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)

BAULAI RIVER IMPROVEMENT PROJECT

PRE-FEASIBILITY STUDY

Draft Final
February 1994

NOT FOR CIRCULATIC
PRELIMINARY DR
For Discussion Only

Shawinigan Lavalin (1991) Inc.
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

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ACRONYMS AND ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
BFRSS	Bangladesh Fisheries Resource System Survey
BIWTA	Bangladesh Inland Water Transport Authority
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DPHE	Department of Public Health Engineering
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
FFW	Food for Work
FPCO	Flood Plan Coordination Organization
FW	future with project scenario
FWO	future without project scenario
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
LLP	low-lift pump
LT	local transplanted
MPO	Master Planning Organization
NERP	Northeast Regional Water Management Project
NGO	non-governmental organization
NHC	Northwest Hydraulic Consultants
NPV	net present value
PD	person-day
PWD	Public Works Department
RCC	reinforced concrete
SLI	SNC-Lavalin International

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 the Baulai River Improvement Project is to:

- reduce pre-monsoon water levels by improving the main channel of the Baulai River;
- improve navigation conditions on the Baulai River and its tributaries; and
- improve post-monsoon drainage from the low-lying haor depressions of the Central Basin between Sunamganj and Dilapur.

Drainage improvements would focus on the Baulai River and six major tributary channels: Old Surma River, Piyain River, Someswari River, Kangsha River, Patnaigang-Upper Baulai River, and Rakti River. The work would benefit 17 existing and three proposed submersible embankment projects in the project area.

Re-excavation work on the tributary outlet channels would be carried out where land gradients flatten out and the channels split into a maze of distributaries. Much of the drainage is accomplished through abandoned or decaying channels that are silting-up as a result of reduced inflows or other upstream morphologic changes. This situation creates "pockets" of poor drainage in areas upstream from the sediment deposition zones. The total length of tributary channel improvements is about 175 km, and would require excavation of approximately eight million m^3 of material.

Channel improvements on the Baulai River would focus on the reach between Kaliajuri and its junction with the Nawa River. The cross section in this reach appears to be noticeably smaller than other locations. In some cases, the river narrows at former loop cuts that have failed to establish a natural "regime" width. Preliminary estimates indicate dredging seven million m^3 of material from this reach could reduce pre-monsoon water levels along the Baulai, Nawa and Surma Rivers as far upstream as Sunamganj. This would benefit several existing submersible embankment projects in the region. However, additional river surveys and hydraulic analysis will be required to further quantify the impacts of this work.

Carrying out the proposed works would require a major upgrading of the existing BWDB/BIWTA dredger fleets. The works on the main channel represent in the order of 12 dredger-years of effort using existing resources. Consideration should be given towards involving the private sector in the expanded dredging program.

The possibility for using dredge spoil as village platform sites was reviewed. This has direct links to the NERP initiative "*Flood and Erosion-Affected Villages Development Project*". It was estimated that the main channel excavation could provide platforms for 27 villages, which could accommodate in the order of 18,000 persons.

It is proposed that a two year Pilot Project be carried out as a first step in the longer-term drainage improvement project. This would initiate work on a major drainage channel such as the Someswari River and involve excavation of about 500,000 m^3 of material at an estimated cost of about US$1.8 million.

The project would be implemented by BWDB/BIWTA at an estimated total cost, including the pilot project, of about US$39 million.

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 River Improvement Project
Mrigi River Drainage Improvement Project
Kushiyara Dredging
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
Surma-Kushiyara-Baulai Basin Project
Kushiyara-Bijna Inter-Basin Development Project
Dharmapasha-Rui Beel Project
Updakhali River Project
Sarigoyain-Piyain Basin Development

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LIST OF TABLES

1. INTRODUCTION

1.1 General Information

BWDB Divisions:	Sunamganj, Netrokona, and Kishoreganj
Districts:	Sunamganj, Netrokona, and Kishoreganj
Thanas:	Sunamganj, Tahirpur, Sullah, Madhyanagar, Dharmapasha, Dowarabazar, Bishwamvarpur, Jamalganj, Derai, Barhatta, Mohanganj, Kalmakanda, Netrokona, Khaliajuri, Atpara, Bajitpur, Itna, Madan, Mitamain, and Nikli.
MPO Planning Area:	21, 22, 23, and 29
Gross Area:	320,300 ha
Net Area:	261,000 ha
Geographic Extent:	90° 44' E, 24° 14' N 91° 30' E, 25° 10' N

1.2 Scope and Objectives

This report examines concepts for improving drainage along the lower Surma-Baulai River in order to arrest trends towards rapid siltation, increased pre-monsoon flooding and drainage congestion. 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. 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 development;

- unresolved issues and additional information that will need to be provided to demonstrate feasibility of the program;

- 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 the Northeast Regional Water Management Project. The study team consisted of a water resources engineer, a river engineering specialist, a socio-economist, an agronomist, and a fisheries specialist. Additional analytical support was provided by an environmental specialist, hydraulic modelling engineer, and an economist.

1.3 Data Base

The project analyses presented in this report were carried out using mainly secondary data sources, and information obtained during field inspections and personal interviews. The Rapid Rural Appraisal (RRA) method was utilized for assessing impacts of project developments on agriculture. Information was obtained during personal field observations and interviews with beneficiaries, recommendations by BWDB officials and local representatives.

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 and MPO developed one square kilometre grid data, historic BWDB hydrological records.

- **agricultural analysis:** Land Resources Appraisal for Agricultural Development in Bangladesh (AEZ Reports) for soils and Water Resources Planning Organization (WARPO) for agricultural inputs.

- **fisheries analysis:** Topographic maps, BFRSS data, NERP Fisheries Specialist Study, field observations and local interviews, information provided by local representatives during two field seminars held in Sylhet in June, 1992 and 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-section of local people, opinion and suggestions from local representatives including NGO personnel, and the Honourable Members of Parliament.

1.4 Report Layout

The report is organized as follows:

- Chapter 2, *Physical 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, *Proposed River Improvement Project*, summarizes the objectives of a project, identifies the key components, provides preliminary estimates of costs and phasing, and describes expected benefits and impacts.

- Chapter 6, *Pilot Project*, outlines the objectives and scope of a two year pilot dredging project to demonstrate the feasibility of conducted an integrated dredging program on the river.

- Chapter 7, *Outstanding Issues*, summarizes some key questions that can not be fully resolved at this stage of analysis.

The annexes provide detailed information in support of the main body of the report.

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2. PHYSICAL DESCRIPTION

2.1 Physical Setting

2.1.1 Location

The focus of this investigation is the 220 km reach of the lower Surma, Nawa, and Baulai Rivers, extending from the town of Chhatak to the junction with the Upper Meghna River near Dilapur (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-Kalni River system