to grow any crop in these areas without improvements to the drainage system.

Damage to local and high yielding varieties of *boro* rice at the reproductive phase will increase in response to continued pre-monsoon spills and bank breaches. Marginal expansion of irrigation facilities will take place due to limited availability of water in the dry season. This will facilitate expansion of high yielding varieties of *boro* areas that will continue to be damaged by pre-monsoon floods. However, before making these investments, farmers are expected to apply their judgements in selecting the sites with the least possibility of flood damage.

Flash floods will continue to damage local varieties of *aus* and deep water *aman* rice. In fact, the extent of damage will increase if the magnitude of flash floods increase.

Local varieties of transplanted *aman* rice are expected to be replaced by high yielding varieties of transplanted *aman* on F0 land. However, the extent of area affected by drainage congestion on F1 land will increase, thereby damaging local and high yielding varieties of transplanted *aman* in the monsoon season. Slow post-monsoon drainage would also restrict the scope of growing *rabi* crops that are to be planted early in the *rabi* season.

Future cropping patterns and crop production are presented in Tables 4.2 and 4.3.

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Table 4.2: Cropping Patterns under Future Without Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
b aman-fallow					83088	72	5400	5	88488
fallow-l boro					0	0	98280	91	98280
fallow-hyv boro	0	0	0	0	9232	8	0	0	9232
b aus-fallow-rabi	0	0	8870	10	5770	5	0	0	14640
b aus-lt aman	6357	13	31045	35	0	0	0	0	37402
b aus-lt aman-potato	2445	5	0	0	0	0	0	0	2445
b aus-lt aman-rabi	4890	10	13305	15	0	0	0	0	18195
b aus-hyv aman	9780	20	0	0	0	0	0	0	9780
b aus-hyv aman-rabi	1467	3	0	0	0	0	0	0	1467
hyv aus-rabi	4890	10	4435	5	0	0	0	0	9325
hyv aus-lt aman	1956	4	6209	7	0	0	0	0	8165
hyv aus-hyv aman	4401	9	1774	2	0	0	0	0	6175
lt aman-fallow	489	1	3548	4	0	0	0	0	4037
lt aman-rabi	5379	11	13305	15	0	0	0	0	18684
hyv aman-wheat	1956	4	0	0	0	0	0	0	1956
hyv aman-potato	0	0	2661	3	0	0	0	0	2661
hyv aman-rabi	4890	10	3548	4	0	0	0	0	8438
b aman-rabi	0	0	0	0	11540	10	0	0	11540
b aman-hyv boro	0	0	0	0	5770	5	0	0	5770
Total	48900		88700		115400		108000		361000

Table 4.3: Crop Production Under Future Without Project condition.

Crop	Damage free area			Damaged Area			Total Prod. (tonnes)
	Area (ha)	Yield (t/ha)	Prod. (tonnes)	Area (ha)	Yield (t/ha)	Prod. (tonnes)	
b aus	76929	1.25	96161	7000	1.05	7350	103511
hyv aus	23665	3.75	88744	0	0	0	88744
b aman	90798	1.75	158897	15000	1.45	21750	180647
lt aman	80428	2.15	172920	8500	1.75	14875	187795
hyv aman	28977	3.95	114459	1500	3.55	5325	119784
l boro	60780	2.25	136755	37500	1.45	54375	191130
hyv boro	7502	4.55	34134	7500	2.75	20625	54759
Paddy	369079		802070	77000		124300	926370
wheat	1956	2.05	4010				
potato	5106	12	61272				
pulses	12343	0.85	10492				
oilseeds	41145	0.75	30858				
spices	4114	2.25	9257				
vegetables	24687	9.25	228352				

4.5 Fisheries

The major fishery resources of the project area are located along the river banks in the Markuli - Madna reach. Increased overbank spills associated with breaches in the river banks, will cause greater floodplain sedimentation and infilling of beels adjacent to the channel over a 40 km long, 1 km wide zone, with negative impacts to fisheries.

There are presently only 10 main duars left between Markuli and Madna. Infilling of these existing duars in the aggrading reach between Markuli and Madna, will cause additional negative impacts to fishery resources in the entire area. In addition, the migration routes during the pre-monsoon season could be infilled along this river reach, causing severe adverse impacts to the total fish production of the project area.

4.6 Water Transport

Ongoing channel aggradation and instability will continue to impede water transport. Although these problems will be most acute during the dry season, navigation problems will occur more frequently even in the monsoon season due to recurring channel shifting and avulsions. Ports such as Ajmiriganj will be unusable for most of the year (September - May). This will adversely a9

impact on transportation of commodities, communication and socio-economic conditions in over 50% of the project area. During these months, the movement of commodities both in and out of the area would only be possible through the Baulai River and via Sherpur. However, transportation of commodities up the Baulai and to Sherpur could only be possible either by bullock carts, or by head loads since the internal channels become dry during the winter months. Use of bullock carts will be cumbersome due to the presence of innumerable channels and khals in these areas. Construction of metalled roads in the deeply flooded areas might alleviate this situation. However, given the remote nature of the area, it is probably not realistic to assume this alternative could be implemented in the near future.

This scenario suggests that cost of commodities will be increased significantly and all other activities will be slowed down to a minimal level which is neither desirable nor acceptable. Moreover, people of this locality are already confined within their homesteads for about three to five months in a year during the monsoon season. Disruption of navigation will make them also confined during the winter months.

4.7 Wetland Resources

Siltation will remain as a major threat to the wetlands and more and more perennial wetlands will be transformed to seasonal ones, so the winter wetlands will decrease substantially. This conversion will further deplete its natural biodiversity.

The lowering of flood depths in the wetlands is expected to modify the plant communities. The changes will be different for different communities, submerged and rooted floating plants might increase their coverage, replacing others. Luxuriant growth of these plants and drainage obstruction might create eutrophication in some areas. The most negatively impacted community will be reeds and other grasses grown on the F2 and F3 lands.

The decrease in the winter wetland area will have a negative impact on the wetland dependent fauna, including fishes. The faunal diversity will be lost and only species capable of adapting to the new environment will survive. The habitat changes due to the change in the local hydrology will have a positive impact on some species and negative impacts on most of the species. The wetland-dependent resident avian species and mammalian carnivores will suffer most. In some instances the habitat may be suitable for the resident species but the population will decrease as a result of human interference.

4.8 Impacts from Tipaimukh Dam

A major water resource project on the Barak River at Tipaimukh in India has been proposed. The project includes a dam at Tipaimukh gorge, for hydro-power, flood control, and irrigation. Construction was scheduled to start in 1993 but has been delayed by a number of issues including the effects of flow regulation on Bangladesh. A description of the project is provided in the Northeast Regional Water Management Plan, September, 1993.

Preliminary simulations of the project using the MIKE-11 hydrodynamic model show that significant impacts could result from implementation of the Tipaimukh Dam and Cachar Plain Irrigation scheme. It is expected that flow regulation will result in lower discharges between June and September, and higher flow volumes between October and May. During the monsoon season, water levels along the Kushiyara River were estimated to be lowered by between 0.7 m - 1.2 m (Figure 19). The expected reduction in monsoon flows will reduce the sediment inflows to the lower Kushiyara/Kalni River, which will decrease the rate of sediment deposition. The rate of channel shifting and bank erosion would also be expected to decrease.

During the winter months, the average flow of the Barak River at Amalshid could be up to 4.2 times larger (in February) and overall dry season flow volumes could increase by 60%. This would increase water levels by 1.0 m to 1.8 m between Fenchuganj and Ajmiriganj during the months of January and February (Figure 19). As a result, an additional area of about 22,300 ha or over 6% of the net cultivable area would not drain out by January/February. Rates of inundation will be more on the right bank of Kushiyara River.

Increased post-monsoon and dry season flows would provide benefits for navigation and irrigation. However, the extent of these benefits has not been assessed at this time.

To-date, information provided through the Joint River Commission on the operation of Tipaimukh Project is limited. Additional information will be needed to improve estimates of future impacts. The preliminary calculations completed so far, serve to illustrate that Tipaimukh dam could significantly alter the hydrologic regime of the Kushiyara/Kalni River system and could potentially produce both positive and negative impacts to the region.

5. RIVER IMPROVEMENT DEVELOPMENT OPTIONS/ SCOPE OF CHANNEL IMPROVEMENT

5.1 Summary of Problems

Critical problems within the area have been highlighted in earlier sections of this report. The main problems that have been addressed in this development project can be summarized as follows:

- Substantial portions of the project area are subject to high velocity spills, bank erosion and sediment deposition due to recurring instability of the Kalni-Kushiyara River. *Boro* crops and homesteads in unprotected areas adjacent to the river are frequently damaged. Water transport has been obstructed particularly in the post-monsoon season and dry season by shoals, inadequate depths and channel shifts. Important duars have become filled-in and fisheries habitat has been depleted.

- Increased pre-monsoon floods along the Kalni-Kushiyara and channels in the Central Basin has reduced the effectiveness of existing submersible embankment projects on both banks of the river (Table 3.3);

- Post-monsoon drainage has been delayed over a major part of the project area due to siltation of the river channel and internal drainage channels. Late plantation of the crops makes it more vulnerable to damage by the pre-monsoon flash floods and accumulated rainfall inundation which limits the cropped area to the higher lands. This has resulted in a substantial decrease in the net cultivable land.

5.2 Scope of Channel Improvement Work

A number of initiatives have been identified for carrying out integrated development in the deeply flooded areas of the NE Region (Strategic Thrust 4: NERP). These initiatives included increasing fisheries production, improving farming systems, improving and rehabilitating drainage systems and, where essential, installing or upgrading submersible embankments. Rehabilitation of major rivers such as the Kalni/Kushiyara was considered an important component of this strategy, since it will be difficult to make substantial improvements inside the haor areas while the main rivers are highly unstable and are driving water levels to increasingly higher levels. Furthermore, main channel rehabilitation works appear to be a necessary prerequisite to long-term sustainable development in the deeply flooded areas since many aspects of the biophysical and socio-economic environment are presently deteriorating.

What types of rehabilitation work could be carried out on a large, complex river system such as the Kalni-Kushiyara? Based on our current understanding, it appears the river is attempting to develop a more stable regime by developing a wider channel with a less sinuous meander pattern, in response to the changes in flood flows, sediment inflows and earlier loop cuts. In some reaches these changes appear to be developing very slowly, probably as a result of cohesive bank materials which are relatively resistant to erosion. Therefore, channel restoration works should be designed to hasten these adjustments so that a new channel equilibrium can be achieved.

Some of the measures that could be carried out are described below.

Channel Constrictions: Remove local constrictions by widening and deepening the cross section where cohesive sediments are preventing natural channel adjustments from occurring. Local constrictions generally occur at former loop cuts or in newly developing distributary channels where the channel has not been able to develop a full cross section. The incised width in these reaches is typically between 140 m - 190 m, while the incised width in fully developed sections averages around 300 m.

Shoals and Channel Obstructions: Dredge major shoals and infilled portions of the channel. Consideration should also be given to using submerged vanes, bandalling, or other training structures (spurs) to deepen the channel locally and re-direct the thalweg. The largest mid-channel shoals have developed in flow expansions where the river widens and the slope flattens out. Major shoals also develop at point bars in meander bends which can extend across most of the channel's width. The main aim for channel improvements in these type of reaches should probably be to assist in maintaining a usable navigation channel rather than attempting to deepen the entire cross section.

Bends and Channel Bifurcations: Guide the river into a sinuous alignment by eliminating sharp bends and abrupt channel bifurcations. In some instances this will require carrying out new loop cuts to bring about these changes. The cuts will require adequate field information and analysis so that the work will prove beneficial and not worsen the situation. Furthermore, downstream impacts to other villages and inhabitants will have to be carefully considered.

Channel Breaches: Construct bank protection (revetments) and structures (spurs) to prevent channel breaches and spills into distributary channels.

Drainage Improvement to Distributary Channels: Consider re-opening some of the major channels that used to inter-connect the main river and haor areas to improve post-monsoon drainage. These channels were formerly major drainage routes for the Central Basin but have been closed off in recent years due to rising water levels on the Kalni River. Regulator structures would be required to prevent spills during pre-monsoon floods.

Ongoing River Management: Carry out regular channel maintenance including ongoing remedial work to diagnose and correct river problems at an early stage before serious channel erosion, channel shifting or bank breaching occurs. This work would emphasize management of hazards associated with future channel instability, flooding and sedimentation, rather than relying solely on flood control structures such as embankments.

A conceptual river improvement programme is illustrated in Figures 20-22. The following comments indicate potential sites where channel modifications could prove beneficial:

Km 187-188 the channel narrows at a former loop cut. Increase the channel area by widening along north bank;

Km 191-194 the channel narrows through irregular bends. Increase the channel cross section by widening and re-aligning the bend to reduce its curvature (Figure 20B).

Km 195-199 the channel narrows at a former loop cut. Increase the channel cross section by excavating along the north bank and re-aligning the bend to reduce its curvature (Figure 20B)

Km 204-208 the channel is wide and shallow, with many shoals and bars exposed at low water. Consider re-excavating a navigation channel and install river training works to improve access to Ajmiriganj (Figure 22).

Km 214-221 the river flows in a highly irregular, split channel with a narrow cross section and very short radius bends. Construct a pilot channel and loop cut to prevent further instability, increase the overall cross sectional area, and steepen the overall channel gradient. (Figure 20A).

Km 234-254 the river splits into the Dhaleswari/Baida channels. Excavate a pilot loop cut to shorten the Dhaleswari branch and steepen the river's gradient (Figure 21).

These works would be carried out through a combination of river dredging, manual excavation and construction of river training works.

5.3 Project Components

5.3.1 Channel Excavation

Manual excavation would be required for portions of the work above the water level at the proposed loop cuts. This would involve excavating a pilot channel along the proposed route to a depth of approximately 2-3 m. Efforts would be made to find beneficial uses of the material, such as submersible embankments or landing facilities. Local labour would be used for this phase of the excavation work.

Suction cutterhead dredgers would be used for completing the underwater portions of all pilot channels in the proposed loop cuts as well as for removing major shoals and obstructions from the main channel. In order to estimate the number of dredgers and the time frame required to complete various project alternatives, a brief review of dredger capabilities was carried out. This was based primarily on information provided by BWDB and BIWTA, as well as technical information on dredgers summarized by the US Army Corps of Engineers (1987).

BWDB dredge operators reported that BWDB has eleven 18 inch suction cutterhead dredges. The dredgers were reported to be capable of pumping at a rate of 225-255 m^3/hr (8,000 - 9,000 ft^3/hr) over a distance of 1,200 - 1,500 m. Assuming it operated 12 hours/day and 20 days per month, the expected production from a single dredger would be about 50,000 - 60,000 m^3/month. The status of BIWTA's dredge fleet was reviewed in the *Bangladesh Inland Water Transport Masterplan (BIWTMAS), 1988.* In that study, it was reported that the total production from the BIWTA dredger fleet (eight vessels) averages around 400,000 m^3/month. The performance of various types of dredgers that have been in-use is summarized in Table 5.1.

Annual production has averaged 2.5 million m^3/year, ranging between 1.8 million in 1985/86 and 3.5 million in 1981/82. BIWTMAS forecast that by 1994/95 the total dredging capacity of the fleet would be at least 4.5 million m^3/year. These production rates appear to be relatively low

Table 5.1: Performance of BIWTA Dredgers, 1978-1987

Type	Number	Range in Daily Production m^3/day	Average Production m^3/month
D-Class	5	874-2,696	54,000
Delta class	2	823-2,242	46,000
Khanak	1	819-2,070	36,000

compared to figures provided for modern dredging equipment. For example, guidelines published by the US Army Corps of Engineers indicate solid output rates of around 5,000 m^3/day for a cutter suction dredger with an 18 inch diameter suction pipe operating in water depths of 7 m and pumping over a distance of around 1 km (US Corps, EM 1110-2-5025). Monthly production rates for these dredgers would be around 100,000 m^3, or double the BIWTA rates. Nevertheless, even with modern equipment, an upper limit for a single 18 inch dredger operating between September and March is probably around 700,000 m^3/season. If dredgers were working every five kilometres along the Kalni River (say six in total), the upper limit on annual production would amount to 3.5 million m^3/year. These figures provide a rough estimate of the scale of work that could be accomplished in a multi-year dredging programme.

5.3.2 Dredge Spoil Disposal

The NERP initiative presented in the pre-feasibility study *Flood and Erosion-Affected Villages, Development Project (FEAVDEP)* considered using dredge spoil as a resource to construct new village platforms above the level of the monsoon flood in the deeply flooded Central Basin. The aim of this project was to raise and enlarge homesteads belonging to families that are vulnerable to flooding and erosion. The most affected victims would be resettled onto new homestead platforms. A typical new village was planned to contain 130 households (700 persons). It was also assumed that the platforms would be constructed up to five metres above the surrounding floodplain land and each platform would occupy around 2.6 ha for households and 0.65 ha for public land. Therefore, each village platform would require roughly 189,000 m^3 of fill material. This volume corresponds approximately to three months operation from an existing BWDB dredger. Other potential beneficial uses of the spoil could include construction of marketing centres, landing facilities, roads and embankments. It is proposed that this approach be adopted for all proposed dredging work on the Kalni-Kushiyara Improvement Project.

Interviews with local residents along the Kalni River has demonstrated there is a strong interest in using dredge spoil to improve their villages by constructing new village platforms (or extending existing ones), as well as for providing landing facilities, and marketing centres. Villagers have also indicated interest in re-locating to newly created platforms that can be located in safer areas that are not threatened by channel instability and bank erosion.

5.4 Effect of Channel Improvements on Water Levels

The impacts on water levels from the proposed channel improvements were assessed by using two different hydraulic models:

- a steady state backwater program (HEC-2, Hydrologic Engineering Centre) which was used to compare various dredging alternatives using specific pre-monsoon and post-u8

Table 5.2: Effect of Loop Cuts on Pre-monsoon Flood Levels

Flow Condition	Water level Reduction (m)		
	Ajmiriganj	Markuli	Sherpur
Pre-Monsoon	0.45	0.20	0.10

monsoon discharge conditions. This program was also used to assess the sensitivity of the water level changes to various dredging methods and excavation layouts.

- an unsteady, hydrodynamic model (MIKE 11), which simulated impacts of a specific dredging proposal on water levels and discharges throughout the Northeast Region during the 1991 water year. These results were compared with runs using the existing channel conditions and with the expected "Future Without" conditions in order to estimate the overall impacts of a dredging program.

These models can be used to simulate the effects of imposed changes in channel topography but can not simulate morphologic changes and sediment deposition.

5.4.1 Loop Cuts

Two major loop cuts have been considered in this investigation. The upstream site (Km 214-221) is located at a point where the river has split into two channels, the former main channel being silted-in and the more recently developed channel being narrow and highly sinuous. The second major proposed loop cut is located at the Baida/Dhaleswari River bifurcation and would shorten the overall channel length by about 7 km. A hypothetical layout of these proposed modifications are illustrated in Figures 20 and 21.

Preliminary estimates on the effect of constructing two new loop cuts below Ajmiriganj are summarized in Table 5.2. It was found that the average pre-monsoon flood level could be reduced by about 0.4 m at Ajmiriganj. However, the impact would attenuate with distance upstream and would not significantly improve conditions at Sherpur.

5.4.2 Channel Re-Excavation

The magnitude of water level impacts from channel excavation depends on:

- the discharge on the Kushiyara River;
- the pattern of spills and overbank flows along the Kalni River;
- the tailwater level from the Meghna River system;
- the location and geometry of the excavation work including the volume of material removed, as well as the width and elevation of the excavation work;
- the distance upstream from the end of the dredged reach.

Impacts will be greatest during the pre-monsoon and post-monsoon seasons when the river is confined within its banks. During the monsoon season, when the river banks are overtopped by several metres and a substantial fraction of the flow is carried on the floodplain, the impact of the channel improvements is reduced. Therefore, channel excavation should not be considered as a feasible option for reducing peak flood levels during the monsoon season or for significantly reducing extreme floods such as occurred in 1991, when the highest flows of the year occurred in May.

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For any specific flow condition, the impact will be governed primarily by the increase in the channel's cross sectional area and the total volume of material removed from the channel. However, the location, depth, and extent of dredging all affect the magnitude of the water level changes that can be produced. For example, for the same volume of excavation, improvements in wide, flat reaches will have much less impact on upstream water levels than improvements in narrow, constricted reaches. A programme of channel improvements needs detailed survey data and analysis in order to develop reliable predictions. At the time of these pre-feasibility investigations, the available channel geometry and hydraulic data was intended for providing region-wide simulations, not for testing the feasibility of specific projects. Therefore, the results presented in this investigation should be considered as preliminary.

In order to maximize the effects of the improvements, test calculations were made with the excavation concentrated in the 20 km reach between Ajmiriganj and Markuli. The computations were made using several different widths of dredge cuts and bed levels in order to establish the sensitivity of the water level changes to the improvements. The relation between the estimated water level reduction at Markuli and Sherpur and dredging effort is summarized in Figure 23. These preliminary calculations indicate that the average pre-monsoon flood level could be reduced by around 0.7 m at Markuli and by 0.4 m at Sherpur by excavating 12.5 million m^3 of material from the reach. This corresponds to increasing the channel cross sectional area by about 500 m^2, or effectively widening the channel by 90 m. Removing 7 million m^3 of material could reduce the average pre-monsoon flood level by 0.5 m at Markuli. Water levels could be reduced by up to one metre at Markuli by increasing the excavation volume to 35 million m^3. The effectiveness of all of these dredging measures would be reduced by about a half during a 1:10 year pre-monsoon flood event.

During the post-monsoon season, water level changes of around 0.6 m at Markuli and Sherpur and approximately 0.3 m at Fenchuganj were estimated for a 12.5 million m^3 dredged channel. Furthermore, water levels could not be reduced much more than 0.6 m during this season even if substantially greater amounts of material were removed.

These preliminary figures indicate that the channel would have to be enlarged by at least 7 million m^3 before pre-monsoon and post monsoon water levels were lowered by any appreciable amount, and by at least 11 million m^3/s before the water levels begin to approach the post-monsoon conditions that were experienced in the 1960's and 1970's. However, it appears that dredging and channel improvements alone will not be able to entirely restore flood levels to the levels that were experienced in the past.

6. PROPOSED RIVER IMPROVEMENT PROJECT

6.1 Rationale

The rationale for carrying out channel improvements by river training and periodic channel re-excavation is that these activities are necessary for the long-term maintenance of the river channel system and for ensuring the operation of infrastructure and river-based transportation in the surrounding area. Simply continuing to raise the height of embankments throughout the project area may provide temporary benefits, but long-term solutions will require remedial works to the channel. River training and channel maintenance are less likely to produce undesirable environmental impacts compared to measures such as flood embankments. Furthermore, the spoil from the channel excavation work can be used as a resource for constructing village platforms and other village infrastructure.

6.2 Objectives

The specific objectives of the project are:

- to improve the stability of the Kalni River between Markuli and Madna;
- to reduce pre-monsoon flood levels on the Kalni-Kushiyara River and to reduce spills into the Darain/Baulai River and Ratna River systems;
- to improve the river's post-monsoon drainage capacity;
- to improve water transport along the river.

6.3 Project Description

6.3.1 Adopted Project

Section 5.2 outlined the scope of potential channel improvements along the Kalni-Kushiyara River. For the purposes of this pre-feasibility investigation, preliminary estimates of project benefits, costs and impacts were made for one adopted project alternative. The improvement works that were evaluated consists of the following elements:

- re-excavate 11 million m^3 from the 20 km reach between Markuli and Ajmiriganj;
- excavate 1.5 million m^3 from the 10 km reach downstream of Ajmiriganj;
- construct a loop cut through the split reach downstream of Ajmiriganj by excavating a 0.4 million m^3 pilot channel; and
- construct a loop cut on the Dhaleswari River channel near Madna by excavating a 0.6 million m^3 pilot channel.

The total volume of material that would need to be excavated amounts to 13.5 million m^3, including 12.5 million m^3 from channel re-excavation and 1 million m^3 from loop cuts. Figure 22 shows the extent and location of the improvements.

The volume of excavation work was determined primarily on the basis of improving water levels during pre-monsoon flood conditions. Additional information would be required to assess the optimum programme of river training and channel excavation that should be conducted along the river. Establishing an optimum programme would require substantially more engineering data than is currently available, as well as quantifying benefits associated with improved river transport and village infrastructure. Consequently, this assessment will have to be carried out during a feasibility investigation.

6.3.2 Impacts of River Improvements

The proposed works will prevent further deterioration of the drainage system by reducing average pre-monsoon flood levels and improving post-monsoon drainage in the reach between Fenchuganj and Ajmiriganj, with most impacts occurring in the 50 km reach downstream of Sherpur. Water levels during the monsoon season will not change as a result of this work.

A preliminary estimate of the project impacts was made by simulating water levels throughout the region with the MIKE-11 hydrodynamic model for the case of a re-excavated Kalni River. These computed daily water levels were then compared with results from two different conditions:

- the existing channel; and
- the simulated FWO condition for the year 2015, which was described in Chapter 4 of this report. This scenario assumes no channel maintenance would be carried out and that an additional 15 million m^3 of sediment will be deposited between Markuli and Madna.

All of the computations were made for the 1991 water year. Results from the runs are summarized in Figures 19, 24 and 25.

In comparison to existing conditions, the proposed channel improvements would lower water levels by up to 0.6 m at Markuli and Sherpur during the pre-monsoon season, and by up to one metre during the post-monsoon season. In comparison with the FWO scenario, water levels would be lowered by up to one metre during the pre-monsoon flood season and by 1.8 m during the post-monsoon season with the proposed channel improvements. This illustrates that the channel improvements are largely preventative in nature; they are intended to stabilize a worsening situation and partially restore conditions to previous times.

Table 6.1 compares the overall extent and depth of flooding under existing conditions (pre-project) and after project implementation.

The impacts to pre-monsoon flood levels will not be uniform throughout the project area. Pre-monsoon water level reductions are greatest along the left bank below Ajmiriganj (Unit 3 on Figure 26), where flood depths will be reduced by 0.5 m - 1.0 m in 55 % of the area. Ajmiriganj, Nabiganj and Sullah thanas will get the most benefit, since the depth of flooding will be reduced by up to 1 m (relative to the FWO condition). Approximately 5 % of the area in the main Central Basin (Unit 4) will become flood-free during the pre-monsoon. Impacts of lower pre-monsoon levels at Fenchuganj (Unit 2) will affect drainage of Damrir Haor, and Maijail-Dubrir Haor in Balaganj (Figure 1).

The proposed channel improvements would also benefit water transportation, which is now being significantly restricted during much of the year (November - April). The project would provide a reliable navigation channel, with a Least Available Draft of 3.6 m throughout the year.

If Tipaimukh dam were constructed, the impacts from the channel improvements would change. For example, re-excavating the Kalni channel would mitigate against the higher discharges during the post-monsoon season due to the dam's releases. As a result, the channel improvements would prevent further drainage congestion and delayed drainage from occurring. This is illustrated in Figure 19 which compares simulated water levels with the dam in-place for the scenarios of "with dredging" and "without dredging".

Table 6.1: Depth of Flooding under a 1:2 Year Pre-monsoon Flood (before May 15)

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project
0-0.3	285,076	301,692
0.3-0.9	66,351	67,246
0.9-1.8	57,410	48,450
>1.8	18,063	9512
Total	426,900	426,900

6.3.3 Expected Benefits

The benefits expected from the project relate to agriculture, navigation, protection of homesteads, fisheries and wetlands habitat, development of new homesteads, and prevent migration of local people and improve socio-economic condition.

Agriculture
Crop damage due to overbank spills, inundation and breaches in the pre-monsoon season will be reduced and the net cultivable area of the project will be increased. The existing flood control infrastructure will be more effective and yields will be increased towards its optimal level under damage-free conditions. Reduced spills in the pre-monsoon season will enable farmers to harvest local and high yielding varieties of *boro* rice. As a result, yield levels are expected to increase at least to the level other farmers are obtaining under damage-free conditions. This may induce the farmers to replace some of the local *boro* by high yielding varieties of *boro* rice. However, pre-monsoon flooding will not be eliminated from the project area (Table 6.1) and it has been assumed that damage to local and high yielding varieties of *boro* rice will continue in these areas but at a reduced scale. Reduction in depth of flooding during the pre-monsoon season will also reduce damage to local varieties of broadcast *aman* to some extent.

There will no change in monsoon season flooding conditions after implementation of the project. Therefore, cropping patterns will remain similar to those under the FWO condition.

Drainage improvements in the post-monsoon season will make more land available for cultivation early in the rabi season facilitating timely plantation of rabi crops. Farmers are expected to utilize residual soil moisture by growing more *rabi* crops and the area under *rabi* crop cultivation is expected to increase. This would include fodder crops to meet the requirement of cattle feed.

Cropping patterns under "future with" project conditions are presented in Table 6.2. Crop production under "future with" project conditions is presented in Table 6.3.

Table 6.2: Cropping Patterns With Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area (ha)
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	
b aman-fallow					40390	35	0		40390
fallow-l boro					0	0	102600	95	102600
fallow-hyv boro	0	0	0	0	5770	5	5400	5	11170
b aus-fallow-rabi	0	0	8870	10	5770	5	0	0	14640
b aus-lt aman	6357	13	31045	35	0	0	0	0	37402
b aus-lt aman-potato	2445	5	0	0	0	0	0	0	2445
b aus-lt aman-rabi	4890	10	13305	15	0	0	0	0	18195
b aus-hyv aman	9780	20	0	0	0	0	0	0	9780
b aus-hyv aman-rabi	1467	3	0	0	0	0	0	0	1467
hyv aus-rabi	4890	10	4435	5	0	0	0	0	9325
hyv aus-lt aman	1956	4	6209	7	0	0	0	0	8165
hyv aus-hyv aman	4401	9	1774	2	0	0	0	0	6175
lt aman-fallow	489	1	3548	4	0	0	0	0	4037
lt aman-rabi	5379	11	13305	15	0	0	0	0	18684
hyv aman-wheat	1956	4	0	0	0	0	0	0	1956
hyv aman-potato	0	0	2661	3	0	0	0	0	2661
hyv aman-rabi	4890	10	3548	4	0	0	0	0	8438
b aman-rabi	0	0	0	0	57700	50	0	0	57700
b aman-hyv boro	0	0	0	0	5770	5	0	0	5770
Total	48900		88700		115400		108000		361000

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Table 6.3: Crop Production With Project Condition

Crop	Damage free area			Damaged Area			Total Prod. (tonnes)
	Area (ha)	Yield (t/ha)	Prod. (tonnes)	Area (ha)	Yield (t/ha)	Prod. (tonnes)	
b aus	63429	1.25	79286.3	20500	1.05	21525	100811
hyv aus	23665	3.75	88744	0	0	0	88744
b aman	88360	1.75	154630	15500	1.45	22475	177105
lt aman	79928	2.15	171845	9000	1.75	15750	187595
hyv aman	28977	3.95	114459	1500	3.55	5325	119784
l boro	95100	2.25	213975	7500	1.45	10875	224850
hyv boro	14440	4.55	65702	2500	2.75	6875	72577
Paddy	393899		888641	56500		82825	971466
wheat	1956	2.05	4010				
potato	5106	12	61272				
pulses	32112	0.85	27295				
oilseeds	44957	0.75	33718				
spices	6422.5	2.25	14450				
vegetables	25690	9.25	237631				
fodder	19267						

Fisheries

The proposed dredging will provide an additional water surface area of about 323 ha during the dry season due to loop cuts and channel widening. In addition, the dredged channel will have a minimum water depth of 3.6 m during the dry season. These developments will facilitate fish migration and increase in fish production by about 57 tonnes from its present level (refer to Section 6.9 for details).

The rate of overbank spill and breaches in the river banks during the pre-monsoon season will be reduced and consequently haor/beel siltation will also be reduced, which will have a positive impact on fish production. The extent of this impact will be assessed during the feasibility studies.

Water Transport

Navigation along the Kalni-Kushiyara River will be significantly improved. The channel improvements will facilitate year round navigation for large mechanized vessels (BIWTA Class I) up to Zakiganj. Given assured operation during the dry season, the In-transit and Inter-Country cargo movement between Bangladesh and India will be improved. Inflow and outflow of major commodities could be increased substantially and it is expected that the Ajmiriganj port

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will regain its former importance. Movement of passenger traffic will also be increased because of direct links with Dhaka (via Bhairab Bazar) and as a result of the shortened travelling times. Economic benefits from improved water transportation will be assessed during feasibility investigations.

Village/Homestead Development

Spoil from the river improvement works will be used to construct new village platforms or upgrade and extend existing villages. Preliminary estimates suggest that a typical village platform, suitable for 130 households (700 persons) would require approximately 189,000 m^3 of fill. This volume corresponds to approximately three months of operation from a typical BWDB dredger. If 2.5 million m^3 of dredging was carried out each year between Markuli and Madna, then village platforms could be constructed at a rate of 10 per year. This assumes 75 % of the spoil was available for platform sites and the remaining 25 % was either disposed in areas that could not be used for village development or was lost during pumping. Over a three year dredging program, it is conceivable that up to 30 villages, containing 3,900 households and 21,000 persons could be constructed from the dredge spoil.

The location of the village sites would be limited by the location the dredgers will operate in and by the distance the sediment can be pumped. The practical limit for pumping has been assumed to be 1.5 km. The overall channel length of the reach requiring dredging (Markuli to Madna) is 47 km. If the sites were located on both banks, this implies the villages could be spaced around 3 km apart, on average. A review of topographic maps and satellite photos was made to provide a crude estimate of the number of villages presently existing in the potential spoil disposal zone (a 47 km long, 1.5 km wide strip on each bank of the river). It was found there were 60 villages on the left bank and 30 on the right bank, excluding major towns such as Ajmiriganj. The fewer number of settlements on the right bank probably reflects the fact that the floodplain is lower and experiences more severe flooding due to the dense channel network that exists there. Therefore, the proposed work could approximately double the number of village sites along this reach of the river.

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

Reduced Homestead damage

Homestead damage due to river bank erosion and channel shifts could be significantly reduced. In this investigation, no estimates have been made on the economic benefits associated with this due to the lack of historical data. However, the economic value of reduced homestead damages should be analyzed at the time of feasibility studies.

6.4 Project Operation and Maintenance

Given the nature of river processes in the NE Region, channel maintenance will be required to manage future channel shifting and erosion along the river, to maintain the navigation channel and to control sediment deposition after major floods. Indeed, the overall thrust of this initiative is to rehabilitate a reach of river that has had little systematic maintenance over the last 30 years. The main types of maintenance activities that would be required include (1) monitoring channel changes and erosion in order to identify and diagnose remedial measures before serious problems develop; (2) carrying out maintenance dredging at shoals to maintain the navigation channel; (3) placing spoil in critical areas on the floodplain to prevent bank breaches from enlarging (4) installing local bank protection or training structures at key areas where bank erosion could lead to undesirable channel shifts (5) excavating new channels to improve the river's alignment and prevent channel shifting or avulsions from developing. These activities would not necessarily be required every year. Monitoring, dredging for maintenance of the navigation channel might be required every year, while the other activities might be carried every two or three years, depending on actual hydrological conditions that are experienced. An important aspect of this programme will be developing an institution that is geared to this type of maintenance approach.

Estimates of annual maintenance requirements are difficult to establish with the available data. Historic surveys suggested the channel may have aggraded by roughly 1 million m^3/year over the period 1963-1988. Post-project deposition rates are expected to be considerably lower than this historic rate since the river was still adjusting to the Bibiyana avulsion and Kalni closure during the 1960's and 1970's. Furthermore, some of the proposed works (such as the loop cuts and channel re-alignments) should improve the river's transport efficiency and reduce local deposition. For the purposes of conducting a preliminary economic analysis of the project, a figure of 500,000 m^3/year has been adopted as a tentative estimate of annual maintenance dredging requirements. However, given the uncertainty of this estimate, a sensitivity analysis was performed to document how the various maintenance requirements affected the project's economic viability. Furthermore, the effect of having an extreme flood or sequence of floods that could cause major sediment infilling and channel instability in the project area was made by assuming that 7 million m^3 of additional re-excavation would be required in addition to the regular maintenance dredging in Year 10-12 of the project's life. Improved estimates of maintenance requirements should be made by monitoring actual dredging operations in the reach and through pilot dredging projects.

6.5 Organization and Management

During the early part of the feasibility study process, a client group would be organized and established to participate in project development, specially the dredged material disposal plan. This group would be organized through intensive consultations and would comprise representatives from the local communities, Chairmen and Members of Union Parishads, and Thana level officials of the Ministry of Land (MOL) and other concerned agencies. Consultations conducted at the pre-feasibility study and finalization of pre-feasibility report stages, revealed keen interest of the communities in participating in the preparation of the spoil disposal plan. Preliminary proposals received from these communities suggest that they would like to form a body and prepare the spoil disposal plan to make best possible use of the dredged materials in raising the village platforms, low areas around the settlement which are vulnerable to flooding and erosion, rebuilding infrastructure like road-cum-embankment etc. These spoil disposal plans would be verified by BWDB to make these consistent with the quantity of the dredged material and distance from the dredging site.

The agreed spoil disposal plan, prepared by both parties, would be made available to the client group who would then participate in the preparation of the disposal sites. Their main function would be to organize the communities so that the dredged material could be disposed as per plan and the concerned members of the communities could take care of their individual properties. Likewise, authorities responsible for community facilities like schools, mosques, temples etc. would be encouraged by the client group thus formed to participate in organizing and managing the spoil disposed for raising their compounds.

These bodies would also be responsible for maintaining the infrastructure, possibly through the local Union Parishads or even through the management committees set up for these common community facilities.

Table 6.4: Capital Cost Summary

Item	Cost (US$ million)
Channel Dredging	26.25
Dredging for Loop Cuts	1.10
EMP Construction	0.60
Relocation & Compensation	0.28
BASE COST	28.23
Physical Contingencies	7.06
SUBTOTAL	35.29
Study Costs (15% of Subtotal)	5.29
Land Acquisition for Channel Improvements	1.20
Land for Spoil Disposal	0.50
SUBTOTAL	42.28
Pilot Project	1.50
TOTAL	43.78

BWDB would be responsible for undertaking technical work related to implementation of the project in accordance with current practice but would be responsive to the client group described above. The general tasks include completion of final dredging plans, preparation of tenders, pre-qualification of contractors, contract awards and supervision. The general management of BWDB activities would possibly be under the Executive Engineers, at Sunamganj and Habiganj. Construction supervision would be carried out by sub-divisional field staff of BWDB.

Preparation of spoil disposal sites and construction of village platforms would be carried out as part of the dredging program. However, at this time it is not clear whether village re-settlement and village development would be included with this project or executed under a separate initiative such as FEAVDEP. An intensive monitoring program should be undertaken to observe project performance.

6.6 Cost Estimates

Total project costs are estimated to be US $43.78 million Tk including pilot project construction costs of US $1.5 million. A break down of the costs by component is shown in Table 6.4. Future dredging costs have been estimated assuming a unit cost of 80 Taka/m^3 (US$ 2.10/m^3). This figure is substantially higher than previously reported costs. For example, BIWTMAS

(1988) reported dredging costs during the 1980's have averaged 42 taka/m^3 (31 taka/m^3 for dredging and 11 taka/m^3 for land disposal). Jansen et al (1989) report dredging costs were around 21.5 taka/m^3 in 1981-82. It is believed that the figure of 80 taka/m^3 is a more realistic estimate of future costs.

Land costs reflect the current prices obtained from field interviews. Land on the higher ridges along the rivers was assumed to be priced at Tk 300,000/ha, land in lowlands was priced at Tk 260,000/ha.

6.7 Project Phasing and Disbursements

Six years are required to implement the project. One year (Year zero) has been assigned for completing pilot dredging operations and conducting field surveys. Monitoring and assessment of the pilot project should be completed in year two. Feasibility studies would be completed during this period, when a full-scale EIA including preparation of an Environmental Management Plan would be undertaken. Preparation of detail design, tendering and mobilization should be completed in year three. Land acquisition should commence in year three, be implemented in phases preceding construction, and completed in year five. The main channel improvements should start in year four and would be completed in year six. An itemized implementation schedule is shown in Table 6.5.

6.8 Relation to Other Projects and Initiatives

The project has direct linkages to several other proposed and ongoing projects in the northeast region, including:

- *Surma-Kushiyara-Baulai Basin Project (NERP)*
- *Kushiyara-Bijna Inter-Basin Project (NERP)*
- *Flood and Erosion-Affected Village Development Project (NERP)*
- *Baulai River Rehabilitation Project (NERP)*
- *Water Transport Study (NERP)*
- *Bangladesh Inland Water Transport Masterplan (BIWTMAS)*

Furthermore, there are a large number of existing submersible embankment projects (refer Figure 1) throughout the Central Basin that will benefit from the project. These existing projects include:

- Tangua Haor Project
- Bhanda Beel Project
- Chaptir Haor Project
- Naluar Haor Project
- Shangair Haor Project
- Udgal Beel Project
- Sutki River Project
- Jhingari Nadi Irrigation Project

Table 6.5: Implementation Schedule

Activity	Year (% Completion)					
	0	1	2	3	4	5
Preconstruction						
Engineering Investigation	50	50				
Implementation Plan	100					
Feasibility Study	40	60				
Detail Design and Tendering			100			
Land Acquisition			30	40	30	
Construction Activities						
Pilot Dredging Operation	100					
Monitoring - Pilot Project		100				
Channel Dredging				30	40	30
Dredging for Loop Cuts				30	40	30
Construction of Disposed Soil Chambers				30	40	30
Completion of Disposed Soil Chambers				30	40	30

6.9 Evaluation

6.9.1 *Environmental*

The key areas of environmental impact for this project are described briefly below. Additional information is given in Annex C, Initial Environmental Evaluation.

Potential environmental impacts need to be considered at two stages: (1) the impacts of the dredging and river excavation work during the time of project implementation (these impacts will be fairly localized, extending along the main river channel and the adjacent floodplain), and (2) long-term impacts in the entire project area resulting from the altered hydrological conditions and land-use.

Local Impacts from Dredging during Project Implementation
Concerns about impacts during dredging are related primarily to physical disturbance to habitat, water quality impairment and release of contaminants in spoil disposal sites. In order to address these issues, the following work has been carried out. First, a detailed literature review was completed to compile information on methods that are used for managing dredging operations and for mitigating environmental impacts. This work included holding discussions with various technical specialists in Bangladesh and North America who are involved in environmental

management of contaminated sediments and dredge spoil disposal. This review is included in Annex C. Second, a preliminary sediment/water quality investigation was conducted in cooperation with the Environmental Engineering Division, BUET. This involved collecting water and sediment samples from three potential dredging sites and carrying out a range of physical and chemical analyses. These results are also summarized in Annex C. Finally, various members of the multi-disciplinary team visited a dredging operation that was being conducted by BIWTA on the Kalni River near Kalimpur. Site surveys and sediment samples were collected after the work was completed. Local residents and fishermen were interviewed to document their perceptions on the effects of the work.

On the basis of this pre-feasibility level investigation it was concluded that the proposed methods of dredging and confined disposal on land will be very protective to the environment. Furthermore, it appears highly likely that the sediments in the Kalni River are essentially uncontaminated alluvial deposits (Annex C - Results of laboratory tests by BUET). This should not be surprising, given the lack of industrial development along the river. Therefore, at this stage of the investigation, there is no indication that releases of contaminants or water quality impairment will occur or that beneficial uses of the river will be seriously impacted. Finally, planned field investigations during feasibility and design investigations should be able to identify local problem sites (if they exist) which can then either be avoided or subjected to further assessment to determine requirements for additional site remediation. This tiered, hazard management approach (Lee and Jones, 1992) can be tested and modified during pilot project operations.

The remaining discussion on environmental impacts concerns long-term, project wide effects resulting from changes in the hydrologic regime and land-use.

Land Use

Land use changes are summarized in Table 6.6. A total of 250 ha of land (about 0.06% of the project gross area) will be required for storing dredged material. Of this, 150 ha will be taken from cultivated areas. Assuming average yields and that this is all under rice, the incremental cereal production foregone would be about 37 tonnes per year or about 0.08% of total incremental cereal production. Approximately 165 ha will be added to the existing homestead areas including extension of existing homesteads. Also, homestead agricultural production from these extended sites will be increased.

Table 6.6: Changes in Land Use

Use	Change in area (ha)
Cultivated	- 150
Homesteads	+ 165
Beels	-
Ponds	-
Channels	-
Hills	-
Fallow[1]	- 100
Infrastructure[2]	-

[1] Multi-use land, wetlands, grazing lands, village grounds.
[2] Government-owned land not appearing elsewhere.

Agriculture

The annual cereal production is expected to increase by about 45,096 tonnes, from 930,380 tonnes (FWO) to 975,476 tonnes (FW) as a result of the project, an increase of about 5%. The cereal production increase implies a per person increase in cereal availability from 420 (FWO) to 440 (FW) grams per person per day, an increase of about + 4.5% (Table 6.7), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice. Current Bangladesh average consumption is 440 grams per person per day.

Table 6.7: Indicators of Food Availability (grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	658	590	440	420
Non-Cereals	245	227	169	154
Fish	29	25	18	18

Non-cereal production is expected to increase from 221,152 tonnes (FWO) to 243,339 tonnes (FW), an increase of about 10%. This results from a 26,893 ha increase in area cultivated to non-cereals from 82,289 ha to 1,09,182 ha and implies an increase in the availability of non-cereals from 154 to 169 grams per person per day (Table 6.7).

Openwater fisheries production

The project is expected to impact on fisheries in three ways: it will facilitate migration, increase the depth of the Kalni-Kushiyara River and consequently increase the volume and wetted surface area, and reduce the rate of siltation in the adjoining haors on both banks of the river.

There will be no reduction in the seasonally flooded area since no embankments are planned under the proposed project. The project is not expected to have a negative impact on aquaculture.

There should be no long-term impacts to the duar fisheries since spoil from dredging and re-excavation will be disposed on land and used for construction purposes. Furthermore, the entire focus of the project is to partially restore the channel depths to near historic conditions, so allowing further infilling would be against the basic aims of the project.

Impacts on open water fisheries production were assessed using a simplified model that represents the major system processes. These factors include migration, overwintering habitat extent, wet season habitat, habitat quality and spawning habitat. The basis for this model is summarized in Annex D. The magnitude and sign of the expected impacts are summarized in Table 6.8.

In summary, the project is expected to have a positive impact on fisheries, providing a net increase of 57 tonnes per year (refer section 6.3.3). The projected per capita fish availability will remain constant since the amount of increase is insignificant in relation to the total population of the project area.

Homestead damage

Homestead damage due to breaches in the river banks, over bank spill and avulsion would be reduced significantly. There are over 100 villages within 1.5 km width on both banks in the reach between Markuli to Madna. Of them about 10% villages are located just on the river bank and are threatened by the river bank erosion and channel avulsion. However, these are very preliminary estimates based on satellite image and reconnaissance field visits but will be detailed through river bank surveys and community organization studies during the feasibility work.

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Wetland Habitats and Grazing Area
Impacts are difficult to quantify, but a general impression is given by Table 6.9, which shows the impact on:

- Winter grazing area: Defined as F0, F1, and F2 lands that lie fallow in the dry season (winter) plus any perennially fallow highlands. This land would have limited residual moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.

- Winter wetland: Defined as F3 land that lies fallow in the dry season, plus any perennially-fallow lowland (F4), beel, and channel areas. This land would likely have considerable residual moisture and could support a range of wetland plant communities.

- Summer wetland: Defined as F1, F2, and F3 land that lies fallow in the summer, plus perennially-fallow lowland (F4 area), beel, and perennial channel areas. This land would be inundated to >0.3 m and would support submerged, free-floating, rooted floating, and sedge/meadow plant communities.

The impact of the project would be to decrease the overall winter grazing area by 28%, decrease the winter wetland area by 12%, and increase the summer wetland area by 16%. There would be no impact on swamp forest trees. Impacts on the reed swamp community would be slightly positive. In Hakaluki Haor, the winter grazing area is expected to increase and the winter wetland would decrease as a result of the slightly earlier drainage. The project is not likely to affect summer wetlands.

Economic and employment impacts of the project on wetland plant and animal production can only roughly be estimated. Assuming an annual economic production of Tk 100 per hectare for both summer and winter wetland areas gives a total annual gain of Tk 1.6 million per year. Assuming 1.0 pd (ha yr)$^{-1}$ for harvesting, the employment impact would be [+] 16 thousand pd per year.

Table 6.8: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ("000kg)	Area (ha)	Area Equivalent	Production Impact ('000kg)	Net Value ('000Tk)
Flood Plain	312100	13732	312100	312100	0.0	0
Beel	18497	7584	18497	18497	0.0	0
Channel/River	13329	2333	13652	13652	+57.0	+ 2544
Net project	361000	26337			+57.0	+ 2544

Transportation/navigation

The channel improvements will provide year round navigation for large mechanized vessels (BIWTA Class I) which will have significant positive impact on the socio-economic conditions of the local people.

Quantifying benefits from improved transportation will be detailed during the feasibility studies based on river traffic and field surveys.

Table 6.9: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	22983	22983	0	
sc/wf F1	42576	42576	0	
sc/wf F2	83088	40390	-42,698	
Fallow Highland	3500	3500	0	
Total	152,147	109,449	-42,698	-28
Land Type	**Winter Wetland**			
sc/wf F3	5400	0	-5,400	
F4, Beel, Channel	38250	38250	0	
Total	43,650	38,250	-5,400	-12
Land Type	**Summer Wetland**			
wc/sf F1	0	0	0	
wc/sf F2	9232	5770	-3,462	
wc/sf F3	83160	108000	24,840	
F4, Beel, Channel	38250	38250	0	
Total	130,642	152,020	21,378	16

FW areas shown here do not reflect cultivable land acquired for infrastructure (see Land Use, Section 7.8.1). 'sc' - summer cultivated. 'wc' - winter cultivated. 'sf' - summer fallow. 'wf' - winter fallow.

6.9.2 Social

The key areas of social impact (or lack thereof) for this project are described below. Additional information is given in Annex C, Initial Environmental Evaluation.

Village Development

The dredge spoil will be used as a beneficial resource for building village platforms, landing facilities and marketing centres on portions of the floodplain that are at lower risk from flooding and erosion than under existing conditions. Up to 30 new village platforms, suitable for accommodating 21,000 people could be constructed initially.

Employment

There will be an overall increase in employment of +2.87 million person-days per year. This is composed of:

- an increase in owner-labour employment of +2.23 million pd/ yr, of which very roughly 20% is in post-harvest processing activities traditionally done by women of the household.

- a net increase in employment opportunities for landless people of +0.64 million pd/yr, composed of changes in the following areas:

    - Agricultural hired labour: + 0.57 million pd/yr, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers).

- Fishing labour: +0.05 million pd/yr; in addition to this, there would be a corresponding increase in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

- Wetland labour (gathering wetland products): +0.016 million pd/yr. Fodder and building material is gathered mainly by men. Food, fuel, and medicine is gathered mainly by women.

Displacement impacts due to land use changes

Households whose homestead land is acquired, for proper cash compensation, by the project will be relocated on the homestead platforms to be developed with the disposed dredged spoil. A relocation program has been incorporated as an integral part of the project.

Conflicts

Improved drainage due to the re-excavation of the internal drainage channel might encourage farmers to extend cultivation further into deeper unprotected haor areas. This will bring them into conflict with fishermen who will find the fishing area reduced. However, in the analysis of crop production benefits, existing wetland areas were kept constant.

Equity

The net equity impact would appear to be progressive. Who benefits?

- Landless people get direct benefit from the development of new village platforms and infrastructure. Strongly *progressive.*

- Families whose homestead areas will be extended will get direct benefits from the disposed dredge spoil. Strongly progressive.

- Agricultural benefits derive entirely from increased rice production not at the expense of fisheries and wetlands. *Progressive.*

- Families dependent upon water transport labour will get direct benefit from the dredging. Progressive.

- Families dependent upon as a daily labour in the business centre and port areas will get direct benefit from the dredging. Progressive.

- Families dependent upon fishing labour will get marginal benefit from the dredging. *Progressive.*

- Families involved in gathering wetland products will get marginal benefit from the project. *Progressive.*

Who loses?

- Families whose land will be acquired for the development of the project particularly for the loop cuts. Slightly regressive.

Gender Equity
The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories.

Notes on Qualitative Impact Scoring
The qualitative criteria shown in Table 6.12 are scored on an 11 level scale of -5 to +5. Scoring of those criteria that are impacts (some are not, like 'responds to public concerns') is shown in Table 6.10. The scoring procedure is analogous to that used in the FAP 16 EIA case studies, but simplified to eliminate half-point scores (1.5, 2.5, 3.5, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each 'true' counting for a value of one and each 'false' for zero. The sign reflects whether the impact is positive or negative.

6.9.3 Economic

The economic analysis has been prepared using an economic model developed by NERP. The analysis has followed the FPCO's *Guidelines for Project Assessment, May 1992* which describes the costing procedures for capital and O&M costs, economic pricing of agricultural inputs and outputs, and the phasing of benefits. Input requirements are based on WARPO data. Notes on the economic model and details of the economic analysis are presented in Annex E. A summary of salient data is provided in Table 6.11.

Table 6.10: Qualitative Impact Scoring

		True=1 False=0					
Qualitative Impact	**Impact Sign**	**Sensitive**	**Magnitude**	**Immediate**	**Sustainable Pos Impact/ Irreversible Neg Impact**	**No Mitigation Required/ Possible**	**Score**
Ecological Character of Key Wetland Site	+	1	0	0	1	1	+3
Regional Biodiversity	+	0	0	0	1	1	+2
Road Transportation	+	0	0	0	0	0	0
Navigation	+	1	1	1	1	1	+5
Flood Levels Outside Project Area	+	1	1	1	1	0	+4
Conflicts	-	0	0	0	0	1	-1
Socioeconomic Equity	+	0	0	0	1	0	+1
Gender Equity	+	1	0	0	1	1	+3

The project has an economic rate of return of 24% excluding benefits from navigation and homestead development, which compares well to the required rate of 12% as prescribed by government. It is a relatively high investment project, at Tk 1607 million, and it covers a large geographic area (426,900 ha gross). The rate of return, however, is sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 21%). The other highly sensitive variable is the timing of the benefits, and earlier benefits by two years would increase the ERR to 36%. For a dredging project, earlier benefits are most likely as opposed to the adopted benefit phasing vectors (20% after completion one year and so on; refer Table 19, Annex E).

The foreign costs associated with the project are low, at 6% (excluding FFW contributions), making it a relatively small project from a donor perspective. Donor funding considerations would clearly need to include funding local costs.

The project benefits have been analyzed only for agricultural production and these are mainly due to increased yields by protecting crops from pre-monsoon flash floods, by facilitating early plantation through improved post-monsoon drainage and conversion of some local *boro* to hyv *boro*. Average crop yields would increase as a result of reduced flood damage, and cropping intensity would increase by 10%. Non-cereal production would increase by 10%. Floodplain fish production will increase by about 57 tonnes as compared with the future-without-project production. The value of the fisheries output amounts to about 0.6% of the value of increased agricultural output. Substantial benefits would result from reduced homestead damage and improved navigation which will be quantified during the feasibility study. A small amount of disbenefits would result from a loss of food, shelter, and tree products that are currently harvested from the seasonal wetlands. A summary of salient data is provided in Table 6.11.

It is anticipated that the established crop marketing system will handle incremental crop production without any reduction in prevailing average price levels. Assuming the current annual growth in the demand for grain remains about 3%, the increased cereal production is unlikely to present any marketing difficulties.

6.9.4 Summary Analysis

From a multi-criteria perspective (Table 6.12), the project is very attractive:

- Agricultural benefits derive almost entirely from increased rice production, not at the expense of fisheries and wetlands.

- The net employment impact is highly positive, because it is composed of a large gain in employment for owners and hired labours, landless people and fishing labour.

- The net employment opportunity will further be increased due to the provision of year round navigation and improved water transport.

- Up to 30 new villages (containing 21,000 inhabitants) would be constructed for the landless and homeless people who have been affected by earlier river erosion and flooding.

The other positive aspects of the project are:

- Rate of return is acceptable.

- Substantial increase in rice production.

- Substantial increase in non-cereal production.

- Increased economic returns to land owners.
- Gender equity of impacts is somewhat progressive.
- Project responds highly to public concerns.

The negative impacts of the project would be:

- Conflicts between farmers and fishermen may increase; though these could be mitigated to a degree through an appropriate community participation process.
- The project has a high dependency on central government for implementation.

6.10 Outstanding Issues

The following issues will require additional field data, background information and analysis before the reliability of predictions made in this pre-feasibility investigation can be improved. This information will be collected during feasibility studies.

1. The magnitude of water level impacts in the haor areas from proposed channel improvements needs to be refined, particularly during the pre-monsoon and post-monsoon seasons when the relation between haor water levels and river water levels is not clearly defined. Additional bank surveys, water level measurements in the haor areas and additional hydrodynamic model development and verification will be required.
2. Additional information on Tipaimukh dam, particularly its proposed operating rules, schedule for construction and expected hydrological impacts at the International border are required.
3. Additional river survey monitoring and sediment data collection is required to provide reliable estimates of maintenance dredging requirements.
4. The location and characteristics of the most appropriate sites for disposing of dredge spoil needs to be defined.
5. The social-economic benefits of using dredge spoil for village platforms and other uses needs to be assessed. The methodology for assessing social impacts, for carrying out resettlement and ensuring social and economic viability of the villages needs to be addressed.
6. Benefits related to improved water transport and navigation need to be assessed and included as part of the project's economic evaluation.
7. The possibility of involving the private sector in dredging operations should be further explored.

Issues related to dredging, beneficial uses of dredge spoil and environmental management of dredging operations can best be addressed through a combination of pilot project operations and feasibility studies. The following section of this report outlines the scope and features that could be investigated during a pilot river improvement project.

Table 6.11: Summary of Salient Data

Economic Rate of Return (ERR)	24			
Capital Investment (Tk million)	1607			
Maximum O+M (Tk million / yr)	75			
Capital Investment (Tk/ha)	4450			
Foreign Cost Component	6			
Net Project Area (ha)	361000			
Land Acquisition Required (ha)	250			
AGRICULTURAL IMPACTS		**Present**	**FWO**	**FW**
Incremental Net Econ Output (Tk million / yr)	446.87			
Cropping Intensity		1.5	1.5	1.6
Average Yield (tonnes/ha)				
Average Gross Margins (Tk/ha)		6669	6116	6660
Owner Labour (md/ha)		115	118	115
Hired Labour (md/ha)		28	32	31
Irrigation (ha)		156224	149145	158715
Incremental Cereal Prod'n (' 000 tonnes / yr)	45			
Incremental Non-Cereal (' 000 tonnes / yr)	34			
Incremental Owner Labour (' 000 pd / yr)	2228			
Incremental Hired Labour (' 000 pd / yr)	574			
FISHERIES IMPACTS		**Flood plain**	**Beels**	**Channels**
Incremental Net Econ Output (Tk million / yr)	+2.54			+2.54
Impacted Area (ha)				323
Average Gross Margins (Tk/ha)		1540	28700	12250
Remaining Production on Impacted Area, %		100	100	100
Incremental Fish Production (tonnes / year)				+57
Incremental Labour ('000 pd / yr)	+0.05			+0.05
FLOOD DAMAGE BENEFITS				
Households Affected				
Reduced Econ Damage Households (Tk M / yr)				
Roads/Embankments Affected -km		250		
Reduced Econ Damage Embankments (Tk M / yr)	106			
OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	+1.04			
Wetland Incremental Labour ('000 pd / yr)	16			
Acquired Cult & Homestead Lands, Incr Net Econ Output (Tk million / yr)	0.36			
Persons Displaced by Homestead Acquisition				

Note: EIRR does not include benefits to navigation and homestead development.

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Table 6.12: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	24
EIRR, Increase Capital Costs by 20%	per cent	21
EIRR, Early Benefits by Two Years	per cent	36
EIRR, Delay Benefits by Two Years	per cent	15
Net Present Value	Tk	966,935

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	45096	5
Incremental Non-Cereal Production	tonnes	34134	10
Incremental Fish Production	tonnes	57	0.2
Change in Floodplain Wetland/Fisheries Habitat	ha	+323	0.1
Homesteads Displaced Due to Project Land Acquisition	homesteads	-	-
Homesteads Protected From Floods	households	3900	+10
Embankments Protected From Floods	km	250	0
Kushiyara Flood Levels	m PWD	-0.6	
Owner Employment	million pd/yr	2.22	3.5
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	0.64	3.7

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Ecological Character of Key Wetland Site	+3
Regional Biodiversity	+2
Road Transportation	0
Navigation	+4
Flood Levels Outside Project Area	+4
Conflicts	-1
Socioeconomic Equity	+1
Gender Equity	+3
Decentralized Organization and Management	-2
Responds to Public Concerns	+5
Conformity to Regional Strategy	+5

[1] Percent changes are calculated relative to future-without-project values of: total production of cereal, non-cereal, and fisheries; total floodplain area; total number of homesteads (for displacement due to land acquisition); flood-affected homesteads; flood-affected roads; Kushiyara water level; and total employment for owners and hired labourers.

[2] Includes incremental production foregone due to acquisition of cultivated land.

7. PILOT DREDGING PROJECT

7.1 Rationale

Conducting pilot-scale channel improvements is an appropriate means for developing technical solutions and for demonstrating the feasibility of larger scale river improvement operations. In fact, conducting pilot scale works is a necessary first step because there has been virtually no maintenance work carried out on the Kalni River in recent years. Consequently, there is no prototype information available to assess requirements for maintenance dredging due to channel infilling, or to evaluate alternative disposal practices, environmental and social impacts, and other public concerns. For example, a key issue that needs to be resolved concerns disposal of the spoil and its possible use for construction of village platforms from the dredge spoil. Appropriate measures for ensuring public acceptance of new homesteads, defining criteria for locating village sites and for administering any re-settlement operations can be determined more reliably through a pilot project than by office and field studies alone.

7.2 Objectives

The objectives of the Pilot Project are:

- to carry out selective channel improvements on the Kalni River by dredging and re-excavation. The work is intended to be the first stage in a longer-term project to stabilize the channel and to improve its conveyance;
- to develop, test, and demonstrate beneficial uses of dredge spoil, including its potential use for creating new village platforms;
- to evaluate the effectiveness of dredging methods in terms of its productivity, maintenance requirements, need for environmental mitigation measures, environmental impacts and costs;
- to maximize public understanding of the dredging process and the dissemination of information about the process and its impacts among communities likely to be affected by future dredging activities.
- to clarify the social aspects of dredging and identify constraints which may affect the design of future dredging activities.
- to develop a methodology and guidelines for public participation activities in future dredging programs.
- to develop a framework for institutional cooperation in Kalni-Kushiyara river dredging activities.

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7.3 Scope of Pilot Project Operations

The overall scale of the Pilot Project has been determined so far by the available capital works budget of 1.5 million US$. This represents approximately 0.5 million cubic metres of excavation by dredging or 0.8 million cubic metres of manual excavation. These volumes represent sufficient material to construct between one and three village platforms.

It should be realized that the benefits of the Pilot Project will be local in nature, not regional. The volume of material that will be excavated during the Pilot Project represent about 5% of the total excavation that is required to significantly lower water levels at Markuli or Sherpur.

It is expected that the main planning for the Pilot Project will commence in January 1995, with construction activities starting around November 1995 and being completed by March 1996. Monitoring will be carried out through the following monsoon season. A schedule of the work is shown in Figure 27.

7.4 Guiding Principles

- Multi-disciplinary nature of the Project: The Project planning and implementation should be truly multi-disciplinary in nature. Environmental management and social dimensions of the project need to be undertaken at the earliest planning stages so that these aspects are fully considered during the project's conception and planning.

- "Consultation" should be genuine. The Project should commit itself to consultation only when there is the genuine opportunity to follow the advice of the persons consulted. Spurious or merely symbolic consultation should be avoided. Consultation will be managed so that people are not misled into thinking they can have an input to issues which will be decided on purely technical or external economic grounds.

- Successful management of the social impact requires intimate knowledge of the communities that are going to be impacted by the work. When we consult with rural people, we should know who we are talking to and what their interests are. When we dispose of spoil, we should have detailed knowledge of who owns what land in the spoil areas. The social impacts should be managed from within a structure of detailed information about the affected communities.

- Local communities should benefit to the maximum extent possible from the activities of the river improvement works. Co-management will attempt to ensure that apart from obtaining benefits from the spoil, members of the impacted population will also participate to the maximum extent possible in whatever economic activity is associated with the dredging.

- For sustainability, the institutional framework of river improvements needs to be part of the social and institutional environment of the pilot.

7.5 Public Consultation

Successful execution of the dredging initiative depends on the support of the riparian communities. Whether the pilot project can be translated into a full-scale program or can be executed at all, depends on whether the dredge spoil can be disposed of in the riverside communities. Whether it can be disposed of or not depends on how people perceive the process; on how they perceive the spoil dumping operations. So far, people near these sites share a near universal interest in participating in a Pilot Project operation.

In an important sense, the public consultation and co-management process is a public relations process. If the initial dredging experiment is well-received there is the potential that communities will be asking for more dredge material. If the initial pilot experiment is a failure, there is the potential for substantial resistance to subsequent initiatives. Hence the intention is to maximize public participation in the management of the program so that the dredging work becomes known as providing an asset to local communities.

To achieve the level of participation required for the work, a number of Community Organizers (COs) have been deployed in the villages and towns alongside the river at the anticipated dredge sites. The work carried out by the COs has several different kinds of focus depending on the stage of the program. The scope of this work is outlined below in the description of the various project activities.

7.6 Project Activities

7.6.1 Information Dissemination

At the start of the work, the initial task is to tell people about the intentions of the pilot project. At this stage, four COs have travelled widely among the villages that may be affected by the program and have described the dredging program to the people they encountered. At this stage there are two goals: (1) to let people know what is going to happen, and (2) to listen to what they say when the COs describe the plans to them. The COs also get a chance to get to know the area and its villages. Villagers get used to having the COs around. This stage lasts until a decision about the actual dredging location has been made. Some observations from the COs are summarized in Annex F.

7.6.2 Selection of Pilot Project Site

Site selection will be based on technical, social and environmental criteria, including:

- physical impacts to channel and water levels - will the work provide lasting technical benefits?
- minimizing negative environmental impacts at both the excavation and the disposal site.
- opportunity to demonstrate social acceptance of the work. The project should respond to local people's needs and desire to participate in a pilot scale project.

- opportunity to assess and test out various beneficial uses for the spoil, eg. for improving homesteads or constructing new homesteads/landings or roads or other purposes.

The final choice of a site will be based on a series of iterations, involving the multi-disciplinary team and the communities involved. As a start to this process, 10 potential sites were identified on the basis of engineering criteria, using the very limited survey data presently available (Figure 22). Table 7.1 summarizes the length and intended purpose of work at each potential Pilot Project site. The sites generally fall into three main categories:

- enlarging the channel at former loop cuts that have not developed full cross sections, (Sites 1, 2 & 3);

- removing major shoals that obstruct navigation and reduce the cross sectional area (Sites 4,5,6, 8 & 9);

- re-aligning the channel by straightening and/or shortening it to stabilize the channel and to reduce water levels (Sites 7 & 10).

There are two possible ways of re-aligning the channel at Site 7 - constructing a new channel through the island (7A) or enlarging the existing side channel (7B). The route shown in 7A is more desirable in terms of providing a stable channel alignment, while 7B requires less land acquisition and less excavation. These channel re-alignments would require a combination of manual re-excavation and dredging. The loop cut near Madna (Site 10) would mainly lower water levels between Madna and Ajmiriganj, but would not have much effect further upstream. Furthermore, this loop cut should probably be made after other works are completed upstream. In terms of improving navigation, the major shoal at Sites 5 and 6 appears to be a significant obstruction during the dry season. From a river engineering perspective, Sites 7A, and Site 3 were considered tentatively to be the most appropriate locations for a Pilot Project.
During field trips by the NERP team in June 1994 it was found that ongoing channel shifting has increased the need for carrying out work at Site 7A. This impression was verified by comments from villagers in the area who expressed strong interest in participating in a Pilot Project.

On the basis of these findings, it was decided that pilot scale work at Sites 7A, 3, 6 and 5 were most likely to provide technical benefits and be feasible to construct. Community organizers were then sent to each site in order to start documenting social conditions, people's interests in participating in a project and concerns that will need to be addressed. So far, people near these sites share a near universal interest in participating in a Pilot Project operation. Environmental studies were also launched by NERP and the Environmental Engineering Division of BUET. This involved carrying out a joint field trip, collecting sediment and water samples and then carrying out preliminary laboratory tests on the sediments and water. Elutriate tests were conducted in order to simulate the mixing of sediments and water during dredging operations and to determine whether releases of contaminants from the sediments into the water could occur. Results of these preliminary tests are summarized in Annex C. So far, these studies have shown the sediments appear to be essentially uncontaminated alluvial materials. There is no reason to eliminate any of the sites from further consideration at this time. Finally, comprehensive river surveys, sediment sampling and mapping studies were initiated along the entire study reach to provide a basis for making further quantitative assessments.

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Table 7.1: Potential Pilot Project Sites

Site	Length (km)	Purpose	Expected Impact
1	2.5	Enlarge former loop cut	Low
2	3.0	Re-align former loop cut, remove constriction	Low
3	3.5	Re-align former loop cut, remove constriction	High
4	1.2	Remove shoal,	Low
5	3.2	Remove major shoal, deepen nav. channel	Med
6	2.0	Remove shoal, deepen nav. channel	Med
7A	3.0	Re-align channel, remove constriction	High
7B	2.0	Re-align channel, remove constriction	High
8	2.0	Remove shoal constriction	Med
9	1.5	Remove shoal, deepen nav. channel	Med
10	2.5	Construct loop cut to steepen channel	High

Note: At Site 7, improvements will be made either along route 7A or route 7B, not along both.

The next iteration by the team will involve synthesizing these new data, collecting supplementary data to refine these assessments and then assigning a new ranking for the sites. If none of the sites appear suitable, then new sites will have to be scrutinized further. A final consensus on the site for the Pilot Project is expected to be achieved in January 1995.

7.6.3 Detailed Consultation

Detailed consultation will start after the site of the pilot dredging program has been selected. When the pilot dredging site has been selected, a comprehensive process of public consultation will be undertaken to explain, in public meetings, the process that will be undertaken. The public meetings will be attended by representatives from all sectors including the elected members of the local Government institutions and all the COs who will be briefed separately so that they can supply reliable and comprehensive information about the project and correct misunderstandings that may arise. A process of detailed consultation will follow the public meetings. The elements of the detailed consultation are set out below.

Participatory Appraisals

The first work of consultation involves getting the different sectors of the impacted population to examine the implications of the dredging for their sector. For example, the work of identifying the owners of land likely to be affected by the dredging will be assisted by the COs using village mapping techniques. This technique will be used in conjunction with one or more planning committees which will be mobilized to examine the locations where dredging spoil can be disposed of. The development of fisher population perspectives will be undertaken using techniques of Participatory Rural Appraisal.

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CO-management Structure
A structure for community organization management of the dredging impacts will be developed using some form of committee which will be constituted to provide a focus for interaction between the project and the various sectors of the impacted community or communities. The final form of these CO-management committees will be decided in consultation with the sectors and communities to be managed.

Process Documentation
In order to realize the benefits of the pilot program it will be necessary to carry out a systematic documentation of the activities and experiences of the project's encounter with the communities involved in the pilot program. Elements of the documentation process would include:

- From the preliminary reconnaissance: categories of impacted populations; eg men and women of fisher families; men and women of trader families; men and women of boat families; men and women of land-holding families; men and women of landless families.

- Monthly: CO field notebooks. Notes of monthly CO debriefings and notes of monthly CO meetings.

- Other: Notes of contractor debriefings. Notes of joint meetings with dredging authority and BWDB officials.

Products
Outputs from this consultation will include a report on the social and institutional dimensions of the dredging pilot project, a strategy for project co-management at the feasibility level, and an institutional cooperation strategy.

7.6.4 Implementation Plan

Results from this ongoing site selection process will be summarized in a Pilot Project Implementation Plan. During preparation of the plan, discussions and liaison will be held with various parties, including MOWR, BWDB, BIWTA, MOL, DOF, local authorities, and the local community. The Plan will include engineering analysis and design, layout maps of proposed spoil disposal sites, a plan for the re-use of spoil material by the local community, preliminary dredging tender documents, and a schedule of implementation.

Approval of Disposal Sites
A review of BIWTA disposal sites showed that no formal land acquisition is usually required for spoil disposal. Therefore, the pilot project will be undertaken at a site that will not require formal land acquisition. However, permission from the legal owners of the land where the spoils will be disposed will be required. The probable owners of the land for the disposal sites may be either individual persons (private owners) or public lands (khas land) or a combination of both private and public lands.

It is understood that the private owners are enthusiastic to volunteer their lands for the probable disposal sites, as they want to develop their lands with the dredged spoil. However, this willingness of the private owners needs to be further reviewed at a local level forum. For this purpose, a local level committee will be formed, including village leaders, local elected representatives, such as the Union Parishad (UP) Chairmen/Members, land owners and Thana Nirbahi Officer (TNO).

A substantial amount of khas land (government) also exists along the river banks. If such lands are to be used for the disposal sites, local government approval might be needed from the relevant authority. The government official responsible at the local level to issue such permission is the Assistant Commissioner (AC), Land. This needs to be endorsed subsequently by the Deputy Commissioner (DC).

Public consultation meetings will be held at the village level to finalize the disposal sites. Such meeting will be represented by the villagers, local elected representatives, local government and semi-government officials, NGOs, and local politicians and elites of the society. The announcement to volunteer the land for the disposal sites by the private owner(s) will be made publicly which will be documented by the elected committee. Demand for the government lands will also be made publicly, if required for the disposal sites, the committee headed by TNO will take necessary the steps to obtain government permission.

Detailed plans and layouts will be prepared for the excavation programme and for the construction of the village platforms. It is proposed that all of the sediment will be pumped onshore into confined disposal retention basins. This approach is reviewed in Annex C, Section 5.4 and illustrated in Figure 33. Designing these structures usually involves meeting two criteria:

- providing adequate storage capacity to meet the project's excavation requirements
- meeting acceptable effluent standards during filling operations.

The Implementation Plan is targeted to be completed by June 1995.

7.6.5 Project Implementation

The excavation work will be conducted over one season, starting in the post-monsoon season (around November, 1995) and ending around March 1996. The main activities will include:

- initiation of pre-project monitoring for environmental and engineering evaluation;
- detailed construction surveys will be carried out, including topographic surveys of soil disposal sites;
- preparation of contract documents, contract negotiations, and selection of contractor(s) for dredging operations;
- site preparation and construction of spoil disposal chambers;
- supervision of dredging operations and spoil disposal. Modifications to operating procedures will be made on the basis of findings from project monitoring;
- organization of public meetings to observe operations, find out community reactions to the work, and revise operations as required;
- completion of the spoil sites for use by the communities.

Table 7.2: Elements of Monitoring Program

Component	Parameters to be Monitored
Agriculture	Impact of spoil disposal on agricultural productivity
Sediment quality at excavation sites	Bulk sediment properties (physical and chemical) Elutriate tests to assess contaminant releases Bioassays using selected organisms to assess toxicity
Fisheries & fisheries habitat	Physical changes to duars Migratory patterns of various species during dredging Species abundance and fish catches
Wetlands	Impacts of spoil disposal on wetland areas Field testing of plantation and turfing on spoil platforms to develop standard planting techniques
Social	Impacts of operations on social life and local community organization. Nature of social conflicts during and after the work
Water quality near disposal site	Turbidity, suspended solids, dissolved oxygen and water chemistry
River morphology	Channel topography and river response after excavation Sediment grain size in the excavated reach Suspended sediment concentrations
Dredger operations	operating times, production volumes

An itemized plan and implementation schedule is presented in Figure 27.

7.6.6 Monitoring

Monitoring will include a season of pre- project monitoring and a follow-up post-project observation period. Project monitoring will include monitoring of technical operations, observation of river-bed changes in response to dredging, environmental monitoring of land and water (including performance of mitigation measures), and monitoring of social impacts and community response.

It should be emphasized that one of the main purposes of monitoring is to provide feedback during the project's implementation so that adjustments can be made to the operating methods and mitigation measures can be initiated. A preliminary list of parameters that will be included in the programme are summarized in Table 7.2.

7.6.7 Project Assessment

Project assessment will include evaluation of the technical performance of the dredger operations, improvements to the river channel, management of dredged spoil, and the possibilities of local communities using the spoil material. Recommendations and guidelines will be provided for technical operations, environmental management, and people's participation in larger scale river improvement works in the region.

7.7 Preliminary Environmental Management Planning

7.7.1 Purpose

The objective of environmental planning and management is to ensure that development activities are environmentally sound. Environmental management requires the project to incorporate several important components, including (1) compliance with legislative/donor requirements, (2) mitigation and compensation: (3) accident and hazards contingency planning, (4) monitoring, (5) ongoing public participation and accountability and (5) reporting. Environmental management will be carried out at all stages of the pilot project.

At this pre-feasibility stage, the main aim of the environmental planning is to identify key issues that need to be addressed and to start developing strategies for resolving environmental conflicts. It is not possible (or even appropriate) to develop a comprehensive site specific environmental management plan at this time while the project's concept is still being defined and quantitative data collection programs are just starting to be initiated. Therefore, at this time the following aspects of the environmental management plan have been discussed:

- potential environmental impacts
- planning and evaluation
- monitoring
- mitigation measures

7.7.2 Potential Environmental Impacts

Potential environmental impacts during the pilot project have been identified on the basis of field reconnaissance trips by the Environmental Team, preliminary laboratory analysis of river sediments and from a review of literature (Annex C). These potential impacts are summarized below for the major activities in the project.

Manual Excavation
Some of the proposed Pilot Project sites (7A) require manual excavation through higher ground that will be dry. This initial excavation work can not be carried out by dredgers and will involve substantial numbers of local people (similar to a FFW-type programme). Agricultural land along the route may be lost, as well as destruction of plants and vegetation and disruption of wildlife. Health and sanitation concerns need to be considered, since large numbers of people will be working along the channel.

Dredging Operations
An upper limit on the amount of material that could be excavated during the Pilot Project is 500,000 m^3. The would be excavated in a relatively short reach (in the order of 5 km) during a single season (lasting around 120 days). Potential dredging impacts have already been discussed in Section 6.9 and Annex C. In terms of the pilot project, potential impacts are likely to be mainly related to physical disturbance of the channel and possibly short-term water quality impairment, related to turbidity and oxygen depletion. For example, channel excavation work could disrupt benthic communities over the short-term and provide additional stress to some species.

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Impacts to the open water fisheries will be affected by the time of dredger operations and the seasonal fish migration patterns through the river/floodplain system. Most of the species follow a common migratory pattern that is governed by seasonal hydrological changes. The following comments provide a very simplified representation of these migration patterns and the type of impacts that could occur in each season:

- post-monsoon season (October-November): as water levels drop in the post-monsoon season, fish start migrating from grazing areas to overwintering habitat. During this phase, the main pilot project activities will be site preparation and monitoring. No in-channel excavation work is planned for this period, so no impacts will occur.

- dry season (December-March): fish abundance declines as the water levels continue to drop. Most fish species try to find shelter in overwintering habitat such as duars and deeper portions of the rivers. This period coincides with the main excavation activities of the pilot project. However, it should be realized that the excavation work will be carried out on shoals and higher portions of the channel, not in deeper sections or duars. Dredging might intercept small fish, which could be sucked into the cutterhead and discharged on land. Localized increases in turbidity might also affect some species that are sensitive to suspended solids, causing a temporary loss of usable overwintering areas. Decreased oxygen levels due to disturbance of contaminated sediments could produce additional stress to fish and other organisms. However, preliminary sediment sampling investigations show no indication so far, that oxygen depletion will occur (Annex C).

- pre-monsoon season (April-May): during the first intense rainstorms and initial rise of the water levels, fish leave their overwintering habitat and start their migration towards suitable areas for spawning. Dredger operations will have to cease before the pre-monsoon flood season, since the dredger can not work in the higher velocities. Some site completion work may extend into this period - for example, re-working the spoil to construct platforms, planting vegetation and providing protection against wave erosion. All of these activities will be conducted on land, not in the river. However, depending on the nature of the pilot project, some channel adjustments may continue to occur after excavation operations are completed. For example, if a portion of the channel is re-aligned, some scour and fill may occur downstream of the site, possibly affecting habitat conditions in some localized areas.

- monsoon season (June-September): the extent of inundation increases dramatically and fish make use of the increased wetted area, using the habitat as a nursery, for grazing and growing. Only monitoring will be carried out at this time. Some channel adjustments may continue to occur; however, it is expected that these will slow down over the monsoon, since channel velocities are very low.

There is also potential for unforseen impacts related to accidental fuel spills, leakage from the pipeline and other industrial accidents. Furthermore, some disruption to the local communities could occur, such as interference with water transport and obstruction of fishing boats.

Disposal Operations

The spoil will be pumped into one or more confined disposal facilities (essentially an enclosed ring dyke with outlets to discharge effluent). Once the operations are completed, and the spoil is compacted, it will be a usable platform. An upper limit to the area occupied by all of these facilities is approximately 6 ha. Environmental managers will screen potential sites so that disruption of sensitive habitat can be avoided. Some land-use impacts may still occur. For example, some agricultural land may be converted to homestead land.

During operations, the dredger's will be pumping in the order of 0.6 m^3/s, which corresponds to a daily volumetric rate of around 26,000 m^3. The suspended solids concentration in the pipeline will be in the order of 15% by weight (150,000 ppm). The solids will settle out in the retention basin, with the coarsest sediment near the discharge line and finer sediments settling out near the end of the chamber. The trap efficiency of the basin will depend on the flow rates, basin volume and settling velocity of the sediments. If the material is composed primarily of clean sand, virtually all of the material will be retained in the basin. Effluent from the confinement structure may be discharged through a single weir or through several openings, with the water then draining into collection ditches. Local practice is to allow the effluent to infiltrate into the ground. Improper disposal of the effluent could cause water logging of the nearby land. Water quality impairment may also occur in the receiving waters and in shallow tube wells adjacent to the site.

Long-term Impacts
Changes in the flow alignment and sedimentation patterns in the vicinity of the channel excavation work may induce upstream and downstream channel adjustments. In fact, the overall engineering objective is to produce just this result. For example, the overall channel depths are expected to increase as a result of the work. This may affect species abundance, location and diversity. Species that prefer this habitat will increase, others may shift to new locations upstream or downstream.

Long-term alterations in sediment chemistry may occur at the village platforms as a result of weathering or other changes in the chemical environment or even bioturbation (Annex C). Consequently, there is a potential for some contaminants (such as heavy metals) to be released from sediments over a period of years after the project is completed. However, this concern is usually only an issue when the sediments are excavated from a highly contaminated source.

If a new village develops on the platform then land-use changes may take place. If an existing village is extended, then the population of the village may increase. These developments will be accompanied by changes in water use and waste water production. Consequently, water quality and biodiversity near these new villages may decline.

7.7.3 Planning and Evaluation

Environmental planning and evaluation will be carried out throughout all stages of the project. Indeed, a substantial amount of work has already been initiated. Some aspects have been described previously. Key inputs will be provided during the following stages of the project:

Site Selection
Work has commenced to identify potential contaminant sources along the river. Initial reconnaissance level examination of sediment and water quality at key sites have also been completed (Annex C). Results of the work has been described previously. Site screening for sensitive habitat and species will be initiated.

Implementation Plan
Detailed field studies and sediment sampling will be carried out to assess spatial variability of sediment quality within the proposed excavation area. A combination of bulk sediment chemistry and elutriate testing will be carried out using laboratories that can evaluate the full range of potential contaminants(Annex C, Table C.3). Habitat mapping and baseline species surveys (land/water) will be conducted. Bioassay tests may be carried out on selected test organisms to assess sediment toxicity effects. On the basis of these studies, project limits will be revised as necessary and timing restrictions for operations will be defined, if required. Measures to ensure compliance of the project's standards regarding water quality, fisheries impacts, etc. will be finalized and incorporated into the environmental monitoring program. Mitigation measures will also be incorporated into engineering plans and Tender documents. A draft Environmental Action Management Plan will be issued.

Monitoring
Environmental monitoring is simply one component of the Project Monitoring component described in Section 7.6.6. The purpose of the environmental monitoring is primarily to ensure that the operations are in compliance with the project criteria. Furthermore, it ensures early detection of unexpected conditions and improper operations so that corrective measures can be made. For example, turbidity levels and dissolved oxygen levels at the disposal site outfall and in the river's mixing zone downstream from the outfall, can be monitored throughout the period of operations and compared to accepted water quality standards. Project operations can be adjusted as required, to ensure impacts are minimized. A preliminary list of environmental parameters that will be monitored is included in Table 7.2.

Mitigation Measures
It should be recognized that the overall project concept is entirely mitigative in nature - it is attempting to restore a river system that has experienced previous adverse impacts. Mitigation measures are incorporated at a second level, since the spoil from the engineering work will be utilized for clearly defined beneficial purposes (constructing village platforms) rather than treated as a waste and dumped back in the river. Finally, at a third level, the village platforms will be constructed by using a confined disposal facility on land. These facilities are normally specified by regulatory agencies as a mitigation measure only when the spoil is highly contaminated and can not be disposed back into the river without producing undesirable impacts.

Nevertheless, there will still be requirements for local mitigation works throughout the project. The need for mitigation works can be minimized by incorporating the results of environmental studies into the site selection process and the implementation plan. Table 7.3 lists mitigation measures that can be implemented to minimize environmental impacts during project operations. The kinds of mitigation measures include:

(1) modifying operating procedures - for example reducing dredger pumping rates or raising pool levels in the retention basin to improve effluent clarification; alternately, if turbidity exceeds the permissible limits, dredging could be suspended during critical periods, particularly in the late monsoon season when fish starts their over wintering migration from the grazing areas. This may also be required during the pre-monsoon season (April-May) when fish start their migration towards suitable area to spawn, and graze.

(2) replacement and compensation - for example, paying compensation for acquired land or re-planting vegetation and trees so there is no net loss of habitat from the project;

(3) project design features - for example, using confined disposal facilities to contain the spoil or constructing drainage facilities around the structures to prevent water logging.

7.8 Social Impacts

It is possible to speculate on three social issues that need to be given careful attention. Initially it is intended only to provide some general caveats on the kinds of social issues that could constitute a constraint to achieving a successful outcome of the pilot program.

Social Conflict
Serious social conflict in the area in which the project has to work represents a potentially difficult problem for community organizers. Particular attention will have to be paid to the presence of irremedial social conflict in the area.

For the proposed pilot project, possible sources of conflict and factionalism will be identified. It will then be necessary to evaluate whether the conflicts are long-term and deeply entrenched. If they are, it may be necessary to eliminate these areas or subprojects, at least initially, from the pilot project portfolio.

Extreme Concentrations of Power
Any project which intends to mobilize local communities to achieve a broadly based system of participation and management of a project has to be aware of extreme concentrations of power. From experience on the CIDA funded Small Scale Project in other areas of Bangladesh, there were reportedly instances where one family can exercise power and influence over all social and economic transactions in that region. Under these circumstances, meaningful community participation in the decision-making process is often very difficult or impossible. In any case, extreme concentrations of power are often associated with extreme concentrations of resource ownership. This constitutes an area as a less attractive opportunity, especially from an equity perspective.

Conflicts Over Disposal Sites
One of the most significant issues that constituted a difficult constraint in the Small-Scale Project was a rather generalized enthusiasm about the project at the outset which sometimes lulled the implementing staff into a kind of false complaisance about land acquisition and permits. At the time of the Small Scale Project's initial encounter with a subproject area, everyone would report considerable enthusiasm for the subproject plan. Local people would assure the project that land acquisition and permits would be not be a problem and sometimes state that the land would be donated free of charge.

However when the time came to actually occupy the land, the situation would change dramatically. Then, the people who were actually going to be impacted and whose personal land was needed for earthworks, or to allow construction of a control structure, would raise objections. People would see or hear about opportunities to make money from the project or would realize that they were in danger of losing money and the whole issue would change in character.

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This experience with other types of projects in other parts of the country, is not necessarily representative of the situation with the pilot project. This matter can only be addressed when the details of the actual land to be affected are known.

7.9 Contracting Arrangements

There are number of test projects being undertaken in Bangladesh whereby the Consultant takes responsibility for contracting, scheduling, and quality of the construction work. One such example is the river engineering works being undertaken by Flood Action Plan No. 21 at their test site in Kamarjani. For the test dredging work described for the Kalni-Kushiyara it has been agreed in principle that NERP would assume responsibilities for the construction of the test works. NERP's responsibilities would include preparation of tender documents, pre-qualification of contractors, invitations to tenderers, evaluation of tenders, award of contract, supervision of the work, and contract administration. Initial investigations indicate that there are only a few organizations and private contractors in Bangladesh who have suitable equipment and would be capable of carrying out the dredging activities. Each contractor will be reviewed and a list of pre-qualified contractors will be prepared by NERP. The tender documents and details of the contracting procedures will be included in the Kalni-Kushiyara Implementation Plan Report which is scheduled to be issued in May, 1995.

Table 7.3: Mitigation Measures for Pilot Project

Item	Possible Impact	Mitigation Measures
1.	Dredger induced fish mortality	- Restrict operations to avoid critical areas or times - Provide adequate compensation
2.	Disruption of navigation	- Maintain close cooperation with BIWTA, local communities and fishermen. - Install markers
3.	Loss of habitat due to excavation or spoil placement	- Ensure sensitive sites are avoided. - Replace habitat by re-planting vegetation, trees, etc.
4.	Loss of agricultural land due to excavation or spoil placement	- Implement strict containment procedures to prevent spills onto adjacent lands - Provide adequate compensation
5.	Water Quality Impairment from Spoil Effluent	- Raise water levels in the retention basin to increase trap efficiency - Decrease pumping rate or pump intermittently - Construct secondary baffles in basin to prevent effluent short circuiting - Move dredger to alternate sites with better sediment quality
6.	Water logging and disruption of surface drainage near disposal sites	- provide adequate drainage ditches
7.	Contaminant releases from spoil and uptake by vegetation	- Avoid dredging from contaminated sites. - Cap spoil with clean sediment - Plant vegetation that does not concentrate contaminants in edible parts
8.	Contaminant releases to groundwater	- Install liners at disposal sites - Provide adequate drainage facilities

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ANNEX A

ENGINEERING DATA AND ANALYSIS

ANNEX A: ENGINEERING DATA AND ANALYSIS

A.1 Physiography and Topography

The project area affected by the lower Kushiyara/Kalni River has been sub-divided into four sub-units according to their drainage, landform and topography. The extent of these sub-units and area-elevation relations for each one are summarized in Figure 4.

Table A1: Land Characteristics in Project Area

ID #	Location	Main Landforms	Important Rivers	Area ha	Area-Elevation 25% < 50% < 75% <
1	Hakaluki Basin	Kushiyara-Manu floodplain	Kushiysrs R. Manu R. Sonai-Bardal R.	59,600	8.4 9.7 10.5
2	Upper Surma Kushiyara Inter-basin	Surma-Kushiyara floodplain	Kushiyara R. Barbhanga N.	56,300	7.5 8.5 9.7
3	Surma-Ratna River Inter-basin	Central Basin Surma-Kushiyara-Kalni floodplain	Surma-Baulai R. Kushiyara R. Kalni R. Ratna-Bijna R. Old Surma R.	291,000	4.5 5.6 6.6
4	Ajmiriganj-Madna Inter-basin	Central Basin Kaln-Baulai floodplain	Kalni R. Dhaieswari R. Darain R.	20,000	4.0 4.5 5.2

A.2 Climatic Data

Weather stations near the project area are listed in Table A2. The climate of the project area as a whole, is best represented by data for Sylhet, located northeast of the project area. Data are available for 1957-1991 (Table A3).

The mean annual temperature is 24.9°C, and average monthly temperatures range from a minimum of 18.9°C in January to a maximum of 28.2°C in August. Monthly mean minimum temperatures range from 12.4°C in January to 25.1°C in July/August, and extreme minimum temperatures of record range from 5.7°C in January to 21.7°C in July. Monthly mean maximum temperatures range from 25.1°C in January to 31.3°C in August, and extreme maximum temperatures have ranged from 28.5°C in January to 40.5°C in April.

The annual mean wind speed is 7.3 km/hour from the east-southeast. Monthly average wind speeds range from 2.1 km/hour to 8.8 km/hour, but the extreme gust of record is 168 km/hour.

Winds are generally from the southeast during the monsoon season, and vary between southeast and east-northeast in the other seasons.

The mean annual rainfall is 4,253 mm. Average monthly rainfalls range from 8 mm in January to 805 mm in June, and monthly rainfalls have ranged from 0 mm in November through February to as much as 1,322 mm in July. The extreme daily rainfall of record is 508 mm.

Potential evapotranspiration averages 1,550 mm/year, and ranges from 103 mm (3.3 mm/day) in December to 162 mm (5.2 mm/day) in March.

The surface water balance shows an annual excess of 2,703 mm which runs off into the river system or recharges the aquifers. The monthly water balance is positive in April through October and ranges up to 680 mm/month in June, but during November through March the balance is negative reaching as low as -98 mm in January. The winter surface moisture deficit is generally met from residual soil moisture until February after which a demand for irrigation normally arises.

Table A2: Climate Stations
Kalni-Kushiyara River Improvement Project

Station No.	Name of Station	Type of Observations	Latitude	Longitude	Since
R-107	Chhatak	R	25°01.2'N	91°42.8'E	1962
R-109	Gobindaganj	R	24°40.8'N	91°41.0'E	1962
R-119	Manumukh	R	24°35.5'N	91°43.5'E	1926
R-120	Markuli	R	24°37.8'N	91°21.0'E	1962
R-124	Pagla	R	24°45.5'N	91°27.0'E	1962
R-127	Sunamganj	R	24°04.5'N	91°25.0'E	1962
R-128	Sylhet	R/E/T/H/W/S	24°53.0'N	91°53.0'E	1960
R-129	Tajpur	R	24°42.0'N	91°44.5'E	1962

A.3 Hydrological Data

The hydrological regime of the Kalni/Kushiyara River is governed by:

- external flows from the Barak River in India
- tributaries from the Tripura Hills (Juri River, Manu River, Dhalai River, Karangi River, Khowai River);
- local drainage and the internal runoff generated from the adjacent flood basins and floodplain;
- the distribution of flows between main channels, floodplain and the network of khals and distributary channels.
- backwater conditions from the Meghna River system.

Hydrological records are available from gauging stations maintained on the boundary rivers, but there are no discharges available downstream of Sherpur on the Kalni River. Furthermore, there are no water level stations in the deeply flooded haor basin (Central Sylhet Basin) situated between the Surma/Baulai and Kushiyara/Kalni River systems.

Table A3: Meteorological Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C) Max.	28.3	32.2	36.7	38.9	40.6	35.0	40.0	35.0	35.0	35.0	31.7	28.9
Min.	9.4	8.9	12.8	16.7	18.3	21.1	23.9	23.3	21.7	18.3	12.8	8.9
Mean	18.7	20.4	24.2	27.2	26.9	27.8	28.8	28.2	28.1	26.6	19.7	19.7
Humidity (%)	76.9	70.9	63.8	75.0	83.5	87.7	89.5	89.5	87.5	87.3	81.0	79.9
Sunshine (hr/day)	8.8	9.0	8.4	7.5	6.8	3.5	4.1	4.4	4.6	7.5	9.0	7.8
Wind speed (kph)	2.4	2.8	5.0	6.0	5.0	5.4	5.6	5.0	3.7	2.4	1.9	1.9
Evapotranspiration (mm/month)	105.6	124.4	162.4	157.1	153.4	124.9	125.0	130.6	121.5	128.4	114.5	102.6
Rainfall (mm) Mean monthly:												
Chhatak	10.6	45.4	75.5	356.4	585.9	1296.5	1330.1	927.2	580.3	243.2	46.7	12.0
Gobindaganj	14.3	35.7	94.3	315.8	537.9	1122.9	898.6	790.3	507.0	194.3	29.7	13.5
Manumukh	39.5	39.5	59.2	162.1	306.5	498.6	451.9	465.9	363.7	183.4	44.6	47.1
Markuli	16.7	26.9	61.4	231.4	458.4	778.6	644.9	622.2	381.8	172.0	56.2	22.2
Pagla	10.7	36.9	69.1	232.0	570.4	995.0	703.7	630.7	495.2	167.4	54.0	46.4
Sunamganj	10.0	37.2	76.4	263.2	563.9	1266.6	1257.7	1027.7	618.6	217.4	21.6	2.2
Sylhet	19.6	47.4	81.8	315.0	494.2	973.7	735.7	600.6	425.4	176.5	35.3	18.0
Tajpur	20.8	34.5	80.0	272.7	506.0	823.9	645.5	543.5	394.1	210.0	49.0	22.6

The location of key hydrometric stations, along with the type of observations that have been carried out are listed in Table A.4. Range of daily water levels and discharges on Kushiyara River at four key locations are presented in Table A.5.

Table A4: Kushiyara-Kalni River Hydrometric Stations

Station No.	Name of Station	Type of Observations	Latitude	Longitude	Available Records
Kushiyara-Kalni River					
172	Amalshid	S	25°52.13’N	92°28.54’E	1947
173	Sheola	S,Q	25°39.50’N	92°11.44’E	1949
174	Fenchuganj	S,Q	24°42.12’N	91°56.48’E	1947
175	Sherpur	S,Q	24°37.69’N2	91°40.98’E	
270	Markuli	S	4°41.62’N	91°22.87’E	1949
271	Ajmiriganj	S	24°33.22’N	91°13.73’E	
272	Madna	S	24°20.14’N	91°14.26’E	1949
272.1	Austagram	S	24°16.30’N	91°06.00’E	1962

Table A5: Range of Daily Water Levels and Discharges on Kushiyara River

	Sherpur 175-5		Markuli 270	Ajmiriganj 271	Madna 270
	Water Level (m)	Q (m^3/s)	Water Level (m PWD)	Water Level (m PWD)	Water Level (m PWD)
Min	1.79	45.6	1.34	1.04	0.68
Mean	5.86	1101	4.85	4.22	3.77
Max	9.30	3950	8.50	8.35	8.15

A.4 Trends in Water Levels

Time series plots of annual maximum daily discharge, maximum pre-monsoon discharge and minimum discharge are shown in Figure 9 for Kushiyara River at Sheola and Sherpur. Average pre-monsoon flood conditions on the Kushiyara River at Sheola during two periods (1965-1975 and 1980-1989) are compared in Table A6.

Table A6: Average Pre-Monsoon Floods at Sheola

Period	Discharge m^3/s	Water Level (m PWD)
1965-75	737	10.303
1980-89	1008	11.627

Table A7 compares average pre-monsoon flood levels over the two periods at Sherpur, Markuli, Ajmiriganj, Madna and Austagram. Average Pre-monsoon flood peaks are between 0.8 to 1.25m higher during the 1980's compared to the period between 1965-1975. A linear regression of pre-monsoon flood peaks at Markuli with time over the period 1948-1990 indicated an average rate of rise of 0.085 m/year.

Water levels at Austagram,on the lower end of the Kalni system showed no trend in pre-monsoon flood levels over the period 1965-1990.

Table A8 summarizes average and peak water levels at Markuli during the post-monsoon season for two periods, 1965-1975 and 1980-1989. Post monsoon water levels have risen over time for all months. The rate of rise increases consistently over the year from October to April.

Table A7: Average Pre-monsoon Flood Peaks

Station	Period	Average Water Level (m)	Change in Water Level (m)
Sherpur	1965-1975	6.40	+0.80
	1980-1989	7.20	
Markuli	1965-1975	4.89	+1.25
	1980-1989	6.14	
Ajmiriganj	1965-1975	3.56	+0.97
	1980-1989	4.53	
Madna	1965-1975	3.15	+0.235
	1980-1989	3.39	
Austagram	1965-1975	3.00	-0.01
	1980-1989	2.99	

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A.5 Flood Frequency Analysis

Flood frequency analysis was carried out separately for the pre-monsoon floods expected before 15 May and for the maximum annual floods expected during the monsoon months. The flood frequency analysis are summarized in Tables A-9 and A-10.

Sediment Data

Suspended sediment concentrations have been measured periodically by BWDB at Sheola and Sherpur on the Kushiyara River. Since 1968, the number of sampling days has ranged from 33 to 7 per year at Sheola and from 28 to 3 per year at Sherpur. Power law-type rating curves of the form

$$C = aQ^{b}$$

were developed by linear regression of the log-transformed sediment concentrations (C in mg/l) and discharges (Q in m^3/sec). Some representative statistical results are summarized in Table A11 and A12.

Table A8: Comparison of Monthly Water Levels at Markuli

Month	Average Water Level (m)		Change (m)	Maximum Water Level (m)		Change (m)
	1965-75	1980-89		1965-75	1980-89	
Oct	6.06	6.43	+0.37	6.59	6.99	+0.40
Nov	4.49	4.82	+0.33	5.36	5.66	+0.30
Dec	3.01	3.46	+0.45	3.53	3.97	+0.44
Jan	2.32	2.93	+0.61	2.63	3.22	+0.59
Feb	1.91	2.65	+0.74	2.20	2.91	+0.71
Mar	2.13	3.06	+0.96	2.69	3.90	+1.29
Apr	3.11	4.40	+1.29	4.18	5.52	+1.34

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Table A9: Frequency and Magnitude of Water Levels on Kushiyara River

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual Floods:							
Sherpur	9.00	9.15	9.22	9.28	9.3	9.35	9.39
Markuli	7.54	7.82	8.01	8.20	8.26	8.45	8.64
Ajmiriganj	7.29	7.68	7.9	8.09	8.15	8.31	8.45
Madna	7.10	7.52	7.74	7.92	7.97	8.11	8.22
Austagram	6.79	7.24	7.49	7.71	7.77	7.95	8.10
Pre-Monsoon Floods (April 1 - May 15)							
Sherpur	7.18	7.73	8.02	8.25	8.32	8.50	8.66
Markuli	5.67	6.30	6.56	6.74	6.78	6.89	6.96
Ajmiriganj	4.12	4.69	4.92	5.08	5.12	5.21	5.28
Madna	3.20	3.59	3.83	4.04	4.10	4.29	4.47
Austagram	2.94	3.27	3.45	3.59	3.63	3.74	3.83

Note: Flood Frequencies based on observed water levels between 1964-1989.

Table A10: Magnitude and Frequency of Flood Discharges

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual Floods:							
Sheola	2162	2492	2652	2773	2806	2894	2963
Sherpur	2575	2771	2852	2905	2919	2952	2975
Pre-Monsoon Floods (April 1 - May 15)							
Sheola	754	1165	1485	1834	1954	2354	2802
Sherpur	1570	1947	2147	2309	2355	2482	2590

Note: Flood Frequencies at Sheola are based on historic discharges between 1964-1989.

Table A11: Sediment Rating Curves, Kushiyara River at Sheola

Year	# of samples	a	b	r^2	SEE
1986	27	-1.28705	1.1652	0.88	0.220
1987	27	-0.43156	0.9007	0.758	0.256
1988	26	-0.70975	0.9954	0.848	0.236
1989	18	0.32912	0.6755	0.384	0.497
1990	18	0.1906	0.810	0.603	0.363
1986-90	116	-0.5451	0.9595	0.671	0.354

Table A12: Sediment Rating Curves, Kushiyara River at Sherpur

Year	# of samples	a	b	r^2	SEE
1986	26	0.0170	0.6440	0.597	0.279
1987	28	0.6403	0.4656	0.335	0.332
1989	15	0.1140	0.6788	0.657	0.268
1990	19	1.7541	0.1447	0.047	0.343
1986-90	88	0.5911	0.4875	0.368	0.330

Annual sediment loads were estimated from the published discharges at Sheola and Sherpur using the sediment rating curves. This involved first estimating the daily concentrations and sediment loads from the rating curves, then summing the daily loads to estimate the annual load. Bias correction factors of Smillie and Koch (1986) were applied to the regressions to correct for under-prediction of the sediment loads due to statistical bias introduced from the linear regression equation. Preliminary estimates of annual loads are summarized in Table A13.

A.7 Navigation Charts

The following BIWTA navigation charts were utilized in the investigation (Table A14):

Approximate bed levels were estimated from the published local low water levels (LLW):

Bed EL. = LLW - Depth

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The bed elevations are apt to be approximate, since local low levels were defined only approximately by BIWTA.

Hydraulic Analysis of Channel Improvements

Existing Conditions Estimated along Kalni/Kushiyara River

Discharge at Sherpur = 1,450 m^3/s (average pre-monsoon flood discharge, 1980-1989).

Channel Improvements:

- Loop cut on Dhaleswari River channel near Madna
- Channel re-location at split downstream of Ajmiriganj
- Dredge 13.1 million m^3 between Ajmiriganj and Markuli with minimum bed level at El -2 m PWD.
- Discharge at Sherpur = 1,450 m^3/s (average pre-monsoon flood discharge, 1980-1989).
- Loop cut on Dhaleswari River channel near Madna
- Channel re-location at split downstream of Ajmiriganj
- Dredge 20.7 million m^3 between Ajmiriganj and Markuli with minimum bed level at El -2 m PWD.
- Discharge at Sherpur = 1,450 m^3/s (average pre-monsoon flood discharge, 1980-1989).

Table A13: Estimated Annual Suspended Sediment Loads

Year	Sheola	Sherpur
	million tonne/year	million tonne/yea r
1982	5.24	3.26
1983	10.18	6.35
1984	5.45	3.84
1985	8.18	3.13
1986	4.94	3.60
1987	6.56	4.25
1988	9.20	5.84
1989	9.21	5.64
1990	11.81	7.00
1991	11.35	7.50

Table A14: Sounding Charts on Kalni/Kushiyara River

Year	Navigation Charts
1963	S58D-K
1977	S179A-SI
1988	S349D-F,S351A-F

Table A15: Existing Conditions for Average Pre-monsoon Flood

Distance from Dhaleswari R. Junction (km)	Cross Section Number	Water Level (m)	Location
0	66.5	3.79	Dhaleswari
5.00	61.50	4.06	
9.00	57.50	4.28	
16.75	49.75	4.6	
25.00	41.50	4.74	
33.50	33.00	4.86	
39.00	27.50	5.12	
40.50	26.00	5.15	
42.50	24.00	5.20	Ajmiriganj
45.90	20.60	5.29	
51.00	15.50	5.47	
56.25	10.25	6.05	
61.80	4.70	6.23	
66.50	0.0	6.32	Markuli
66.60		6.25	
76.60	122.5	6.60	
93.90	105.2	6.91	
108.10	91.0	7.27	Sherpur

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Table A16: Hydraulic Conditions After Channel Improvements

Distance from Dhaleswari R. Junction (km)	Cross Section Number	Water Level (m)	Volume Excavated (million m^3)	Location
0	66.5	3.40	0	Dhaleswari
5.00	61.50	3.76	0	
9.00	57.50	4.04	0	
16.75	49.75	4.37	0	
25.00	41.50	4.42	0	
33.50	33.00	4.44	0	
39.00	27.50	4.80	0	
40.50	26.00	4.86	0	
42.50	24.00	4.94	0	Ajmiriganj
45.90	20.60	5.03	0	
51.00	15.50	5.10	4.7	
56.25	10.25	5.33	2.98	
61.80	4.70	5.50	2.61	
66.50	0.0	5.60	2.79	Markuli
66.60		5.50	0	
76.60	122.5	5.96		
93.90	105.2	6.36		
108.10	91.0	6.84		Sherpur

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Table A17: Hydraulic Conditions after Improvements

Distance from Dhaleswari R. Junction (km)	Cross Section Number	Water Level (m)	Volume Excavated (million m^3)	Location
0	66.5	3.40	0	Dhaleswari
5.00	61.50	3.76	0	
9.00	57.50	4.04	0	
16.75	49.75	4.37	0	
25.00	41.50	4.42	0	
33.50	33.00	4.44	0	
39.00	27.50	4.80	0	
40.50	26.00	4.86	0	
42.50	24.00	4.94	0	Ajmiriganj
45.90	20.60	5.01	0	
51.00	15.50	5.08	.29	
56.25	10.25	5.23	4.90	
61.80	4.70	5.36	4.76	
66.50	0.0	5.43	4.74	Markuli
66.60		5.32	0	
76.60	122.5	5.80	0	
93.90	105.2	6.24	0	
108.10	91.0	6.75	0	Sherpur

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Table A.18: Estimated Ground Water Recharge

Thana	Usable Recharge			Available Recharge		
	STW	DSSTW	DTW	STW	DSSTW	DTW
	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)
Itna	0.00	1.89	7.56	0.00	0.36	1.44
Mitamain	0.00	3.60	15.08	0.00	2.01	8.44
Astagram	0.00	3.86	12.84	0.00	2.16	7.19
Baniachong	0.81	12.58	40.18	0.70	10.83	34.61
Ajmiriganj	0.00	2.41	22.00	0.00	2.16	19.70
Nabiganj	0.00	19.15	76.18	0.00	11.98	47.66
Sylhet	0.00	8.59	30.36	0.00	4.74	16.75
Balaganj	0.00	2.80	20.41	0.00	1.55	11.34
Fenchuganj	0.00	0.00	4.92	0.00	0.00	2.94
Biswanath	0.00	9.22	37.35	0.00	8.03	32.55
Sunamganj	9.10	21.55	55.06	3.94	9.33	23.84
Dowarabazar	0.00	8.48	29.96	0.00	6.15	21.72
Chhatak	3.30	18.00	56.70	1.80	9.84	31.01
Derai	1.97	6.64	17.37	1.45	4.89	12.80
Jagannathpur	2.79	11.63	37.17	2.32	9.67	30.90
Sulla	3.40	6.85	19.30	2.62	5.27	14.85
Kulaura	0.00	0.00	14.10	0.00	0.00	5.08
Barlekha	0.00	0.00	22.02	0.00	0.00	12.46
Beanibazar	0.00	0.99	18.98	0.00	0.69	13.34
Golapganj	0.00	1.87	5.47	0.00	1.41	4.13
Total	21.38	140.11	543.01	12.83	91.09	352.74

Source: MPO (currently WARPO)

Table A.19: Surface Water Irrigated Area, AST 1991

Thana	Low Lift Pumps (LLP's) in Cusec				Traditional Irrigation
	< 1.0	1 .0	2.0	3.0-5.0	
	(ha)	(ha)	(ha)	(ha)	(ha)
Ajmirganj	0	1061	3409	40	5974
Baniachong	0	1781	5251	24	4396
Nabiganj	0	1296	868	0	3921
Chhatak	613	974	651	0	9257
Derai	52	604	2416	0	11872
Dowarabazar	12	778	427	0	5674
Jagannathpur	9	991	978	0	10284
Sullah	210	2480	2429	0	10324
Sunamganj	30	1178	1206	0	12730
Balaganj	0	838	587	0	3987
Biswanath	36	209	436	0	3672
Fenchuganj	42	46	11	0	829
Sylhet	17	226	266	0	2584
Austagram	5	2538	949	0	4172
Itna	8	1302	477	0	330
Mitamain	51	553	4236	0	1439
Barlekha	12	104	79	0	350
Kulaura	8	57	86	0	1056
Beanibazar	48	280	72	0	1136
Golapganj	12	77	73	0	627
Total	1166	17373	24906	64	94613

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Table A.20: Ground Water Irrigated Area, AST 1991

Thana	STW (ha)	DSSTW (ha)	DTW (ha)	MOSTI (ha)
Ajmirganj	0	0	0	0
Baniachong	555	0	1042	0
Nabiganj	227	0	178	1
Chhatak	0	0	255	0
Derai	0	0	0	0
Dowarabazar	0	0	17	28
Jagannathpur	0	0	36	0
Sullah	0	0	0	0
Sunamganj	0	0	0	0
Balaganj	0	0	91	0
Biswanath	22	0	33	2
Fenchuganj	0	0	0	0
Sylhet	49	0	88	0
Austagram	964	0	0	0
Itna	183	0	0	0
Mitamain	55	0	0	0
Barlekha	0	0	0	0
Kulaura	17	0	5	3
Beanibazar	3	0	37	0
Golapganj	0	0	5	0
Total	2075	0	1787	34

ANNEX B

SETTLEMENT AND RESOURCE MANAGEMENT

ANNEX B: SETTLEMENT AND RESOURCE MANAGEMENT

B.1 Human Resources

Quality of Life Indicators:
Quality of life is usually determined by several key indicators. Those described here are literacy, access to health, sanitation, and pure drinking water facilities.

Literacy
In the project area the literacy rate is found to be varied. According to the 1991 census, the literacy of the population at 7 years of age and above varied from 15.6% in Mitamain thana to 44.1% in Sylhet Sadar thana. The corresponding figures for females were 10.2% and 37.6% respectively for the same thanas. The rate appears to have moderately increased over the last 10 years. According to the 1991 census, the literacy rate for all people of Habiganj, Sunamganj Sylhet and Kishorganj districts is recorded as 18.87%; 17.20%, 25.42% and 16.42% respectively for both male and female.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 12.2% in Astagram thana to 33.4% in Fenchuganj thana. Attendance for females in this age cohort in these two thanas varies from 9.8% to 31.2% respectively. Attendance for all youths between the ages of five and 24 is 12.1% and 28.7% for these thanas while the corresponding attendance for females is 8.2% and 24.8%.

The situation is worse for the rural poor. They can not afford to send their children to school. Moreover, many villages, especially in Astagram, Mitamain and Ajmiriganj thanas, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 5.4 for Habiganj district, while such figures are 5.6; 4.1 and 5.5 for Sunamganj, Kishorganj and Sylhet districts. (BANBEIS, 1990).

Access to Health Services
The district headquarters of Sylhet has a medical college with a hospital and other district headquarters of Habiganj, Sunamganj and Kishorganj have hospitals, and all thanas have hospital facilities located at their headquarters. Access to health services is generally limited for rural villagers and is out of reach of the poor. According to the Directorate General of Health Services (1992), there is one hospital for every 195,780 persons and one doctor for every 23,377 persons in the district of Habiganj. One hospital bed is meant for 5,866 people in the district. Similar situation prevails for the other two districts (Sunamganj and Kishorganj) of the project area. Immunization coverage of children below two years of age is high for the project area expect for Itna, Astagram and Mitamain thanas. The rate varies from 22% in Itna thana to 63% in Derai thana (1990).

Rural Water Supply
Detailed information on access to rural water supply for drinking purposes is not available for the project area. However, for the rural areas of the district of Habiganj, DPHE[1] reports the availability of one working tube well for 110 persons. In 1990, 85% of the households

[1] DPHE, 1991-92

reportedly had access to potable water in the district. The situation is comparatively worse in Sunamganj and Kishorganj districts. It is noted that most tube wells are located in the houses of the rich. This results in the poor having very limited access to potable water.

Sanitation
Specific information on sanitation facilities are not available at the project level. During field reconnaissance, it was noted that open space defecation is a common practice in the rural villages, particularly for males. Women generally use kutcha latrines or defecate at a fixed spot which is protected by bamboo mats or betel nut leaves. The villagers of haor areas of Ajmiriganj, Derai, Sullah, Jagannathpur, Baniachang, Astagram, Itna, and Mitamain thanas generally defecate in running water during monsoon months. Sanitary latrines are uncommon in the village environment, except for the very well-off and educated families.

Employment and Wage Rates
Village employment opportunities are mainly limited to agricultural activities. The major crop in the area is boro and t.aman. Employment for men mainly consists of transplanting, etc. for boro which occurs between January and February and harvesting which occurs in late April and May. Employment during aman cultivation is mainly available during July-August for transplantation, and November-December for harvesting.

The wage rates for male agricultural labourers vary from Tk 25 to 50 with two meals per day during peak agricultural months. During months when there is no agriculture work, the daily wage rate varies from Tk 15 to 30 with two meals. Some poor people are emploed by the well-off farmers on seasonal contract with wage rate varies from 750 kg to 1200 kg of rice for six to eight winter months. Employment is also available for the poor fishermen to catch fish in the jalmohals during winter season. In most cases, the wages are fixed on catch basis, i.e 35% - 40% of the catch value are reported to be paid as wages for the fishing labourers.

During months when employment opportunities in agriculture are limited, some poor people migrate to their respective district headquarters to work as rickshaw pullers, as construction workers, or sometimes in household activities. Some poor also migrate to Chittagong district for agricultural activities and a few migrate to Chhatak-Bholaganj area to work on stone collection and carrying. Employment opportunities for women are very limited in the area. Some poor women are employed by the well-off farmers on seasonal contract with wage varies from 225 to 300 kg of rice for six to eight winter months. A few poor women are also employed for the Rural Maintenance Program of CARE. Sometimes, a few women migrate to towns to perform household works, but their numbers are very limited. Many villages have no such migrant woman labourers.

Migration to outside countries, particularly to the UK, is common in Balaganj, Bishwanath Jagannathpur and Nabiganj thanas. However, such migration is less in other thanas of the project area.

There is in-migration into the project area, mainly from Mymensingh, Manikganj, Pabna, Comilla and Barisal. They come to the project area and stay seasonally to work on harvesting of rice crops and earth work. Fishing labourers from Brahmanbaria district and Bhairab thana also migrate to the project area, especially in Derai, Sullah, Itna, Mitamain, Ajmiriganj and Baniachong thanas during winter months to fish in the jalmohals.

Land Ownership Pattern
Land ownership is extremely skewed in the project area. More than 50.6% of the households are landless (with cultivable land less than 0.2 ha). Among the landless, about 2.5% have no homesteads of their own. If the definition of landless includes landholdings up to 0.4 ha, the proportion of households included increases by 9.0%. Among the others, the small (0.21 - 1.00 ha), medium (1.01 - 3.00 ha) and large farmers (more than 3.00 ha) are 22.7%, 20.1%, and 6.6% respectively.

The project area has substantial amount of uncultivable land, which include the deeper wetlands, *kanda* and community pastures. The price of agricultural land varies from Tk 5,000 to Tk 100,000 per ker (0.12 ha) depending on the demand and quality of the land, and the intensity with which it can be cropped.

Land Tenure
Owner operation is common in the area. The large land owners, generally share out their lands to tenants for operation. The share cropping system is that one-half of the produce for local varieties is retained by the land owners but they provide no inputs. For HYV rice, the land owners provide 50% of the inputs costs. The leasing out of land in kind (chukti) is declining in the area. However, leasing out of land with advance cash (rangjama) is commonly practised. The usual rate for such arrangements varies from Tk 500 to Tk 1,000 per ker (0.12 ha) and this is paid in advance to the land owner for one season. Landless people have very little access to land under this tenurial arrangement due to their inability to provide the cash after which they must still purchase agricultural inputs.

Fishermen
Fishing is an important activity in the project area, and competition over the fish resource is increasing every year. There are mainly two types of fishermen-traditional and non-traditional, who catch fish for generating an income. Traditional fishermen live on fishing and have been engaged in the profession since generations. The jalmohals are generally leased out to them through their cooperatives. However, the rich among them, act as the financiers and appropriate most of the profit from the catch while the poor catch fish on a regular basis and sell out for their survival. They also work as fishing labourers. There are an estimated 12,000 to 15,000 traditional fisherman households in the project area.

The non-traditional fishermen are mainly an emerging group from the landless and poor agriculturists. They fish in open water especially during monsoon months and sell the catch. Such non-traditional fishermen are increasing day by day and nearly 35-40% of the households, especially from the haor areas, are reportedly engaged in catching fish.

Another group of people who catch fish but should not be referred to as "fishermen" are the common residents. They do not sell fish but catch for their own family consumption. Sometimes, the rich among them lease the jalmohals for earning a profit from the catch and also act as financiers for the fishermen cooperatives.

Situation of Women
Women's role in agricultural production is important, especially in post-harvesting activities. Women's contribution, however, tends to be devalued and under reported. Though women generally do not work in the field, some poor women are reported to be working outside their homes, mainly for the Road Maintenance Program of CARE and activities like gathering wild

vegetables and collecting fuel. The village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, per-boiling and storing of rice. Most women prefer working on homestead gardening and raising poultry/duck in addition to other common household works. The women of the fishing community work on fish processing activities and the poor women work in fishing khola also.

B.2 Navigation

The following comments on impacts of navigation improvements on the Kushiyara River have been extracted from the draft final report "Bangladesh Inland Water Transport Master Plan (BIWTMAS) prepared in 1988. A portion of this study was directed towards outlining navigation projects which, in the coming years, are most likely to yield economic benefits to the IWT sector. One project that was examined at a pre-feasibility level, was to improve navigation on the Kushiyara River between Ikardia and Ajmiriganj by dredging.

BIWTMAS assumed that navigation was restricted by the available depths during part of the dry season. This depth was taken to be at 0.90 m Least Available Depth (LAD). By dredging, it would be possible to provide 1.5 m LAD. The additional water depth would then allow lower transport costs to be achieved through the use of more optimal vessels, both over the immediate stretch of the river dredged, and over a longer overall journey to and from ultimate origins/destinations.

Based on the above methodology and analyses, out of six possible dredging cases, the Meghna-Kushiyara River dredging from Ikardia - Ajmiriganj ranked first with an EIRR of 37.8%. This benefits were analyzed from dredging to 1.5 m and then maintaining the river at that point by annual dredging, as opposed to leaving them at a 0.90 m LAD level. A summary of the evaluated economic benefits of dredging is given in Table B.1.

Table B.1: Summary of Meghna - Kushiyara Dredging

River	Length (km)	Total freight traffic (000 t)	Total passanger traffic ('000)	Potential transport saving (mtk)	Total dredged quantity (Mm^3)	Total dredging costs (mtk)	Net trans port saving (mtk)	EIRR (%)	B-C ratio NPV rates (%)
Meghna-Kushiyara River	15	11,968	16,466	110,359	1.848	26,598	58,615	37.8	1.09:1

Source: Draft Final Report, Volume I, BIWTMAS November 1988.

In this scenario it was assumed that the total dredged quantity required for navigation improvements would be 1.848 million m^3.

B.3 Wetlands and Swamp Forest

There are about 40 major haor complexes existing in the Kalni-Kushiyara River Improvement Project area. A list of these wetlands with their categories of importance for wildlife is presented in Table B.2. Most of these haor complexes comprise several beels and located largely in the south-west portion of the project area (Figure 5).

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Table B.2: List of Wetlands (Haors) With Their Ranking

Haor	Rank*	Haor	Rank*
Abdullahpur	C	Kacharia	C
Baram	B	Kaliagota	B
Chaptir	B	Kayma	C
Chaier	B	Khai	C
Chankhai	C	Majail	B
Chaudhuni	C	Matikata	B
Chaular	C	Medarkandi	C
Chular	C	Mokar	B
Chatla	A	Morir	B
Dabhanga	C	Naluar	C
Dekker	B	Pagnar	B
Dhailong	C	Pangasiar	B
Dhamalia	C	Pruber	C
Dubrir	B	Rukshi	C
Fater	C	Sanghair	B
Gutumanik	C	Shapardhar	C
Haitola	C	Talka	C
Hakaluki	A	Tanguar	B
Jaliar	C	Teli	C

Ranking*

A = Site of outstanding importance for wildlife (international)
B = Site of considerable importance for wildlife (national)
C = Site only of limited importance for wildlife (local)

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

ANNEX C: INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

This Initial Environmental Examination (IEE) (pre-feasibility level Environmental Impact Assessment or EIA) follows the steps specified in the *Bangladesh Flood Action Plan Guidelines for Environmental Impact Assessment* (ISPAN, 1992). These steps are illustrated in Figure 2 of ISPAN (1992).

Much of the information required for the IEE appears in the main body of the study. The section and chapter references given below cite this information.

C.2 Proposed Channel Improvement and Dredging Project

C.2.1 Project Design and Description (Step 1)

As in Section 6.3, Project Description.

C.2.2 Environmental Baseline Description (Step 2)

As in Chapter 2, Physical Description, and Chapter 3, Settlement, Development, and Resource Management.

C.2.3 Scoping (Step 3)

Technical:

Literature review: Navigation studies summarized in Annex B.2 and Review of Environmental Imapcts from Dredging is summarized in Annex C.

Local community: As described in Section 3.7, People's Perception, Annex B.1 and Chapter 7, Pilot Dredging Project.

C.2.4 Bounding (Step 4)

Physical:

Gross area: 426,900 ha.
Impacted (net) area: 361,000 ha.
Impacted area out side project: The project does not have any negative impact outside the project area.

Temporal:

Pre-construction: year 0 through year 3 (see Table 6.5)
Construction: year 4 through year 6 (see Table 6.5)
Operation: Ongoing annual maintenance dredging anticipated after end of channel improvements and development dredging.

Cumulative impacts:

With other development projects and processes: The intent of the project is to improve the river environment. Impacts of dredge spoil disposal needs to be controlled and supervised.

With pre-existing no-project trends. Described in Chapter 4.

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C.2.5 Field Investigations (Step 5)

Morphological surveys carried out regularly over a 24 month interval. Other field investigations were conducted over a period of three months by a multi-disciplinary team's field visit, public consultation meetings and through four CO's deputed in the project area.

C.2.6 Impact Assessment (Step 6)

A screening matrix (Table C.1) was filled out by the project team. Impacts are designated by:

+	positive impact
-	negative impact
•	neutral impact (such as conversion from one productive land use to another)
?	insufficient information to designate

Impacts are discussed in Section 6.3.2 to 6.3.3 and 6.9.

C.2.7 Quantify and Value Impacts (Step 7)

Quantification and evaluation of impacts is documented in section 6.8 and Tables 6.10 through 6.12.

C.2.8 Environmental Management Plan (Step 8)

A preliminary Environmental Management Plan is presented in Chapter 7.

Mitigation and enhancement. Documented in Section 7.6.3.

Compensation. Mandated requirements for land acquisition must be adhered to. Beyond this, consideration should be given to:

- In-kind rather than cash compensation for households whose homestead land is taken. Example: Either by extending the existing homestead area with the dredged spoil and relocating the affected homesteads on the newly built homestead platforms or relocate the affected families to the homestead platforms built on the khas lands.

- Compensation for persons other than land owners who are negetaively impacted by land acquisition and dredging operations. Example: These persons should be employed for the construction and management of disposed soil chambers and also could be settled to the homestead platforms developed on the khas lands under local initiative; local communities could work with NGO,s to accomplish this.

Monitoring. Monitoring needs and methodologies will be established during Pilot Project investigations. Monitoring of village platform development could be carried out as part of FEAVDEP "Flood-and Erosion-Affected Villages Development Project".

People's participation. There is a need at regional, institutional, and project levels to maintain enthusiasm for people's participation, and to develop effective and efficient public participation modalities. Aspects concerning village development from spoil may be incorporated in FEAVDEP or FEAVDEP could be a part of the dredging project.

Disaster management (contingency planning). Not relevant to this project.

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EMP institutionalization. Arrangements for sharing EMP responsibility between BWDB and local people would need to be worked out. Project implementation should be contingent upon agreement on this matter between BWDB and local people.

Residual impact description. This should be generated as part of the feasibility-level EIA.

Reporting and accountability framework. Project implementation should be contingent upon development of satisfactory arrangements at the local level, at a minimum.

Budget estimates. These should be generated as part of the feasibility study.

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ANNEX C: REVIEW OF ENVIRONMENTAL IMPACTS FROM DREDGING

1. INTRODUCTION

1.1 Purpose

This Annex reviews the status of knowledge about physical and environmental impacts associated with dredging operations along inland waterways. The review is intended to assist in formulating a comprehensive Environmental Management Plan (EMP) for the "Kalni-Kushiyara River Improvement Project". This project proposes to utilize dredged spoil for a number of beneficial uses, including construction of village platforms, landing facilities and marketing centres. It is proposed that the sediments will be dredged with hydraulic suction dredgers and the spoil will be disposed on land in confined containment facilities.

A substantial amount of research has been conducted on the environmental impacts of dredging, and on approaches for regulating and managing dredging operations. For example, between 1973 and 1978 the Dredged Materials Research Program of the US Army Corps of Engineers conducted a US$33 million programme to evaluate impacts of dredging. Although most of the world-wide research has been directed towards open water disposal of dredged materials in the ocean, there still remains a substantial amount of experience with use of confined disposal facilities on land. Issues of particular interest to this review include:

- methods for identifying potential contaminated sites,
- investigative strategies and field sampling requirements at various phases of the project investigations;
- appropriate mitigation procedures that can be used to reduce or eliminate undesirable impacts;

The literature review was carried out using the libraries associated with the Bangladesh University of Engineering and Technology (BUET), University of British Columbia, Environment Canada, Pacific and Yukon Region and Waste Management Branch, BC Ministry of the Environment. Additional information was provided during discussions with several specialists who are actively engaged in sediment quality investigations, including:

Dr. M. Feroze Ahmed, Dept of Civil Engineering, Environmental Engineering Div, BUET
Dr. Kent Ackhurst, Biologist, Public Works Canada
Ms. D. Sullivan, Ocean Disposal Program, Environment Canada
Dr. J. Ward, Waste Management Branch, Ministry of Environment, BC, Canada
Mr. R. Ord, Contaminated Sites Unit, Ministry of Environment, BC, Canada

1.2 Report Outline

This annex consists of six chapters and a bibliography. Chapter 2 describes typical dredging equipment and disposal operations along inland waterways, including equipment and disposal practices that have been used on rivers in Bangladesh. Chapter 3 summarizes information about sediment properties that affect contamination and environmental impacts. Chapter 4 reviews the main potential impacts from dredging on water quality and summarizes the results of several case histories and field monitoring studies. Chapter 5 summarizes various approaches and criteria that are being used to regulate dredging operations. Chapter 6 summarizes the main conclusions that are relevant to proposed developments on the Kalni-Kushiyara River Improvement Project.

2. DREDGING METHODS AND OPERATIONS

2.1 Scope of Worldwide Dredging Activities

The total volume of dredging carried out by BIWTA in Bangladesh has averaged around 2.5 million m^3/year, ranging from 1.8 million in 1985/86 to 3.5 million in 1981/82 (BIWTMAS, 1988). However, additional dredging may also be conducted for special projects - for example 3.8 million m^3 of material was dredged at the Port of Chittigong in 1981 using a dredge from the Netherlands (Burren et al, 1983). These quantities are relatively small in comparison to other parts of the world. Somayajulu (1983) reported the annual maintenance dredging on the Hooghly River at the Port of Calcutta amounts to 18 million m^3/year. Total dredging at the main east coast and west coast Indian ports has averaged 39 million m^3/year.

According to the US Army Corps of Engineers, about 250 million m^3 of material is dredged from US ports and waterways each year. The dredging effort on the Mississippi River between Cairo Illinois and Baton Rouge, Louisiana amounts to around 24 million m^3/year (Vanoni, 1977). Leeuwen et al (1983) estimated the Port of Rotterdam produces 23 million m^3 of dredge material annually from the Rhine and Meuse Rivers. PIANC (1990) carried out a survey of worldwide dredging activity and estimated total disposal volumes amounted to nearly 800 million m^3 (Table C1). Approximately 80 % of the operations were carried out in the ocean or along shorelines and estuaries. Only about 5% of the material was disposed on land.

2.2 Dredgers

Modern dredgers are normally classified as either hydraulic or mechanical. Hydraulic dredgers include pipeline dredges, sidecasting dredges, hopper and agitation dredging. Pipeline dredges can be fitted with several different cutting heads, and include the suction cutterhead, plain suction dredge or the agitation dredger. Conventional suction cutterhead dredges consist of a large centrifugal pump mounted on a barge (Figure 28). The bottom of the suction pipe is most commonly equipped with a rotating cutterhead that breaks up the bottom materials so it can be sucked into the pipeline. The sediment is then pumped through a discharge pipeline to dyked onshore reclamation sites for disposal. Slurry concentrations in the pipeline typically range between 10-15 % by weight. The pipeline floats on pontoons and can extend for several kilometres when booster pumps are used to overcome friction losses. During operations the dredge is anchored by steel piles mounted on either side of the stern (termed "spuds"). The dredge can be made to "walk" along the channel as the cutter swings from side to side. Pipeline dredges are the most economical method for conducting large reclamation projects and are well adapted for onshore disposal operations. The overall size of the dredge is described by the diameter of the discharge pipe. A modern large capacity (760 mm diameter) dredger with 5000 to 8000 Hp supplied to the pump should be able to pump 1500 - 3400 m^3/hour in soft sediments through pipeline lengths of up to 4000 m (Herbich, 1992). Figure 29 shows typical performance criteria for other sizes.

Suction cutterhead dredges are used by both BIWTA and BWDB on rivers in Bangladesh. BWDB have eleven 18 inch diameter suction cutterhead dredges in their fleet. The dredges were reported to be capable of pumping at a rate of 225 - 255 m^3/hour over a distance of 1200 - 1500 m. The production from a single dredge was reported to be in the order of 50,000 - 60,000 m^3/month. These values are in the low range when compared to typical values from modern dredgers. BIWTA has eight suction cutterhead dredgers which can produce in the range of 36,000 - 54,000 m^3/month (BIWTMAS, 1988). Some operational characteristics of BIWTA dredgers are summarized in Table C3.

It should be noted that suction cutterhead dredgers are often specified by environmental authorities at contaminated sites because they do not generate large sediment plumes or stir-up large amounts of sediment into the water column. Several specialized suction cutterheads have been developed specifically for use at contaminated sites to reduce re-suspension and prevent the escape of re-suspended sediment. The American "Mud-Cat" (Ellicott Machine Corp, 1988) uses a hydraulically adjustable shield around the cutterhead which entraps suspended sediment and minimizes turbidity. Consequently, the dredgers can operate in highly contaminated sites such as sewage lagoons, paper mill settling ponds or in extremely sensitive sites such as around fish hatcheries.

The self-propelled trailing suction hopper dredge is commonly used in Europe for channel maintenance and port construction work. It consists of a ship - type hull with hoppers to hold the dredged material and a suction pipe and drag head to excavate the channel bottom. Hopper dredges have been constructed with capacities ranging from 500 m^3 to 10,000 m^3. Once the hoppers are filled, the vessel cruises to the disposal area and then dumps the spoil through bottom opening doors. Therefore, they are most suitable for offshore work or for open water disposal operations. Sediment re-suspension and turbidity will be generated at the suction pipe, from overflow of effluent from the hopper and at the open water disposal site when the spoil is dumped from the hopper.

Mechanical methods include draglines, clamshells, dippers, and bucket dredges. These utilize a bucket or grapple mounted on a floating platform to remove the bottom materials. The spoil is dumped on a barge or scow which can be towed by a tug boat to the disposal site. This type of equipment is commonly used in confined areas such as docks or slips where boat traffic is congested. These dredges generally also have relatively low production rates in comparison to hydraulic methods.

2.3 Disposal Operations

2.3.1 Open Water Disposal

Open water disposal is the most common method used in channel maintenance dredging throughout the world. When dredge spoil is dumped into unconfined waters, its ultimate fate will depend on the sediment characteristics (grain size, cohesive properties, flocculation properties), as well as the depth of water, current velocities, salinity and bottom topography at the disposal site. The most visible water quality effect from open water disposal is usually a plume of very turbid water that may extend several kilometres from the disposal area. In the case of navigation dredging along inland waterways, dredging is often restricted to specific shoals and bars and the spoil may be disposed in deeper reaches of the river or the thalweg (Lagasse, 1975). Typical open water disposal operations by BIWTA are described by Kibria (1983):

> *"As regards the dumping of the dredged spoils from the maintenance dredging sites in Bangladesh, these are in most of the cases dumped by floating pipelines of more than 300 metres in length to deeper and quieter parts of the wide channel from where these spoils will not get a chance to flow back to the dredged channel."*

Since the 1970's, environmental concerns about impacts of open water disposal operations have led to greater regulation and control in many countries, particularly the United States. Consequently, when contaminants are found in sediments, authorities have refused to issue open water disposal permits and have specified confined disposal on land.

2.3.2 Land Disposal

Disposing spoil on land is usually more expensive than open water disposal due to the need to construct containment dykes and drainage structures and to acquire land. Therefore, most dredging organizations prefer to use open water disposal methods unless the spoil can be used for some beneficial use.

BIWTA and BWDB occasionally pump dredge spoil on land in order to provide material for construction purposes or to raise land for building foundations. In the past, such operations have not involved the use of confinement dykes to retain the spoil. In these cases, the effluent from the dredge outfall is allowed to drain into the ground by infiltration or is directed into adjacent khals and low-lying channels.

An alternative approach is to pump the spoil into an enclosure that is confined by dykes. Confined disposal reduces the area required for spoil disposal, allows effluent to be retained until it is suitable for discharge and provides better control of releases through drains or ditches. This approach has been considered most appropriate for the proposed drainage improvements in the Northeast Regional Project, including the Kalni-Kushiyara River Improvement Project.

Comprehensive guidelines for planning confined disposal facilities are available from the US Army Corps of Engineers (1983, 1987a, 1987b). EM-1110-2-5025 stated that planning a confined disposal facility usually involves addressing two main issues:

- providing adequate storage capacity to meet the project's dredging requirements;
- meeting applicable effluent standards during filling operations.

Figure 30 shows the main features in a confined disposal facility. Containment dykes are usually constructed from available soil at the site. When operations are by hydraulic dredging, filling is usually carried out through a series of inlets to allow a uniform distribution of deposition in the containment area. The rate of effluent discharge and the concentration of suspended solids in the effluent can be controlled by an outlet weir at the downstream end of the structure. The sediment trapping efficiency of the facility will depend on its storage volume and retention time

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in the enclosure, the rate of discharge from the dredge and the physical properties of the dredged material. Furthermore, the trap efficiency will be reduced as the thickness of the dredged deposits increases over time. As a result, the outlet weir must be raised during the filling operations to ensure the effluent characteristics remain at acceptable values.

3. SEDIMENT CONTAMINATION

This chapter characterizes sediment properties that are relevant to sediment contamination, identifies pollutant sources and describes the main ways that contaminants become attached to sediments. Discussion of actual impacts expected from dredging and sediment disposal are reserved for Section 6.

3.1 Contaminant Sources

The Marine Board Committee study on the extent of contaminated sediments in the United States defined "contaminated sediments as:

> *those that contain chemical substances at concentrations which pose a known or suspected environmental or human health threat".*

The list of potential sediment contaminants is very large (Table C2). Broad groups include:

- heavy metals
- pesticides
- complex organohalogens such as PCB's and PCP's
- nutrients (nitrogen and phosphate compounds)
- organics such as oils and grease

Sources of contaminants include atmospheric fallout, household discharges and sewage effluent, runoff from agricultural lands, industrial wastewater discharges and storm drains, and from leaching of waste products. Ali (1994) listed the main kinds of industrial pollutants and their principle sources in Bangladesh:

- Non-specific bio-degradable organic materials that deplete oxygen (tanneries, textiles, food products, pulp and paper mills);

- nitrogen compounds that are either toxic for specific receptors, chemically reducing (exerting oxygen demand) or stimulating aquatic growth (urea fertilizer factories);

- pollutants susceptible to bio-accumulation in the food chain. An example cited by Ali was the Bangladesh Chemical Industries Corporation DDT plant in Chittigong.

Anwar (1992) listed various sources of heavy metals in Bangladesh, including:

arsenic: agriculture, phosphate manufacturing, fertilizer production, leather tanning
cadmium: leather tanning, metal plating, phosphate manufacture, fertilizer production

chromium:	pulp and paper mills, fertilizers, leather tanning, cement, steel and glass works;
copper:	pulp and paper mills, fertilizer manufacturing, chemical works;
cyanide:	iron and steel production, electroplating;
lead:	paint manufacturing, battery manufacturing, pulp and paper mills, fertilizer manufacturing and petroleum refining;
mercury:	paint and chemical manufacturing, plastic and pharmaceutical manufacturing, electrical manufacturing;
manganese:	fertilizers;
nickel:	pulp and paper mills, petroleum refining;
titanium:	paint manufacturing, textiles and paper production;
zinc:	pulp and paper mills, fertilizers and leather tanning.

3.2 Sediment Properties

Sediments parameters that are known to affect sediment quality include:

- sediment grain size, especially the fraction of the sediments containing clay;
- the organic content of the material expressed in terms of the per cent volatile solids;
- the pH and oxidation/reduction characteristics of the environment;

Most alluvial river channels are composed primarily of sandy sediments (coarser than 0.063 mm), although finer silt may be contained within the voids of the coarser particles. Sandy sediments are usually composed of relatively stable minerals such as quartz, feldspar, micas, or carbonates and precipitates such as limestone and dolomite. Sands also have high void ratios, porosity and permeability which allows fluids to migrate within the pore structure of the particles.

"Clays" refers to a group of predominately aluminum silicate minerals that are arranged in sheet structures. Clay minerals dominate sediments finer than 2-4 micron. Clay minerals are formed by erosion and weathering of other rocks and sediments. The main clay minerals include illite, montmorillonite, chlorite and kaolinite. The fall velocity of clay particles is very low, typically less than 1 cm/s. Consequently, once suspended clay size particles can normally be maintained in suspension by low velocities and form part of the river's "wash load". As a result, clay size sediments are not found in significant quantities in most alluvial river channels. Instead, they are deposited in slack water conditions such as in flood basins, beels and in deeply flooded portions of the floodplain. Clays have significant absorption capacity through which they can bond and transport many compounds, including contaminants such as heavy metals.

Organic matter is either derived from wind-blown or eroded materials or produced in the water. Organic compounds are primarily bitumens, lipids and humic substances and have sites for both physical and chemical sorption. Humic compounds form stable complexes (chelates) with most cations, including calcium, iron and pollutants such as mercury and copper.

3.3 Sediment Contamination

Contaminants rarely become part of the geological structure of the sediment. Instead, most contaminants:

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- remain dissolved in the sediment's interstitial pore water;
- become absorbed or adsorbed to the sediments ion exchange portion as ionized constituents;
- form organic complexes and become involved in complex sediment oxidation-reduction reactions and precipitates;

The amount of interstitial pore water depends on the size range of the sediments and its void ratio. Coarse grained sands can hold larger quantities of interstitial water than clays. Therefore, there is a potential for more contaminants to be in solution in sandy sediments than in finer sediments.

Sorption and cation exchange takes place on fine-grained sediments with large surface areas. The sorption capacity of a soil is a measure of the ability of a soil to trade cations in the soil for those from the contaminant. A generalized sequence for the capacity of solids to sorb heavy metals is as follows:

$$MnO_2 > \text{humic acids} > \text{hydrous iron oxide} > \text{clay}$$

The ability of herbicides and pesticides to ionize in water determines whether theses substances will have an ionic charge in water. Cationic herbicides such as cyperquat, difenzoquat and paraquat are readily absorbed by the negatively charged colloidal particles of mixed clay and organic composition and become fixed within the clay minerals. Nonionic biocides may be physically adsorbed on to sediments but their association with such particles depends on the lipophilic nature of the sediment - low solubility pesticides such as aldrin, BHC, lindane, trifluralin, DDT, dieldrin, endrin and oryzalin are not adsorbed by the strongly hydrophylic clay particles (UNESCO, 1983).

The capacity of soil to retard contaminant migration also depends on the presence of numerous hydrous oxides, particularly iron oxides, phosphates and carbonates. These compounds precipitate heavy metals out of solution, making them unable to travel further. For example, cadmium, zinc and copper will be co-precipitated with iron hydroxide. Calcium carbonate has been found to remove most metal carbonates from solutions that have low solubilities such as cadmium and lead. However it is less competitive for precipitating heavy metals than iron hydroxide.

Table C4 compares concentrations of various contaminants in alluvial sediments using sample results from the Jamuna River (JMBA, 1994), Rhine River, the Netherlands (Leeuwen et al 1983), Fraser River, Canada (Environment Canada 1975) and Lake St Clair, Canada (Thomas et al, 1975). This table provides some indication of the ranges in contaminant levels between highly industrialized sites such as on the Rhine River and those where this contaminant sources are less evident, such as in the sediments of the Jamuna River. Unfortunately, there are relatively few measurements of sediment contaminant concentrations in Bangladesh to compare with these values. An example of sediment contamination from a fertilizer factory was reported in Khan et al (1994):

> *"The discharges in and around the Gorasal fertilizer factory caused an accumulation of arsenic in the nearby soil as high as 3,778 ppm.*

In general, the spatial variation of contaminant concentrations in river sediments will be much greater than the concentration of contaminants dissolved in the water column. For example, contaminants attached to the clay fraction of the sediments will tend to be concentrated in deposition zones such as back basins, slack water areas and sloughs. Channel reaches subject to active scour and fill or remobilization of sediments due to passage of dunes will be essentially devoid of finer clay-size sediments and may appear uncontaminated. Consequently, the localized nature of sediment transport and deposition needs to be considered when planning sediment quality sampling programmes or when interpreting sediment quality data. This approach was used to identify and plan long-term sediment quality monitoring programs along the Fraser River, British Columbia (NHC, 1994). Furthermore, identification of potential sources of contaminants along the river is also clearly very important.

4. POTENTIAL IMPACTS FROM DREDGING

Potential impacts from dredging are generally grouped into five main categories (Environment Canada, 1975; Corps of Engineers, 1985):

- physical disturbance to habitat due to excavation or placement of spoil;
- increased turbidity either at the dredge site or the disposal site;
- reduced oxygen levels in the water column at either the dredge site or disposal area;
- increased nutrient loadings
- release of contaminants that will impair water quality, such as heavy metals and biocides;

4.1 Physical Impacts to Habitat

Ali (1994) has attributed changes in physical habitat and fisheries impacts to dredging (with open water disposal) on the Jamuna River. Fishermen reported that dredging of the bed of the Jamuna river in the Nagarbari region had resulted in reduction of depth of deeper pools downstream of the river below which there are two riverine jalmohals. Fishermen of these areas reported that schools of a fish, Pangas (Pangasius pangasius) used to congregate earlier in the deeper pools in these jalmohals providing them with rich fishery. In 1986 and 1987, individuals of this particular species were no longer seen in traditional locations. According to fishermen, depths of rivers in such traditional fish habitats have undergone reduction due to silt and sand flowing and depositing downstream as a result of dredging upstream.

Several case histories documenting short-term changes in habitat, substrate characteristics and benthic organisms at open water disposal sites have been documented in Environment Canada (1975). Impacts were generally described as being temporary, lasting from a few months to over a year. It was concluded that the spoil dumping had an immediate effect but not a lasting effect on benthic fauna at these particular sites.

Potential problems may occur at confined disposal sites if they are located on valuable wetlands or other productive habitat. This situation can be particularly critical since so much dredging is carried out in estuaries and near shorelines (Table C1). Consequently, great care must be given to identifying important habitat sites and incorporating this information into the planning process before dredging starts.

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4.2 Increased Turbidity

Localized increases in turbidity are often the most visible sign of dredging operations in a river. Initial concerns about increased turbidity levels were directed to two main issues:

- a reduction in primary productivity due to reduced light transmission;
- gill damage to fish

However, experience has shown increased turbidity levels are normally associated with particular types of dredgers and disposal operations (mechanical, hopper and sidecasting dredgers produce greater impacts than suction cutter dredgers; open water disposal produces much larger sediment turbidity plumes than confined disposal).

Results of field trials at Calumet Harbour, Illinois indicated cutterhead dredgers were able to limit sediment resuspension to the lower portion of the water column. The marked difference in the effect of the cutterhead and clamshell dredgers is illustrated in Table C6. The table shows the areal extent in acres of the sediment plume at various depths. The extent of the plume was defined by the point where sediment concentrations were 10 mg/l above normal background levels.

Vertical concentration profiles reported by Blokland (1988) during operation of a suction dredge in Dutch harbours showed similar findings. Sediment concentrations were:

- 880-1600 mg/l near the bottom, close to the cutterhead;
- 333-427 mg/l near the mid-depth (around 5 m from the bottom);
- under 20 mg/l at the surface.

which again confirms the restricted effect on turbidity from properly operating suction dredgers.

Potential turbidity effects from operations using unconfined open water disposal and confined, upland disposal also need to be clearly distinguished. In the case of open water disposal, all of the dredged sediment is returned to the river system, either by continuous pumping or intermittent dumping from barges or hoppers which can generate sediment plumes that extend over many kilometres. In the case of properly functioning confined disposal operations, virtually all the sediment should be retained in the settling basin. Recent technical manuals (EM 1110-2-5025) generally discount the effect of turbidity from modern dredging operations:

> *"there are now ample research results indicating that the traditional fears of water quality degradation resulting from the re-suspension of dredged material during dredging and disposal operations are for the most part unfounded".*

4.3 Oxygen Depletion

Re-suspension of fine grained, organic rich sediments during dredging may cause dissolved oxygen levels to be lowered. Isaccs (1962) showed that the BOD of sediments can range from 16-330 grams O_2/kg volatile solids for various bottom deposits. Sediments contaminated from domestic waste or from other highly organic sources may exert an oxygen demand several times this amount.

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Bella (1971) studied the oxygen uptake from bottom sediments using laboratory and field measurements. It was concluded that a large fraction of the oxygen uptake was due to the release of free sulphides, which were rapidly oxidized in the aerobic zone of the sediment or the overlying water. This situation is mainly found in estuaries where the sediments consist of a thin surface layer of oxidized sediments which are in turn underlain by a darker anaerobic mud. Within the aerobic zone the sulphur is most commonly found in the form of sulphate ($SO_4^{=}$). Within the anaerobic zone, sulphates that diffuse downwards are reduced by bacteria (genus Desulfovibrio) to free sulphides such as hydrogen sulphide. Re-suspension of sediment containing sulphides by dredging or other physical disturbance could release toxic hydrogen sulphide as well as lower oxygen levels in the water column.

One of the earliest documented examples of this problem was reported by Hourston and Herlinveaux (1957) at Alberni Inlet on Vancouver Island, Canada where a mass mortality of small fish occurred after a bucket dredging operation occurred in a docking area at a pulp mill. They concluded the bucket dredge had re-suspended sediments containing hydrogen sulphide, which resulted in poisoning and oxygen depletion. A somewhat similar case was reported by Brown and Clarke (1968) at Arthur Kill, New Jersey where a bucket dredge was operating in a long, narrow channel. Dissolved oxygen levels dropped from 9 mg/l to 1 mg/l during dredging. The sediments were found to be highly contaminated from waste discharges and were described as "black, soft oily, silt emanating odours of chemicals, oil and hydrogen sulphide. Measurements of the COD yielded an uptake rate of 49 mg/l. The problems experienced at Alberni Inlet and Arthur Kill should be avoidable if adequate pre-project monitoring and sediment sampling are carried out.

Windom (1972) studied the effects of dredging sediments contaminated with industrial and municipal wastes in the Savannah River, USA. A hydraulic pipeline dredge was used to pump the spoil onshore to a dyked retention basin. The dissolved oxygen level in the return flow from the basin was found to exceed the natural levels in the river upstream of the dredging. Sceva and O'Neil (1971) reported that dissolved oxygen levels in Depot Slough, Oregon were not affected by hydraulic dredging in the Yaquima river. The spoil was pumped into a dyked basin with the return flow draining directly to the slough. Dissolved oxygen levels remained between 7.3 - 8.5 mg/l throughout the project, even though the sediments contained up to 21.8% volatile solids.

4.4 Nutrients

Nutrients are found in dissolved form, adsorbed on particulates, in bottom sediments and bound to organic matter. DMRP concluded that the effect of nutrient release from dredged spoil material is generally of little significance (Lac and Wester, 1973). Sceva and O'Neil (1971) reported that onshore, dyked spoil disposal could reduce the amount of nutrients that were released into the receiving water. During excavation in Portland harbour, Oregon, spoil was pumped into a 150 m x 200 m dyked basin. The overflow was discharged through two 1 m diameter culverts back into the receiving water. Values of total Phosphorous and Ammonia Nitrogen were 74 mg/l and 3.2 mg/l respectively in the inflow and were reduced to 3.8 mg/l and 0.7 mg/l in the return flow.

4.5 Release of Contaminants During Dredging

The main factors governing release of contaminants from dredged sediments include:

- physical disturbance and mixing of the sediments

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- chemical changes in the soil environment
- microbial transformations

Lee (1970) reported that the primary release mechanism of contaminants from sediments into the water column is the mixing and disturbance of the sediments (for example, when sediments are turned into a slurry in a hydraulic dredge).

> *"This mixing causes a change in the liquid-solid ratio which would tend to promote release of contaminants from a sediment surface to water. Further, the stirring enables the contaminants in the interstitial water to be brought to the surface at a significantly greater rate than typically occurs by diffusion controlled processes. Since in most instances the concentrations of contaminants in interstitial waters are greater than the overlying water, the primary factor controlling release of contaminants from sediments is the mixing or stirring process"*

However, once released, other chemical processes may take place to rapidly remove the contaminants from the water column. Studies by the Dredged Materials Research Program found that as long as the sediment remained oxic (contained dissolved oxygen), out of 30 chemical contaminants that were studied, only ammonia and manganese were released from the sediments when they were dredged. However, if the sediments were mixed in anoxic conditions, a large number of contaminants were released to the water. This finding was related to the role of $Fe(OH)_3$ as a scavenger for contaminants released from the sediments:

> *"Iron in most sediments exists in ferrous form. Upon contact with water containing dissolved oxygen, it is rapidly oxidized to ferric iron, which precipitates as ferric hydroxide. Freshly precipitated ferric hydroxide can sorb significant amounts of a wide variety of contaminants. It is for this reason that few contaminants present in interstitial water or which are desorbed during slurrying remain in the water column. While they are released, they are rapidly taken back to the sediments by the ferric hydroxide scavenging"*

It was also pointed out that the scavenging ability of the precipitate may tend to decrease over time, particularly when the sediment is stored in the dry. Consequently, some contaminants could gradually be released over time as the sorption capacity of the material is reduced.

According to UNESCO (1983), the release of sediment contaminants due to chemical changes may be brought on by:

- increasing salinity
- lowering of pH and leaching by organic acids
- changes in oxidation-reduction potential (Eh) and/or oxygen deficit
- the presence of synthetic complexing agents (NTA)

Increasing salinity such as occurs under conditions of high evaporation, can lead to competition between dissolved cations and adsorbed heavy metal ions. This can cause a pronounced re-mobilization of mercury, zinc, chromium, lead copper and arsenic as they become partially replaced.

Lowering of pH can lead to increased desorption of metal cations, particularly in waters that are low in bicarbonate ions. The presence of dissolved organic acids such as humic acid and fulvic acid also significantly contributes to the leaching and dissolution of many minerals and the extraction of metals.

Organic matter in solution, may reduce precipitates such as $Fe(OH)_3$ (which are part of the sediments), to soluble Fe^{2+}. Any heavy metal co-precipitates associated with the $Fe(OH)_3$ may become partly remobilized into soluble form at the same time.

Laboratory studies by Miles (1980) investigated releases of biocides from sediments. These tests involved treating sediments with a number of insecticides, then centrifuging a sediment/water mixture and analyzing the elutriate to see whether any compounds were released. It was found that little or no DDT was removed and significant amounts of ethion and dieldrin still remained absorbed even after the testing was repeated four times. However, only 17% of the lindane and less than 10 % of the more soluble organo-phosphorous and carbamate insecticides (diazinon, carbaryl) remained adsorbed (UNESCO, 1983).

Contaminants can also be released as a result of microbial activity and bioturbation. For example, contaminant releases can occur in the intestinal tract of aquatic organisms that consume sediment. Of particular concern is the trophic level build-up of contaminants in aquatic organisms, where higher level organisms have greater concentrations of contaminants in their tissue than lower levels. Contaminants which have a potential for trophic magnification include chlorinated hydrocarbons, pesticides, methyl mercury, PCBs and PAHs and possibly kepone and mirex (UNESCO, 1983).

Another potential concern is the conversion of inorganic metal compounds to organic molecules, as a result of processes catalyzed by enzyme activity (UNESCO, 1983). For example, the conversion of mercury into methyl-mercury is a bacteriological process involving methane producing bacteria:

$$Hg^{2+} \rightarrow CH_3Hg^{+} \rightarrow (CH_3)_2Hg$$

The methylated mercury produced from this process is much more toxic than mercury itself. However, Peguegnat (1983), using results from Fujiki, Hirota and Yamaguchi (1977) concluded that mercury uptake by aquatic organisms is predominately via water rather than bioaccumulation in food chains:

> *"in Japan, where it well known, Hg contamination in some sediments has been a problem, methyl mercury was found to enter benthos from water and not from sediments"*

The Corps of Engineers report EM 1110-2-5025 included the following summary statements on contaminant releases from dredged sediments:

> *"There is no biologically significant release of heavy metals, petroleum and chlorinated hydrocarbons from <u>typical</u> dredged material to the water column during or after dredging or disposal operations.*
>
> *Release of sediment-associated heavy metals and chlorinated hydrocarbons to the water column has been found to be the exception, and bioaccumulation of most metals from sediments is generally minor. Organochlorine compounds (DDT, dieldrin, and*

chlorinated biphenyls) generally are not soluble in surface waters in concentrations greater than 20 ppb. They are released from sediments until an equilibrium is reached, but concentrations are reduced to background levels in a few hours. Bioaccumulation of chlorinated hydrocarbons occurs, but only very highly contaminated sediments would result in tissue concentrations of potential concern.

Oil and grease residues are also tightly bound to sediment particles, and bioaccumulation of these materials from sediment also appears to be minor. Of the thousands of chemicals in the oil and grease category, only a few can be considered a significant threat to aquatic organisms as a result of dredging and disposal operations."

These broad generalizations do not imply contaminant releases can not occur during dredging operations. Rather, they suggest that problems are rare and are usually associated with relatively unusual circumstances or special conditions. It is important to be able to recognize when potential problems are likely to occur, so that environmental management efforts can be focused on those sites. Some indicators of concern include:

- sites located near major sources of pollutants (such as industrial facilities or sewage treatment plants) and whose sediments contain primarily sandy materials with a low capacity to bind contaminants;

- sites located near major sources of industrial pollutants and whose sediment contains a high fraction of volatile solids which may produce oxygen depletion and release hydrogen sulphide when disturbed by dredging.

5. MANAGEMENT OF DREDGING OPERATIONS

5.1 Issues and Objectives

Regulatory agencies have strived to develop quantitative sediment quality criteria that would be analogous to water quality criteria and could be used for assessing dredging operations and disposal plans. Unfortunately, after over 30 years of research, there is still considerable difficulty in establishing technically sound benchmarks for evaluating sediment quality.

UNESCO (1983):

"The fact that clear sediment/biota relationships have not been established... has resulted in a complete failure todate, in producing sediment bio-assay tests of sufficient simplicity and reliability to be used in routine assessment of sediment metal concentrations for legislative purposes".

Lee and Jones (1992), whose research during the 1970's contributed to much of the understanding of water quality impacts from dredging wrote:

"It can be generally, if not universally assumed that... if the EPA criteria are not violated, there is little or no likelihood that the contaminants present in the dredged sediments will have an adverse effect on aquatic life. If, however, the criteria or standards are violated, it is highly likely that such violations do not constitute an adverse

impact on the beneficial uses of the water. Certainly, it would be highly inappropriate to cause a particular dredging project to alter the proposed approach that is to be used for dredged sediment disposal, based on finding that the EPA criteria and/or state water quality standards would be violated."

Furthermore, the aim of most legislation has been to decide whether or not contaminated sediments can be disposed in open water or must be placed in confined disposal facilities on land. Therefore, the standards that have been developed are of limited relevance to projects which plan to use dredge spoil for beneficial uses at confined disposal sites. Consequently, this section has avoided a detailed discussion of existing dredging legislation and sediment quality criteria that are in use in various parts of the world. Instead it summarizes some of the planning tools, testing procedures and strategies that have been developed for evaluating dredging disposal operations.

5.2 Methods of Characterizing Pollution Potential

5.2.1 Bulk Sediment Properties

The concentration of contaminants found in the bulk sediments to be dredged provides an indication of the presence or absence of potentially hazardous substances. Comparison of concentration values along a reach may also help to identify contaminant sources. However, the mere presence of a contaminant or its concentration in dredged material can rarely be used to predict whether or not it will have adverse effects upon biota. Results from testing of sediments have failed to demonstrate clear relationships between sediment contaminants and biological effects. This is because the actual mobility and bioavailability of the contaminants depends on a wide range of physical and chemical variables. Nevertheless, many agencies utilize bulk properties because of its simplicity and close analogy to water quality criteria.

An example of sediment quality criteria for handling and storage of contaminated sediments is shown in Table C7. The criteria are intended to be used in different ways:

Investigation criteria: represent contaminant concentrations which when exceeded require detailed investigation to assess the extent of contamination and nature of the hazard;

Remediation criteria: represent contamination concentrations which when exceeded require action to reduce the exposure of humans or other receptors to contaminants.

Three benchmark concentrations are defined:

Level A: This level represents approximate achievable analytic detection limits for organic compounds in soil, and natural background levels of metals and inorganics. For soils with constituents at or less than this level, the soils are considered "uncontaminated". For residential and agricultural land use, Level A represents the investigation criteria. For soils containing contaminants at concentrations greater than level A, but less than Level B, the soil is considered slightly contaminated but remediation is not required.

Level B: this level, approximately 5-10 times above level A, is considered the remediation level for residential and agricultural land-use. If the site will be used for

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commercial or industrial land-use, Level B represents the investigation level. For soils containing contaminants with concentrations exceeding level B, but less than level C, the soil is considered contaminated and requires remediation to levels less than level B, if the land is to be used for residential or agricultural purposes. Remediation would not be required if the land is used exclusively for commercial or industrial purposes.

Level C: At this level, the sediment contamination is significant. For soils containing contaminants exceeding this level, all uses of land will be restricted pending the application of appropriate remedial measures.

The sampling effort required for evaluating the dredged materials generally will depend on the quantity of sediment to be removed. For example, interim guidelines in Canada specify a minimum of three bulk samples from the surface of the channel for projects less than 4000 m^3 and up to six surface samples and six sediment cores for projects exceeding 60,000 m^3.

5.2.2 Water Column Chemistry

In the early 1970's the US Environmental Protection Agency (EPA) developed the "Elutriate Test" as a means for assessing the release of contaminants from sediments during dredging. This test involves mixing the sediment with water from the dredging site for a prescribed period, then separating the two and analyzing the elutriate for nutrients and various chemicals to see if any contaminants were released into the water column. The general procedures are shown in Figure 31. Details and various modifications to the test are described in UNESCO (1983) and Jones et al (1978).

The underlying principle of the test was that the fraction of a chemical that is available for release is approximated by the interstitial water content concentration and the loosely bound fraction in the sediment. The elutriate test is an idealized simulation of the dredging process wherein a predetermined amount of sediment and site water are mixed together to approximate the sediment-water slurry pumped in a hydraulic dredge.

The results can be interpreted in different ways. For example, the concentrations in the elutriate can be compared against the concentrations in the natural water to see if significant releases in contaminant concentrations have occurred. Alternately, the concentrations in the elutriate can be compared to water quality criteria, to assess whether contaminant concentrations in the effluent might exceed existing standards.

5.2.3 Bioassays

Bioassays involve exposing test organisms to dredged material or the elutriate for a specific period of time (usually 96 hours), then measuring the response of the organism. Often three different test organisms are used. Bioassays provide a direct indication of the overall effects of the dredged sediments. They also indicate the cumulative effect of all contaminants present in the spoil, including interactions between contaminants.

Bioaccumulation tests may also be used to assess whether contaminants will build-up in organisms subject to long-term exposure. EPA currently uses a laboratory based 28 day test for organic contaminants.

5.3 Management of Dredging Operations

The following examples of management programs illustrate how various agencies cope with sediment quality issues.

5.3.1 Jamuna Multipurpose Bridge:

There are no sediment quality standards in Bangladesh for the control of dredging or disposal of dredged sediments. The Jamuna Multipurpose bridge project is probably the first project to explicitly consider measures for managing environmental aspects of dredging in Bangladesh. Therefore, the environmental management programme has been reviewed to assess the scope of work that has been carried out at the end of feasibility and detailed design studies.

Construction of the main bridge, bridge end facilities, approach roads and river training works involves massive dredging activities. For example, approximately 30 million m^3 of sediments will be dredged for construction of the river training works, excavation of charlands along the bridge axis, and at various locations in the Padma and Jamuna River to maintain water transport during construction activities. Most of the dredged spoil is intended to be used to reclaim land to construct the bridge end facilities and approach roads and to fill up borrow pits.

A Feasibility Study and Environmental Impact Assessment of the bridged were completed in 1989. In May 1994, the Jamuna Multipurpose Bridge Authority issued an Environmental Action Plan which reviewed previously prepared environmental studies and identified the possible nature and magnitude of impacts from the project. As part of this study, the effects of the massive dredging effort was assessed. The assessment involved collecting two bed material samples from the east and west banks of the river and then carrying out a laboratory analysis of the bulk sediment properties. On the basis of these two samples the EAP concluded:

> *"the bed material does not contain toxic and hazardous elements or compounds in excess of maximum acceptable concentrations for sediments to restrict the use of dredged material for the above mentioned uses".*

The test results were compared with standards used by the Netherlands prior to 1989.

In August 1994, JMBA issued a "General Environmental Guidelines for Construction of Jamuna Multipurpose Bridge", which was intended to define guidelines and standards to detect, monitor, control or mitigate all undesirable environmental impacts related to bridge construction. It was reported that intermittent monitoring of the dredge spoil and dredge effluent should be conducted during the first year of construction, and possibly later on. The parameters to be measured and the frequency of sampling are listed in Table C7. Proposed effluent sampling will involve measurements at one location on four dates over the year. Spoil samples will be collected at two sites. It was indicated that if pollutants are detected in the effluent from the spoil disposal facilities, the quality of this effluent should meet "Standards for Industrial Sewage Effluent". Specifications for turbidity during dredging and effluent disposal were contained as part of General Conditions from FIDIC Standard Contract:

"Any water discharged at the site into natural or existing water courses... shall never contain more than 4000 ppm of soil matter. Retaining dikes shall have such properties that fine soil particles will not percolate through the dike."

The scope of this environmental management plan provides one point of reference for assessing the environmental programme that have been planned for the Kalni-Kushiyara River Improvement Project.

5.3.2 Environmental Protection Agency/Corps of Engineers Tiered Assessment Approach:

This approach was developed in Puget Sound primarily to evaluate whether dredged sediments can be disposed in water or on land at a confined site. The general methodology provides a useful example of how various biological and chemical tests can be used as a screening tool for project evaluation.

A dredging proposal will be subjected to a three level review process. Tier 1 involves reviewing existing information to see if there is a reason to believe the sediments at the proposed site are contaminated. This requires a data base of sediment quality to be available for review. If there is reason to believe contaminants may be present then testing will be specified. Tier 2 relies on bulk sediment analysis to see if the dredged sediments are more contaminated than the existing materials at the proposed disposal site. Elutriate tests are also conducted to compare the amounts of contaminants released during the tests with existing water quality criteria. If the criteria are exceeded, then additional bioassay tests are required before a decision is reached on whether to allow the operation to proceed. Tier 3 requires acute aquatic organism bioassays using the EPA-CE multiple species test approach. Bioaccumulation assessments are also carried out on various organisms. If these tests indicate mortality may be induced by the dredging then the spoil will have to be disposed on land, at an approved confined disposal site.

This approach illustrates how managers can deal with the unresolved problem of sediment quality criteria. In this case the results of the testing in Tier 2 are used as a "trigger" to initiate more complex biological tests if an apparent threshold is exceeded.

5.3.3 Tiered Hazard Assessment Approach

Figure 32 summarizes an alternative approach developed by Lee and Jones (1981) to assessing hazards from dredging and disposal operations on the upper Mississippi River. The aim was to appraise various disposal methods and sites by using a combination of sediment bioassays, elutriate tests and physical, chemical and biological characterization of the sites. The first stage (Tier 1) would involve developing "least cost" site options and then assessing the ecological sensitivity of the proposed sites. If a highly sensitive site was identified, that site would be rejected and other locations would be proposed. If the disposal site is not a sensitive area and it can be verified that the site is not near a source of contamination, then the recommendation would be that there should not be significant impacts on beneficial uses of the site. If the sediments were considered to be situated near a source of contamination, the potential for the release of chemicals would be evaluated at the Tier 2 testing level by means of conducting standard elutriate tests. Depending on the outcome of these tests, three possible scenarios may develop:

- other methods of disposal or other sites should be considered;
- the site will be considered suitable for the intended purposes;
- if uncertainty still exists, further testing at the Tier 3 level should be conducted.

Tier 3 tests would be more site specific, involved and expensive than the previous level of effort. These tests would involve conducting elutriate bioassays, and possibly specialized studies to assess dilution, dispersion and pathways of contaminant release. At the end of this programme, another decision would be made on how to proceed. The final stage of investigation, Tier 4, would involve implementation of one or more pilot dredging projects with detailed monitoring.

An advantage of this approach is that the need for elaborate and costly laboratory tests may be avoided if the results of Tier 1 investigations show pollutant sources are absent and spoil sites are not situated in critical habitat areas.

5.4 Management of Confined Disposal Sites:

Disposal of dredged material in confined sites is usually considered to be more protective of the environment than other methods such as open water disposal. However, the DMRP has identified five special issues that need to be considered when planning confined disposal operations:

1. release of contaminants in the effluent during disposal operations;
2. surface runoff of contaminants in either dissolved or suspended particulate form after disposal is completed;
3. contamination of groundwater due to leaching processes;
4. control of turbidity from the settling basins;
5. uptake of contaminants by plants, followed by indirect animal uptake from feeding on vegetation.

Figure 33 illustrates some of the main interactions that need to be considered.

The Tiered evaluation approach described above can be applied to a confined disposal operation. Standard elutriate tests provide a means for determining whether short-term releases of contaminants may occur during dredging operations. However, alterations in sediment chemistry due to weathering, leaching and other changes may cause marked changes in the mobility of some contaminants over time. Chemical analyses of bulk sediment properties provides a means for identifying the potential for such releases. If the sediments are contaminated, disposal sites should not be selected where sub-surface drainage could affect water supplies or adjacent surface waters. Mitigative measures such as artificial liners have been used at highly contaminated sites. Many fine textured dredged materials become self-sealing over time as particles deposit in the pores of the underlying soils. This can reduce the need for installing permanent liners (Corps of Engineers, 1987) .

Turbidity impacts at the outlet of properly designed confined disposal sites should be minor since virtually all of the sediment will be retained in the storage basins. However, the trap efficiency of the confinement structures will be greatest for coarse grained (sandy) sediments and lower for silts and clays. Adequate pre-project planning and soil sampling needs to be carried out to ensure the confinement facilities have adequate trap efficiency and storage

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capacity. Furthermore, adequate monitoring of the outfall needs to be carried out during operations. Some effluent standards for turbidity levels at various US Corps of Engineers districts are listed in Table C8. It can be seen that the "acceptable" increase in turbidity that is allowed varies from place to place. Standards vary according to the physical characteristics of the sediments, the sensitivity of aquatic species present to the sediment and peoples acceptance of turbidity impairment.

If the sediments unexpectantly contain substantial amounts of fine sediments, then some portion may pass over the weir at the basin's outlet unless remedial measures are carried out. Accepted procedures for regulating the turbidity of the effluent from confined storage facilities have been developed by the Corps of Engineers (1987). These measures include:

- increasing the depth of the storage basin by raising the water levels;
- pumping intermittently to all for longer retention times;
- using flocculating agents to increase settling rates.

Covering contaminated dredged material with clean soil or clean dredged sediment can also be done to prevent exposure of contaminants. Plant populations may be managed to minimize uptake of metals from contaminated sediments, particularly if they are intensively managed in agricultural practice. For example, it is possible to select plants in which metals tend to accumulate in portions of the plant that are not harvested.

6. RELEVANCE TO KALNI-KUSHIYARA IMPROVEMENT PROJECT

6.1 General

Past experience has shown that in the vast majority of cases, dredging can be carried out with minimal or no detectable impact to the environment. Serious impairment of water quality can arise when harbours, or channels containing highly contaminated sediments are dredged without remediation or mitigation measures in-place. In areas that are not highly industrialized and river sediments are "clean", water quality problems are usually restricted to the presence of suspended solids, and temporary increases in turbidity.

6.2 Sources of Sediment Contaminants

There are no major industrial facilities currently operating along the Kalni-Kushiyara River. A fish packing plant operated at Ajmiriganj, however this plant was closed down in 1993. A fertilizer factory operated at Fenchuganj (60 km upstream of Ajmiriganj and outside the project area), however this plant also ceased operation in 1993.

The largest source of domestic waste is probably from the town of Ajmiriganj. Therefore, if any excavation was planned in the back channels and sloughs of the Old Kushiyara channel near the town, then detailed pre-project sediment sampling in this area would certainly be warranted. However, there are no plans to dredge this particular area so that problems are unlikely to arise.

6.3 Sediment Properties

The Kushiyara River is composed of fine sand (median size 0.12 mm) with only minor silt. However, downstream of Markuli the sediments of the Kalni River are more variable and are generally finer. Surface bed material samples between Markuli and Madna show alternating reaches of fine sand and silty sand, with the silt fraction in some sections amounting to 20-40%. Clay sized sediments are absent from the channel bed. Fine grained silty sediments are more easily re-suspended during dredging and could induce more turbidity than sandy sediments. Furthermore, finer sediments will require longer retention times to drain before they can be used for construction purposes.

Out of the 12 sediment samples collected by NERP in the project area, none of the samples contained any visible contaminants such as oils, grease or organic matter and none had any noticeable odour. The sediments appear to be essentially clean, natural alluvial sediments.

Preliminary laboratory investigations by BUET using sediment samples from three proposed dredging sites showed the sediments did not have a high BOD (Tables C9 through C17). Furthermore, three separate elutriate tests showed the sediments did not appreciably lower the dissolved oxygen content of the water column when mixed. These Elutriate tests also showed no signicant releases of copper, cadmium, zinc or iron. The presence of other trace metals and biocides could not be analyzed at this time. Given the fact that there are no major point sources of contaminants it is expected that most of the sediments in the project area are relatively clean. However, additional testing will be carried out to confirm this during the planning stages of the Pilot Project and during feasibility studies.

6.4 Proposed Dredging Method

The use of suction cutter dredgers with confined disposal on land will be more protective of the environment than other dredging methods that are commonly used in Bangladesh and abroad. Suction cutter dredgers will reduce sediment re-suspension and turbidity in comparison to hopper dredgers or mechanical dredgers.

Furthermore, pumping the spoil into dyked containment chambers will ensure that virtually none of the dredged sediment is returned back to the river. This will eliminate most impacts associated with open water disposal such as downstream changes to habitat due to sediment desposition, oxygen depletion during disposal operations and generation of high turbidity levels. It is intended that the spoil will be used for a range of beneficial purposes. However, this construction could give rise to a range of land-use conflicts. Special concern needs to be given to identifying critical shoreline habitat so that disposal sites are not located near ecologically sensitive areas.

6.5 Environmental Management

Environmental planning needs to be carried out at the earliest stages of project development in order to properly identify potential hazards and problems and to ensure adequate pre-project monitoring and analysis is carried out. A multi-disciplinary approach to planning and site evaluation is required. The following comments indicate the type of investigations that

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would be appropriate during various phases of the project.

Pre-Feasibility Investigations:
Identify important issues, review available secondary data sources and past experience at other dredging operations, carry out site reconnaissance, collect reconnaissance level background information on land-use, geomorphology, sedimentology, and ecology. Develop conceptual and prelimary plans for programme implementation, monitoring and mitigation.

Pilot Project:
Carry out a multi-disciplinary investigation to develop a comprehensive environmental management plan for dredging and disposal operations. As part of the site selection proecess, conduct field surveys and site investigations to assess land-use practices near the proposed dredging and disposal sites, their proximity to pollutant sources, the ecological sensitivity of proposed sites, and the sedimentogical characteristics. Sites located near sensitive habitat, near pollutant sources or having poor sediment quality can be eliminated. Identify critical times of the year for wildlife and aquatic species and use this information to help define start-up and end dates for dredging operations.

Characterize the water and sediment quality at the proposed site using a combination of bulk sediment properties, elutriate tests and bioassays. These results will be used to help define design parameters for the disposal operations (such as required retention times, pumping rates), and mitigation requirements (need for impervious liners or sediment caps, need for intermittent pumping).

Include appropriate specifications in all contract documents to ensure dredging is carried out according to the implementation plan, including provision for breakdowns, equipment failure, unforseen actions (such as fuel spills, pipeline breakage).

Monitor pilot project operations to ensure the facilities are working according to plans and provide supervision so that the operations can be modified if necessary. Provide follow-up monitoring after the work is completed.

Feasibility Investigations:
The amount of channel excavation, type of works (including manual excavation and river training), location of channel works, beneficial uses of dredged spoil, size and location of spoil sites and mitigation requirements all need to be assessed during feasibility studies. Drawing on the findings from the pre-feasibility studies and the Pilot Project, a comprehensive, multi-disciplinary environmental management plan will need to be developed to address these issues.

Baseline land-use, ecological and sedimentological studies will be required to identify sensitive sites and critical times of the year for channel excavation and spoil disposal operations. A tiered investigation approach can be used to screen out critical sites and potential problem areas that will require more detailed field and laboratory studies. Depending on local site conditions, elutriate tests and bioassays will be conducted to assess expected impacts at these sites.

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Table C1: Environmental Screening Matrix

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Planning & Design	Normal	Surveys - topographic, benchmark, hydrologic, socio-economic, land use, natural resource										
		Land acquisition for spoil disposal sites	±						+			
		People's participation activities		+	+	+			+			
Short Term Development Dredging and Channel Improvements	Normal	Site preparation for spoil disposal: vegetation removal, relocation, restlement, temporary structure installation (godowns, waste disposal sites, drainage, sanitary facilities)	−	−					+			
		Channel dredging, spoil transport, spoil disposal			±	−			+	±		
	Abnormal	Spoil discharged outside of disposal area due to incorrect operations or breakdown	−	−	−	−					−	
		River-bed aggradation due to major floods	−	−	−				−			
		Damage to spoil sites due to floods/erosion	−	−					−			
Post-Project & Maintenance Dredging	Normal	Reduced pre-monsoon flood levels	+	+	±		+		+		+	
		Modified post-monsoon drainage	+	+	±							
		Reduced overbank siltation/spills	+	+	+						+	
		Village development	+					+	+			
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)	−	−	−	−	−	−	−		−	
		River Bank overtopping	−	−								
		Extreme deposition after major floods	−	−	−		−	−	−	−	−	

Table C2: Worldwide Method of Disposal (volume in Million of Cubic Yards)

Region	Number of Rsponses	Upland	Near Wetlands	Shore	Ocean	Other	Total
Northern Europe (21%)	26	39.196	59.502	42.936	62.044	29.412	233.09
Mediterranean (3%)	3	0	13.774	15.001	0.664	0	29.439
Africa (24%)	2	0	152.942	76.471	25.549	0	254.962
Southern Asia (27%)	12	62.484	11.197	121.831	89.149	0	284.661
Southeast Asia (2%)	8	0	3.078	3.698	15.190	0	21.966
East Asia (13%)	16	5.83	32.220	102.451	4.323	0	144.824
South Pacific (5%)	18	3.972	2.687	26.335	32.585	0	65.574
North America (4%)	18	6.012	9.696	8.459	16.549	0.159	40.716
Caribbean	5	0.820	0.646	0	2.484	0	3.95
Total (100%)	108	118.267	285.742	397.18	248.522	29.571	1079.182

**Includes estuaries, marsh, shallow water etc.*
Source Ad Hoc Dredging Commission, 1981

Table C.3: BIWTA Dredgers

Procurement Date	Number	Pipe Size (mm)	Daily Production (m^3/day)	Average Production (m^3/month)
1975	5	450	874-2700	54,000
1973	2	450	823-2240	46,000
1970	1	400	820-2070	36,000

2Cd

Table C4: Sediment Contaminants and Sediment Quality Criteria (mg/kg)

Contaminant	A	B	C
1. Heavy Metal			
arsenic	5	30	50
barium	200	500	2000
cadmium	1	5	20
chromium	20	250	800
cobalt	15	50	300
copper	30	100	500
lead	50	500	1000
mercury	0.1	2	10
molybdenum	4	10	40
nickel	20	100	500
selenium	2	3	10
silver	2	20	40
tin	5	50	300
zinc	80	500	1500
2. OTHER INORGANICS			
bromide	20	50	300
cyanide	5	50	500
fluoride	200	400	2000
sulphur	500	1000	2000
3. GROSS PARAMETERS			
oil & grease	100	1000	5000
LAH	100	150	1000

Note: *A =* *Detection Limit*
B = *Remediation level for residential and agricultural land*
C = *Land use restricted for levels exceeding this amount* (see section 5.2.1, Annex C)

Table C4: Sediment Contaminants and Sediment Quality Criteria (mg/kg)
(Cont"d)

Contaminant	A	B	C
3. Monocyclic Aromatic Hydrocarbons			
benzene	0.1	0.5	5
ethylbenzene	0.1	5	50
toluene	0.1	3	30
chlorobenzene	0.1	1	10
1,2 dichlorobenzene	0.1	1	10
1,3 dichlorobenzene	0.1	1	10
1,4 dichlorobenzene	0.1	1	10
xylene	0.1	5	50
styrene	0.1	5	50
PHENOLICS			
non-chlorinated phenols	0.1	1	10
5. POLYCYCLIC AROMATIC HYDROCARBONS			
benzo[a]anthracene	0.1	1	10
1,2 benzanthracene	0.1	1	10
dibenzo[a,h]anthracene	0.1	1	10
chrysene	0.1	1	10
3-methylcholanthrene	0.1	1	10
benzo[b]fluoranthene	0.1	1	10
pyrene	0.1	10	100
acenaphlhene	0.1	10	100
fluoranthene	0.1	10	100
fluorene	0.1	10	100
naphthalene	0.1	5	50
phenanthrene	0.1	5	50
TOTAL PAH	0.1	20	200

Table C4: Sediment Contaminants and Sediment Quality Criteria (mg/kg)

(Cont"d)

Contaminant	A	B	C
6. CHLORINATED HYDROCARBONS			
aliphatic	0.3	7	70
chlorobenzene	0.1	4	20
hexachlorobenzene	0.1	2	10
pcb	0.1	5	50
7. PESTICIDES			
Organochlorinated			
aldrin			
dieldrin			
chlordane			
DDT			
endrin			
heptachlor epoxide			
lindane			
methoxychlor			
Carbamates			
Organophosphates			
Bipyridyl compounds			
Trichloroaetates			

From: "Criteria for Managing Contaminated Sites in British Columbia", Ministry of Environment, Victoria, BC, Canada.

Table C5: Range of Contaminant Concentrations in Sediments

Compound	Jamuna R.	Fraser R.	St. Clair R.	Rhine R.
Arsenic	<10	.	3.4	22
Cadmium	<0.8	nd	1.4	14
Lead	15	nd-39	26.7	217
Mercury	<0.02	nd-0.15	0.568	2.4
Zinc	23-36	46-80	46.2	814
Copper	3-5	11-100	9.2	126
PCB	nd	nd	0.01	0.31
Dieldrin	nd	nd		0.01

Table C6: Extent of turbidity plumes at various depths for two kinds of dredgers

Depth %	Cutterhead	Clamshell
5	0	1.7
50	0	1.8
80	0	---
95	1.2	3.5

ddn

Table C7: Environmental Quality Parameters to be measured during Construction

Env. Comp. Effluents/Emission	Parameters	No.of Sample/ Location	Sampling Frequ. No./Yr.	Remarks
Air - emissions - immissions	Part. CO. NO_x, SO_2, Lead Part. CO. NO_x, SO_2, Lead	4 4	2 2	No. of samples is source dependent. Baseline value to be set before construction.
Noise: - emissions - immissions	Noise level in dB (A) Noise Level in dB (A)	4 10	4 4	
Surface Water: (River and Inland Waterbodies)	TDS,SS, TVS, COD, BOD Nutrients, pH, Toxics Oils	4	2	Baseline value to be established at the beginning of construction
Drinking Water:	pH, TDS, Fe, Mn, Cl, SO_4, TC, FC, Turbidity, Color	2	4	Parameters listed in Table 2.1 Annex 2 are to be measured once.
Effluent Waste Water	pH, TDS, SS, BOD, COD, NO_3, PO_4, TC, FC	2	4	Parameters listed in Table 2.1 Annex 2 are to be measured once.
Effluent from Dredge Spoil:	SS, COD, BOD, Heavy Metals, Pesticide Residue	1	4	As and when dredging is in operation.
Dredge Spoil:	Heavy Metals, Pesticide, Residues, NO_3, PO_4	2	2	Materials to be dredged / Dredge spoils after deposition. Monitoring will not be required after 1 year, if pollutants are not found.
Solid Wastes:	Ground water quality at dump site	3	1	Procedures and practice of solid waste disposal to be reviewed.
Soil	Heavy Metals, Oil and Grease	2-start 8-end	1	Once before and once after the construction of the bridge.
Health & Safety:				Continuous

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Table C8: Allowable Turbidity Levels at Various Corps of Engineer Districts

District	Turbidity Standard
Galveston	8 g/l
Norfolk	13 g/l
Philadelphia	8 g/l
New York	8 g/l
Detroit	8 g/l
Jacksonville	50 JTU
Wilmington	50 JTU
Portland	5 JTU
Seattle	5-10 JTU

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY, DHAKA
DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL ENGINEERING LABORATORY

ANALYSIS OF WATER, SUPERNATANT AND SEDIMENT

BRTC NO. : 659/94-95/CE DATE : 7-9-94
SENT BY : Harry King
Team Leader, Northeast Regional Project
House 3A, Road 22, Gulshan, Dhaka
YOUR REF. NO.: 406 DATE : 6-9-94
DATE OF TEST : 15th September - 3rd October, 1994

COMMENTS ON TEST RESULTS

Analysis of Water, Supernatant and Bulk Sediment:

The quality of river water in all sections is relatively good and characterized by high turbidity and higher concentration of suspended solids. The high turbidity and the presence of high suspended solids are very common during this period of the year due to high sediment loads in almost all the rivers in Bangladesh. The low BOD and COD values indicate that the sediments are inorganic in nature. The concentrations of oxygen consuming organics, nutrients, heavy metals and toxic elements are all within the permissible limits for natural surface waters in Bangladesh. Comparing the test results of the river water, supernatant from Elutriate tests and sediments it can be concluded that the dredging operation will not release additional nutrients or toxic elements in river water which may have adverse environmental impacts in the downstream region.

It may be observed that the quality of the supernatant water of sediment collected from Section - III is comparable with that of the river water. It may be concluded that the effluent from the dredged hydraulic fill, after sedimentation in detention basin, may be discharged in river without affecting the quality of the river water. Since the sediment samples collected from Sections V and VI contain clay particles the supernatant obtained from Elutriate test of sediment samples from those sections contain high concentrations of suspended particles. It is likely that the effluents from the dredged fills in these sections will be highly turbid and containing high suspended solids unless special measures are taken to control the releases.

Analysis of Particle Size of Bed Materials:

Particle size distribution of three samples of bed materials collected from the sections of the Kalni-Kushiyara river is presented. The sample collected from Section III consists of uniform graded fine Sand with some Silt. The effective size (d_{10}) of the bed materials of this section is 0.08 mm. The samples collected from Sections V and VI are Clayey Silt having effective sizes 0.026 and 0.028 mm, respectively. The dredged materials deposited in Section III by hydraulic fill is likely to settle quickly creating firm lands while materials in Sections V and VI will have delayed settling and the reclaimed lands will take longer time for consolidation. Since, the dredging activities are planned to be conducted during dry seasons, sediment samples should be collected, during the dry season and from a greater depth and subsequently tested to determine the variation of particle size distribution with depth.

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DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL ENGINEERING LABORATORY

ANALYSIS OF WATER, SUPERNATANT AND SEDIMENT

BRTC NO. : 659/94-95/CE DATE : 7-9-94
SENT BY : Harry King
Team Leader, Northeast Regional Project
House 3A, Road 22, Gulshan, Dhaka
YOUR REF. NO.: 406 DATE : 6-9-94
DATE OF TEST : 15th September - 3rd October, 1994
SAMPLE: **RIVER WATER** LOCATION: **Kalni-Kushiyara River, Section - III**

TEST RESULTS OF WATER SAMPLE

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Temperature	°F	87
2	pH	---	7.00
3	Turbidity	NTU	176.0
4	Total Suspended Solids	mg/l	1283.0
5	Total Dissolved Solids	mg/L	148.0
6	Total Acidity as $CaCO_3$	mg/L	16.0
7	Total Alkalinity as $CaCO_3$	mg/L	37.0
8	Dissolve Oxygen, DO	mg/L	5.7
9	BOD_5	mg/L	0.4
10	COD	mg/L	1.15
11	Nitrate-Nitrogen, NO_3-N	mg/L	4.5
12	PO_4	mg/L	Trace
13	Cadmium, Cd	ppm	0.001
14	Chromium, Cr	ppm	0.041
15	Lead, Pb	ppm	0.072
16	Copper, Cu	ppm	0.051
17	Nickel, Ni	ppm	0.007

SAMPLE: **SUPERNATANT WATER** LOCATION: **Kalni-Kushiyara River, Section - III**

TEST RESULTS OF SUPERNATANT WATER (***ELUTRIATE TEST***)

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Suspended Solids	mg/l	1732.0
2	Total Dissolved Solids	mg/L	148.0
3	BOD_5	mg/L	1.5
4	COD	mg/L	1.8
5	Nitrate-Nitrogen, NO_3-N	mg/L	4.0
6	PO_4	mg/L	Trace
7	Cadmium, Cd	ppm	0.0
8	Chromium, Cr	ppm	0.023
9	Lead, Pb	ppm	0.025
10	Copper, Cu	ppm	0.065
11	Nickel, Ni	ppm	0.038

SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - III**

TEST RESULTS OF BULK SEDIMENT

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Nitrogen, TN	mg/l	1.2
2	PO_4	mg/l	Trace
3	Coal & Lignite	%	0.0264
4	Total Organic Carbon, TOC	ppm	691.0
5	Copper, Cu	ppm	0.101

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DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL ENGINEERING LABORATORY

BRTC NO. : 659/94-95/CE DATE : 7-9-94
SENT BY : Harry King
Team Leader, Northeast Regional Project
House 3A, Road 22, Gulshan, Dhaka
YOUR REF. NO.: 406 DATE : 6-9-94
DATE OF TEST : 15th September - 3rd October, 1994
SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - III**

PARTICLE SIZE DISTRIBUTION

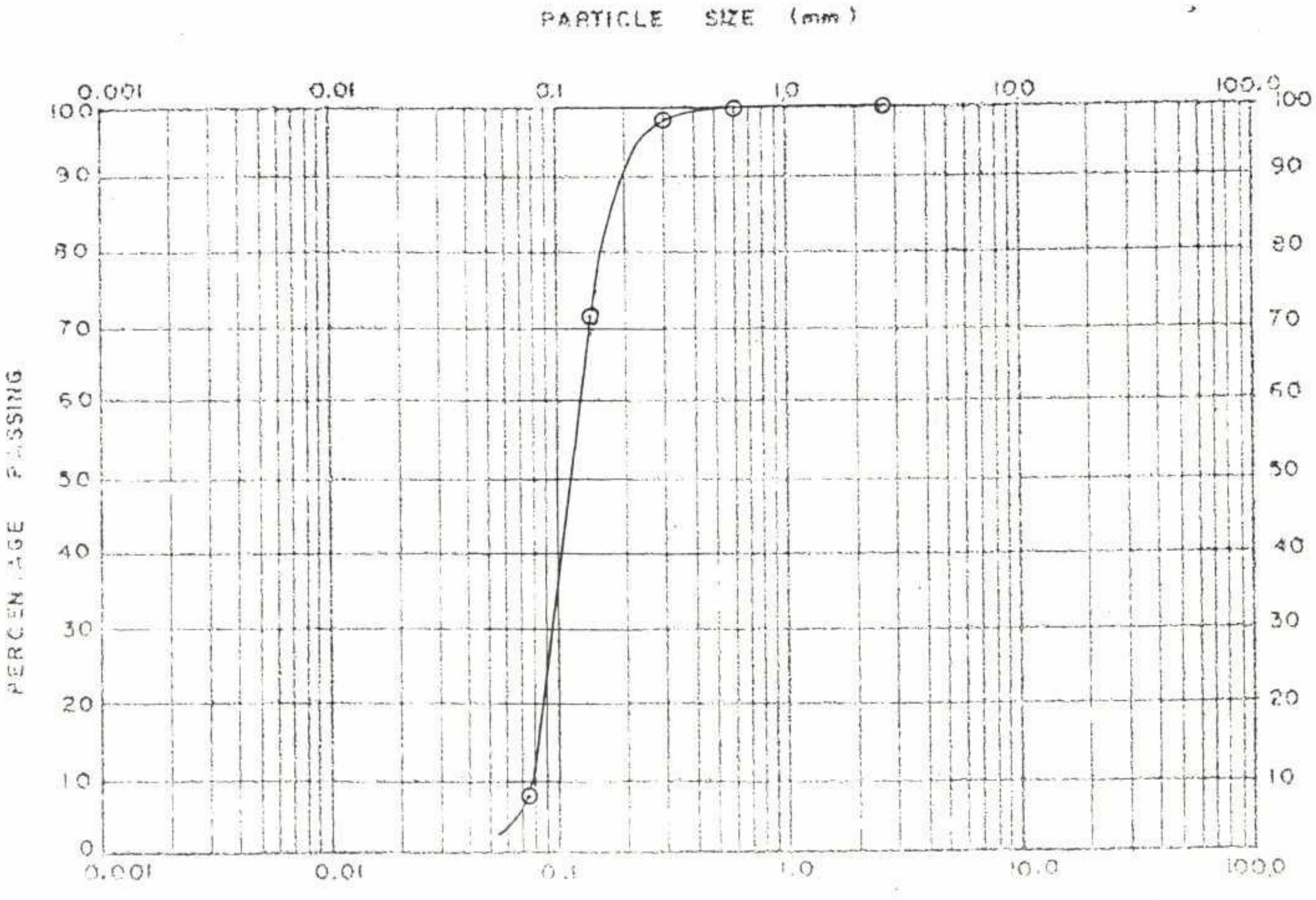

Table C12

BRTC NO. : 659/94-95/CE DATE : 7-9-94

DATE OF TEST : 15th September - 3rd October, 1994

SAMPLE: **RIVER WATER** LOCATION: **Kalni-Kushiyara River, Section - V**

TEST RESULTS OF WATER SAMPLE

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Temperature	°F	88
2	pH	---	7.00
3	Turbidity	NTU	162.0
4	Total Suspended Solids	mg/l	1154.0
5	Total Dissolved Solids	mg/L	148.0
6	Total Acidity as $CaCO_3$	mg/L	14.0
7	Total Alkalinity as $CaCO_3$	mg/L	35.0
8	Dissolve Oxygen, DO	mg/L	5.7
9	BOD_5	mg/L	0.5
10	COD	mg/L	1.10
11	Nitrate-Nitrogen, NO_3-N	mg/L	4.5
12	PO_4	mg/L	Trace
13	Cadmium, Cd	ppm	0.006
14	Chromium, Cr	ppm	0.042
15	Lead, Pb	ppm	0.026
16	Copper, Cu	ppm	0.045
17	Nickel, Ni	ppm	0.037

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Table C13

SAMPLE: **SUPERNATANT WATER** LOCATION: **Kalni-Kushiyara River, Section - V**

TEST RESULTS OF SUPERNATANT WATER (*ELUTRIATE TEST*)

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Suspended Solids	mg/l	6104.0
2	Total Dissolved Solids	mg/L	148.0
3	BOD_5	mg/L	1.8
4	COD	mg/L	1.9
5	Nitrate-Nitrogen, NO_3-N	mg/L	4.0
6	PO_4	mg/L	Trace
7	Cadmium, Cd	ppm	0.0
8	Chromium, Cr	ppm	0.013
9	Lead, Pb	ppm	0.015
10	Copper, Cu	ppm	0.086
11	Nickel, Ni	ppm	0.023

SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - V**

TEST RESULTS OF BULK SEDIMENT

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Nitrogen, TN	mg/l	1.2
2	PO_4	mg/l	Trace
3	Coal & Lignite	%	0.0258
4	Total Organic Carbon, TOC	ppm	954.0
5	Copper, Cu	ppm	0.099

Table C14

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DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL ENGINEERING LABORATORY

BRTC NO. : 659/94-95/CE DATE : 7-9-94
SENT BY : Harry King
Team Leader, Northeast Regional Project
House 3A, Road 22, Gulshan, Dhaka
YOUR REF. NO.: 406 DATE : 6-9-94
DATE OF TEST : 15th September - 3rd October, 1994
SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - V**

PARTICLE SIZE DISTRIBUTION

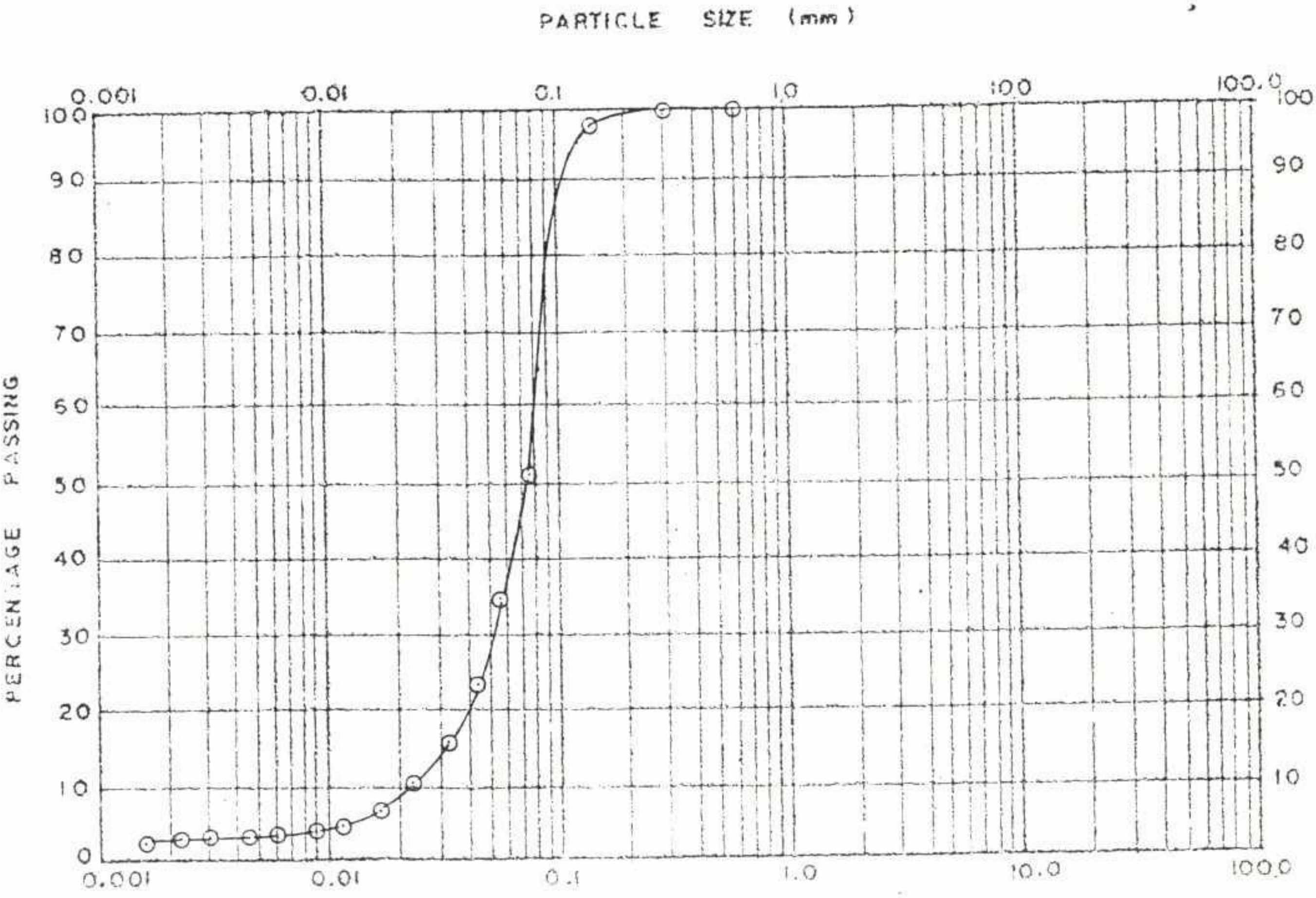

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Table C15

BRTC NO. : 659/94-95/CE DATE : 7-9-94

DATE OF TEST : 15th September - 3rd October, 1994

SAMPLE: **RIVER WATER** LOCATION: **Kalni-Kushiyara River, Section - VI**

TEST RESULTS OF WATER SAMPLE

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Temperature	°F	88
2	pH	---	7.0
3	Turbidity	NTU	170.0
4	Total Suspended Solids	mg/l	1301.0
5	Total Dissolved Solids	mg/L	148.0
6	Total Acidity as $CaCO_3$	mg/L	16.0
7	Total Alkalinity as $CaCO_3$	mg/L	35.0
8	Dissolve Oxygen, DO	mg/L	5.7
9	BOD_5	mg/L	0.5
10	COD	mg/L	1.1
11	Nitrate-Nitrogen, NO_3-N	mg/L	4.0
12	PO_4	mg/L	Trace
13	Cadmium, Cd	ppm	0.003
14	Chromium, Cr	ppm	0.016
15	Lead, Pb	ppm	0.038
16	Copper, Cu	ppm	0.553
17	Nickel, Ni	ppm	0.029

Table C16

SAMPLE: **SUPERNATANT WATER** LOCATION: **Kalni-Kushiyara River, Section - VI**

TEST RESULTS OF SUPERNATANT WATER (*ELUTRIATE TEST*)

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Suspended Solids	mg/l	15778.0
2	Total Dissolved Solids	mg/L	146.0
3	BOD_5	mg/L	2.0
4	COD	mg/L	2.2
5	Nitrate-Nitrogen, NO_3-N	mg/L	4.0
6	PO_4	mg/L	Trace
7	Cadmium, Cd	ppm	0.006
8	Chromium, Cr	ppm	0.035
9	Lead, Pb	ppm	0.042
10	Copper, Cu	ppm	0.100
11	Nickel, Ni	ppm	0.006

SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - VI**

TEST RESULTS OF BULK SEDIMENT

Sl. No.	Water Quality Parameters	Unit	Actual Concentration Present
1	Total Nitrogen, TN	mg/l	1.3
2	PO_4	mg/l	Trace
3	Coal & Lignite	%	0.0171
4	Total Organic Carbon, TOC	ppm	2444.0
5	Copper, Cu	ppm	0.119

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Table C17

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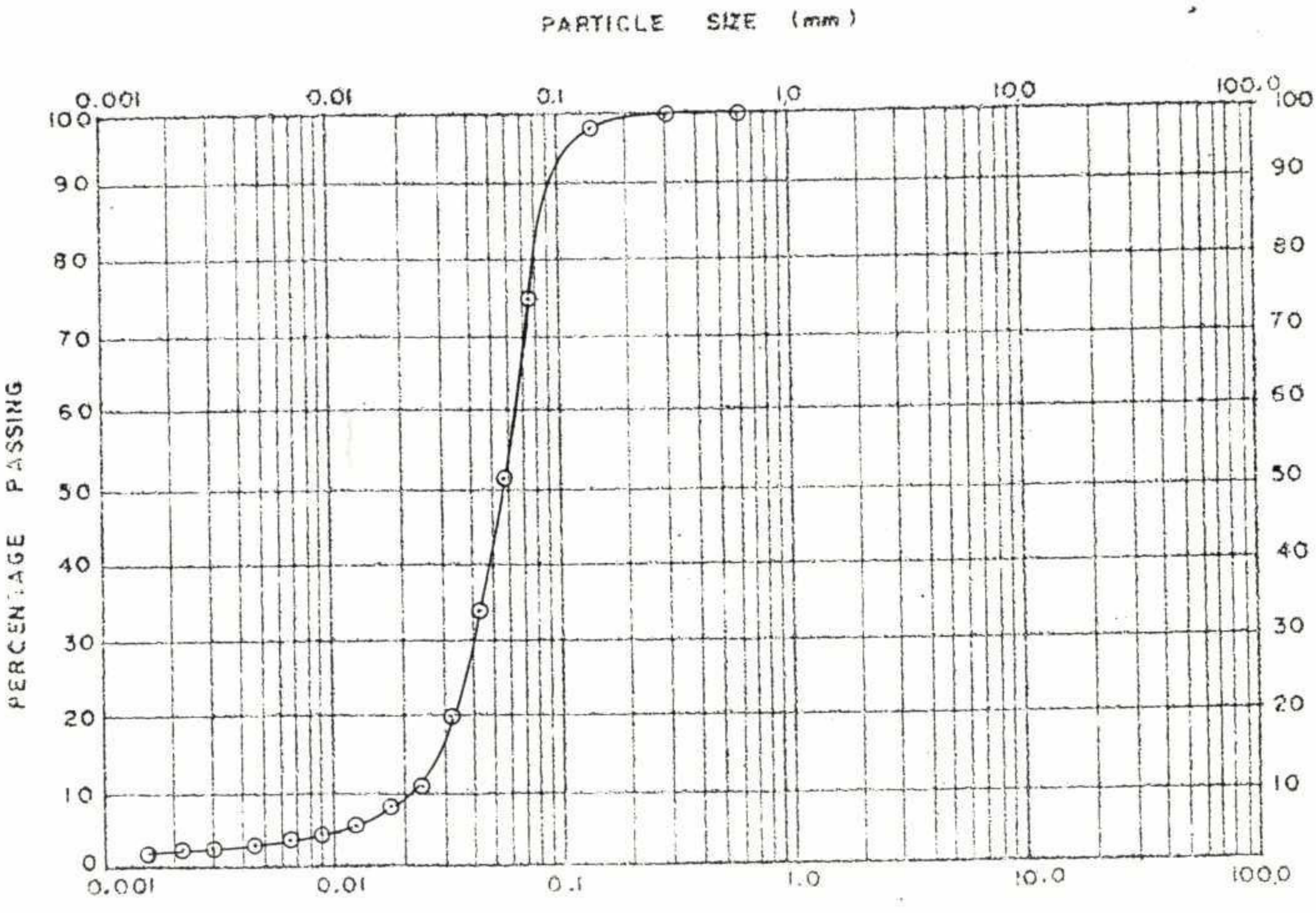
DEPARTMENT OF CIVIL ENGINEERING
ENVIRONMENTAL ENGINEERING LABORATORY

BRTC NO. : 659/94-95/CE DATE : 7-9-94
SENT BY : Harry King
Team Leader, Northeast Regional Project
House 3A, Road 22, Gulshan, Dhaka
YOUR REF. NO.: 406 DATE : 6-9-94
DATE OF TEST : 15th September - 3rd October, 1994
SAMPLE: **BULK SEDIMENT** LOCATION: **Kalni-Kushiyara River, Section - VI**

PARTICLE SIZE DISTRIBUTION



Countersigned By:

Test Performed By: 09/10/94
DR. A.B.M. BADRUZZAMAN
Assistant Professor
Dept. of Civil Engineering
BUET, Dhaka, Bangladesh.

NO. BRTC 659/94-95/CE Dt.: 07/09/94

ANNEX D

FISHERIES MODEL

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ANNEX D : FISHERIES MODEL

This annex briefly describes the model used to analyze fisheries impacts for the project.

The openwater fishery ecosystem is extremely complex. Impacts on production are assessed here using a highly simplified model. The limitations of the model mirror the limitations of the current understanding of and information about the system.

The major system processes about which some insight exists are:

- Migration access and timing. It seems to be accepted that:
  - a multiplicity of access points is desirable (i.e. that closing any or some channels is still deleterious,
  - the most important channels are those at the downstream end of the system (that with flood onset, fish mainly migrate upstream and onto the floodplain, and downstream out of the beels into the river), and
  - delay of flooding, as in partial flood control schemes, is highly disruptive

- Overwintering (dry season) habitat extent.

- Wet season habitat (floodplain grazing extent and duration). [It is expected that production also varies as a function of land type (F1, F2, F3) — probably such that shallower (F1, F2) land is more productive than deeper (F3) land — but as data to show this has been lacking it has been neglected from the model.]

- Habitat Quality. Habitat quality would include water quality, vegetation, and other conditions (presence of preferred types of substrate e.g. rocks, sand, brush). Water quality would appear to be most relevant during low volume/flow periods, and during the time of flood onset and recession when contaminants can disperse or accumulate.

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

The foregoing is represented quantitatively here as:

FWO production =

$$(R_0 * P_{R0}) + (B_0 * P_{B0}) + (W_0 * P_{W0})$$

FW production =

$$[M * Q * (R_1 * P_{R0})] + [M * Q * (B_1 * P_{B0})] + [M * (W_1 * P_{W0})]$$

Thus,

Impact = FW - FWO production =

$$\{ [(M * Q * R_1) - R_0] * P_{R0} \} +$$

$$\{ [(M * Q * B_1) - B_0] * P_{B0} \} +$$

$$\{ [(M * W_1) - W_0] * P_{W0} \}$$

where

sub-0 and sub-1 refer to FWO and FW respectively
R, B, and W are river/channel, beel, and floodplain (F1+F2+F3) areas, in ha
P is the unit FWO production in kg/ha for the respective habitats. Estimated regional average values are 175, 410, and 44 respectively.
M is the FW quality-weighted migration access remaining, relative to FWO conditions (range 0 to 1 for negative impacts, >1 for positive impacts)
Q is the FW acceptability of habitat/water quality relative to FWO conditions (range 0 to 1 for negative impacts; >1 for positive impacts).
A_M is the area of mother fishery and key beels affected times a factor (range 0 to 1 for negative impacts, >1 for positive impacts) reflecting the degree of degradation/enhancement
T is the estimated annual regional fish production attributable to spawning exported from mother fisheries/key beels (a constant of 50,000 tonnes, which is 50% of the total regional fish production of 100,000 tonnes)
A_T is the estimated regional mother fishery/key beel area (a constant of 100,000 ha).

Estimated values for this project are shown in Tables D.1. Where standard values, established for the region or for a particular project type, are used, this is noted. Comments on project-specific values are also shown.

It is estimated that one person-day is required to capture half kilogram of fish on the flood plain, eight kilograms in the beel, three kilograms in river/channel and nine kilograms in pond.

Table D.1: Fisheries Parameters

Kalni-Kushiyara River Improvement Project

Var	Value	Stnd value?	Comments
M	1.0	1.0	Fish migration routes will be improved with dredging and access to the adjacent haors will be maintained.
Q	1.0	1.0	Water quality is expected to improve since water will not stagnate in the system.
R_0	13329		-
R_1	13652		About 25 km channel will be re-excavated including channel widening and loop cuts in the reach between Markuli to Madna.
B_0	18479		-
B_1	18479		-
W_0	312100		-
W_1	312100		-
P_{R0}	175	175	-
P_{B0}	410	410	-
P_{W0}	44	44	-
A_M	-	100000	There is a "mother fishery" in the project benefitted area about 50 km upstream of the proposed dredging site.

ANNEX E
ECONOMIC ANALYSIS

ANNEX E: ECONOMIC ANALYSIS

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ANNEX E: ECONOMIC ANALYSIS

NOTES ON THE ECONOMIC MODEL

Agriculture:

1) Labour costs include farmer-owner and hired labour, both with a market price of Tk.50/day and an economic price of Tk. 37.5/day as per FPCO guidelines.

2) The normal (non-damaged) and damaged crop yields for both the FWO and FW conditions are taken as the same. The same unit non-labour inputs (Kg/ha) have been used for both FWO and FW project conditions. Weighted average of normal and damaged yield rate has been used for the present condition.

3) The same crop market prices are used for the present, FWO, and FW conditions.

4) LLP/Shallow tube well costs have been included for HYV boro. Traditional irrigation methods have been assumed for local boro, wheat, potato, spice and vegetables and lower unit costs have been used.

5) the average yield used for vegetables is based on NERP field observations. There are many high yielding vegetable varieties in the Northeast Region.

Land Acquisition, Resettlement and EMP:

1) Land acquisition costs have not been included in the base construction cost, and are excluded from the physical contingencies and engineering costs. The costs are included in the financial analysis.

2) The study cost component of the Environmental Management Plan (EMP) is included in the overall study costs which are taken as 15% of base cost plus contingencies. The structural measures of EMP, relocation and compensation are included in the capital costs.

Agricultural Extension

1) No additional expenditure has been considered for agricultural extension work for the FW condition. The Department of Agricultural Extension (DAE) is responsible for carrying out agricultural activities nation-wide. As part of a policy decision of the Government of Bangladesh, through a reorganized program of the DAE, an adequate number of staff have been placed at the Union and village levels for extension work through training. Under the national extension network, DAE personnel will be responsible for agricultural extension irrespective of whether a project is implemented or not.

Line Ministries:

1) It is considered that work related to livestock, fishery, health, education, and so on will be taken care of by the respective line ministries in a similar manner to that described

above for the DAE. No additional expenditure has been considered for the FW condition for these line ministries.

O & M:

1) The cost of Environmental Management Plan (EMP) during operation is icluded as study costs which are taken as 15% of base O & M cost plus contingencies (25%). From first year of O & M activities, 100% O&M costs have been included for each year.

Two additional sensitivity analyses have also been conducted with the cost of "periodic unscheduled channel maintenance due to occurrences of extreme floods or unusual events". Preliminary estimate shows that about 7 million m^3 could be deposited by the extreme floods. Therefore, with an additional cost of 7 million m^3 including 25% contingencies plus 15 % study cost, the analyses have been carried out which include:

- cost of 7 million m^3 is superimposed on the 10 and 11 years of the annual maintenance costs; and
- cost of 7 million m^3 is evenly distributed over the annual maintenance costs starting from the first year.

In both the cases, this additional cost has reduced the EIRR only by an average rate of 1.5% (refer Table 20 and 21).

Farm Budget:

1) A financial analysis has been carried out for farm budget. This being a pre-feasibility level study, the farm budget has been prepared using secondary data sources: data on levels of input use were taken from MPO publications, financial prices were taken from the GPA of FPCO, and consumption figures were obtained from BBS publications. Cropping patterns and crop damage data were collected through RRA studies and were adjusted for a 1.5 hectare farm based on the judgement of the NERP agronomist. A summary of the farm budget is presented in Table 5. The gross financial incomes from crops for the present, FWO, and FW conditions are presented in Tables 6 to 8 and show the assumed shifts in cropping for the different conditions.

Benefit Stream:

1) It is assumed that full crop development will be achieved five years after the completion of physical works (20% increase per year).

2) Fishery and wetland benefits are assumed to be 50% in the last year of construction activity. For each year after completion of physical work, 100% fishery benefits have been included. However, these benefits are not significant and have a very little impact on the overall EIRR.

3) Benefits resulting from dredging for the existing flood control infrastructures are assumed to be 50% in the last year of construction activities. After completion of physical work, 100% benefits are included for each year.

EIRR:

1) The Economic Internal Rate of Return (EIRR) considers a 30 year discounting period from the start of the project construction.

Kalni – Kushiyara River Improvement Project
Table 1: Market & Economic Prices of Agricultural Outputs (Tk/ton)

Crop	Main Product			By–Product			By Product Factor
	Market	Conversion Factor	Economic	Market	Conversion Factor	Economic	
L Aus	6074	0.88	5345	950	0.87	827	2.0
HYV Aus	6074	0.88	5345	700	0.87	622	1.0
B Aman	6438	0.88	5665	950	0.87	827	1.0
LT Aman	6438	0.88	5665	950	0.87	827	2.0
HYV Aman	6438	0.88	5665	700	0.87	622	1.0
L Boro	6212	0.88	5467	950	0.87	827	2.0
HYV Boro	6212	0.88	5467	700	0.87	622	1.0
Wheat	6312	1.29	8142	600	0.88	528	1.0
Potato	4580	0.87	3985				
Jute	8012	1.06	8493	2550	0.87	2219	2.0
Sugarcane	1012	0.95	961				
Pulses	14919	0.87	12980				
Oilseeds	13466	0.88	11850				
Spices	9047	0.87	7871				
Veg	4481	0.87	3898				
Tobacco	24783	0.87	21561				

Source: Guidelines for Project Assesment, Dhaka May 1992,FPCO, Ministry of Irrigation, Water Development and Flood Control.

Kalni – Kushiyara River Improvement Project
Table 2: Market & Economic Prices of Agricultural Production Inputs (Tk/kg)

Fertilizer	Price		
	Market	Conversion Factor	Economic
Urea	4.58	1.45	6.64
TSP	5.4	1.88	10.15
MP	4.05	2	8.10
Seeds			
L Aus	10.5	0.88	9.24
HYV Aus	10	0.88	8.80
B Aman	10	0.88	8.80
LT Aman	10	0.88	8.80
HYV Aman	9	0.88	7.92
L Boro	10	0.88	8.80
HYV Boro	10	0.88	8.80
Wheat	12	1.29	15.48
Potato	8.5	0.87	7.40
Jute	24	1.06	25.44
Sugarcane	1	0.95	0.95
Pulses	25	0.87	21.75
Oilseeds	19	0.88	16.72
Spices	600	0.87	522.00
Veg	400	0.87	348.00
Tobacco	40	0.87	34.80
Other			
Pesticide	504	0.87	438.48
Labour	50	0.75	37.50
Bullock	45	0.87	39.15
Mech. Irrig	2000	0.8	1600.00
Trad. Irrig	1000	0.8	800.00

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Kalni – Kushiyara River Improvement Project

Table 3: Financial Production Costs per Hectare

(Present)

Crop	Labour			Bullock			Seed			Pesticide			Urea			Fertilizer TSP			MP			IRRI	Total
	pd	uc	Tk	bd	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	(Tk)	(Tk)
L Aus	146	50.00	7300.0	44	45.00	1980.0	100	10.50	1050.0		504.00	0.0	25	4.58	114.5	2.00	5.40	10.8		4.05	0.0		10455.30
HYV Aus	190	50.00	9500.0	49	45.00	2205.0	25	10.00	250.0	0.5	504.00	252.0	158	4.58	723.6	65.00	5.40	351.0	4	4.05	16.2		13297.84
B Aman	107	50.00	5350.0	42	45.00	1890.0	100	10.00	1000.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		8240.00
LT Aman	130	50.00	6500.0	42	45.00	1890.0	30	10.00	300.0	0.25	504.00	126.0	24	4.58	109.9	8.00	5.40	43.2		4.05	0.0		8969.12
HYV Aman	165	50.00	8250.0	45	45.00	2025.0	30	9.00	270.0	0.5	504.00	252.0	79	4.58	361.8	30.00	5.40	162.0	3	4.05	12.2		11332.97
L Boro	156	50.00	7800.0	40	45.00	1800.0	30	10.00	300.0	0.12	504.00	60.5	27	4.58	123.7	7.00	5.40	37.8		4.05	0.0	1000	11121.94
HYV Boro	213	50.00	10650.0	52	45.00	2340.0	30	10.00	300.0	0.5	504.00	252.0	132	4.58	604.6	54.00	5.40	291.6	7	4.05	28.4	2000	16466.51
Wheat	117	50.00	5850.0	42	45.00	1890.0	140	12.00	1680.0	0.25	504.00	126.0	130	4.58	595.4	98.00	5.40	529.2	20	4.05	81.0	750	11501.60
Potato	222	50.00	11100.0	50	45.00	2250.0	1200	8.50	10200.0	0.5	504.00	252.0	76	4.58	348.1	56.00	5.40	302.4	38	4.05	153.9	750	25356.38
Jute	210	50.00	10500.0	48	45.00	2160.0	9	24.00	216.0	0.5	504.00	252.0	31	4.58	142.0	9.00	5.40	48.6	5	4.05	20.3		13338.83
Sugarcane	263	50.00	13150.0	66	45.00	2970.0	5000	1.00	5000.0	0.5	504.00	252.0	103	4.58	471.7	77.00	5.40	415.8	30	4.05	121.5		22381.04
Pulses	45	50.00	2250.0	30	45.00	1350.0	30	25.00	750.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		4350.00
Oilseeds	71	50.00	3550.0	36	45.00	1620.0	10	19.00	190.0	0.1	504.00	50.4	26	4.58	119.1	62.00	5.40	334.8	15	4.05	60.8		5925.03
Spices	132	50.00	6600.0	38	45.00	1710.0	0.1	600.00	60.0		504.00	0.0	22	4.58	100.8	18.00	5.40	97.2	10	4.05	40.5	750	9358.46
Veg	328	50.00	16400.0	53	45.00	2385.0	0.1	400.00	40.0	0.25	504.00	126.0	64	4.58	293.1	43.00	5.40	232.2	20	4.05	81.0	750	20307.32
Tobacco	222	50.00	11100.0	58	45.00	2610.0	0.1	40.00	4.0	0.5	504.00	252.0	26	4.58	119.1	17.00	5.40	91.8	17	4.05	68.9		14245.73

Table 4: Financial Production Costs per Hectare

(Future Without/With Project)

Crop	Labour			Bullock			Seed			Pesticide			Urea			Fertilizer TSP			MP			IRRI	Total
	pd	uc	Tk	bd	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	(Tk)	(Tk)
L Aus	146	50.00	7300.0	44	45.00	1980.0	100	10.50	1050.0		504.00	0.0	29	4.58	132.8	2	5.40	10.8		4.05	0.0		10473.62
HYV Aus	200	50.00	10000.0	52	45.00	2340.0	25	10.00	250.0	0.5	504.00	252.0	160	4.58	732.8		5.40	0.0	5	4.05	20.3		13595.05
B Aman	115	50.00	5750.0	45	45.00	2025.0	100	10.00	1000.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		8775.00
LT Aman	133	50.00	6650.0	42	45.00	1890.0	30	10.00	300.0	0.25	504.00	126.0	48	4.58	219.8	21	5.40	113.4		4.05	0.0		9299.24
HYV Aman	165	50.00	8250.0	45	45.00	2025.0	30	9.00	270.0	0.5	504.00	252.0	102	4.58	467.2	45	5.40	243.0	9	4.05	36.5		11543.61
L Boro	160	50.00	8000.0	41	45.00	1845.0	30	10.00	300.0	0.12	504.00	60.5	53	4.58	242.7	20	5.40	108.0		4.05	0.0	1000	11556.22
HYV Boro	227	50.00	11350.0	54	45.00	2430.0	30	10.00	300.0	0.5	504.00	252.0	187	4.58	856.5	96	5.40	518.4	28	4.05	113.4	2000	17820.26
Wheat	123	50.00	6150.0	43	45.00	1935.0	140	12.00	1680.0	0.25	504.00	126.0	158	4.58	723.6	120	5.40	648.0	37	4.05	149.9	750	12162.49
Potato	242	50.00	12100.0	52	45.00	2340.0	1500	8.50	12750.0	0.5	504.00	252.0	135	4.58	618.3	94	5.40	507.6	84	4.05	340.2	750	29658.10
Jute	220	50.00	11000.0	50	45.00	2250.0	9	24.00	216.0	0.5	504.00	252.0	40	4.58	183.2	14	5.40	75.6	8	4.05	32.4		14009.20
Sugarcane		50.00	0.0		45.00	0.0		1.00	0.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		0.00
Pulses	46	50.00	2300.0	30	45.00	1350.0	30	25.00	750.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		4400.00
Oilseeds	75	50.00	3750.0	36	45.00	1620.0	10	19.00	190.0	0.1	504.00	50.4	37	4.58	169.5	86	5.40	464.4	25	4.05	101.3		6345.51
Spices	141	50.00	7050.0	38	45.00	1710.0	0.1	600.00	60.0		504.00	0.0	58	4.58	265.6	46	5.40	248.4	38	4.05	153.9	750	10237.94
Veg	372	50.00	18600.0	54	45.00	2430.0	0.1	400.00	40.0	0.25	504.00	126.0	163	4.58	746.5	100	5.40	540.0	64	4.05	259.2	750	23491.74
Tobacco		50.00	0.0		45.00	0.0		40.00	0.0		504.00	0.0		4.58	0.0		5.40	0.0		4.05	0.0		0.00

Tobacco	50.00	0.0	45.00	0.0

Table 5: Economic Production Costs per Hectare
(Present)

Crop	Labour			Bullock			Seed			Pesticide			Fertilizer Urea			Fertilizer TSP			Fertilizer MP			IRRI	Total
	pd	uc	Tk	bd	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	(Tk)	(Tk)
L Aus	146	37.5	5475.0	44	39.2	1722.6	100	9.25	925.0		438	0.0	25	6.64	166.0	2.00	10.2	20.3		8.08	0.0		8308.90
HYV Aus	190	37.5	7125.0	49	39.2	1918.4	25	8.88	222.0	0.5	438	219.2	158	6.64	1049.1	65.00	10.2	659.8	4	8.08	32.3		11225.78
B Aman	107	37.5	4012.5	42	39.2	1644.3	100	8.88	888.0		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		6544.80
LT Aman	130	37.5	4875.0	42	39.2	1644.3	30	8.88	266.4	0.25	438	109.6	24	6.64	159.4	8.00	10.2	81.2		8.08	0.0		7135.88
HYV Ama	165	37.5	6187.5	45	39.2	1761.8	30	7.92	237.6	0.5	438	219.2	79	6.64	524.6	30.00	10.2	304.5	3	8.08	24.2		9259.39
L Boro	156	37.5	5850.0	40	39.2	1566.0	30	8.88	266.4	0.12	438	52.6	27	6.64	179.3	7.00	10.2	71.1		8.08	0.0	800	8785.35
HYV Boro	213	37.5	7987.5	52	39.2	2035.8	30	8.88	266.4	0.5	438	219.2	132	6.64	876.5	54.00	10.2	548.1	7	8.08	56.6	1600	13590.08
Wheat	117	37.5	4387.5	42	39.2	1644.3	140	15.5	2167.2	0.25	438	109.6	130	6.64	863.2	98.00	10.2	994.7	20	8.08	161.6	600	10928.12
Potato	222	37.5	8325.0	50	39.2	1957.5	1200	7.4	8880.0	0.5	438	219.2	76	6.64	504.6	56.00	10.2	568.4	38	8.08	307.0	600	21361.82
Jute	210	37.5	7875.0	48	39.2	1879.2	9	25.4	229.0	0.5	438	219.2	31	6.64	205.8	9.00	10.2	91.4	5	8.08	40.4		10539.99
Sugarcan	263	37.5	9862.5	66	39.2	2583.9	5000	0.95	4750.0	0.5	438	219.2	103	6.64	683.9	77.00	10.2	781.6	30	8.08	242.4		19123.51
Pulses	45	37.5	1687.5	30	39.2	1174.5	30	21.8	652.5		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		3514.50
Oilseeds	71	37.5	2662.5	36	39.2	1409.4	10	16.7	167.2	0.1	438	43.8	26	6.64	172.6	62.00	10.2	629.3	15	8.08	121.2		5206.09
Spices	132	37.5	4950.0	38	39.2	1487.7	0.1	522	52.2		438	0.0	22	6.64	146.1	18.00	10.2	182.7	10	8.08	80.8	600	7499.48
Veg	328	37.5	12300.0	53	39.2	2075.0	0.1	348	34.8	0.25	438	109.6	64	6.64	425.0	43.00	10.2	436.5	20	8.08	161.6	600	16142.38
Tobacco	222	37.5	8325.0	58	39.2	2270.7	0.1	34.8	3.5	0.5	438	219.2	26	6.64	172.6	17.00	10.2	172.6	17	8.08	137.4		11300.97

Table 6: Economic Production Costs per Hectare
(Future Without/With Project)

Crop	Labour			Bullock			Seed			Pesticide			Fertilizer Urea			Fertilizer TSP			Fertilizer MP			IRRI	Total
	pd	uc	Tk	bd	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	kg	uc	Tk	(Tk)	(Tk)
L Aus	146	37.5	5475.0	44	39.2	1722.6	100	9.25	925.0		438	0.0	29	6.64	192.6	2	10.2	20.3		8.08	0.0		8335.46
HYV Aus	200	37.5	7500.0	52	39.2	2035.8	25	8.88	222.0	0.5	438	219.2	160	6.64	1062.4		10.2	0.0	5	8.08	40.4		11079.84
B Aman	115	37.5	4312.5	45	39.2	1761.8	100	8.88	888.0		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		6962.25
LT Aman	133	37.5	4987.5	42	39.2	1644.3	30	8.88	266.4	0.25	438	109.6	48	6.64	318.7	21	10.2	213.2		8.08	0.0		7539.69
HYV Ama	165	37.5	6187.5	45	39.2	1761.8	30	7.92	237.6	0.5	438	219.2	102	6.64	677.3	45	10.2	456.8	9	8.08	72.7		9612.84
L Boro	160	37.5	6000.0	41	39.2	1605.2	30	8.88	266.4	0.12	438	52.6	53	6.64	351.9	20	10.2	203.0		8.08	0.0	800	9279.09
HYV Boro	227	37.5	8512.5	54	39.2	2114.1	30	8.88	266.4	0.5	438	219.2	187	6.64	1241.7	96	10.2	974.4	28	8.08	226.2	1600	15154.56
Wheat	123	37.5	4612.5	43	39.2	1683.5	140	15.5	2167.2	0.25	438	109.6	158	6.64	1049.1	120	10.2	1218.0	37	8.08	299.0	600	11738.85
Potato	242	37.5	9075.0	52	39.2	2035.8	1500	7.4	11100.0	0.5	438	219.2	135	6.64	896.4	94	10.2	954.1	84	8.08	678.7	600	25559.26
Jute	220	37.5	8250.0	50	39.2	1957.5	9	25.4	229.0	0.5	438	219.2	40	6.64	265.6	14	10.2	142.1	8	8.08	64.6		11128.04
Sugarcane		37.5	0.0		39.2	0.0		0.95	0.0		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		0.00
Pulses	46	37.5	1725.0	30	39.2	1174.5	30	21.8	652.5		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		3552.00
Oilseeds	75	37.5	2812.5	36	39.2	1409.4	10	16.7	167.2	0.1	438	43.8	37	6.64	245.7	86	10.2	872.9	25	8.08	202.0		5753.53
Spices	141	37.5	5287.5	38	39.2	1487.7	0.1	522	52.2		438	0.0	58	6.64	385.1	46	10.2	466.9	38	8.08	307.0	600	8586.46
Veg	372	37.5	13950.0	54	39.2	2114.1	0.1	348	34.8	0.25	438	109.6	163	6.64	1082.3	100	10.2	1015.0	64	8.08	517.1	600	19422.96
Tobacco		37.5	0.0		39.2	0.0		34.8	0.0		438	0.0		6.64	0.0		10.2	0.0		8.08	0.0		0.00

Note: Unit costs apply for each of the four proposed projects

Table 7: Summary of Medium Size Farm Budget
(Taka / Year)
Average farm size: - ha 1.5

INFLOW	Present	FWO	FW		
Gross Value of Production	**36583**	**35095**	**43561**		
OUTFLOW					
DIRECT CROP COSTS	5933	6245	6934		
INDIRECT COSTS	4729	5039	6314		
- Hired labour @ Tk 50/p-d	2661	2937	3820		
- Irrigation	1018	998	1268		
- Loan Interest \1	415	437	485		
- Miscellaneous \2	635	668	742		
TOTAL OUTFLOW	**10661**	**11285**	**13248**		
GROSS FARM INCOME	**25922**	**23810**	**30313**		
INCREMENTAL GROSS FARM INCOME				6503	
RETURN TO FAMILY LABOUR					
Family Labour (person-days)	262	259	278		
Net value of Production/person-day	99	92	109		
Net value of Incremental Production/person-day				17	
RETURN PER FAMILY MEMBER					
Average no. of Family members \3	5.53	5.53	5.53		
Net Value of Production/person	4688	4306	5482		
Net Value of Incremental Production /person				1176	
VALUE OF FOOD CONSUMPTION \4					
				Kg/capita/yr	Tk/Kg
Rice -	5679	5679	5679	163.78	6.27
Wheat -	749	749	749	21.46	6.31
Pulses -	635	635	635	7.70	14.92
Vegetables -	1187	1187	1187	47.92	4.48
Oilseeds -	894	894	894	12.00	13.47
Potato -	345	345	345	13.61	4.58
Spice	174	174	174	3.47	9.047
TOTAL FOOD CONSUMPTION \5	**9662**	**9662**	**9662**		
OTHER CONSUMPTION EXPENDITURE \6	**13668**	**11767**	**17619**		
NET INCOME	**2592**	**2381**	**3031**		
NET INCOME/FAMILY MEMBER	**469**	**431**	**548**		

Note:
1. Short term credit for 80% of cash costs for 6 months @ 17.5% per year.
2. At 10% of total cash costs including loan interest.
3. NERP Estimation.
4. Household Expenditure Survey 1988-89, BBS.
5. Assuming same amount of food consumption in Present, Future Without & Future With project period.
6. According to the Household expenditure survey, BBS, other expenditure includes beverage, clothing & footwear, housing & house rent, fuel & lighting, household effects, and miscellaneous items.

MEDIUM SIZE FARM BUDGET

Table 8: Gross Financial Income from Crops
(Present)

Crop	Area	Main Product				By-Product				Total (Tk 000)
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	
L Aus	0.05	1.3	0.06	6074	0.38	2.00	0.13	950	0.12	0.498
HYV Aus	0.00	0.0	0.00	6074	0.00	1.00	0.00	700	0.00	0.000
B Aman	0.45	1.7	0.74	6438	4.78	1.00	0.74	950	0.71	5.486
LT Aman	0.31	2.1	0.65	6438	4.21	2.00	1.31	950	1.24	5.456
HYV Aman	0.00	0.0	0.00	6438	0.00	1.00	0.00	700	0.00	0.000
L Boro	1.20	2.1	2.46	6212	15.28	2.00	4.92	950	4.67	19.956
HYV Boro	0.04	4.1	0.16	6212	1.02	1.00	0.16	700	0.11	1.134
Wheat	0.00	0.0	0.00	6312	0.00	1.00	0.00	600	0.00	0.000
Potato	0.02	12.0	0.24	4580	1.10	0.00	0.00		0.00	1.099
Jute	0.00	0.0	0.00	8012	0.00	2.00	0.00	2550	0.00	0.000
Sugarcane	0.00	0.0	0.00	1012	0.00	0.00	0.00		0.00	0.000
Pulses	0.04	0.9	0.03	14919	0.51	0.00	0.00		0.00	0.507
Oilseeds	0.14	0.8	0.11	13466	1.41	0.00	0.00		0.00	1.414
Spices	0.01	2.3	0.02	9047	0.20	0.00	0.00		0.00	0.204
Veg	0.02	9.3	0.19	4481	0.83	0.00	0.00		0.00	0.829
Tobacco	0.00	0.0	0.00	24783	0.00	0.00	0.00		0.00	0.000

Table 9: Gross Financial Income from Crops
(Future Without Project)

Crop	Area	Main Product				By-Product				Total (Tk 000)
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	
L Aus	0.04	1.3	0.05	6074	0.30	2.00	0.10	950	0.10	0.399
HYV Aus	0.00	0.0	0.00	6074	0.00	1.00	0.00	700	0.00	0.000
B Aman	0.45	1.6	0.73	6438	4.68	1.00	0.73	950	0.69	5.376
LT Aman	0.28	2.1	0.59	6438	3.80	2.00	1.18	950	1.12	4.919
HYV Aman	0.00	0.0	0.00	6438	0.00	1.00	0.00	700	0.00	0.000
L Boro	1.20	2.0	2.42	6212	15.04	2.00	4.84	950	4.60	19.634
HYV Boro	0.03	4.0	0.12	6212	0.74	1.00	0.12	700	0.08	0.819
Wheat	0.00	0.0	0.00	6312	0.00	1.00	0.00	600	0.00	0.000
Potato	0.02	12.0	0.24	4580	1.10	0.00	0.00		0.00	1.099
Jute	0.00	0.0	0.00	8012	0.00	2.00	0.00	2550	0.00	0.000
Sugarcane	0.00	0.0	0.00	1012	0.00	0.00	0.00		0.00	0.000
Pulses	0.04	0.9	0.03	14919	0.51	0.00	0.00		0.00	0.507
Oilseeds	0.13	0.8	0.10	13466	1.31	0.00	0.00		0.00	1.313
Spices	0.01	2.3	0.02	9047	0.20	0.00	0.00		0.00	0.204
Veg	0.02	9.3	0.19	4481	0.83	0.00	0.00		0.00	0.829
Tobacco	0.00	0.0	0.00	24783	0.00	0.00	0.00		0.00	0.000

Table 10: Gross Financial Income from Crops
(Future With Project)

Crop	Area	Main Product				By-Product				Total (Tk 000)
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	
L Aus	0.05	1.3	0.06	6074	0.38	2.00	0.13	950	0.12	0.498
HYV Aus	0.00	0.0	0.00	6074	0.00	1.00	0.00	700	0.00	0.000
B Aman	0.34	1.8	0.60	6438	3.83	1.00	0.60	950	0.57	4.396
LT Aman	0.31	2.1	0.65	6438	4.21	2.00	1.31	950	1.24	5.456
HYV Aman	0.00	0.0	0.00	6438	0.00	1.00	0.00	700	0.00	0.000
L Boro	1.20	2.3	2.70	6212	16.77	2.00	5.40	950	5.13	21.902
HYV Boro	0.15	4.6	0.68	6212	4.24	1.00	0.68	700	0.48	4.717
Wheat	0.00	0.0	0.00	6312	0.00	1.00	0.00	600	0.00	0.000
Potato	0.02	12.0	0.24	4580	1.10	0.00	0.00		0.00	1.099
Jute	0.00	0.0	0.00	8012	0.00	2.00	0.00	2550	0.00	0.000
Sugarcane	0.00	0.0	0.00	1012	0.00	0.00	0.00		0.00	0.000
Pulses	0.11	0.9	0.09	14919	1.39	0.00	0.00		0.00	1.395
Oilseeds	0.16	0.8	0.12	13466	1.62	0.00	0.00		0.00	1.616
Spices	0.02	2.3	0.05	9047	0.41	0.00	0.00		0.00	0.407
Veg	0.05	9.3	0.46	4481	2.07	0.00	0.00		0.00	2.072
Tobacco	0.00	0.0	0.00	24783	0.00	0.00	0.00		0.00	0.000

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Table 11: Gross Economic Income from Crops
(Present)

Crop	Area	Main Product				By–Product				Total
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	Total (Tk 000)
L Aus	83929	1.233	103511	5345	553280	2.00	207023	827	171104	724384
HYV Aus	23665	3.750	88744	5345	474346	1.00	88744	622	55199	529545
B Aman	103860	1.707	177255	5665	1004228	1.00	177255	827	146501	1150729
LT Aman	94796	2.114	200411	5665	1135419	2.00	400823	827	331280	1466699
HYV Aman	24609	3.926	96606	5665	547313	1.00	96606	622	60089	607402
L Boro	105840	1.982	209740	5467	1146556	2.00	419480	827	346700	1493257
HYV Boro	13700	3.959	54235	5467	296479	1.00	54235	622	33734	330213
Wheat	1956	2.050	4010	8143	32652	1.00	4010	528	2117	34769
Potato	5106	12.000	61272	3985	244144	0.00	0		0	244144
Jute	0		0	8492	0	2.00	0	2219	0	0
Sugarcane	0		0	961	0	0.00	0		0	0
Pulses	12695	0.850	10791	12980	140059	0.00	0		0	140059
Oilseeds	42318	0.750	31739	11850	376104	0.00	0		0	376104
Spices	4231	2.250	9520	7870	74920	0.00	0		0	74920
Veg	25391	9.250	234867	3897	915276	0.00	0		0	915276
Tobacco	0		0	21561	0	0.00	0		0	0

Table 12: Gross Economic Income from Crops
(Future Without Project)

Crop	Area	Main Product				By–Product				Total
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	Total (Tk 000)
L Aus	83929	1.233	103511	5345	553280	2.00	207023	827	171104	724384
HYV Aus	23665	3.750	88744	5345	474346	1.00	88744	622	55199	529545
B Aman	105798	1.707	180647	5665	1023442	1.00	180647	827	149304	1172746
LT Aman	88928	2.112	187795	5665	1063942	2.00	375590	827	310425	1374368
HYV Aman	30477	3.930	119784	5665	678630	1.00	119784	622	74506	753136
L Boro	98280	1.945	191130	5467	1044824	2.00	382260	827	315938	1360762
HYV Boro	15002	3.650	54759	5467	299344	1.00	54759	622	34060	333404
Wheat	1956	2.050	4010	8143	32652	1.00	4010	528	2117	34769
Potato	5106	12.000	61272	3985	244144	0.00	0		0	244144
Jute	0		0	8492	0	2.00	0	2219	0	0
Sugarcane	0		0	961	0	0.00	0		0	0
Pulses	12343	0.850	10492	12980	136175	0.00	0		0	136175
Oilseeds	41145	0.750	30859	11850	365679	0.00	0		0	365679
Spices	4114	2.250	9257	7870	72849	0.00	0		0	72849
Veg	24687	9.250	228355	3897	889898	0.00	0		0	889898
Tobacco	0		0	21561	0	0.00	0		0	0

Table 13: Gross Economic Income from Crops
(Future With Project)

Crop	Area	Main Product				By–Product				Total
		Yield T/ha	Production (Tonnes)	Unit Price (Tk/tonne)	Value (Tk 000)	Yield Factor	Production Ton	Unit Price (Tk/tonne)	Value (Tk 000)	Total (Tk 000)
L Aus	83929	1.201	100811	5345	538848	2.00	201623	827	166641	705489
HYV Aus	23665	3.750	88744	5345	474346	1.00	88744	622	55199	529545
B Aman	103860	1.705	177105	5665	1003378	1.00	177105	827	146377	1149755
LT Aman	88928	2.110	187595	5665	1062809	2.00	375190	827	310095	1372904
HYV Aman	30477	3.930	119784	5665	678630	1.00	119784	622	74506	753136
L Boro	102600	2.192	224850	5467	1229156	2.00	449700	827	371677	1600833
HYV Boro	16940	4.284	72577	5467	396747	1.00	72577	622	45143	441889
Wheat	1956	2.050	4010	8143	32652	1.00	4010	528	2117	34769
Potato	5106	12.000	61272	3985	244144	0.00	0		0	244144
Jute	0		0	8492	0	2.00	0	2219	0	0
Sugarcane	0		0	961	0	0.00	0		0	0
Pulses	32112	0.850	27295	12980	354279	0.00	0		0	354279
Oilseeds	44957	0.750	33718	11850	399558	0.00	0		0	399558
Spices	6423	2.250	14451	7870	113726	0.00	0		0	113726
Veg	25690	9.250	237633	3897	926054	0.00	0		0	926054
Tobacco	0		0	21561	0	0.00	0		0	0

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Table 14: Net Economic Benefit from Crops
(Present)

Crop	Area (ha)	Gross Income (Tk 000)	Production Cost (Tk/ha)	Production Cost (Tk 000)	Net Benefit (Tk 000)
L Aus	83929	724384	8308.90	697358	27026
HYV Aus	23665	529545	11225.78	265658	263887
B Aman	103860	1150729	6544.80	679743	470986
LT Aman	94796	1466699	7135.88	676453	790246
HYV Aman	24609	607402	9259.39	227864	379537
L Boro	105840	1493257	8785.35	929841	563415
HYV Boro	13700	330213	13590.08	186184	144029
Wheat	1956	34769	10928.12	21375	13394
Potato	5106	244144	21361.82	109073	135071
Jute	0	0	10539.99	0	0
Sugarcane	0	0	19123.51	0	0
Pulses	12695	140059	3514.50	44617	95442
Oilseeds	42318	376104	5206.09	220311	155793
Spices	4231	74920	7499.48	31730	43190
Veg	25391	915276	16142.38	409871	505405
Tobacco	0	0	11300.97	0	0
TOTAL					3587420

Table 15: Net Economic Benefit from Crops
(Future Without Project)

Crop	Area (ha)	Gross Income (Tk 000)	Production Cost (Tk/ha)	Production Cost (Tk 000)	Net Benefit (Tk 000)
L Aus	83929	724384	8335.46	699587	24797
HYV Aus	23665	529545	11079.84	262204	267340
B Aman	105798	1172746	6962.25	736592	436154
LT Aman	88928	1374368	7539.69	670490	703878
HYV Aman	30477	753136	9612.84	292971	460165
L Boro	98280	1360762	9279.09	911949	448813
HYV Boro	15002	333404	15154.56	227349	106055
Wheat	1956	34769	11738.85	22961	11808
Potato	5106	244144	25559.26	130506	113639
Jute	0	0	11128.04	0	0
Sugarcane	0	0	0.00	0	0
Pulses	12343	136175	3552.00	43842	92333
Oilseeds	41145	365679	5753.53	236729	128950
Spices	4114	72849	8586.46	35325	37524
Veg	24687	889898	19422.96	479495	410404
Tobacco	0	0	0.00	0	0
TOTAL					3241860

Table 16: Net Economic Benefit from Crops
(Future With Project)

Crop	Area (ha)	Gross Income (Tk 000)	Production Cost (Tk/ha)	Production Cost (Tk 000)	Net Benefit (Tk 000)
L Aus	83929	705489	8335.46	699587	5902
HYV Aus	23665	529545	11079.84	262204	267340
B Aman	103860	1149755	6962.25	723099	426656
LT Aman	88928	1372904	7539.69	670490	702415
HYV Aman	30477	753136	9612.84	292971	460165
L Boro	102600	1600833	9279.09	952034	648799
HYV Boro	16940	441889	15154.56	256718	185171
Wheat	1956	34769	11738.85	22961	11808
Potato	5106	244144	25559.26	130506	113639
Jute	0	0	11128.04	0	0
Sugarcane	0	0	0.00	0	0
Pulses	32112	354279	3552.00	114062	240217
Oilseeds	44957	399558	5753.53	258661	140897
Spices	6422.5	113726	8586.46	55147	58580
Veg	25690	926054	19422.96	498976	427078
Tobacco	0	0	0.00	0	0
TOTAL					3688666

Incremental Net Economic Output: (FW–FWO) = 446806

Kalni–Kushiyara River Improvement Project
Table 17: Capital Cost Investment Schedule

Item	Financial Price (Tk 000)	Conversion Factor	Economic Price	Capital Cost Investment – Year 0 Finan.	0 Econo.	1 Finan.	1 Econo.	2 Finan.	2 Econo.	3 Finan.	3 Econo.	4 Finan.	4 Econo.	5+ Finan.	5+ Econo.
Channel Closure	1039300	0.7	727510							311790 30%	218253	415720 40%	291004	311790 30%	218253
EMP construction	22800	0.7	15960			6840 30%	4788	9120 40%	6384	6840 30%	4788				
Resettlement	10600	0.8	8480							3180 30%	2544	4240 40%	3392	3180 30%	2544
Base Costs	**1072700**		**751950**			6840	4788	9120	6384	321810	225585	419960	294396	314970	220797
Phys Contin 25%	268175	0.87	233312			1710	1488	2280	1984	80453	69994	104990	91341	78743	68506
Study Costs (15% of [Base + Contin])	201131	0.87	174984	20113 10%	17498	40226 20%	34997	60339 30%	52495	40226 20%	34997	40226 20%	34997		
Land Acquisition	64600									19380 30%		25840 40%		19380 30%	
Total	**1606606**		**1160246**		17498		41273		60863		330576		420734		289303

Kalni–Kushiyara River Improvement Project
Table 18: O&M Cost Schedule

Item	Financial Price (Tk 000)	Conversion Factor	Percent of Capital cost	Financial Cost	Economic Cost	O & M Cost Schedule – Year 0	1	2	3	4	5	6	7	8	9	10+
Channel Dredging	1039300	0.7	5%	51965	36376							36376 100%	36376 100%	36376 100%	36376 100%	36376 100%
Base Costs	**1039300**			51965	36376							36376	36376	36376	36376	36376
Phys Contin 25%	259825	0.87		12991	11302							11302	11302	11302	11302	11302
Study cost (15% of Base + Contin)	194869	0.87		9743	8477							8477	8477	8477	8477	8477
Total:				74700	56155							56155	56155	56155	56155	56155

Kalni–Kushiyara River Improvement Project
Table 19: Benefit and Cost Streams
(Phasing of Benefits/Disbenefits and Economic Costs)

Benefits/Disbenefits	Incremental Net Economic Output (Tk 000)	Year 0	1	2	3	4	5	6	7	8	9	10 to 30
1. Crop	446806					0 0%	0 0%	89361 20%	178722 40%	268083 60%	357445 80%	446806 100%
2. Fisheries	2544						1272	2544	2544	2544	2544	2544
3. Wetland	1039						520	1039	1039	1039	1039	1039
4. Flood Protection	106400						53200	106400	106400	106400	106400	106400
Total	556789	0	0	0	0	0	54992	199344	288705	378066	467428	556789
Costs	Disbursement											
1. Capital Cost	1160246	17498	41273	60863	330576	420734	289303					
2. O & M Cost	56155	0	0	0	0	0	0	56155	56155	56155	56155	56155
Total	1216401	17498	41273	60863	330576	420734	289303	56155	56155	56155	56155	56155
Net Benefits	**−659612**	**−17498**	**−41273**	**−60863**	**−330576**	**−420734**	**−234311**	**143189**	**232551**	**321912**	**411273**	**500634**

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Table 20 : CASE – A : Benefit and Cost Streams (Considering Additional O & M Cost in the 11 & 12 Year for Extreme Flood Events)
(Phasing of Benefits/Disbenefits and Economic Costs)

Benefits/Disbenefits	Incremental Net Economic Output (Tk 000)	Year												
		0	1	2	3	4	5	6	7	8	9	10	11	12
1. Crop	446806					0	0	89361	178722	268083	357445	446806	446806	446806
						0%	0%	20%	40%	60%	80%	100%	100%	100%
2. Fisheries	2544						1272	2544	2544	2544	2544	2544	2544	2544
3. Wetland	1039						520	1039	1039	1039	1039	1039	1039	1039
4. Flood Protection	106400						53200	106400	106400	106400	106400	106400	106400	106400
Total	556789	0	0	0	0	0	54992	199344	288705	378066	467428	556789	556789	556789
Costs	Disbursement													
1. Capital Cost	1160246	17498	41273	60863	330576	420734	289303							
2. O & M Cost	540313	0	0	0	0	0	0	56155	56155	56155	56155	56155	324188	540313
Total	1700559	17498	41273	60863	330576	420734	289303	56155	56155	56155	56155	56155	324188	540313
Net Benefits	**–1143771**	**–17498**	**–41273**	**–60863**	**–330576**	**–420734**	**–234311**	**143189**	**232551**	**321912**	**411273**	**500634**	**232601**	**16476**

CASE – A : Economic Internal Rate of Return

Indicator	Units	Value
Economic Internal Rate of Return (EIRR)	per cent	22
EIRR, Increase Capital Costs by 20 %	per cent	19
EIRR, Delay Benefits by Two Years	per cent	13
EIRR, Delay Implementation Five Years	per cent	21
EIRR, Early Benefits Two Years	per cent	35
Net Present Value	Tk '000	787181

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Table 21: CASE – B : Benefit and Cost Streams (Considering Additional O & M Cost Evenly Distributed in each year for Extreme Flood Events)
(Phasing of Benefits/Disbenefits and Economic Costs)

Benefits/Disbenefits	Incremental Net Economic Output (Tk 000)	Year										
		0	1	2	3	4	5	6	7	8	9	10 to 30
1. Crop	446806					0	0	89361	178722	268083	357445	446806
						0%	0%	20%	40%	60%	80%	100%
2. Fisheries	2544						1272	2544	2544	2544	2544	2544
3. Wetland	1039						520	1039	1039	1039	1039	1039
4. Flood Protection	106400						53200	106400	106400	106400	106400	106400
Total	556789	0	0	0	0	0	54992	199344	288705	378066	467428	556789
Costs	Disbursement											
1. Capital Cost	1160246	17498	41273	60863	330576	420734	289303					
2. O & M Cost	90735	0	0	0	0	0	0	90735	90735	90735	90735	90735
Total	1250981	17498	41273	60863	330576	420734	289303	90735	90735	90735	90735	90735
Net Benefits	**−694193**	**−17498**	**−41273**	**−60863**	**−330576**	**−420734**	**−234311**	**108609**	**197970**	**287331**	**376693**	**466054**

CASE – B : Economic Internal Rate of Return

Indicator	Units	Value
Economic Internal Rate of Return (EIRR)	per cent	22
EIRR, Increase Capital Costs by 20 %	per cent	19
EIRR, Delay Benefits by Two Years	per cent	13
EIRR, Delay Implementation Five Years	per cent	22
EIRR, Early Benefits Two Years	per cent	35
Net Present Value	Tk '000	829529

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ANNEX F

COMMUNITY ORGANIZERS' FIELD NOTES

ANNEX F: COMMUNITY ORGANIZERS' FIELD NOTES

F.1 GENERAL

The initial work carried out by the NERP Community organizers was at six possible dredge disposal sites: Sections 3, 5, 6, 7, 8, and 9. (for locations of sections see Figure 22). The COs' field notes for these sites are presented below:

F.2 SECTION 3

Section 3 is located in Sullah and Ajmiriganj thanas. The villages of Sullah thana are situated in the right bank of the Kalni- Kushiyara River while the villages of Ajmiriganj thana are in the left bank of the river. The local people estimate that there are about 12,500 people in 2,150 households residing in 11 villages. (Table F1).

Villages

It must be noted that many of the people who are traditionally engaged in agriculture also get involved in activities like fishing. Large farmers do not sell fish while the poor and the landless have recently been found to be selling fish in the local market and to the *nikari* (people who are engaged in the buying and selling of fish). The fishermen also cultivate lands. The trend of fishermen becoming more involved in agriculture has increased recently due to the decline of fish production in the area as well as limited access to the fishing grounds (jalmohals).

Among the agriculturists 40%-60% households are landless. On the other hand, the concentration of land is quite high (about 10% of households own more than 65% of the land).

Problems and Solutions Identified by the Local Residents

The general problems the people have identified so far relate to flooding, drainage, and river bank and homestead erosion. Specifically, the people have mentioned the following problems:

Problem 1. Pre-monsoon flash floods damage boro crops. The intensity of such damage has increased in recent years due to the siltation of the Kalni-Kushiyara river, and breaches along the river banks. Boro crops in the right bank of the river have been inundated and destroyed during the flash floods of April 1994. For example in Sullah village, the extent of damaged boro is as follows:

1990: 60%
1991: 65%
1993: 75%
1994: 90%

Flood waters enter at the following points on the right and left bank of the river within Section 3:

- Faizullahpur dhala
- Gachherduar dhala
- Kalnir Nala

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- Aktarparar dhala
- Purba Pituya Kandar dhala
- Mora Kalni
- Bhera Mohonar khal
- Niklir dhala
- Mora ganger dhala (Dharmanagar)
- Paharpur dhala
- Ramjoyer dhala (Katakhali)
- Fomer khal (Nadipur)
- Gopir dhala
- Kaiyar dhala (recently closed)
- Barobander dhala - 2 nos. (Pahar pur)
- Gaganir khal (Noagaon)

Problem 2. Siltation of the Kalni-Kushiyara river especially between Markuli and Madna.

Problem 3. Erosion of villages along the river especially Pirijpur village.

Problem 4. Overspilling of the bank near Durlavpur village.

Problem 5. Erosion of the village homesteads by strong waves during the monsoon months especially in the right bank of the river.

Table F1: Villages in Section 3

Name	Location & Type	HHs	Population
Sulla Thana, Sulla Union			
Sullah	RB: Agriculture Community	700	4,500
Durlavpur	RB: Agriculture Community	100	650
Pituyakanda	RB: Agriculture Community	300	2,000
Musapur	LB: Agriculture Community	150	975
Ajmiriganj Thana, Badalpur Union			
Katakhali	LB: Mainly fishing community	200	1,300
Nadipur	LB: Mainly fishing community	75	490
Horipur	LB: Fishing community	80	520
Badalpur	LB: Fishing community	87	570
Dighalbak	LB: Fishing community	80	520
Pirijpur	LB: Agricultural community	350	2,275
Hilalpur	LB: Fishing community	25	150
Totals (11)		2,147	12,507

Note: HHs = Households

Suggested Solutions
(It is interesting and useful to note that many suggested solutions involved dredging.)

Solution 1. Dredge the river particularly from Ajmiriganj to Madna. Similar dredging is suggested from Markuli to Hilalnagar.

Solution 2. Make some of the sections of the river straight through loop cuts especially in Pituakanda. If the loop cut near Pituakanda is not done, it would be difficult to control flood water passing though Kaiyer dhala.

Solution 3. Close the various flood entry points mentioned above in particular, the Chhantertaler dhala near Faizullahpur village. This will stop entry of pre-monsoon flood water.

Solution 4. Closure of the canal at Kaiyer dhala and installation of a sluice gate in order to allow water for irrigation.

Solution 5. Construction of an embankment from Badalpur to Ajmiriganj to control over-bank spilling of pre-monsoon floods. The embankment could also serve as a village road.

Solution 6. Use the dredge spoil to raise and extend village homesteads.

Solution 7. Control flood water which enters through the Chhantertaler dhala near Faizullahpur village carrying huge amounts of sand and silt which get deposited in lands being used for boro cultivation. It is very likely that farmers will face difficulty in farming these lands in the near future.

Suggested Disposal Sites
Following are the different disposal sites recommended by the villagers. The sites include village homesteads, markets, school playgrounds, graveyards, ditches, fallowland, as well as agricultural lands.

1. Pirij pur: 20 acres in plot number 102, and 10 acres near Fulkuni river. In addition, 45 villagers have offered 110 acres in two separate locations (70 and 40 acres in each) as disposal sites. This measure will render these lands suitable for HYV boro crop production.

2. Nadipur: In and around all the village homesteads;

3. Matiakara: Ten to twelve acres of khas land for homestead development.

4. Road cum embankment on both banks of Kalni-Kushiyara from Markuli to Ajmiriganj.

5. Twelve acres of khas land between Dhigalbak and Badalpur for homestead development.

6. Extension of village homesteads of Dhigalbak.

7. On low-lying agricultural land south of Nadipur village

8. A 15 acre plot in Paharpur village for the development of school playground, market and football field.

9. Paharpur village homesteads (10 acres).

10. Durlavpur village homesteads (5 acres).

11. A road connecting Durlavpur and Sullage villages.

12. About 6-7 acres of land between the homesteads in Pituyakanda village

13. A twenty five acres plot in the west of Bheradahar village.

Other Information

Labour Migration
Due to frequent crop failures in the area, a lot of people migrate to other places to find work. For example, in 1994 about 500 poor male laborers from Sullah village migrated to Syhlet (150), Chhatak (150), Moulvi Bazar (100) and Dhaka (100) during the last monsoon months. In the same year and from the same village 30 women sought jobs outside the village.

In 1994 about 180 male labourers from Pituakanda migrated to Chhatak (80), Belabor (80), Shylet (10) and Dhaka (10) during the monsoon months.

These men worked from 4-5 months during the period June through October. They return to their own villages to provide labour during boro cultivation.

People mentioned that half of all agricultural labourers come from outside the area (i.e. greater Mymensingh district). More than 80 percent of boro harvesters are from Mymensingh, Faridpur, Tangail and Manikganj.

Miscellaneous Cost Data
Peat coal is available in the west of Sullah village covering an area of about 300 acres. It is lifted during winter months of December to mid-April. There are 25-30 contractors in the village. They lease land from the villagers at Tk. 2000-2500 per ker (30 dec) per season. The amount of coal lifted from each ker of land varies from 2000 to 2500 maunds. Ten labourers are required for two months to lift coal from one ker of land. Each contractor can lift about 10,000-15,000 maunds of coal per season. Sometimes, they store the coal to await a better price and sometimes they sell it right away. Hauling coal from field to river ghat costs about Tk. 2.00 per maund. Retailers buy from the contractors at Tk 12-13 per maund and go from village to village selling it at Tk.17-18 per maund. During monsoon months, the price goes up to Tk 35-40 per maund.

Land Value
Tk. 4,000-10,000 per ker (28 decimal of boro land).

Wage Rate for Agricultural Labourers
Labourers are employed from the village and paid on a weekly basis, Tk. 200-250 per week. Contract Seasonal Labourer: Men 18-20 maunds of rice plus Tk. 1,500-2,000 (cash paid in advance) with food and clothing for 7-8 months; Women: 7-10 maunds of rice plus Tk. 200-500; Harvesting Period For Boro Rice: Men: 8-10 maunds of rice with food and one *longi* and for a period of 4-6 weeks in the months of April-May; Women: 3 maunds of rice and a *sari* for the same period.

Daily Labourer: Men: Tk. 25-40 per day with or without food; Women: Tk. 15-20 per day with or without food. Many women work for food only during the crisis months of February and March.

F.3 SECTION 5

There are 28 villages in Section 5, twenty-two on the left bank and six on the right bank of the river. The total population, on the basis of Union Parishad records, is approximately 20,000 in 3,444 villages (Table F2) . All these villages are within 1.5 km on the left as well as the right sides of the river. Ajmiriganj is the thana headquarters and the marketing centre.

Problems Identified by Villagers

1. Pre-monsoon flood damage of boro has been extensive since last 4-5 years. During the year 1994 it has been reported that about 90% boro crop of villages located along the right bank has also been destroyed. Boro crop damage in the right bank villages between 1988-93 varied between 50%-90% damaged by pre-monsoon floods.

2. The siltation of the Kalni-Kushiyara River from Ajmiriganj to Madna has created the following problems:

   - reduced fish production. For example, the supply of hilsha fish and chingri has dwindled significantly over the last 10 years.
   - over bank spilling
   - disrupted river communication in the area especially with Ajmiriganj
   - increased transportation costs of commodities which result in higher prices of goods
   - reduced income of fishing communities

3. Increased rate of out-migration during monsoon months is due to limited job opportunities and successive crop failures during the last 4-5 years.

4. The drainage channels from various haors to the river have been silted up which delays transplantation of boro crops. In addition, the haor beds have also been silted up which were the only sources of irrigation water supplies during winter months. This has resulted in a scarcity of irrigation water supplies in the winter months.

5. The water which spills over the bank of the river carries with it sand and silt which reduces quality of lands for production. The overbank spilling points are:

- Bomar gang near Oara village;
- Bomar khal near Barobari village
- Darain river
- Godaraghat khal
- Duiya beel,

6. The three kilometre section of the Godi River which is a tributary of the Kalni-Kushiyara is silted up. This problem hampers navigation and contributes to poor drainage of post monsoon flood waters from various haors along the right bank of the river.

7. The silting up of the Old Kushiyara River affects efficient navigation in the area and contributes to poor crop production.

8. The closure of the mouth of the Bheramohona River has created drainage congestion in the right side beels such as Behramohona beel and others. In addition, this has also increased over-bank spilling of the Darain River causing massive damage to boro crops of about 6-7 Unions.

9. Year-round water logging in Gochidomar beel, Katiar beel, Bhurinail beel, Baspatia beel which prohibits cultivation of boro.

10. The silting up of the Kushiyara and the closure of some channels in the area have significantly reduced the important economic activities in the area. For instance, Ajmiriganj which was once a very important and busy trading centre has almost lost its role as major player in the economic life of the area. Closure of the Kalni mouth at Markuli has also totally stopped traders of Derai areas. Similarly, closures of Bheramohona and Goda rivers have paralyzed trading activities with traders of northwestern areas of Ajmiriganj such as Ghungiargaon, Dhanpur, Itna, and Shyamarchar.

11. Lack of drying areas and threshing grounds for boro crops.

12. Erosion of village homesteads during monsoon months.

13. Pre-monsoon flood damage to boro crops causes shortage of fodder which compels the farmers to sell their cattle. For example, Mr. Tajuddin of Prajakanda sold 56 head of cattle out of 60 during last six years.

14. Erosion of several homesteads in Kalnipara village due to the intrusion of flood water through Ranaiyar khal. This khal also threatens boro crops in various haors on the left side of the river.

Suggested Solutions

1. Dredge the Kalni-Kushiyara River from:

   - the mouth of Bherramohona River to Birat village;

Table F2: Villages in Section 5

Name	Comments	No. of HHs	Population
Ajmiriganj Thana & Union			
Ilamnagar	LB	82	492
Noyanagar	LB	92	552
Nabinagar	LB	96	576
Araliartuk	LB	31	186
Azimnagar	LB	128	768
Lambahati	LB	45	270
Munsihati	LB	92	552
Jummahati	LB	132	792
Kamarhati	LB	58	348
Sharifnagar	LB	228	1,368
Pukurpar	LB	82	492
Ajmiri Bazar	LB	218	1,308
Sarafnagar	LB	62	372
UZ Office Para	LB	56	336
Samipur	LB	96	576
Jagatpur	LB	62	372
Sukribari	LB	145	870
Rahania	LB	61	366
Kalnipara	LB	97	582
Gopalnagar	LB	20	120
Krishnanagar	LB	41	246
Nagar	LB	288	1,728
Itna Thana, Mriga Union			
Prajakanda	RB	350	2,100
Andhair	RB	50	300
Shantipur	RB	97	582
Barobari	RB	125	750
Gajaria	RB	360	2,160
Modhupur	RB	20	120
Total for 28 villages		3,444	20,298

Notes: LB: Left Bank, RB: Right Bank, HHs = Households

- Markuli to Madna; and
- near Rahela, Shantipur, Ajmiriganj and Paharpur villages

2. Construct embankment:

   - along the river bank of Kalni-Kushiyara to control over-bank spilling;
   - from Sulla to Joysiddhi (Itna) where 2500 meters out of 4700 meter embankment has already been completed.

3. Loop cut

   - near Pirojpur and Shantipur to increase flow of water
   - near Shantipur and Katkhal Union (section 6)

Suggested Disposal Sites

1. Bhurinail beel in front of Barobari village for agricultural purpose.

2. About 1 ker of land inside Projakanda village for homestead and school premises development;

3. Barobari, Gazaria, Projokanda, Shantipur, Andair, Noyanagar, Azimnagar, Pukurpar, Samipur, Jagatpur, and Ilamnagar villages for expansion of homesteads.

4. About 1 ker of land in the southeast portion of Kalnipara village for homesteads development and control of flood flows in the haor.

5. About 20 decimals of land around Madhupur village to expand homesteads as well as prevent the erosion of existing homesteads.

6. Along the Kalni-Kushiyara River from the mouth of Bheramohona to Shantipur village for flood protection.

7. Gazaria beel for homesteads, drying yards, and threshing grounds.

8. Ten kers of land near Nabinagar and Ajmiriganj to develop college premises.

9. Left bank of the Kalni-Kushiyara River in front of Ajmiriganj Bazar for market development.

10. West of Sharafnagar to develop homesteads and a road cum embankment from Sharafnagar to Samipur.

11. About 12 kers of land between Noyanagar and Nabinagar for homestead and agriculture development.

12. About 30 kers of land behind Ajmiriganj Bazar for market and agriculture development.

13. East and west sides of Pukurpar village for homestead and road construction up to Ajmiriganj.

14. About 10 kers of land between Jagatpur and Samipur for homestead development, road communication with Ajmiriganj and community plantation.

15. About 7 kers of land in the west of Shanir Akhra near DC road for homestead and Akhra premises development.

16. Between the river bank and Azimnagar Bazar to develop homesteads, road, and plantation.

17. Barobari village along the left bank of the river in front of the village for flood protection.

18. About 15 kers of land in the south-west of Raniya canal for development of homesteads, drying yards, threshing ground, roads and community plantation.

19. A 12 kers of land east of Kalnipara village for development of homesteads, primary school premises, and drying and threshing.

20. Ten ker plot in the eastern side of Andair for development of homesteads, roads and community plantation.

21. A 10 ker plot south of Shantipur for homestead development.

Social Issues

Conflicts

False Lease of the Kalni River:
In 1990, the Kalni river was leased by a certain Mr. Rashid (not his real name) of Ajmiriganj. He did this in the name of 420 members of the fishers coop of various villages around Ajmiriganj. After the lease agreement, Rashid began fishing in the jalmohal for the next three years without paying rent to the government.

He was able to do this with the knowledge and consent of the thana fishery authorities and other concerned officials.

The cooperative members were unaware of the deal until they were asked by the relevant authority to pay the three years rent of the jalmohal. The members were shocked with the demand notice and explained their position to the authority. However, the authority did not listen to the cooperative member. Instead, a court case was filed against them in order to realize the rental fee of Tk. 14,04,000. The case is still in court while in the meantime the members are being subjected to frequent harassment from the court.

A section of the accreted plot of Kalni-Kushiyara River in front of Ajmiriganj bazar has been leased to some landless cooperatives of Jagatpur, Samipur and Pukurpur. Similarly another group of landless people from Ajmiriganj, Sharifpur, Azimpur and Noyanagar,led by an influential local politician applied for the lease of another section of the same accreted plot. Unfortunately, the boundaries of these two sections were not demarcated. But both groups cultivated rice crop in

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the undemarcated accreted land. Before harvest time, a court case was filed by the said influential person over the operational right of the cultivated land. A tense situation between these two parties developed before harvest time. However, the former Upasila chairman took up the issue and harvested the whole crop himself and put the produce under his custody saying that he would return the due share of produce to whomsoever wins the court case. The case still awaits court decision.

These two factions are led by two influential persons. One of them is interested in buying the above mentioned piece of land. To achieve this, he is trying to influence the poor cooperative members to sell the land to him. Until now, however, his attempts have been unsuccessful.

Migration

There is out-migration of both poor men and women members of different villages of Barobari to Dhaka, Shrimangal, Chhatak, Sylhet and Moulvi Bazar in search of work. Similarly, 64 men and 40 women from Shantipur village migrated to Sylhet, Moulvi Bazar and Dhaka for jobs. This is a new trend in this locality which has happened only during the last 5-6 years due to successive crop failures and poor fish production.

F.4 SECTION 6

There are 14 villages in three unions of Kakailcheo (Ajmiriganj thana), Jojsiddhi and Mriga (Itna thana) in the section. Eleven of these villages are on the left side and three are on the right side of Kalni-Kushiyara River. There are about 26,000 people who reside in 4,116 households (i.e. 1700 households on the right bank and 2336 households on the left bank). (Table F4). There are no villages in section 6 that are threatened by river bank erosion.

The CO visited all the 14 villages and met the local people of this section. He explained to them the objectives of the project. In the course of many meetings with the local residents, the CO developed an open and cordial relationship with them.

One limitation of these meetings is that they were often not so well organized. Moreover, the different sectors of the communities were not represented in these discussions. Hence, although the information the CO had gathered give clues to the actual situation in the section, it is necessary to check them in future meetings to determine their accuracy.

Problems Identified

1. Pre-monsoon floods damaged boro crops in the right bank haors through over-bank spill along the low-lying areas near Anandapur.

2. In 1994, seventy five (75%) percent boro was damaged by pre-monsoon floods which entered through the Raniar khal. In April 1992, floods also devastated 50% boro crops.

Suggestions

1. Straighten the river through loop cuts and dredging in front of Rahela and Shantipur villages.

2. Dredge in front of Kakailcheo bazar in order to stop over-bank spilling especially on the

Table F3: Community Leaders (Matbar)

Village	Leaders
Gazaria	Hanif Miah, Abbas Ali, Hazrat Ali member Cherag Ali, Kamrul Islam , A. Ramiz Mollah Ambar Ali, Yasin Mia, Chan Mia, Tamir Uddin, Innus Ali, Shamaul Islam (Ex UP member), Hazi Sirajuddin, A.Noor, Chhami uddin, Nur Islam.
Andair	Abdul Halim, Joysundar,
Projakanda	Mainul Haque, Amir Hossain-UP Chairman, Mahsin Miah, Nur Islam-Primary School teacher, Ali Hossain,Hazi Badiuzzaman, Muluk Chand, Tajuddin, Idris Ali, Askar Ali,Abdul Matin, Ambar Ali, Manfar Ali, Jahur Ali.
Sharafnagar	Rana choudhury, Ahmad Miah, Abhinas Roy,
Nabinaga	Badshah Mia, Mangla Mia, Nayan Mia
Noyanagar	Sk Farid ex member, Mahmud Ali, A. Rahman, Lokman Mia, Ukil Mia, Prafulla Das.
Azimnagar	Hafizuddin Miah- ex UZ chairman (leader of one faction), AL local leader Mohibur Hasn Badal- UP chairman- Ajmiriganj (leader of another faction), local BNP leader Faruk- co-leader of Badal's faction, local BNP leader
Pukurpar	Rathindra Lal Kuri, Jyotish Kuri,
Sukribari	Afjal Miah - member Ajmiriganj UP, Shahid Miah, Rajab Ali,
Nayanagar	Sk Farid, Mahmud Miah, Prafulla Das,
Nagar	Fazlu Miah- UP member, Ahad Miah, Lakai Miah, Nurul Hoque Miah,
Jagatpur	Anil Roy- ex-UP member, Kalipada Roy-UP member,
Samipur	Dhananjay Choudhury, Rati Choudhury, Kalidas, Roy,Naresh Roy,

left bank of the river.

3. Close the following khals to protect the haors from pre-monsoon flooding:

   - Badarpur khal: 3-4m deep, 50-60m wide.
   - Kadirpur khal: 2-3m deep, 50-60m wide,
   - Binnakhali khal 2/4m deep, 150m wide.
   - Kamalganj khal: 2/3m deep, 30/40m wide.
   - Basira River.

4. People are concerned that the dredging of section 6 may threaten downstream areas like the homesteads in Shantipur. Dredging of the old channel of the river might have less negative impact on settlements and agricultural land.

Proposed Disposal Sites

1. Kakailcheo village:

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- West of the bazar: a privately-owned 4 acre doba;
- South of the bazar: a privately-owned 10 acre doba for crop production;
- North of the Kakaicheo bazar: a privately-owned 40 acres for new homesteads.
- Between Ajmiriganj and Anandapur for construction of road cum embankment
- Various areas from Kakailcheo to Sahebnagar for development of homesteads, bazar, road networks and agricultural land.

Many private lands owned by Nurul Hoque Bhuiya, Jamil Hazi, and Mohibur Sowdagar for agricultural production.

2. Kanda from Kamalganj bazar of Kakailcheo to Rahela:
    - A char land with an area of 150 acres along the river bank.

3. Wara village for homestead and agricultural development and from the Kakailcheo ferry ghat to Wara Primary school for embankment protection.

4. Anandapur
    - a 70-80 acre area on the eastern side of the river to allow for double cropping.
    - about 30-40 acres of doba attached to Kamalganj for agricultural and playground development
    - Kamalganj khal to develop about 30-40 homestead plots.

5. Rahela
    - Doba in the east of the village, about 30-40 acres in size,to be raised for construction of homesteads, development of play ground, threshing/drying yards,and village afforestation.
    - Primary school:(to be raised).

6. Badarpur
    - Bhimkhali khal in the north of the village for homestead development.
    - Western side of the village for extension of homesteads.
    - All the canals inside the village for homestead development, etc.

7. Solori
    - About 15 acres plot in front of the village up to the road for bisra

cultivation,and threshing/drying yards.

- Solori to Najorkanda, and Sahnagar to Kakailcheo for homestead development.
- Between Mirzapur and Puber hati, Binnakhali khal (50mx15m).
- From Solari to Gardail for homestead and agriculture development.

Table F4: Villages in Section 6

Name	Comments	HHs	Population
Ajmiriganj thana			
Gardaigram	LB	550	3575
Badarpur	LB	140	842
Manipur	LB	30	190
Salari	LB	50	302
Kadirpur	LB	35	210
Najrakandi	LB	140	840
Shahanagar	LB	50	300
Mahmudpur	LB	65	390
Kakailcheo	LB	619	3714
Anandapur	LB	450	2925
Rahela	LB	207	1500
Kamalpur	LB	650	4225
Itna thana			
Wara	LB	900	5500
Kaittarkanda	LB	230	1495
Total for 14 villages		4,116	26008

Note: LB = Left Bank
HHs = Household

8. Kamalpur
   - Five acre of land for village graveyards, and improvement of school yards, mosque,etc.
   - Khas char land along the river bank for new homesteads.

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9. Kaiterkanda
   - On the khas land along the river bank.

10. Najrakanda
   - Binnabari khal for homestead development

11. Shahnagar
   - One 2.1 acre pond of Mohitosh and others for crop production.

12. Gordairgram
   - Kalnipara, Binnakhali, Badapur and Anandapur khals.

Social Issues

Migration
Kaiterkanda: Approximately 300 men and 300 women went to Chhatak, Sylhet, Sunamganj, Dhaka, and Chittagong as rickshaw pullers, agricultural labourers, and transportation of sand and stones, etc.

Kakailcheo:20-25 korati (sawer) go out to saw wood in different villages in the locality.

Najrakanda:150-200 labourers come from greater Mymensingh to work as contract labourers for 8 winter months, wage varies from 20 to 25 maunds of rice + adv. of Tk 2000-2500.

About 150 men go outside every monsoon season to Chhatak, Sylhet, Dhaka, and Chittagong to work on various jobs.

F.5 SECTION 7

Section 7 has 18 villages in two thanas, namely, Ajmiriganj and Mitamain. The villages of Ajmiriganj thana are in Kakailcheo Union while those of Mitamain thana are in Katkhal and Keyorjuri Unions. Out of the 18 villages, 8 are on the left bank and 10 are on the right bank of the Kalni-Kushiyara River. There are about 14,000 population in about 2,600 households. (Table F6)

Majority of the villages in Section 7 are engaged in agriculture. The local people have said that 40%-60% of the population are landless. In order to augment their income the poor of these villages also catch fish during monsoon months.

Problems Identified by the People
Some of the water and drainage-related problems the local people have identified are listed below.

1. Overspilling of the banks causing damage to boro crops.

Table F5: Crop Damage in Five Unions

Union	Amount of Crop Damaged (%)	Ha (approx)
Katkhal	75	7,500
Joysiddhi	75	7,500
Dhaki	75	8,750
Keyorjuri	50	2,500
Ghagra	75	1,250

2. River bank erosion which damaged homesteads at Shantipur, Katkhal village, Katkhal Bazar and Sahebnagar.

3. Entry of flood waters through Sakni khal which destroys boro crops in the nearby haors of six Unions of Mithamain thana. During April '94,about 3,000-4,000 people of the area tried day and night prevent the entry of flood water, but could not protect it, causing damage to the boro crop of about 27,500 acres of land of 22 villages of the five Unions shown in Table F5.

4. Erosion of about 300 households of Shantipur and Sahebnagar as a result of the new diversion channel of the Kalni-Kushiyara River.

5. Siltation on the Kalni-Kushiyara River bed results in many meanderings around Katkhal Bazar causing more erosion and over-bank spilling.

6. Due to river erosion, about 300 households of Sahebnagar have left the village during April 1994, and have gone to various cities.

7. Due to heavy siltation the launch cannot ply from Shantipur to the Basia River mouth (about 2-3 km) during the winter months of February and March.

8. The Buritala khal near Nowa Bisorikona village has been heavily silted up resulting in the failure to drain out water from the haor of some 25 villages during the post monsoon months. This delays boro transplantation. In addition, this khal threatens the boro crops during the pre-monsoon flood period.

9. The river has created a new meandering bend in the west of Rahela village behind Shanti pur. This has eroded agricultural lands in Barobaria *haor* causing the people to fear further erosion through the *haor* up to Bander beel.

10. Due to erosion of Sahebnagar village, some of the victims have resettled in the nearby agriculture land in Koramara *haor* which is also threatened by erosion.

11. About 30-35 homesteads and 200-250 acres of agricultural lands of Char Kathkal village are eroded and people are afraid that more erosion will occur in the coming years.

Some of the pre-monsoon flood entry points for flood waters are:

- Kata Khal
- Buritular Khal
- Shinai Nadi
- Shankir Khal(rt. bank)

Suggested Solutions of the People

1. Dredge the Kalni-Kushiyara River from Ajmiriganj to Madna

2. Make the river straight from Kakailcheo to the ferry ghat of Bisorikona village by three loop cuts: one in the west of Rahela village; second, in the east of Shantipur village and the third loop cut through the Koramara *haor*. The total length of these loop cuts will

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Table F6: Villages in Section 7

Name	Comments	HHs	Population
Ajmiriganj Thana, Kakailcheo/Union			
Rahela	LB	220	1,315
Matabpur	LB	200	1,220
Alipur	LB	50	400
Mitamain Thana, Katkhal Union			
Shantipur	RB: threatened by severe erosion	85	465
Katkhal	RB: Includes 125 new HHs from Shantipur and Sahebnagar,	289	1,550
Sahebnagar	RB: threatened by severe erosion	100	681
Charkatkhal	LB: threatened by erosion	145	712
Kalna	LB	230	1,230
Nowabisorikona	LB	35	210
Bisorikona	LB	125	755
Dillir Akra	LB	15	100
Jatrapur	RB	60	407
Hasimpur	RB	180	920
Satrish	RB	80	565
Kaisor	RB Includes 20 HHs from eroded land at Sahebnagar	260	1,140
Kanchanpur	RB	300	1,825
Kurerkanda	RB	280	1,725
Kurerkandanowa	RB	60	315
Totals (for 18 villages)		2,588	14,140

Note: *RB = Right Bank*
LB = Left Bank
HHs = Households

be about 2.5 kilometres. About 100 acres of land in Koramara *haor* need to be acquired for loop cutting purpose. This piece of land could be compensated with lands from the existing river channel. The existing channel could be developed with the use of dredge spoils.

3. Construct sluice gates at the mouths of various khals like Buritalar, Noya Bund, Goalghata and Baragop khals and re- excavate Shankir khal and Buritalar khal for proper drainage.

4. Re-excavate the Basia River (about one km) near Kadamchal to drain out post- and pre-monsoon water from the haor, and construct a sluice gate at the mouth of the river.

5. Construct embankments along the river bank from Madhabpur to Alipur to stop bank overspilling.

Spoil Disposal Sites
The villagers are enthusiastic about the Kalni-Kushiyara project. They have also indicated their willingness to actively participate in the management of spoils. They said that dredge spoils could be used in the following:

- Katkhal bazar to raise and expand it and develop school premises;
- Construction of 1200 meters of embankments cum roads from Char Kahkhal village to Madhabpur village to protect boro crops in the eastern Kakua *haor*.
- Fill-up the existing river channel near Sahebnagar which will be left out of the loop cutting process.
- Extension of the village homesteads of Shantipur, Kathkal, Char Katkhal, Alipur and Sahebnagar.
- Raising of low-lying agricultural lands of some villages like Noya Bisorikona, Dillir Akra and Kaisor.
- Flood protection embankment along the river near Jadabpur village

Labour Migration
One hundred fifty (150) men from Shantipur migrated to Shylet, Dhaka, Chhatak and Habiganj during the monsoon months of June-October in search of various types of jobs. The trend of migration from other villages has also increased in recent years due to successive boro crop failures.

More than 60% boro harvesters come from outside the area, such as Faridpur, Tangail, Manikganj, Pabna and Barisal. The wage rate for the harvesters varies from 1/8 to 1/10 of the amount harvested.

Market and Commodities Transacted
Since the original location of Katkhal bazar has been eroded, the bazar now sits on a new location. There are about 125 shops in this bazar which sell different things ranging from grocery goods to kitchen utensils. The shop owners are mainly from Katkhal, Kaisor, Sahebnagar and Char Katkhal. Market days are Tuesdays and Saturdays. On these days, no less than 3000 people from nearby Unions come to the Katkhal bazar to buy things. More temporary shops are also set up on market days by merchants coming from Kakailcheo, Ajmiriganj, Rashidganj, Keorjuri Nilganj, Kuliarchar, Karimganj and Bithangal. These local merchants generally sell vegetables and clothes bought from Bhairab Bazar.

The local traders import commodities from Bhairab Bazar. There is a bazar committee consisting of 50 members, 15 are executive members.

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Fisheries
There are five "duars"in the Kalni-Kushiyara River from Rahela to Kadamchal. The most famous of these "duars" is Kaunir duar where many species of fishes are available such as rui, katla, bual, chital, ghagot and pangas.

Many poor and landless people of Katkhal catch fish during monsoon months, and sell it to the local aaratders (fish merchants). The common species caught are prawns (chingri). On the average, a fisher can earn Tk. 55.00 per day catching chingri. There are 8 aarat in Katkhal bazar and 7 in Char Katkhal which are engaged in the buying and selling of chingri. On average, these merchants buy about Tk. 100,000 worth of chingri per day which they in turn sell in Bhairab bazar.

Transport/Communication
During monsoon months, engine boats ply from Katkhal bazar to Ajmiriganj and Bhairab Bazar as well as Itna, Mithamain, Chamraghat, Astagram, and Habiganj. Launches can ply during monsoon months from the bazar to Ajmiriganj and Bhairab bazar. Both passengers and cargo are transported. But during the dry months of February and March, launches cannot ply to and from Ajmiriganj due to silting up of the river.

Wetland Resources
Chailla is being cultivated by many farmers in the area. It is used to protect homesteads from wave erosion. It is also utilized as fodder and fuel. A bundle of chailla is sold for Tk 2.00 while the cost of chailla in one decimal land ranges from Tk.150-200. Production of chailla on the open fallow land (kanda) has reduced nearly 75% in the area due to scarcity of available land.

Wetland fruits, like gechu, singra, pukal, and dhep though available have become quite scarce in the area.

Social Issues

- The people of Shantipur, Char Katkhal and Sahebnagar are worried that the dredging of the upstream portion of the river in section 6 will cause their homesteads and agricultural lands to disappear. In order to prevent this, they are demanding that dredging and straightening of the river by loop cuts should be done first in section 7 around Rehela, Shantipur and Katkhal villages. In the event that dredging takes place first in section 6 instead of section 7, the people of the above mentioned villages have vowed to vigorously oppose the dredging activity by any means.

- The people whose homesteads had been previously eroded and had to move elsewhere are insisting that a quick decision on the dredging of the river be done soon inorder to help them decide their future settlement plan. Otherwise, if no decision is forthcoming in the near future, they would be forced to migrate to the cities like Dhaka and become slum dwellers.

- The people are insisting that if a loop cut and dredging are done through Khoramara *haor* about 100 acres of private lands which will be affected by these activities must be compensated preferably with land. This piece of land could be obtained from the existing river channel which will be left as a result of the loop cut.

Table F7: Village Leaders (Matbar)

Rahela	Dewan Ali, Mafil Mia, Abdul Hakim
Shantipur	Hazi Rahmat Ali, Suban Ali, Taleb Ali, Hazrat Ali, Omar Ali, A. Rahim, Muttalib Mia, Khaleque Mia
Kamalpur	Abdul Gani, Lal Mia, Mantaz Ali.
Madhabpur	Akkas Ali, Samauddin, Hazi Jan Masud.
Alipur	Sabir Mia. Fazil Mia.
Char Katkhal	A. Latif, A. Hasim. Jinnat Ali, YunusAli, A. Salam.
Kakua	Hazi A. Mannan, Mangal Mia, Kenu Mia, Raja Mia, Musleh Uddin.
Noyahati	Sohrab Uddin, Hazi Hasan Ali.
Jadabpur	Motiur Rahman, Samsul Hoque, Abdul Aziz (ex-UP Chairman).
Bisorikona	Motalib Mia, Rouf Mia, Hazi A. Sattar, Janb Ali.
Dillir Akra	Banabasi Mohonta
Sahebnagar	A. Khaleque Munshi, A. Mannan, Siddiqur Rahman, Idris Mia, Khursed Ali, Ohab Ali.
Katkhal	Rais Uddin (UP Chairman), A. Gafur (ex-UP Chairman), Hazi A.Barek, Chhanda Mia, Nurul Hoque (Hd master), A. Razzak,
Dhalar gaon (Jatrapur)	Murad Ali mir, Jafar Ali.
Chhatris	Aminuddin, Nurul Islam (ex-UP chairman), Garge Mia.
Khaisor	Meher Ali, Yusuf Ali, Ali Nuyas, Hazrat Ali.

F.6 SECTIONS 8 & 9 (BIWTA Dredging Site)

BIWTA carried out dredging at a number of locations in the Kalni-Kushiyara River during 1992-94 to increase river draft in order to keep the river navigable. The dredge sites were located at Abdullahpur, Kalimpur, Madna and Adampur.

The CO visited the sites towards the end of October 1994 and collected some basic information from all the four sites. Information collected from one site is summarized below:

Abdullahpur Site

The CO gathered the information from about 30 village people who were involved in initiating the idea of using the dredge spoils for land development. These people came from different sectors of the community and were considered to be the key respondents of the village. Their age group varies from 26 to 70 years and their professions ranged from school teachers, healers, agriculturists, wage labourers and students.

Abdullahpur is a large village, inhabited by some 20,000 people in 4,000 households. It is situated in Austagram thana of Kishorganj district. The settlements were constructed along the

222

left bank of the Kalni-Kushiyara River (section 9). Abdullahpur is mainly an agriculture village. As in many places in Bangladesh, land holdings in Abdullahpur is largely concentrated in the hands of few individuals. This village is generally considered a rich one by those who live in the neighbouring villages.

Abdullahpur is divided into two para (cluster of homesteads); an eastern and a western one. There are also two other smaller para. Abdullahpur has a market, a junior high school, a post office, a wireless office, a UP office, six primary schools, one madrasa, nine mosques, about 300 hand tubewells, two registered clubs, and 10 BRDB coops.

There are about 300 government employees in the village, one of them is a joint secretary. About 145 persons are reported to be employed in the Middle East and European countries. During the last monsoon months, at least 300 poor people migrated to Sylhet, Chittagong, Chhatak and Moulvibazar in search of jobs.

The village is mainly connected with the outside world by river transport. In recent years, however, river communication has been disrupted to a large extent due to silting up of the Kalni-Kushiyara. During the months of February and March launches find it very difficult to navigate around this area.

The BIWTA initiated dredging operations in sections 8 & 9 as part of their routine work. Dredging was done in the Abdullahpur site during three consecutive years from 1992 to 1994. The dredging operation of 1994 has some speciality features because it opened new avenues for effective use of the dredge spoils to fulfil basic needs as well as demands of the local people.

The villagers reported that during 1992 and 1993 dredging was done on a small scale in front of the village. Dredge spoil was dumped along the river bank opposite to the village without much planning. Most of the spoil was left in the river itself. The dumped material washed away during the monsoon months leaving almost nothing on the dump site. When the villagers asked the dredger operators about such dumping, they answered that they were performing the operation as per plan.

In 1994, when the people learned about the dredging activities being done in the same sections, the village leaders (*matbar*) met the dredger operators and asked them whether they could dump the spoils around homesteads so they could be further developed. The dredger operators agreed.

The villagers discussed among themselves to identify the places they would like to develop. They also decided to contribute money for the construction of the pockets and to meet other expenses. The amount of contribution which was collected was in proportion to the size of land and financial condition of the villagers.

The villagers identified and developed two pockets in Abdullahpur. One is situated along the river bank in between the eastern and western paras. The size of this pocket is 12 ha while the north para's size is slightly less than one hectare.

The 12 ha plot covers the village graveyard, the market, the high school play ground and private lands like ponds, ditches, low lying fallow land and agricultural lands.

The people said that they raised Tk.200,000 from individual contributions in order to meet necessary expenses. They spent Tk.40,000 to construct a dyke around the plot and another Taka 50,000 to initiate the dredging process. The operation went on for a few weeks then it stopped. Consequently, the pocket was never filled up as per agreement.

The villagers said that the dredging work was only half finished and that the dredge spoil was not enough to make possible the construction of the homesteads. But they did mention that about 400 households, whose lands were raised, have benefitted. More spoil is needed to construct homesteads.

Benefits from the Dredging Operation

Even though the dredging work was stopped prematurely, the villagers acknowledged that some benefits had been derived from it. They were happy that their lands were filled up. They even compared the present situation with the past when they had to face multiple problems like getting around in the monsoon and no proper place to bury their dead.

They are also pleased that people are now able to go to the bazar quite easily; their children can play in the fields; their dead can be decently buried and that, even during monsoon months, they can walk to their neighbours' houses .

In addition, monsoon wave erosion of homesteads is less now. This has reduced the cost of construction of the monsoon protection wall to a large extent. This year 1994 some 500 households did not construct the monsoon wave protection wall.

Farmers are also cultivating potato, chili, and radish in their respective raised plots. They told that yield was not good in the first year, but is better in the second year. They are using the plots for other purposes too, such as *khola* (drying yard), drying place for fuel from cow dung.

The land value in the developed pockets, especially in Madna and Abdullahpur market sites has gone up by some 10 to 12 times (from Tk.1000 per ker to Tk.10,000-12,000 per ker, 25 dec a ker).

The north para pocket which has been raised is now ready for the construction of homesteads.

The negative impacts of the dredging work are quite few. For example, because the dredging was not accomplished properly, the river bed was silted up quickly. Also as ponds and ditches are filled up the sources of water near their homesteads have disappeared. This causes enormous burden on women who now have to walk long distances to fetch water for washing and cleaning clothes and kitchen utensils.

Finally, the villagers fervently hope that BIWTA would resume their dredging activities to honour their original commitment with the people to raise their lands up to the level of the homesteads. Unless this is done, the soil will likely be eroded by monsoon waves.

ANNEX G

FIGURES

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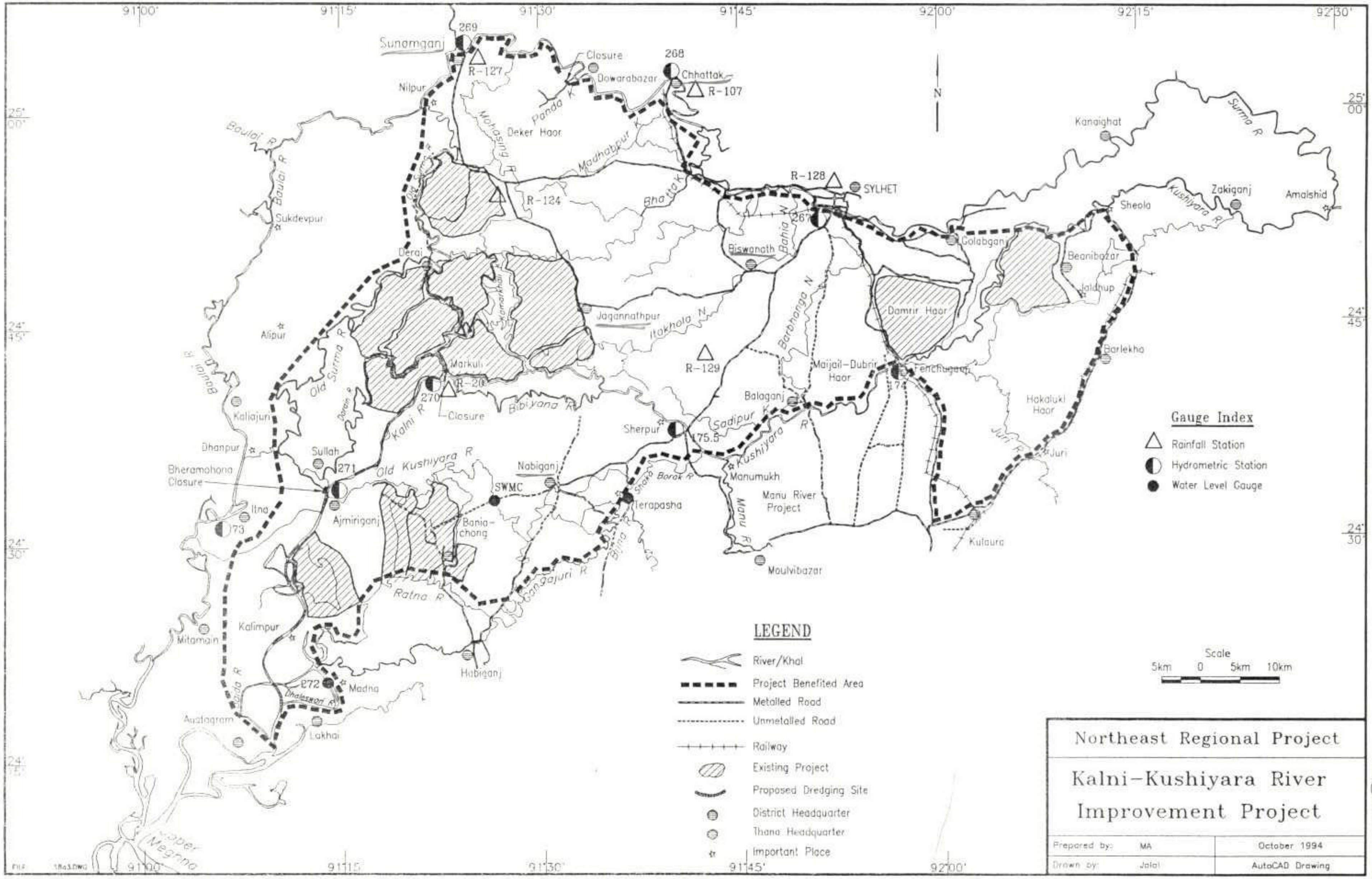


Northeast Regional Project
Kalni-Kushiyara River Improvement Project
Prepared by: MA
Drawn by: Jalal
October 1994
AutoCAD Drawing
LEGEND
River/Khal
Project Benefited Area
Metalled Road
Unmetalled Road
Railway
Existing Project
Proposed Dredging Site
District Headquarter
Thana Headquarter
Important Place
Gauge Index
Rainfall Station
Hydrometric Station
Water Level Gauge
Scale
5km 0 5km 10km
N
Sunamganj
Nilpur
Closure
Dowarabazar
Chhattak
R-107
R-127
R-124
R-128
R-129
R-20
SYLHET
Deker Haor
Panda K
Madhabpur
Mohasing R
Bhattak K
Biswanath
Bahia N
Jagannathpur
Itakhola N
Barbhanga N
Golabganj
Beanibazar
Jaldhup
Sheola
Zakiganj
Amalshid
Kanaighat
Surma R
Kushiyara R
Damrir Haor
Fenchuganj
Barlekha
Hakaluki Haor
Juri R
Juri
Kulaura
Maijail-Dubrir Haor
Balaganj
Sadipur K
Sherpur
Manumukh
Manu River Project
Manu R
Moulvibazar
Borak R
Terapasha
Nabiganj
SWMC
Bania-chong
Gangajuri R
Ratna R
Habiganj
Markuli
Closure
Bibiyana R
Kalni R
Old Kushiyara R
Old Surma R
Sullah
Ajmiriganj
Bheramohona Closure
Itna
Dhanpur
Kaliajuri
Alipur
Sukdevpur
Baulai R
Derai
Kalimpur
Mitamain
Madna
Dhaleswari R
Lakhai
Austagram
Upper Megna
269
268
267
270
271
272
273
174
175.5
91°00'
91°15'
91°30'
91°45'
92°00'
92°15'
92°30'
25° 00'
24° 45'
24° 30'
24° 15'
FILE 1843.DWG

Figure 1

Note abandoned Bibyana R

Manu R.

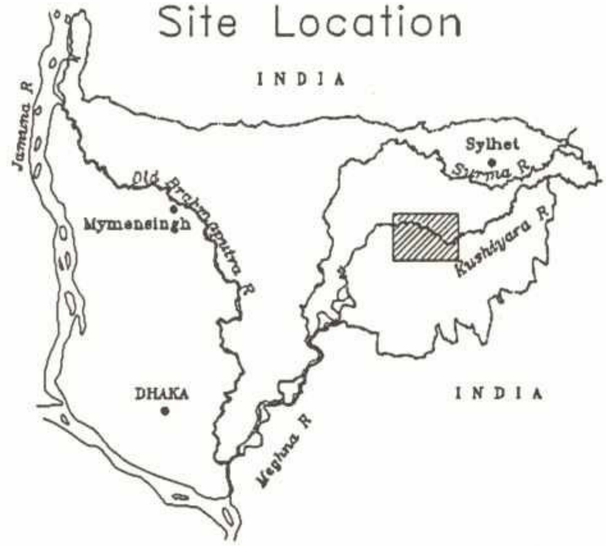
Scale

2 0 2 4 km

Approx.

N

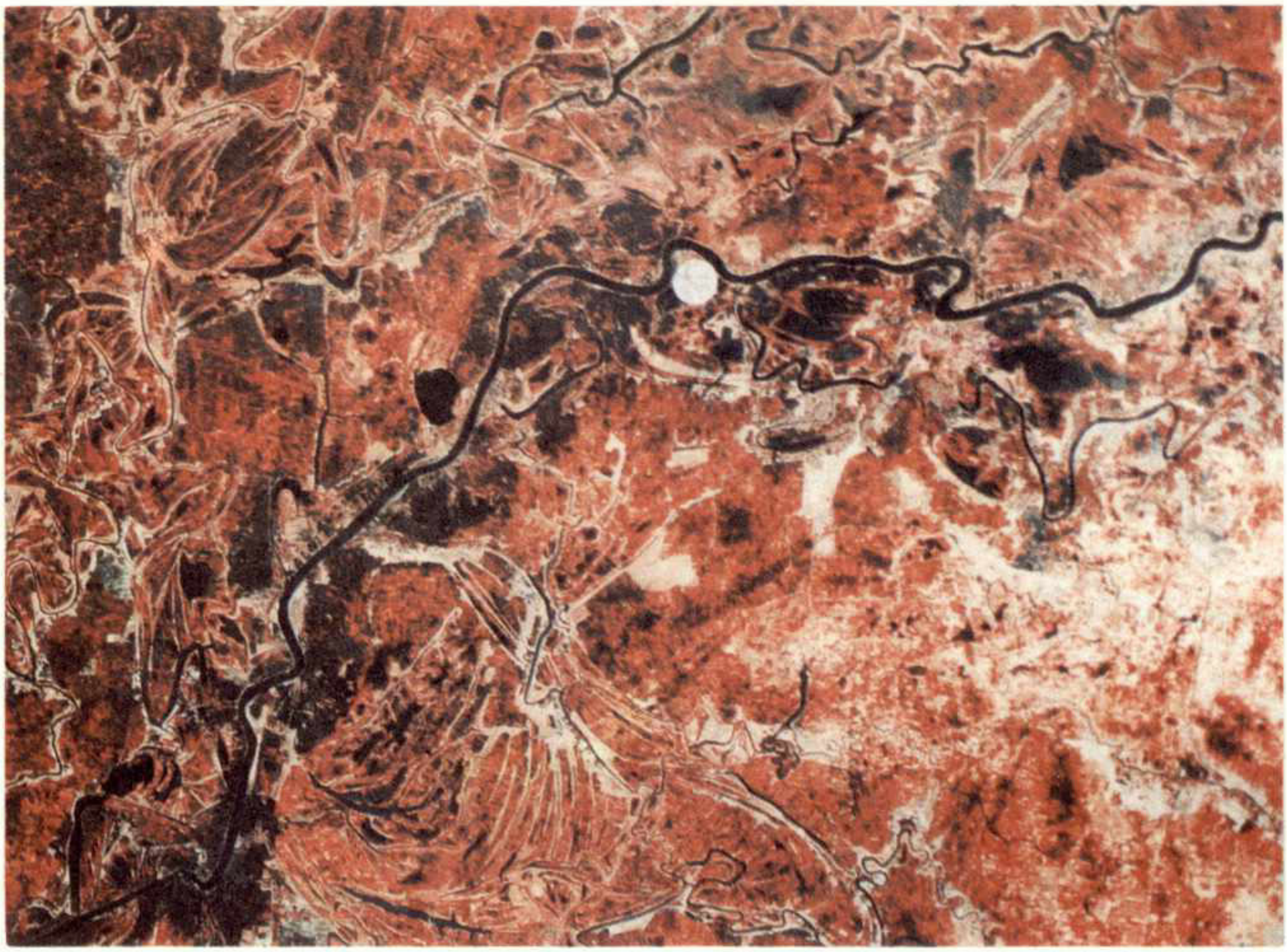
Site Location



SPOT image 78P10

Northeast Regional Project	
Kushiyara River Near Sherpur	
Prepared by: DMc	May 1993

FILE: dm193.DWG



Note Loop cuts and abandoned Bibyana R

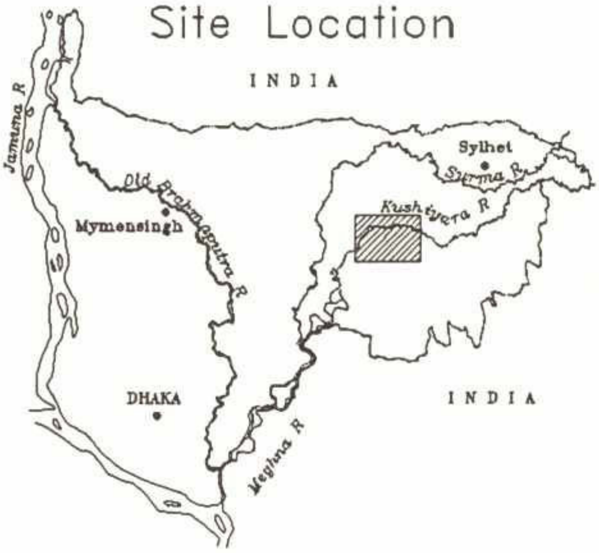
Scale

2 0 2 4 km

Approx.

N

Site Location



SPOT Image 78P6

Northeast Regional Project	
Kalni River Near Markuli	
Prepared by: DMc	May 1993

FILE: dm194.DWG

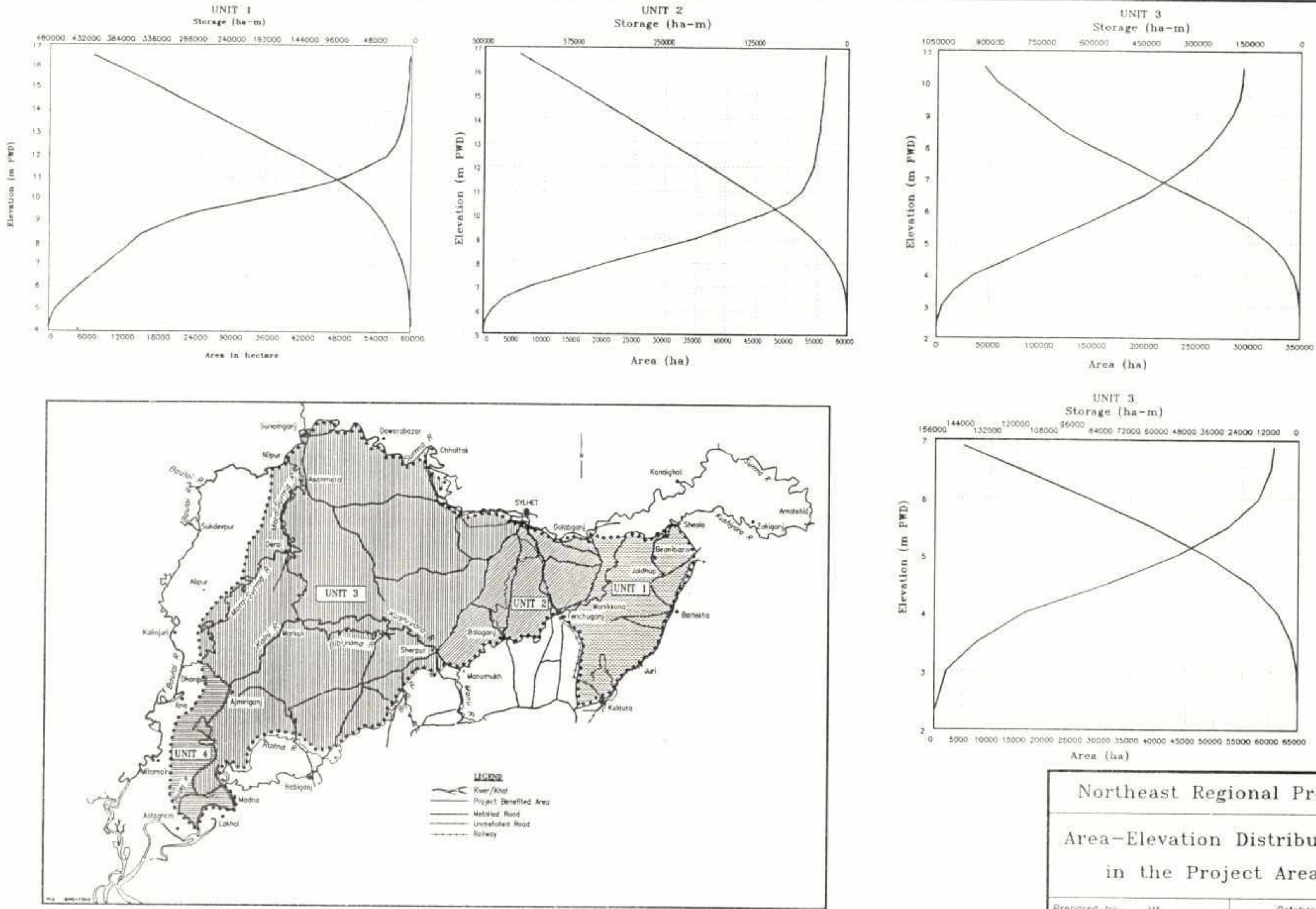


Figure 4

Northeast Regional Project

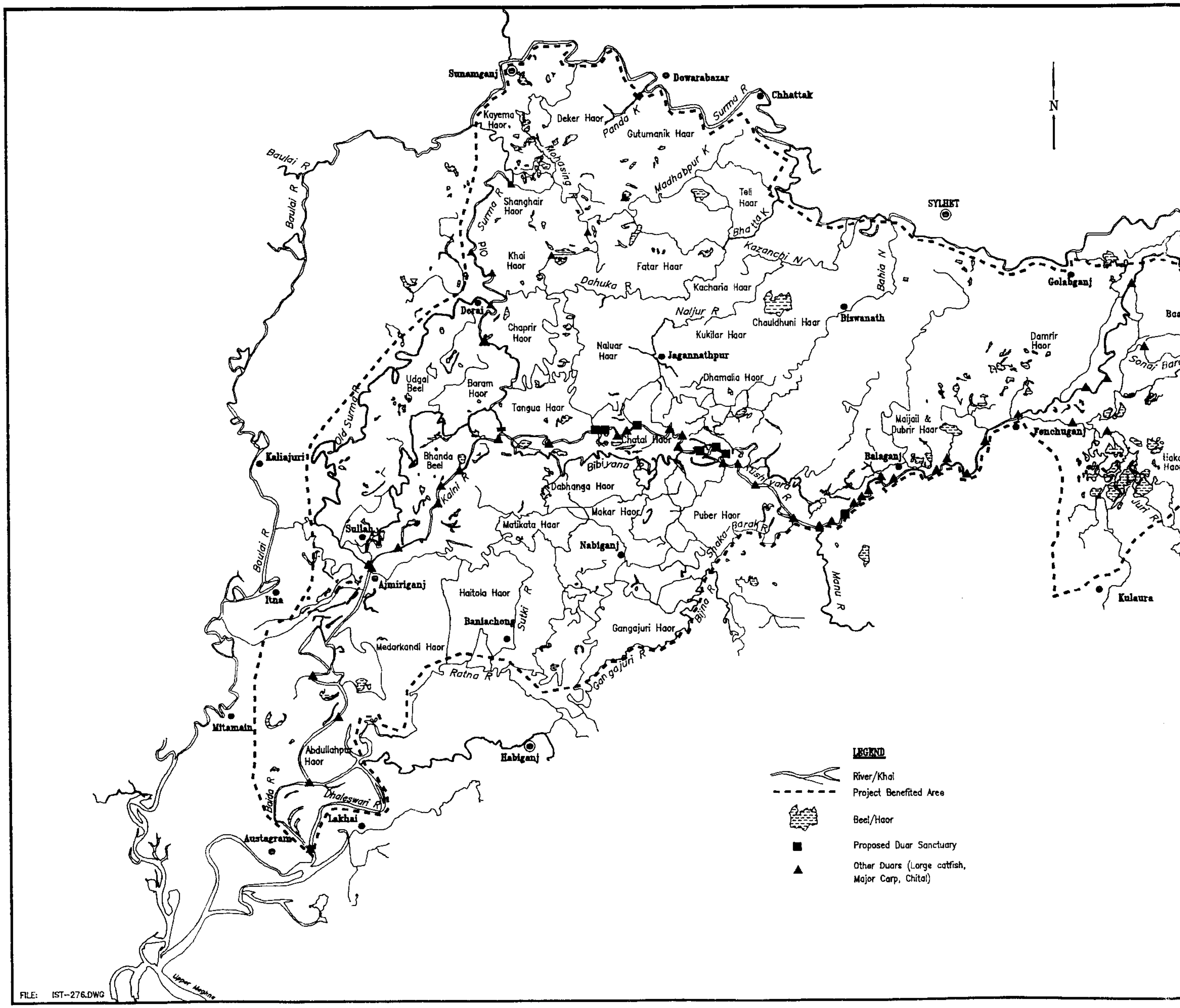
Area-Elevation Distribution in the Project Area

Prepared by:	MA	October 1994
Drawn by:	Mamun	AutoCAD Drawing

FILE: NERP-B96.DWG

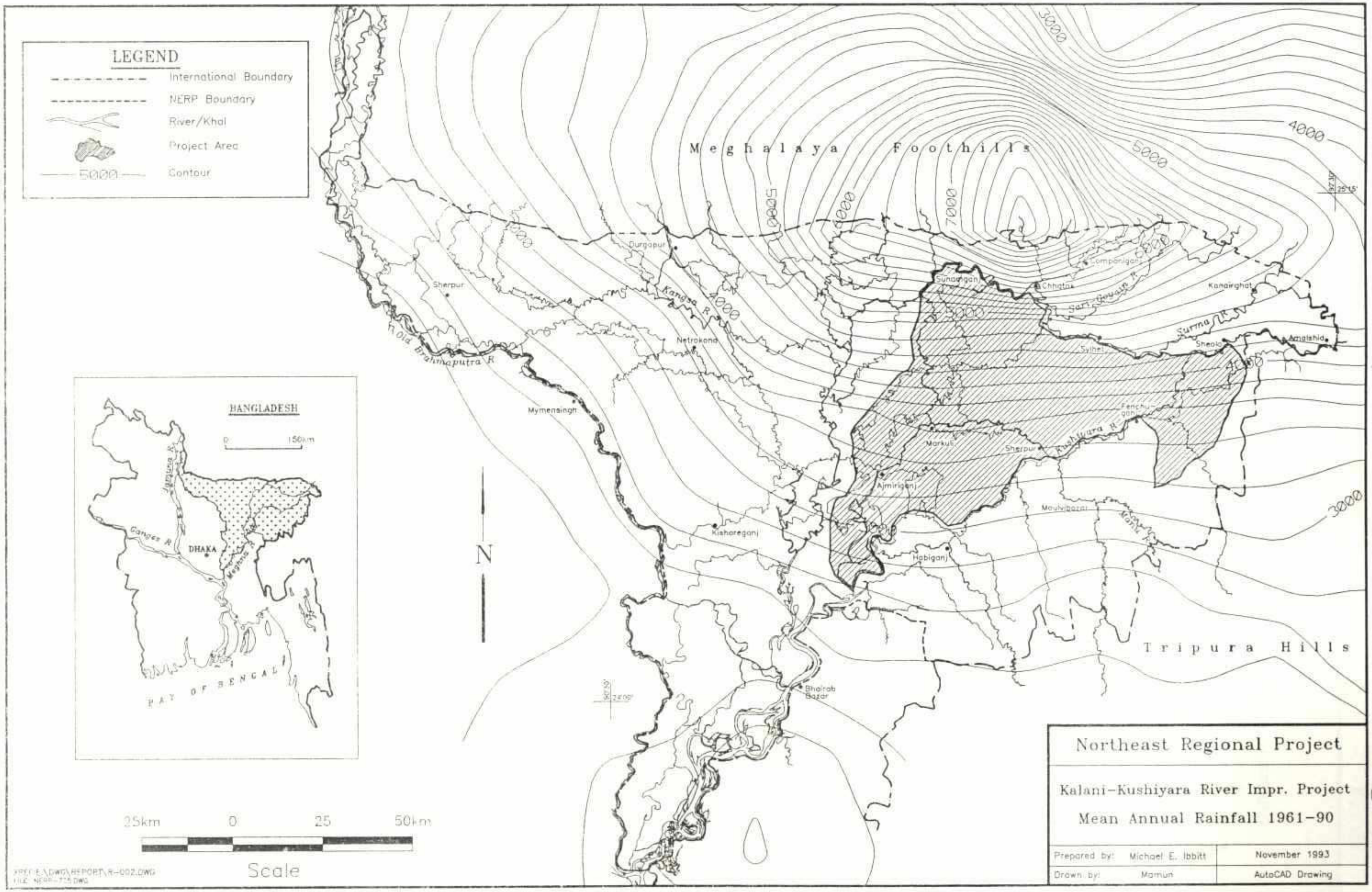
Figure 5

221



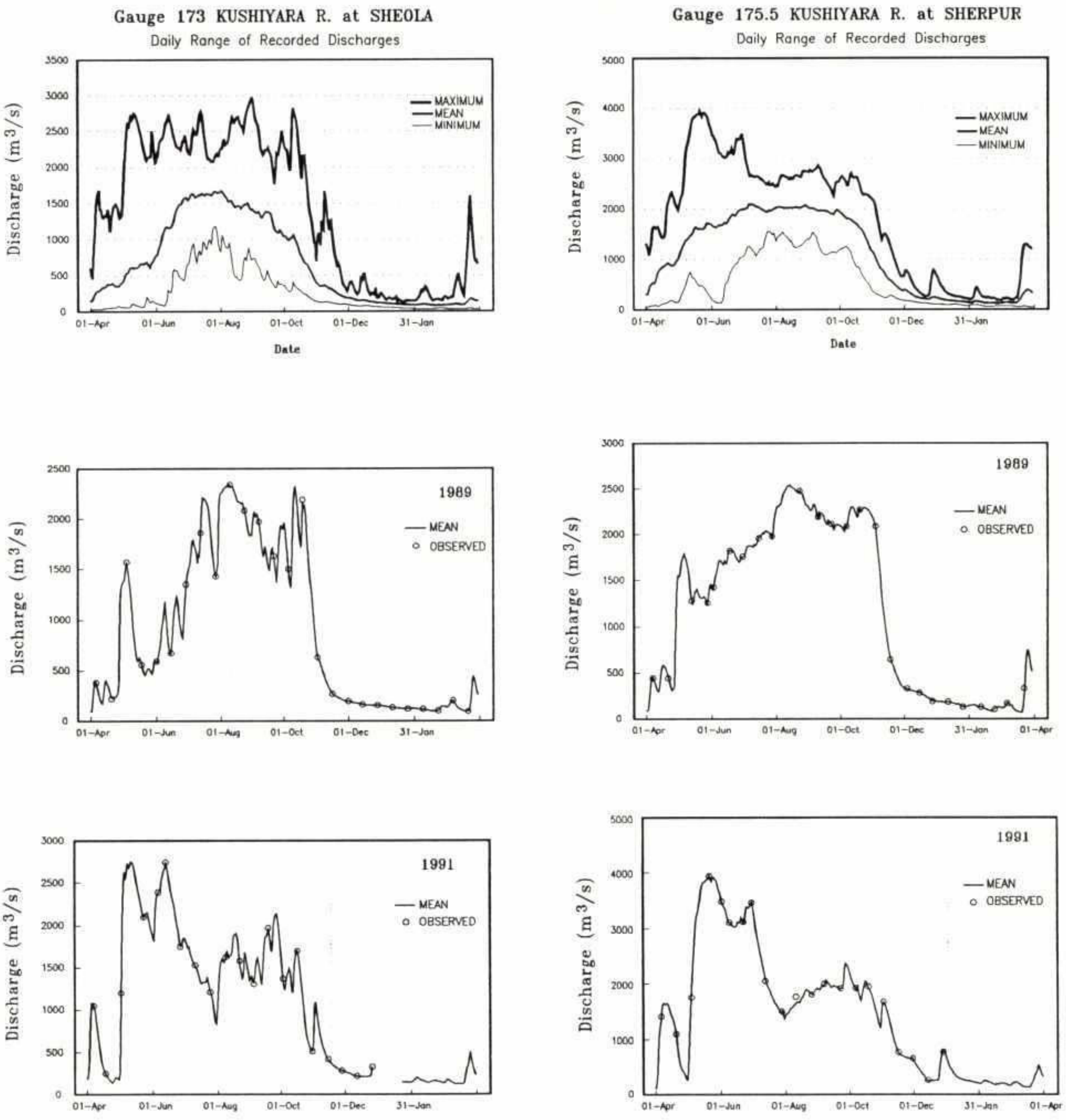
Northeast Regional Project	
Permanent Water Bodies	
Kalin-Kushiyara River Impr. Project	
Prepared by: MA/Istiak	September 1994
Drawn by: Mamun/Jalal	AutoCAD Drawing

Figure 6



LEGEND
International Boundary
NERP Boundary
River/Khal
Project Area
5000
Contour
Meghalaya Foothills
Tripura Hills
3000
4000
5000
6000
7000
Durgapur
Sherpur
Kangsa R.
Netrokona
Old Brahmaputra R.
Mymensingh
Kishoreganj
Sunamganj
Chhatak
Companiganj
Kanairghat
Sari Goyain R.
Surma R.
Sylhet
Sheola
Amalshid
Fenchuganj
Kushiyara R.
Sherpur
Markuli
Ajmiriganj
Moulvibazar
Manu R.
Habiganj
Bhairab Bazar
N
BANGLADESH
150km
Jamuna R.
Ganges R.
DHAKA
Meghna R.
BAY OF BENGAL
25km 0 25 50km
Scale
Northeast Regional Project
Kalani-Kushiyara River Impr. Project
Mean Annual Rainfall 1961-90
Prepared by: Michael E. Ibbitt
November 1993
Drawn by: Mamun
AutoCAD Drawing

Figure 7



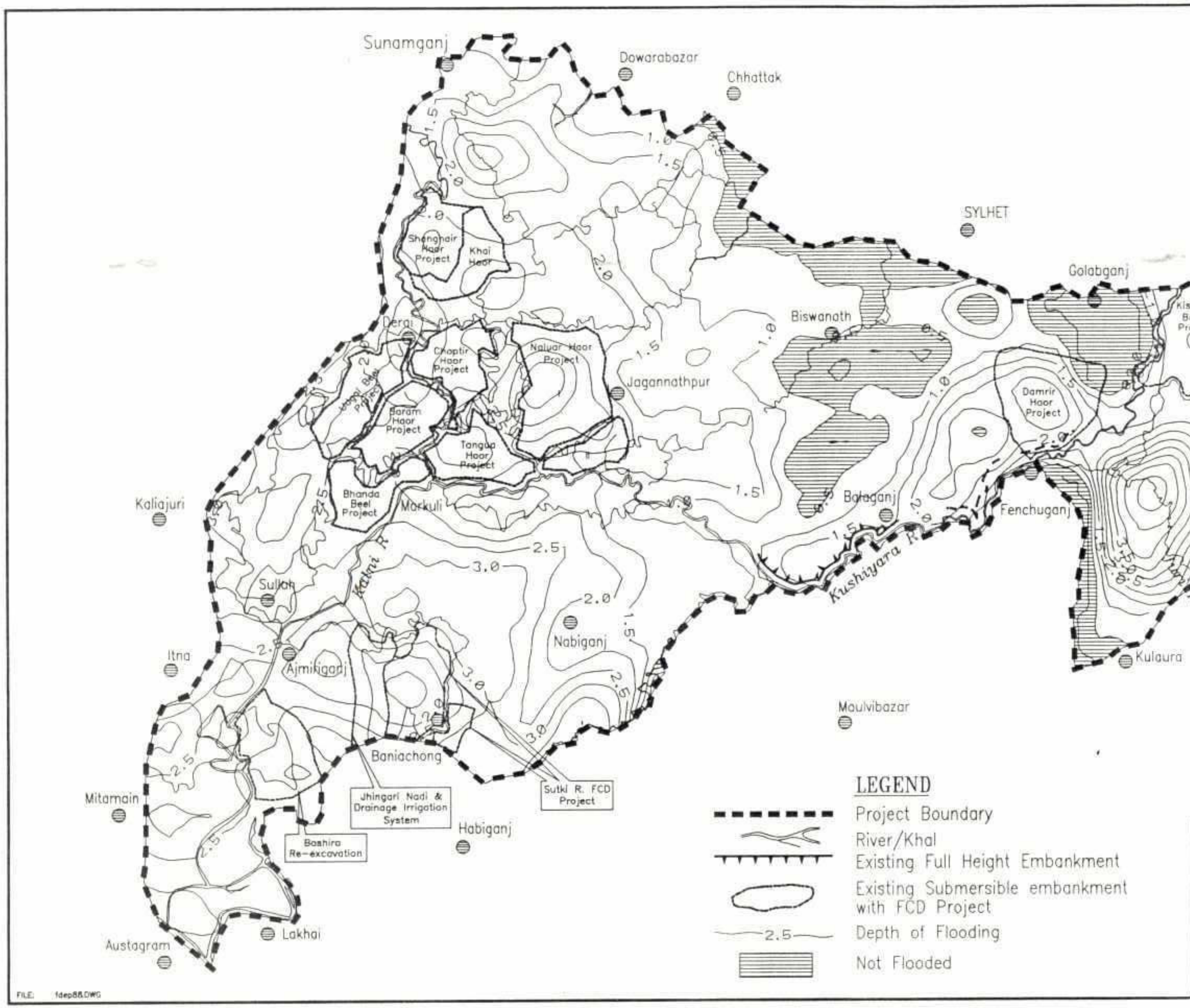
Northeast Regional Project

Discharge Hydrographs on Kushiyara River

Prepared by: Nahid	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: NERP-774.DWG

Figure 8

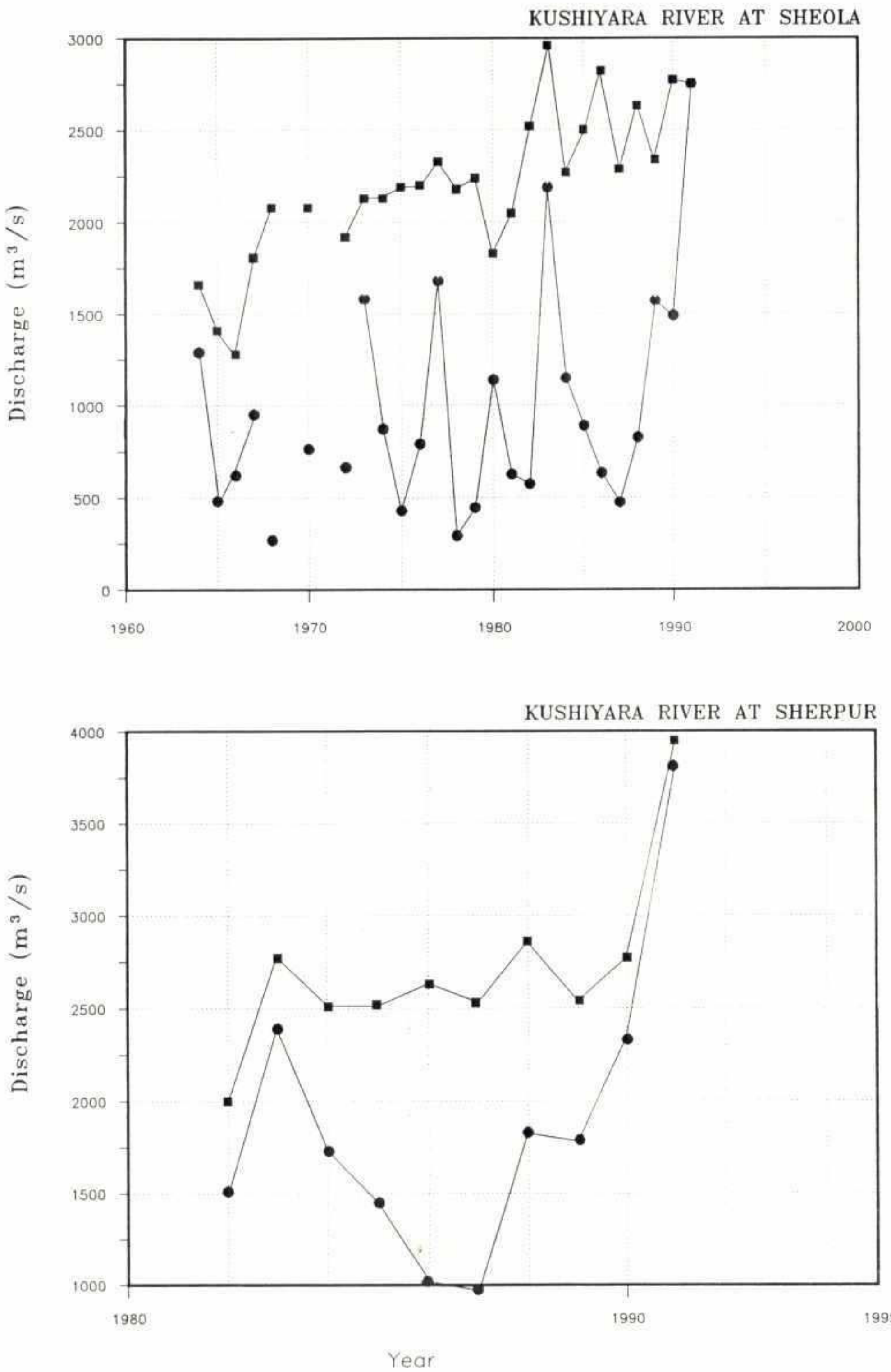


Northeast Regional Project

Flooding in 1988 Relative to Existing Project

Prepared by: MA	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

Figure 9



Legend:

- ■ Annual Maximum
- ● Maximum in Pre-monsoon

Note:

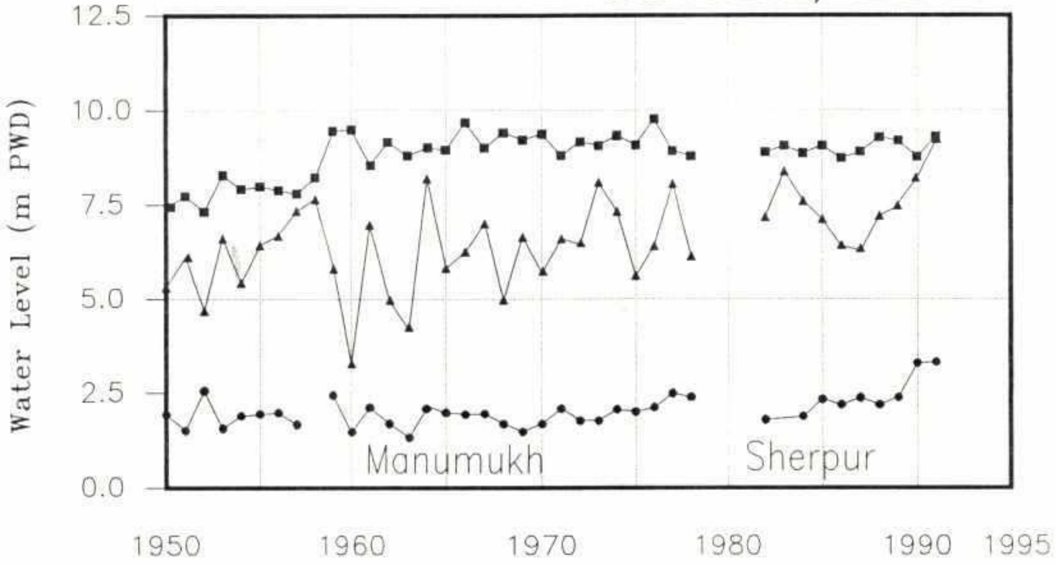
Pre-monsoon season is period from March 1 - May 15

Northeast Regional Project	
Maximum Daily Discharges Kushiyara River	
Prepared by: Dave G. Mclean	May 1993
Drawn By: Mamun	AutoCAD Drawing

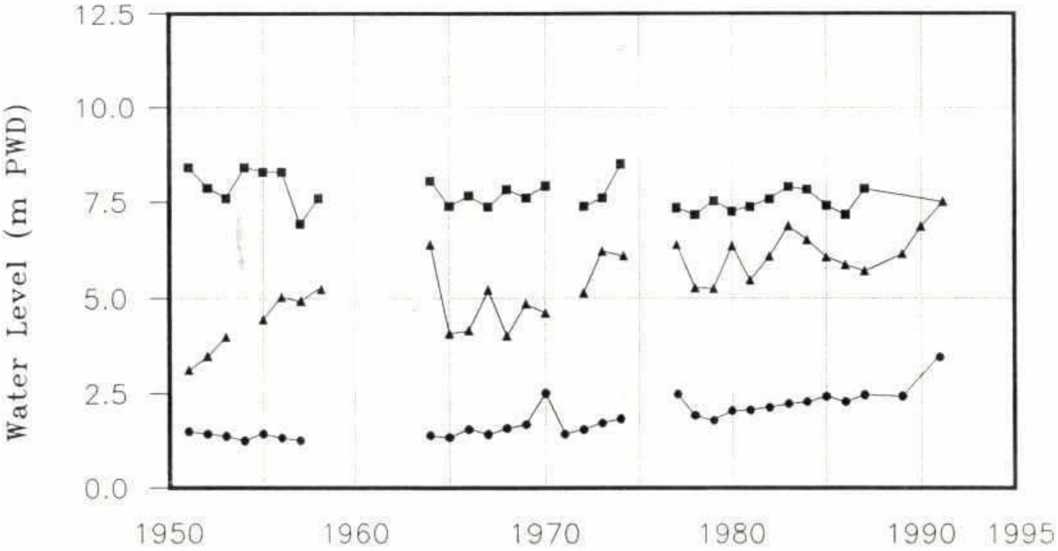
FILE: NERP-689DWG

Figure 10

MANUMUKH/SHERPUR



MARKULI



LEGEND

- ▪ Annual Maximum
- ▴ Pre-Monsoon
- • Manimum

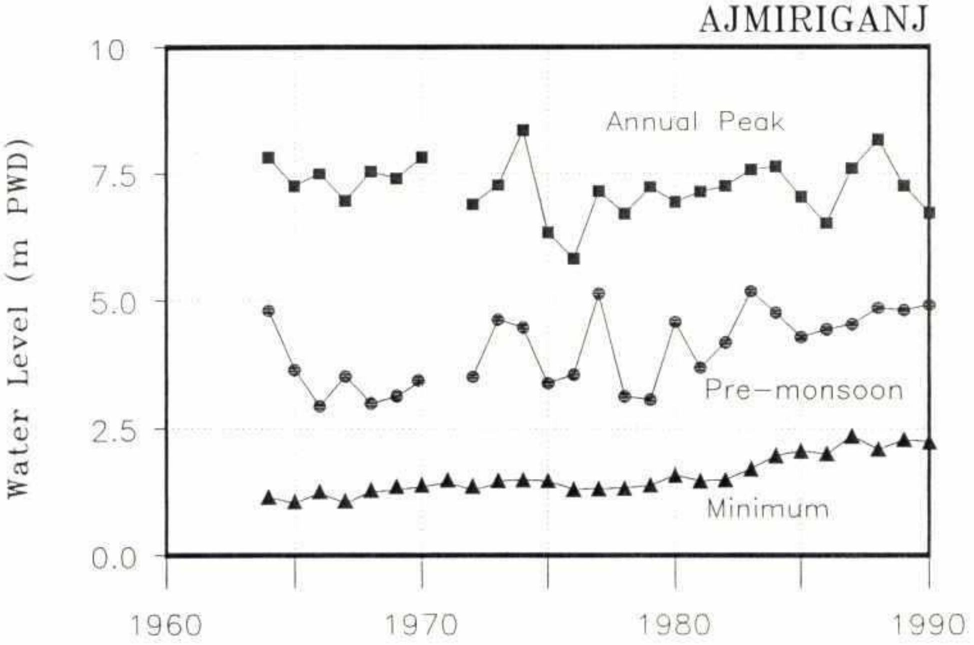
Northeast Regional Project

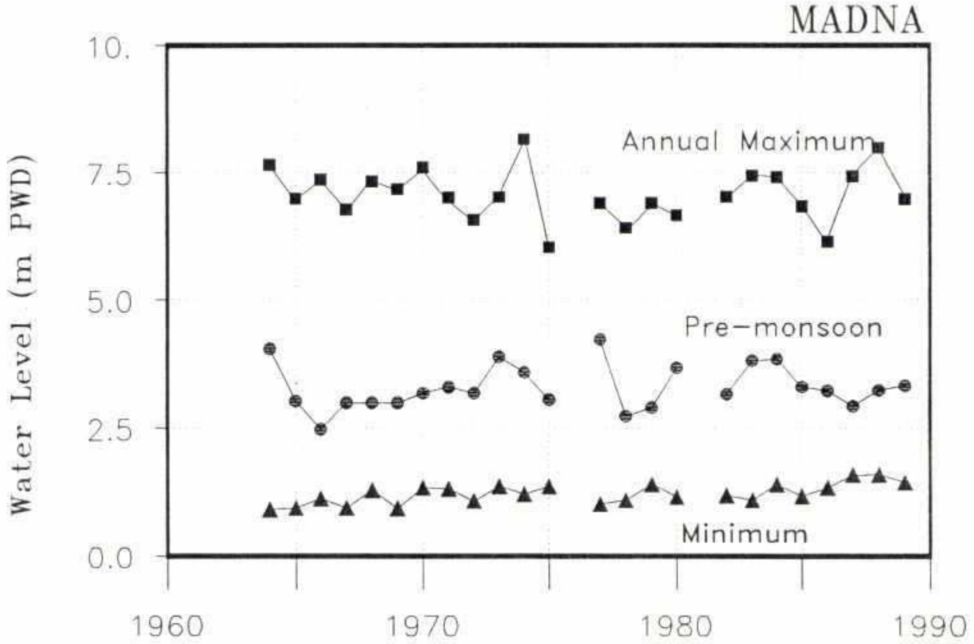
Annual Water Levels
Kushiyara River

Prepared by: DMc	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: dm254.DWG

Figure 11





LEGEND

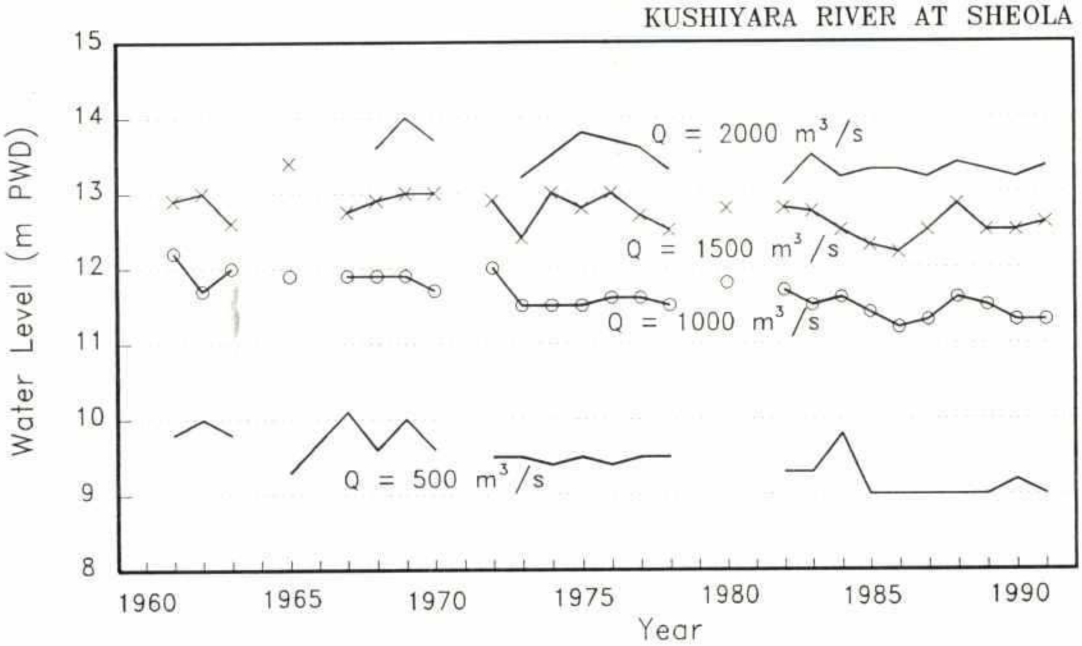
- ■ Annual Maximum
- ● Pre-monsoon
- ▲ Minimum

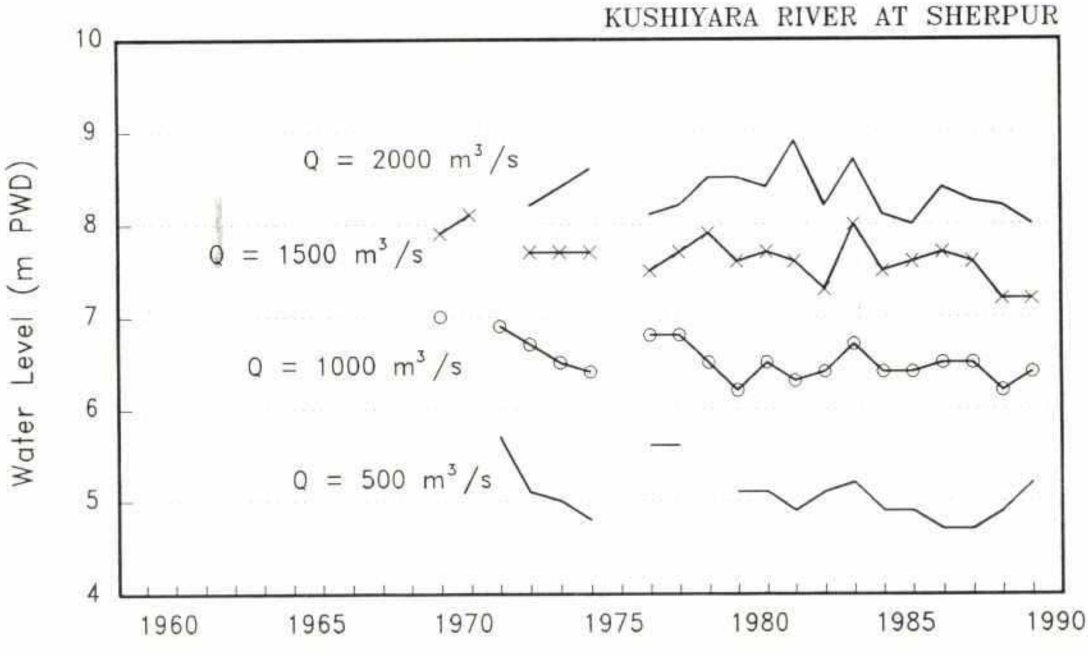
Northeast Regional Project

Annual Water Levels
Kalni River

Prepared by: DMc	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: dm255.DWG





Note:
These Specific Gauge plots show trends in aggradation or degradation by comparing water levels at specified discharges. The plots are based on observed discharges and stages at BWDB hydrometric stations.

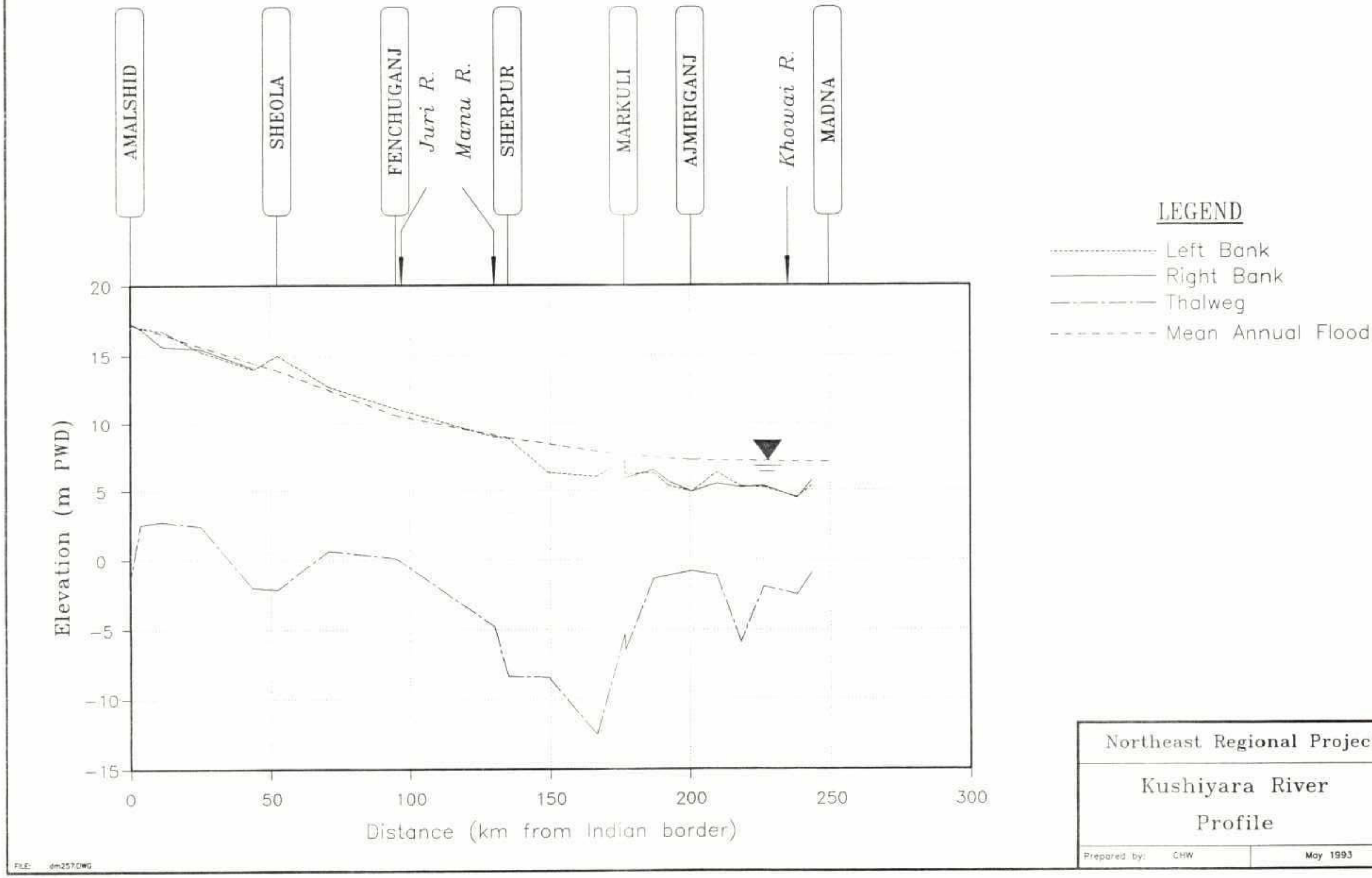
Northeast Regional Project

Specific Gauge Analysis Kushiyara River

Prepared by: DMc	November 1994
Computer Drafting by:Mamun	AutoCAD Drawing

FILE: dm237.DWG

Figure 13



Northeast Regional Project

Kushiyara River Profile

Prepared by: CHW | May 1993

229

Figure 14

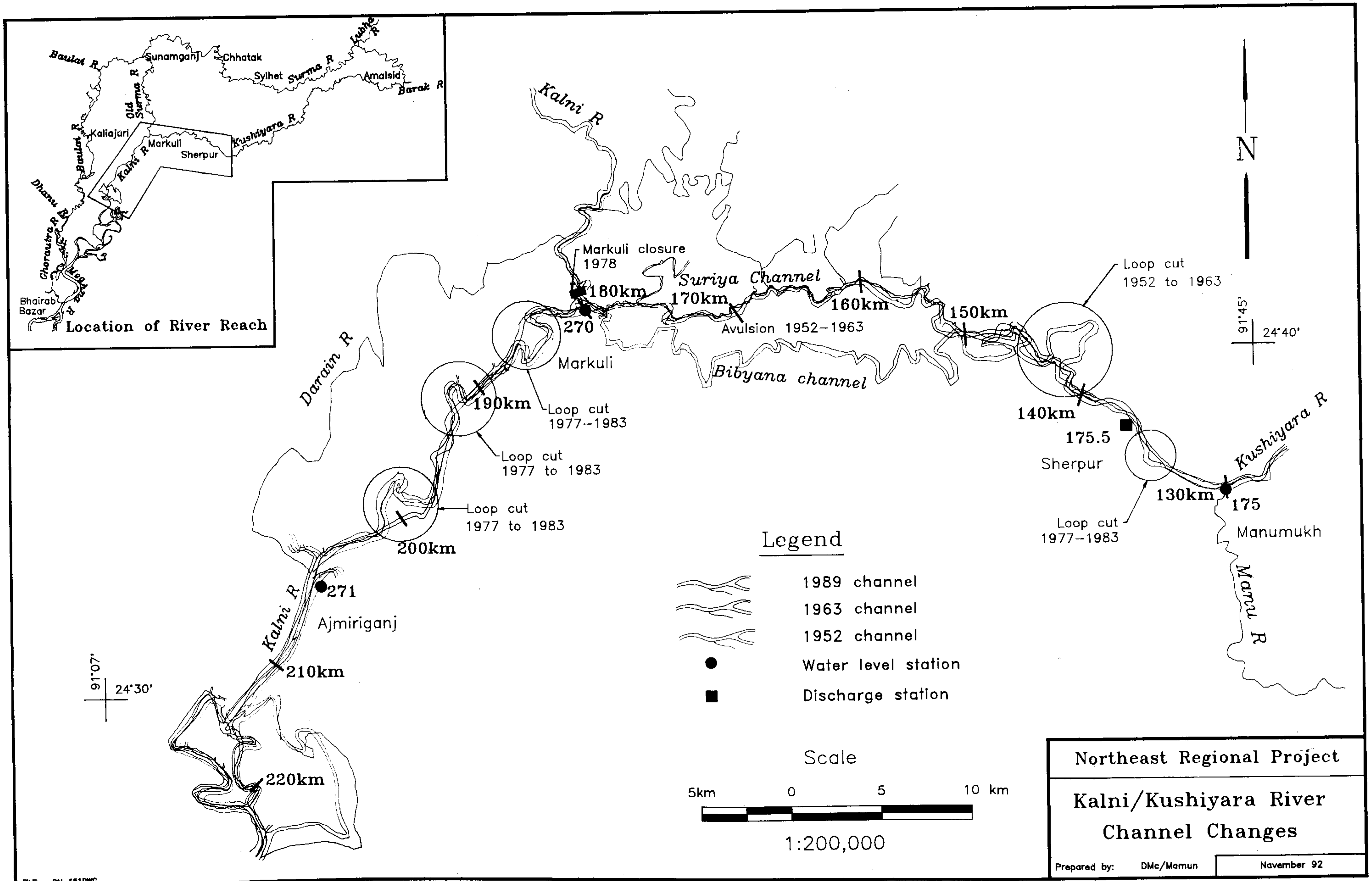
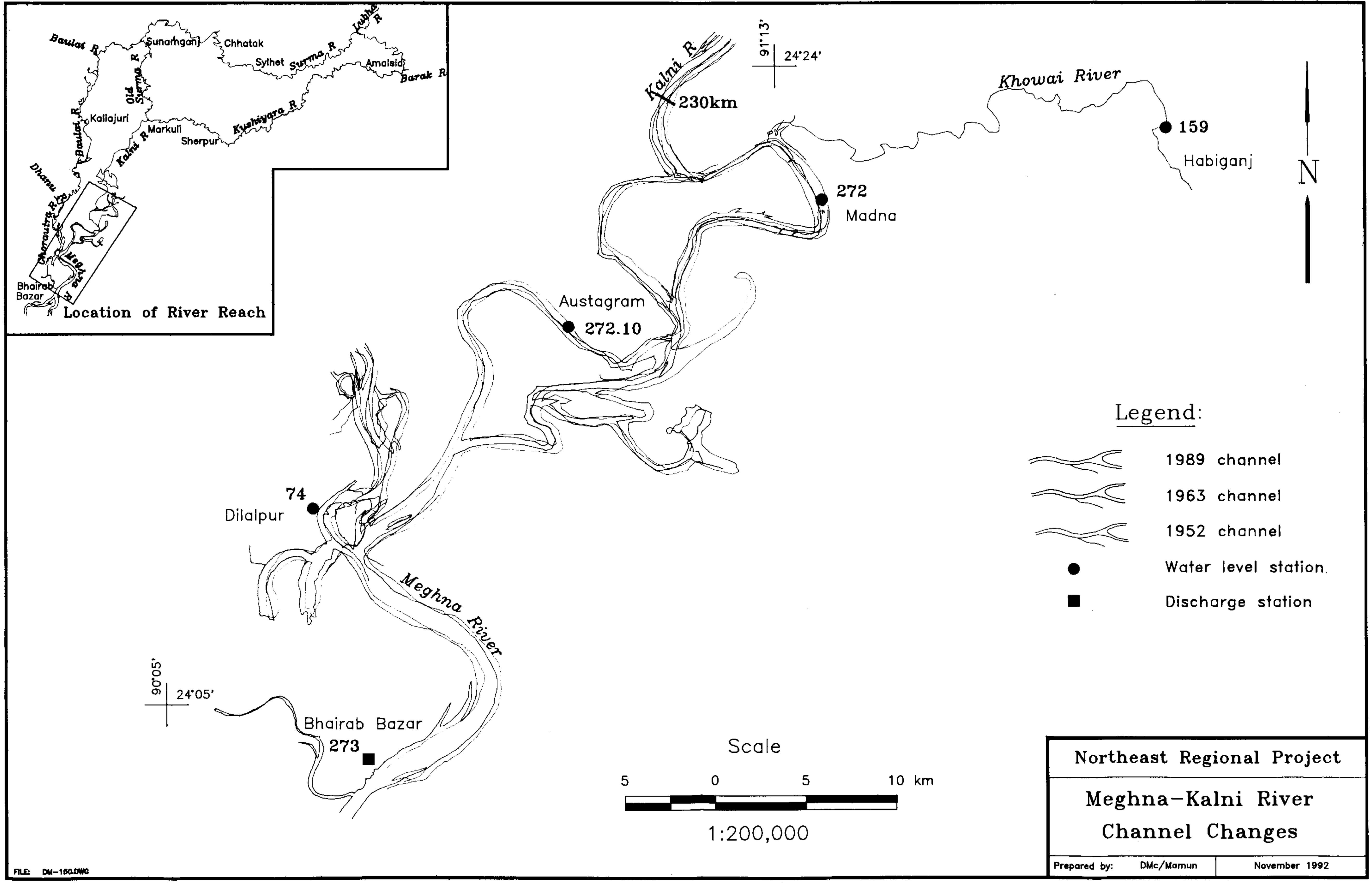
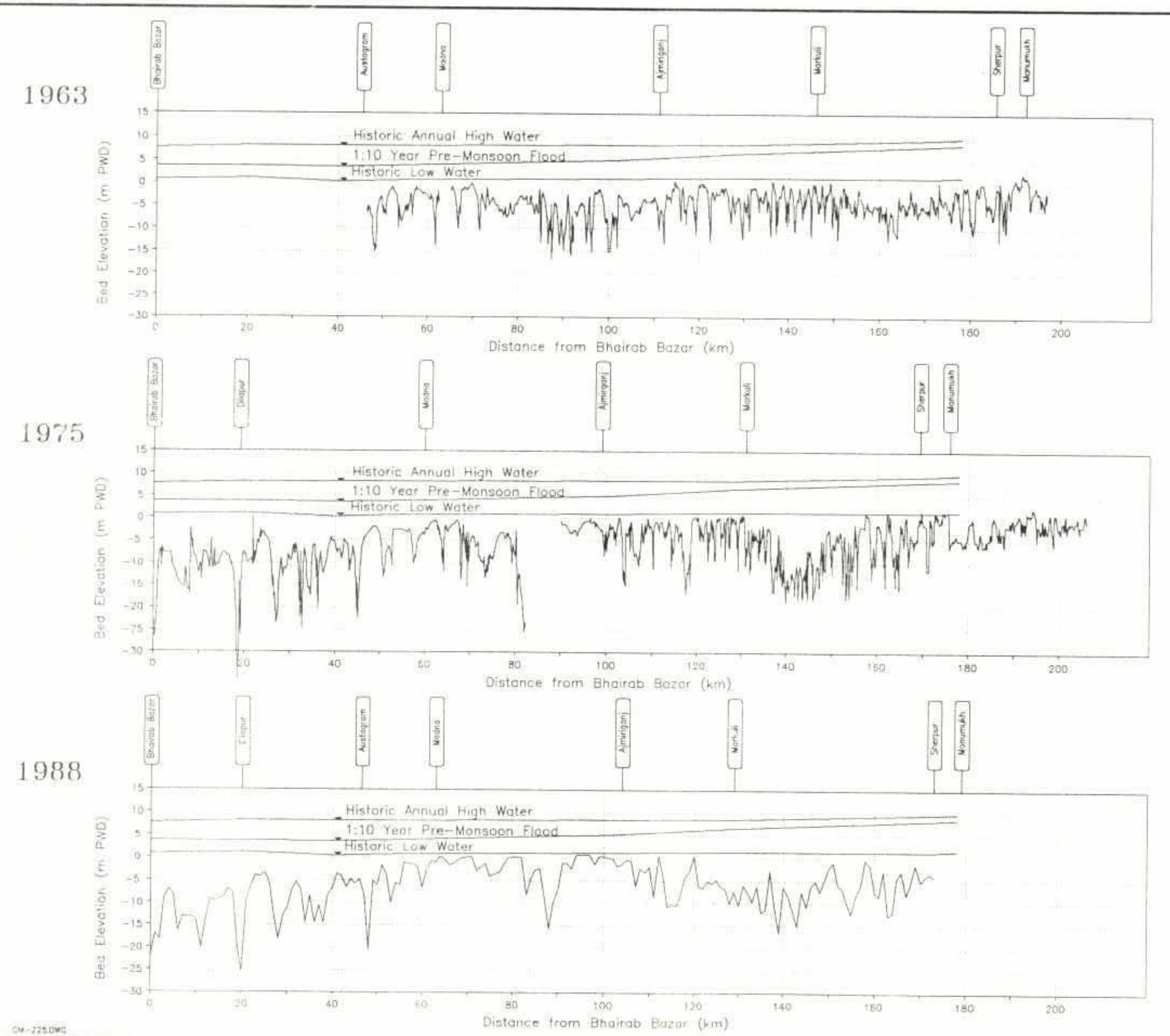


Figure 15



Northeast Regional Project	
Meghna–Kalni River Channel Changes	
Prepared by: DMc/Mamun	November 1992

Figure 16



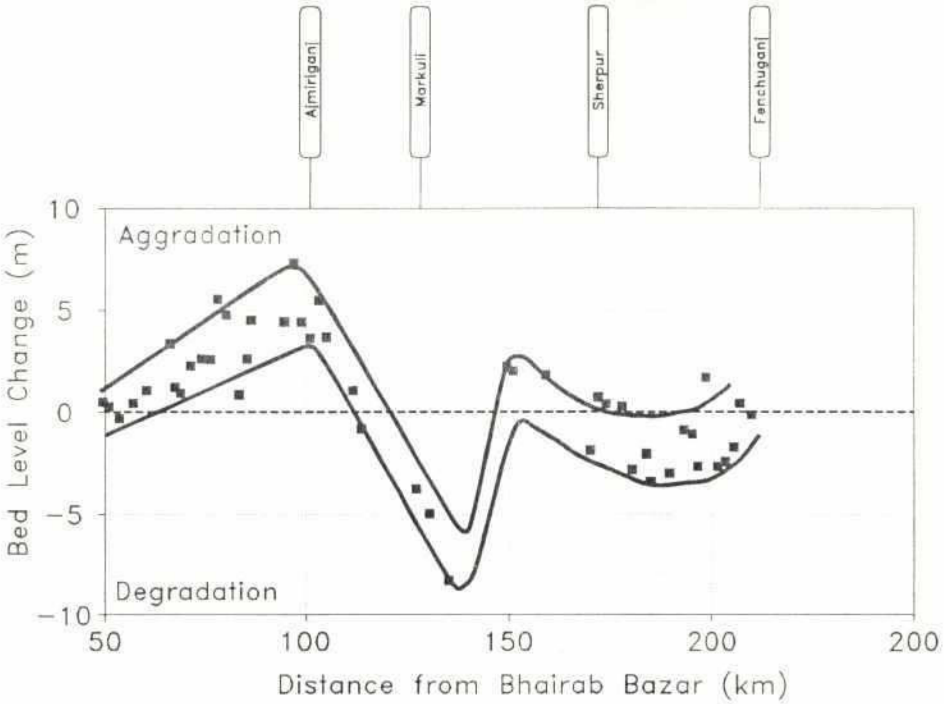
Note:
1. Bed levels from BIWTA navigation charts

Northeast Regional Project

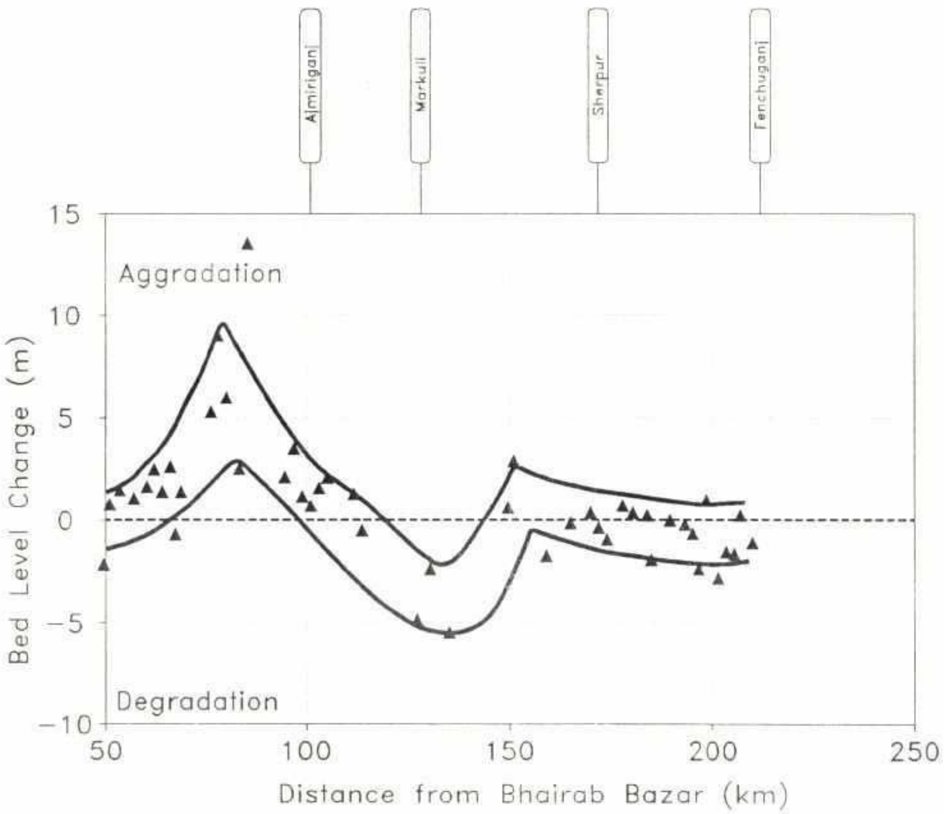
Longitudinal Profile of Kushiyara River

Prepared by: CHW | May 1993

২৩০



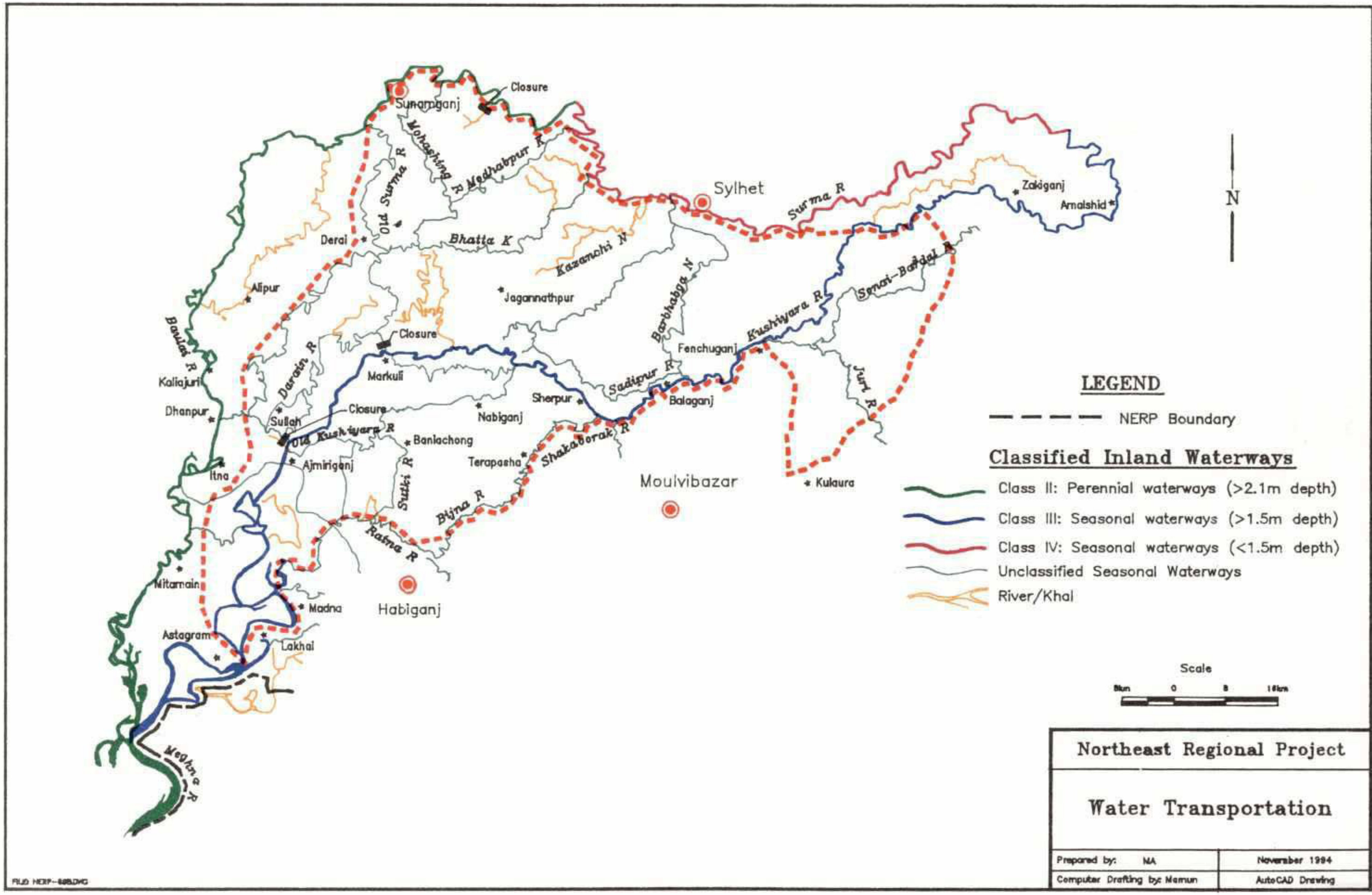
1963-1988



1975-1988

Northeast Regional Project	
Bed Level Changes Kusiyara River	
Prepared by: CHW	May 1993

FILE: dm-258.DWG

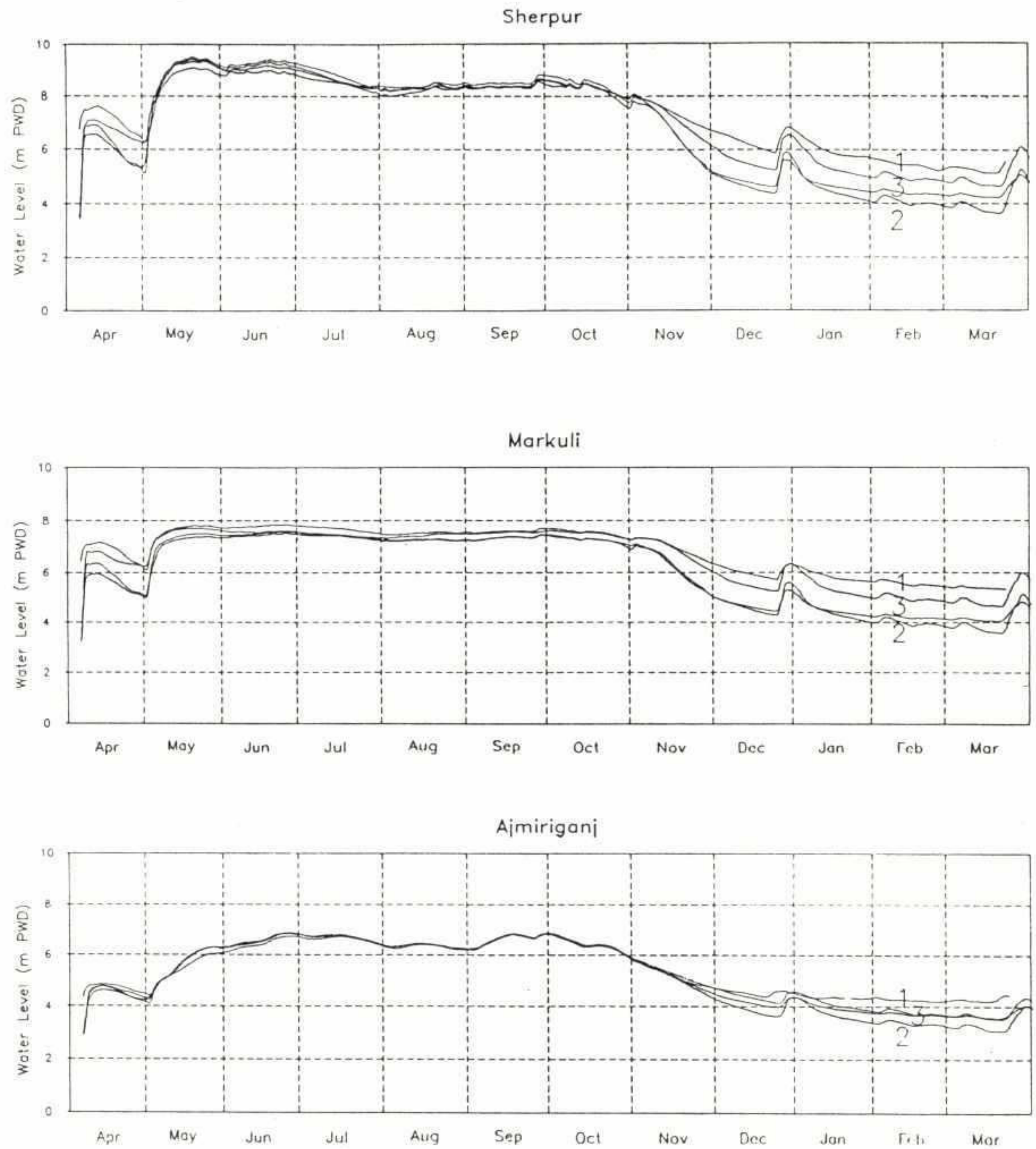


Northeast Regional Project

Water Transportation

Prepared by: NA | November 1994
Computer Drafting by: Mamun | AutoCAD Drawing

Figure 18



Legend:
1 FWO (Continued siltation)
2 Existing Conditions
3 With Channel Improvements

Note:
Tipaimukh dam included.
Simulations shown for 1991 water year.
Simulations made with MIKE11 hydrodynamic model.

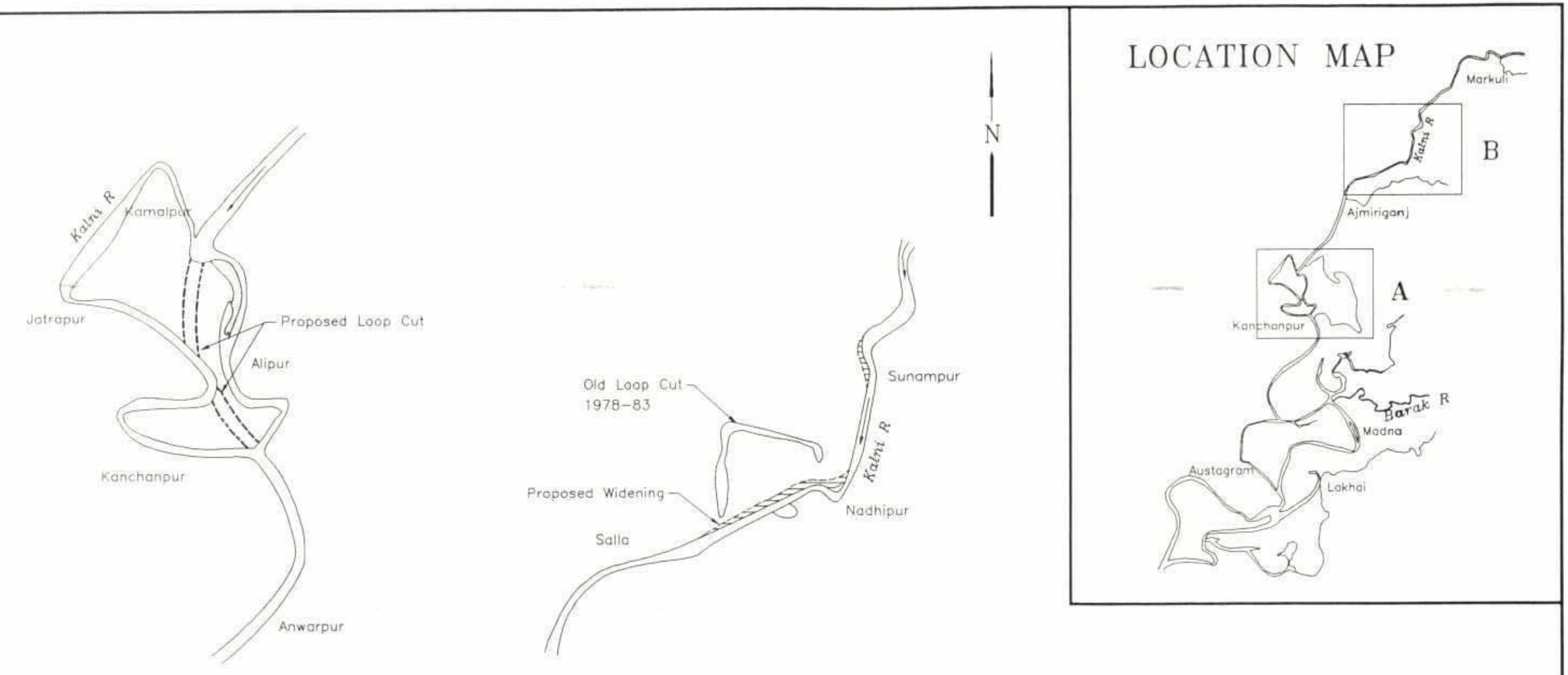
FILE: DM-261DWG

Northeast Regional Project

Water Levels After

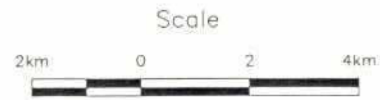
Tipaimukh Dam

Prepared by: DMc Jan 1994



A. Channel Re-alignment
in Split Reach
Downstream of Ajmiriganj

B. Channel Widening
at Former Loop Cut
near Ajmiriganj



FILE: NERP-780.DWG

Northeast Regional Project	
Proposed Channel Improvement on Kalni River	
Prepared by: DMc	January 1994
Drawn by: Mamun	AutoCAD Drawing

Figure 20

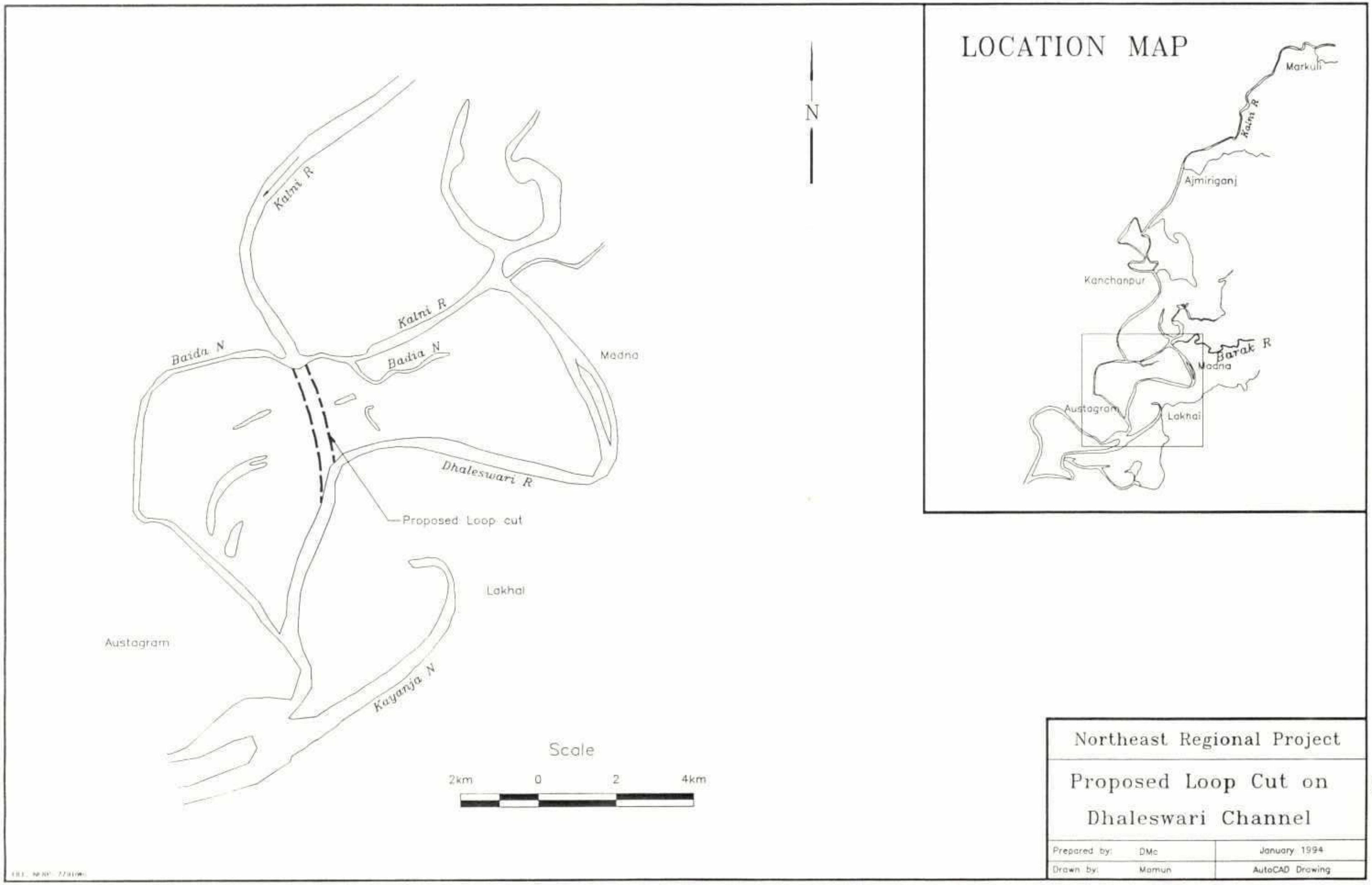
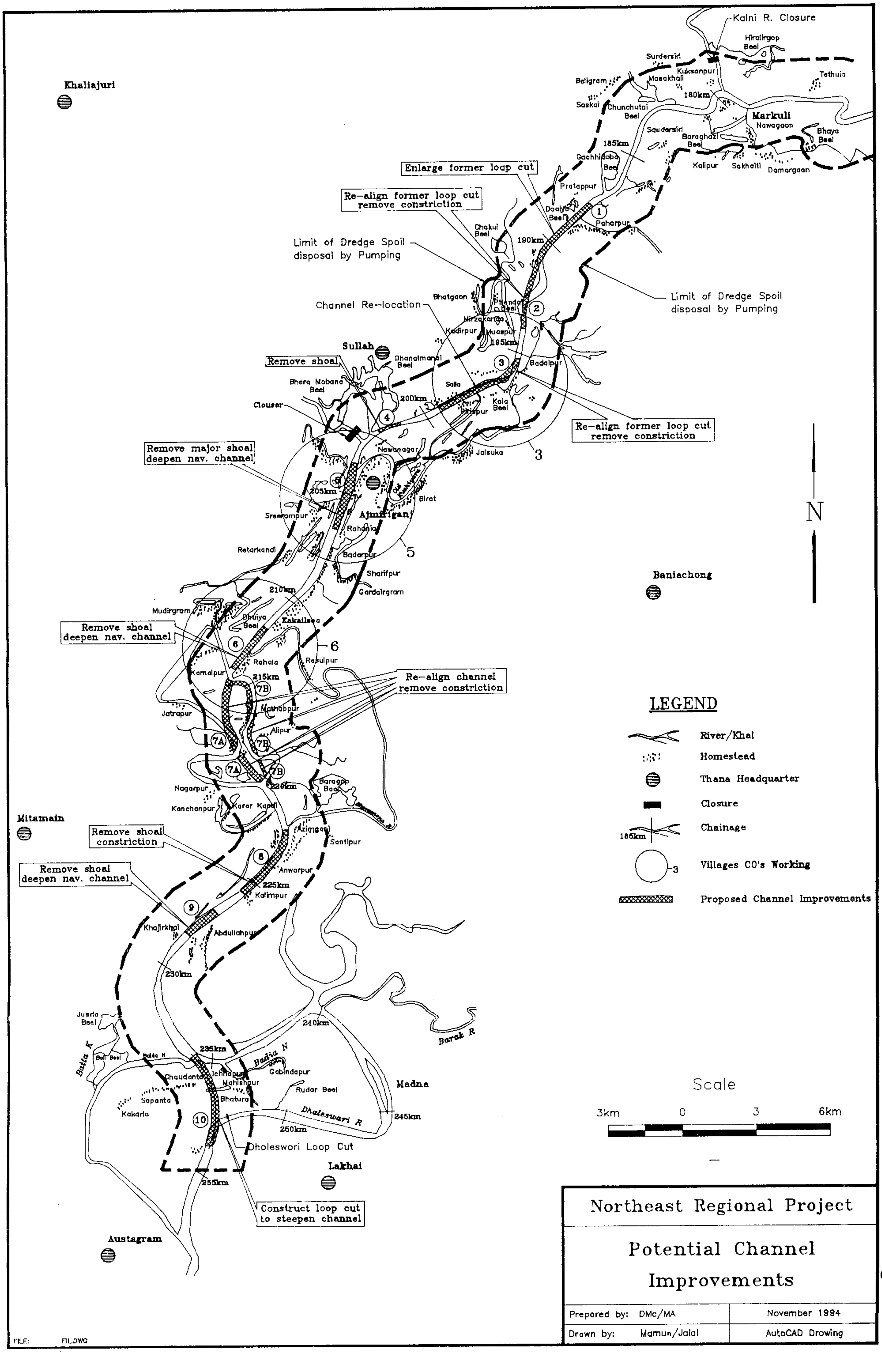

LOCATION MAP
Markuli
Kalni R
Ajmiriganj
Kanchanpur
Barak R
Madna
Austagram
Lakhai
N
Kalni R
Kalni R
Baida N
Badia N
Madna
Dhaleswari R
Proposed Loop cut
Lakhai
Austagram
Kayanja N
Scale
2km
0
2
4km
Northeast Regional Project
Proposed Loop Cut on
Dhaleswari Channel
Prepared by: DMc
January 1994
Drawn by: Mamun
AutoCAD Drawing

Figure 21



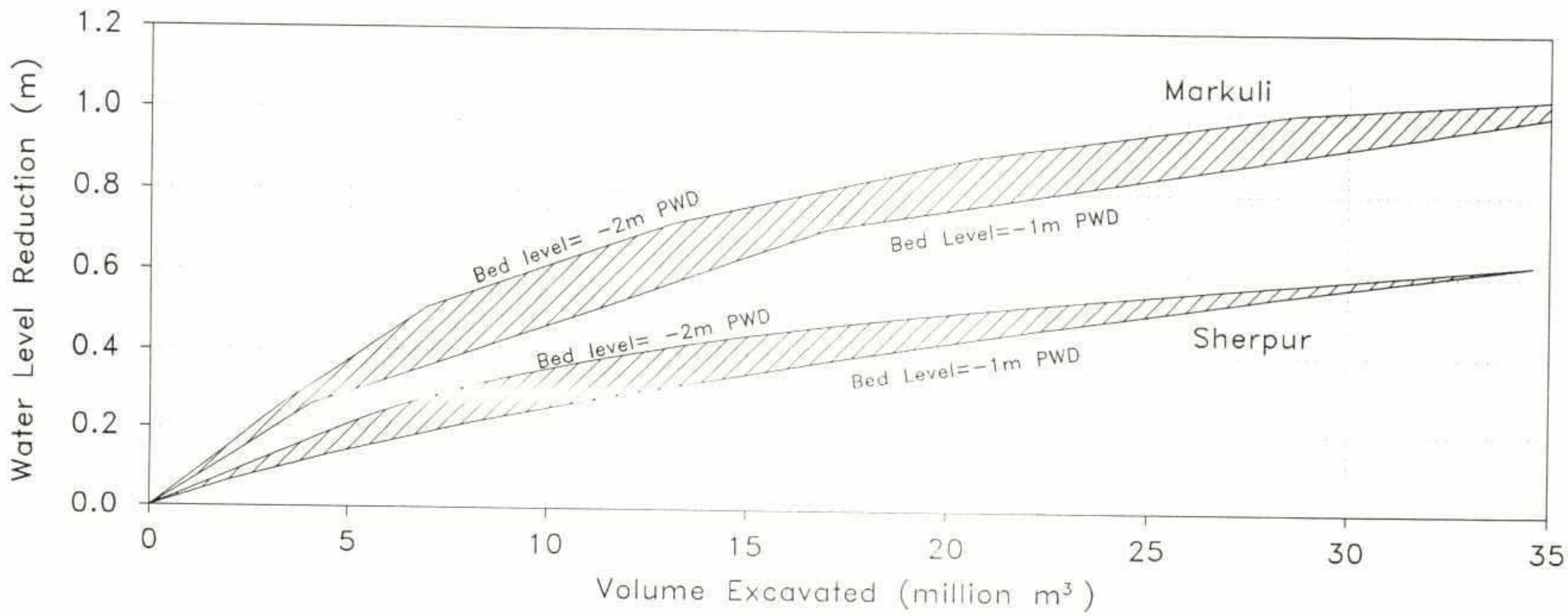
Northeast Regional Project

Potential Channel Improvements

Prepared by: DMc/MA	November 1994
Drawn by: Mamun/Jalal	AutoCAD Drawing

Figure 22

Figure 23



Note:

1. Computed for average pre-monsoon flood, 1980-1989.
2. Discharge at Sherpur=1,470 m^3/s
3. Effect of excavation varies with discharge and Meghna River stage.

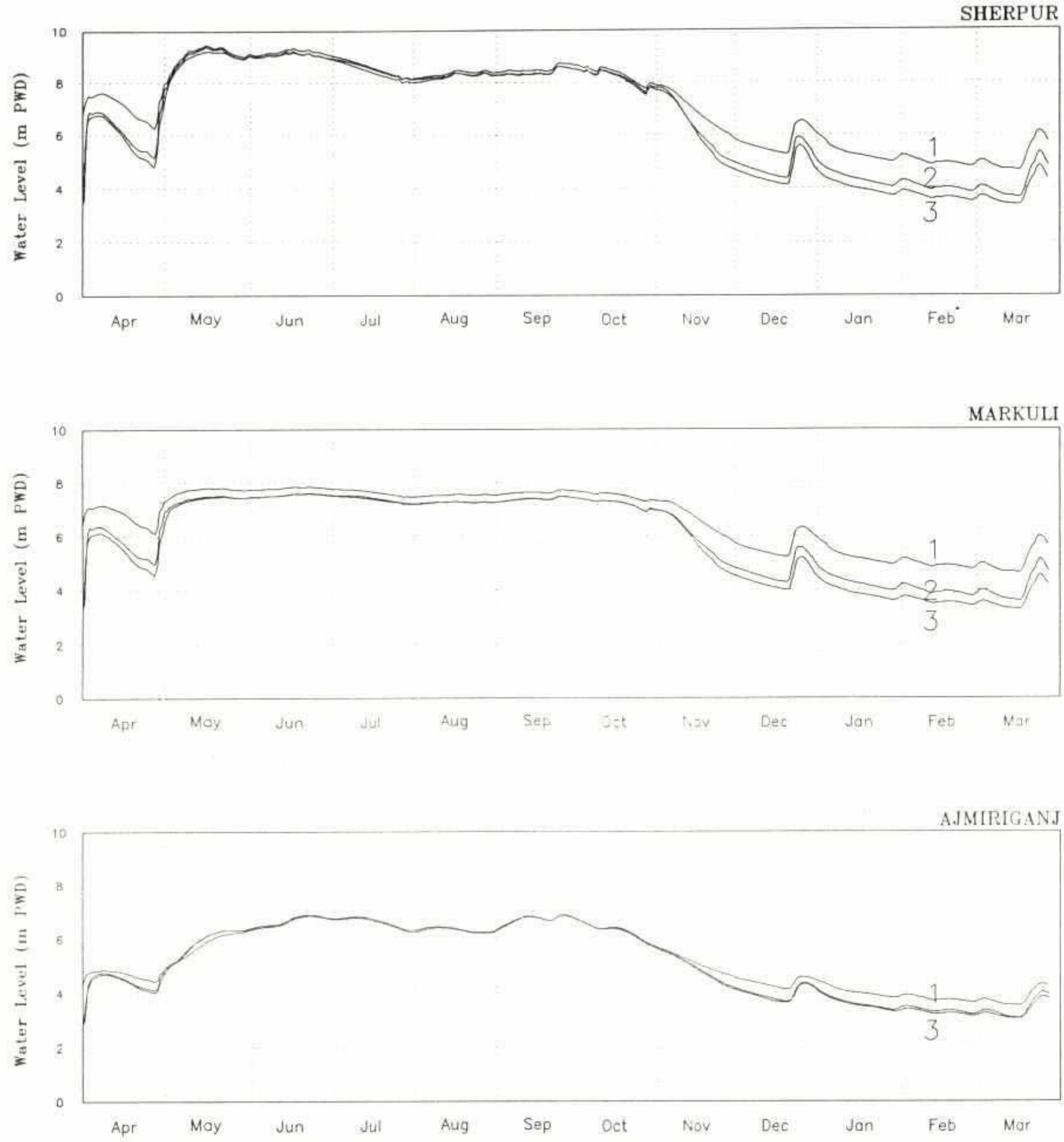
FILE: dm-231.DWG

Northeast Regional Project

Effect of Channel Excavation on Pre-Monsoon Water Levels

Prepared by: DMc | Jan 1994

Figure 24



Legend:
1 FWO (Continued siltation)
2 Existing Conditions
3 With Channel Improvements

Note:

Tipaimukh dam not included.

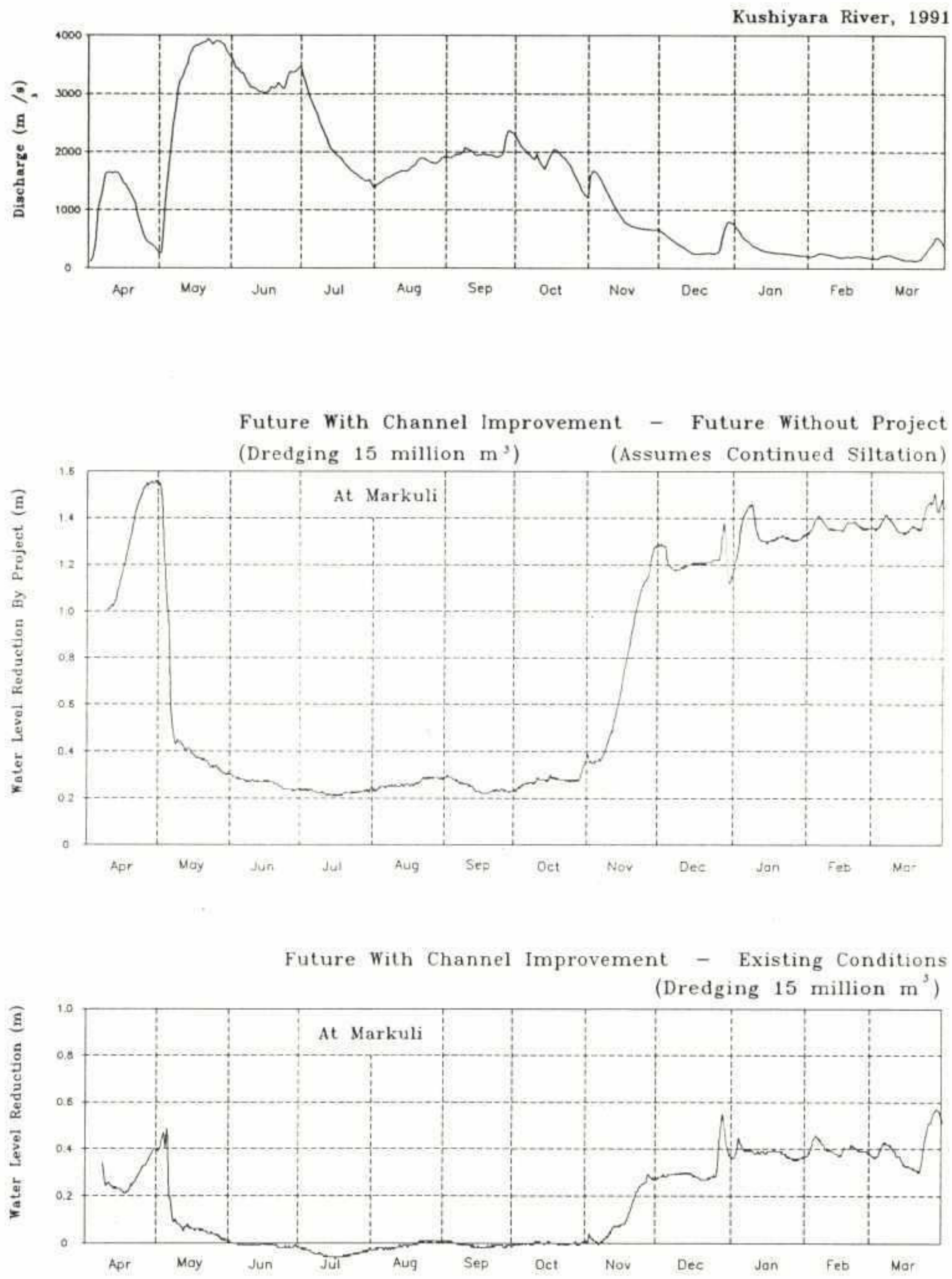
Simulations shown for 1991 water year.

Simulations made with MIKE11 hydrodynamic model.

Northeast Regional Project	
Water Levels For Three Scenarios	
Prepared by: DMc	January 1994

FILE: dm-259.DWG

Figure 25



Note:
Tipaimukh Dam not included in this simulation.

Water level changes estimated with MIKE11 hydrodynamic model.

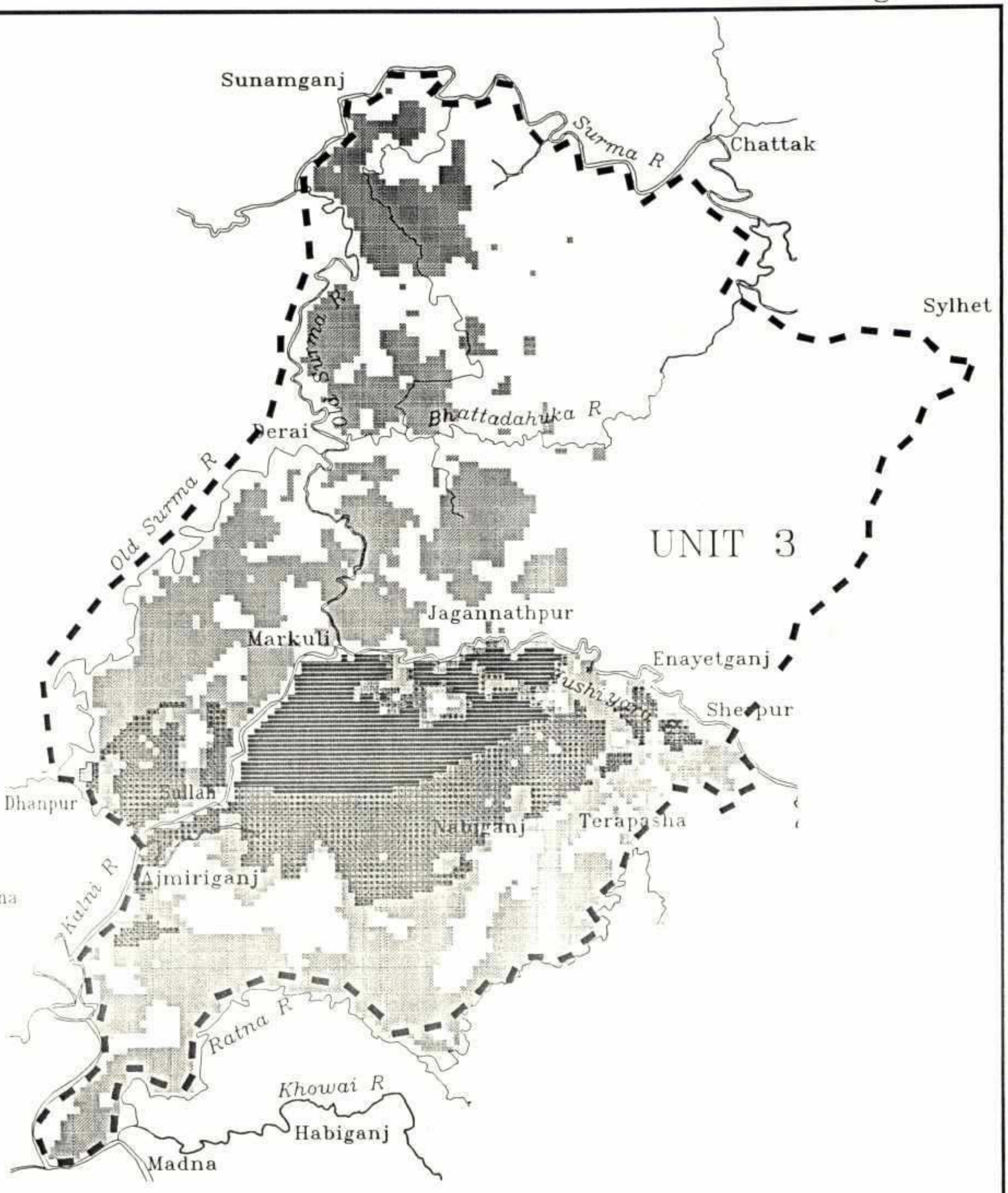
Northeast Regional Project

Simulated Future Water Level Changes

Prepared by: DMc | January 1994

FILE: dm-260.DWG

Figure 26



Note: Based on 1:2 year Pre-monsoon Flood Condition

Key:

- *Flood Depth reduced by 0.0 – 0.5m*
- *Flood Depth reduced by 0.5 – 1.0m*
- *Flood Depth reduced by more than 1.0m*

not clear

Northeast Regional Project

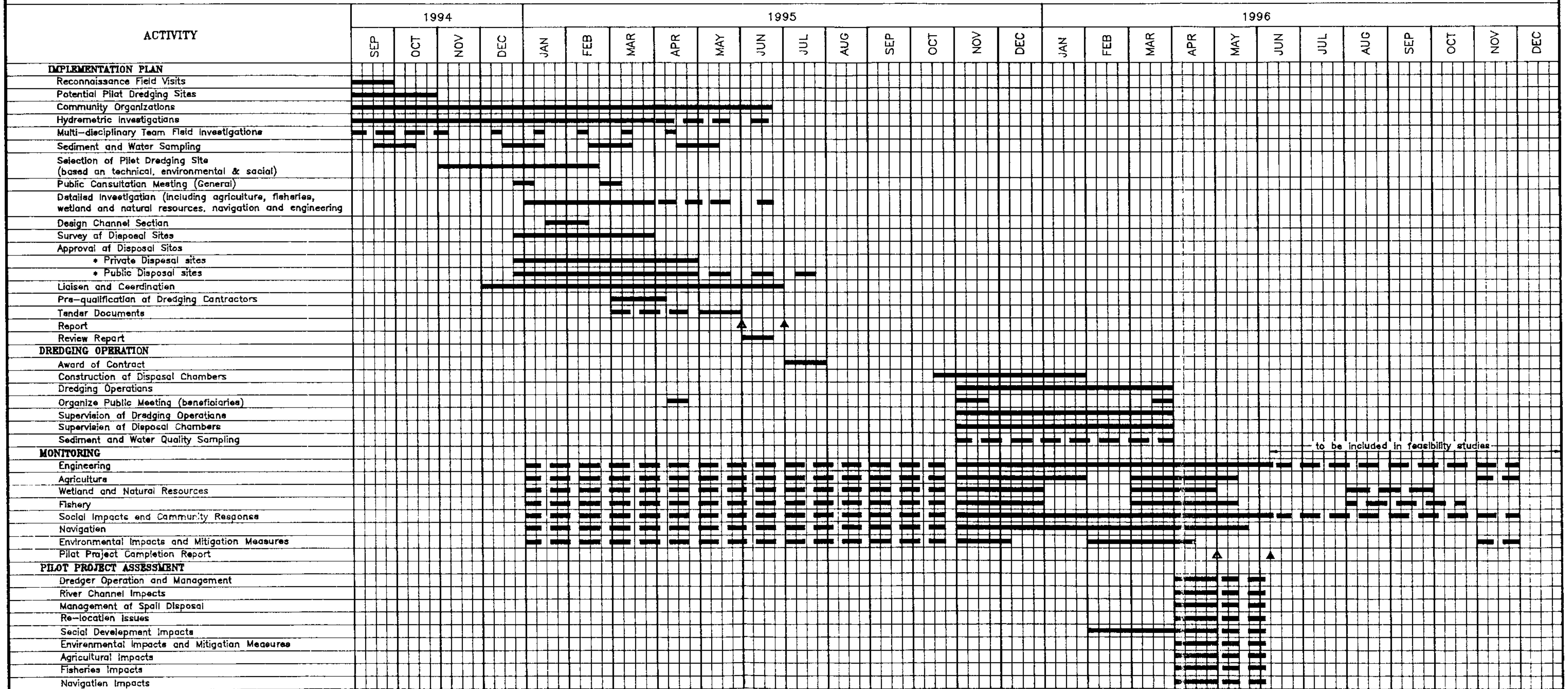
Pre-monsoon Flood Benefits Kalni-Kushiyara Dredging

Prepared by: Awlad/MA	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: Modl-135.DWG

Figure 27

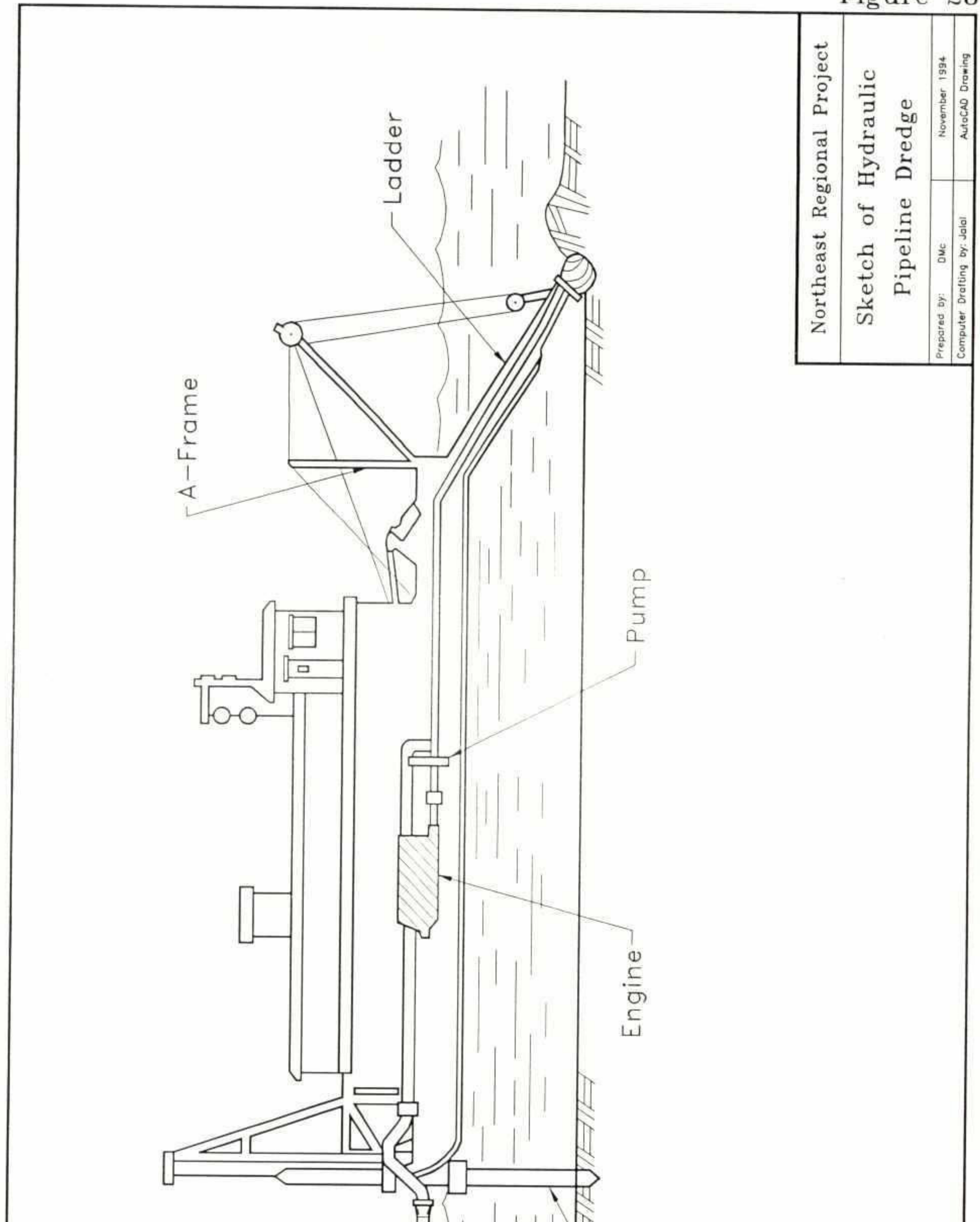
DRAFT ACTIVITY SCHEDULE
PILOT DREDGING PROJECT



NOTE :
△ : Draft Report
▲ : Draft Final Report

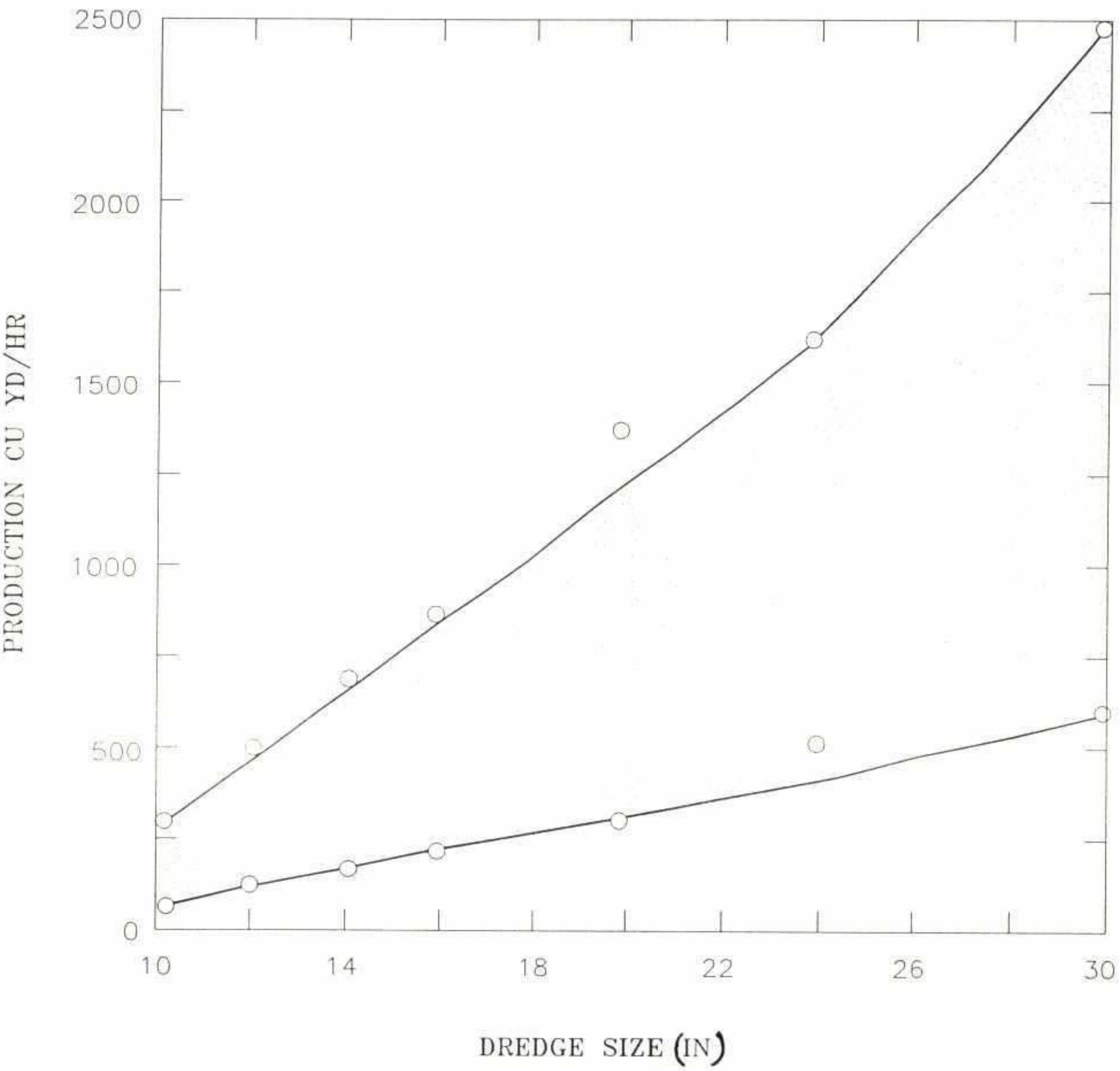
NERP-877

Figure 28



A-Frame
Ladder
Pump
Engine
Spud
Discharge Line
Northeast Regional Project
Sketch of Hydraulic Pipeline Dredge
Prepared by: DMc
November 1994
Computer Drafting by: Jalal
AutoCAD Drawing
FILE: 1 .DWG

Figure 29

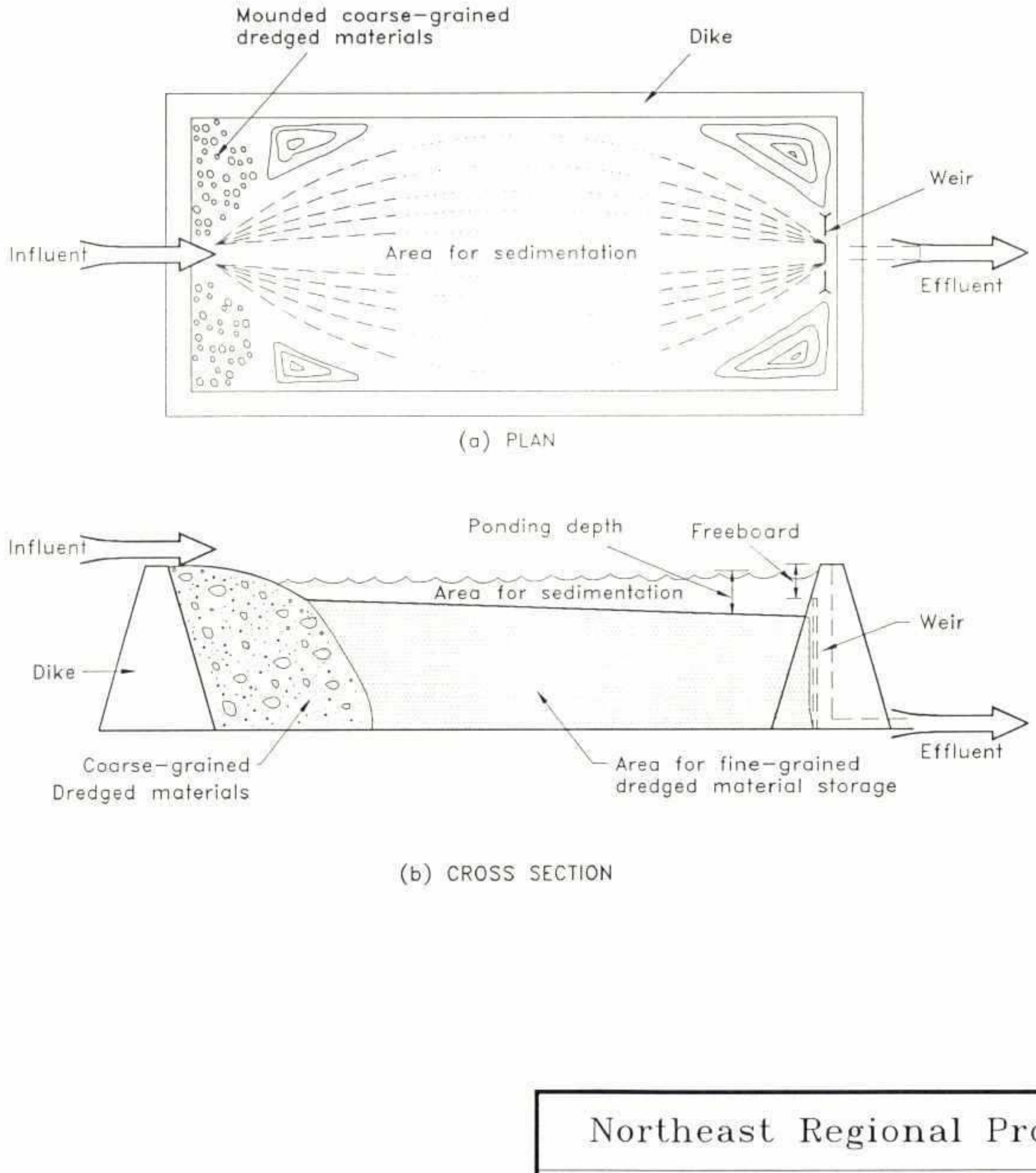


Northeast Regional Project	
Typical Cutterhead Dredge Production	
Prepared by: MA	November 1994
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: 4.DWG

28

Figure 30



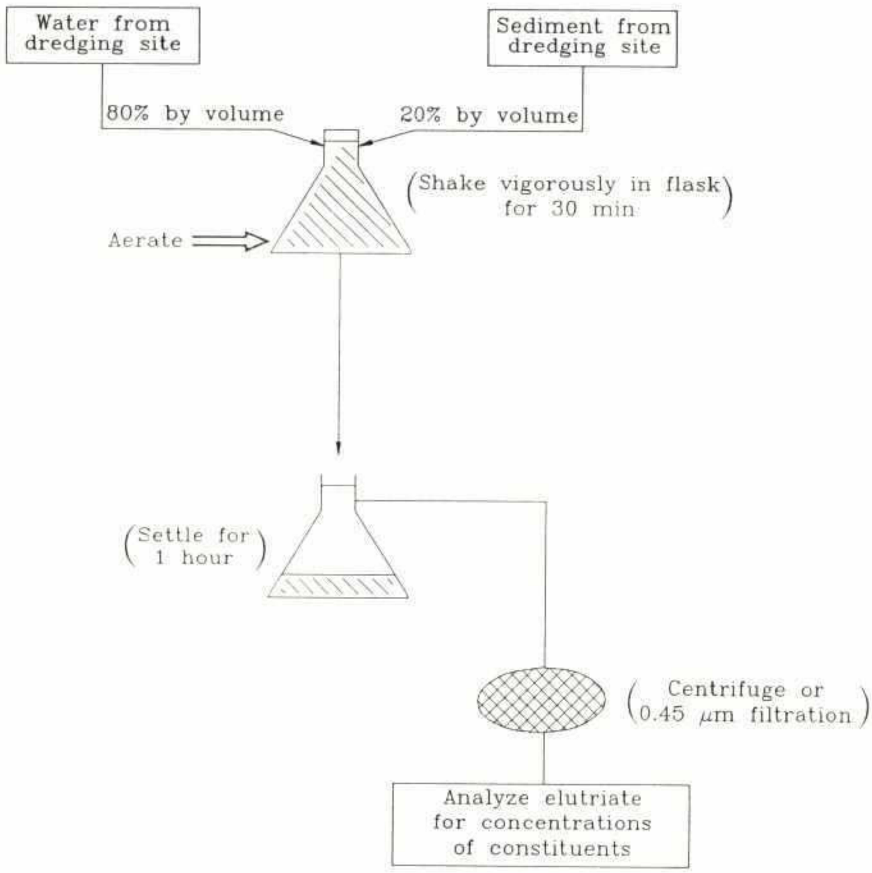
Northeast Regional Project

Main Features of Confined Disposal Chamber

Prepared by: DMc	November 1994
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: 2.DWG

Figure 31



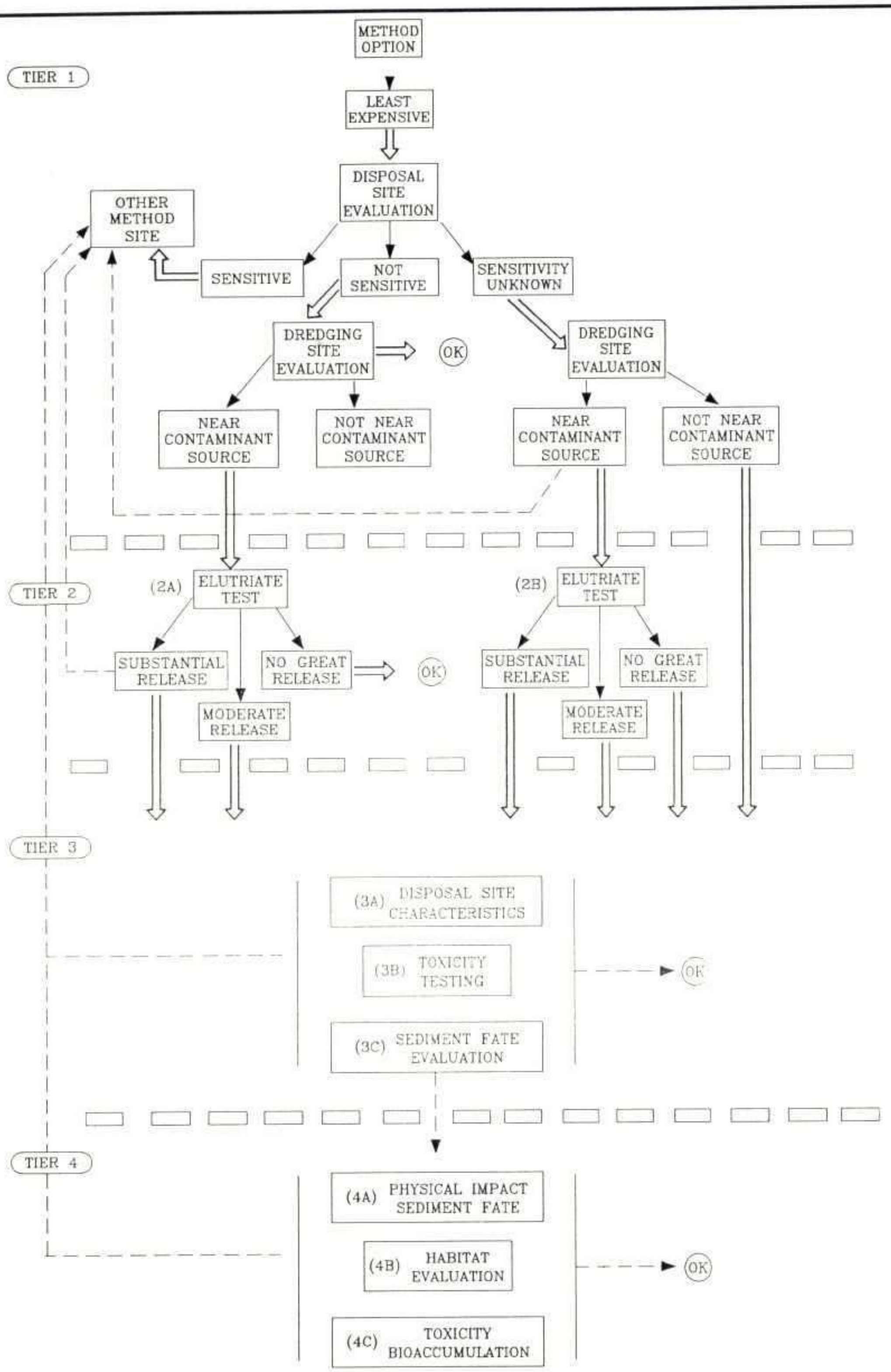
Northeast Regional Project

General Procedure of Elutriate Test

Prepared by: DMc	November 1994
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: MCL-02.DWG

Figure 32

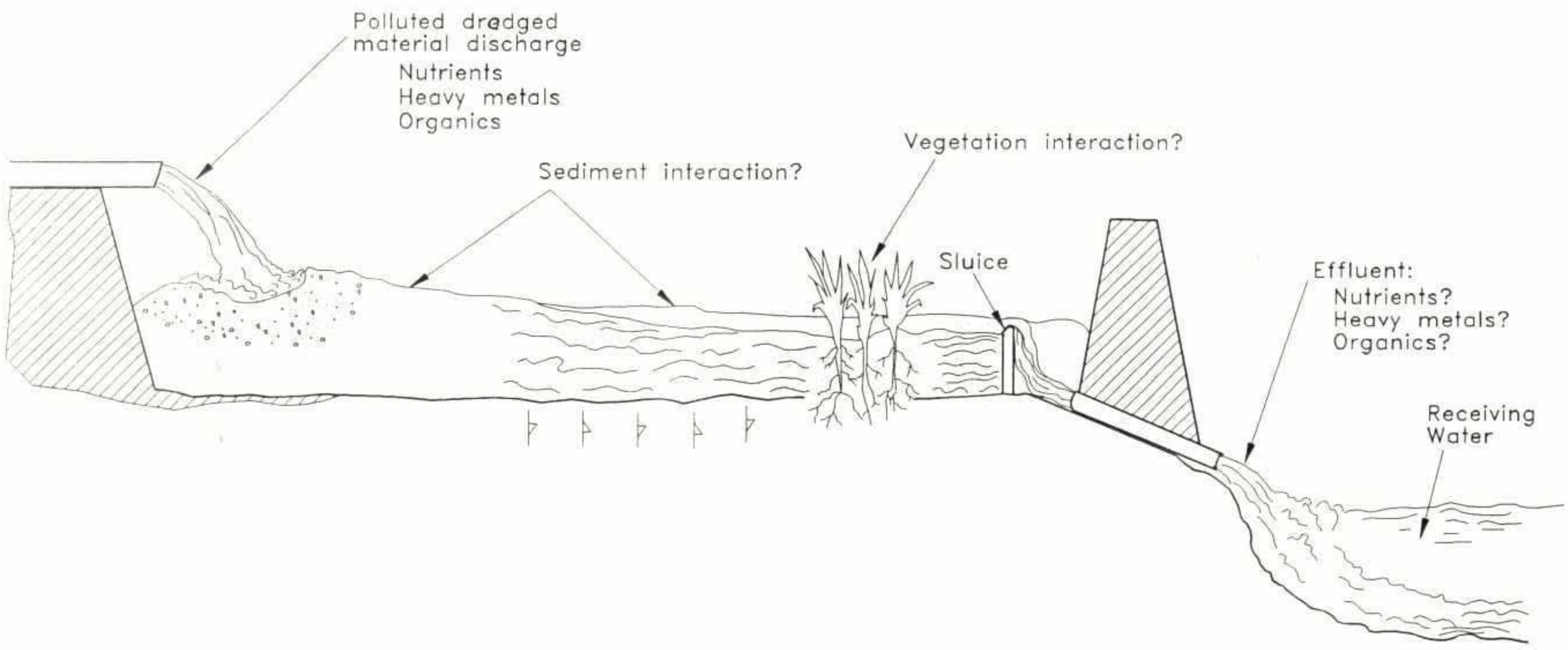


Northeast Regional Project

Tiered Hazard Assessment Approach

Prepared by: DMc	November 1994
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: MCL-03.DWG



Northeast Regional Project

Schematic of environmental interaction in a disposal area

Prepared by: DMc	November 1994
Computer Drafting by: Jalal	AutoCAD Drawing

Figure 33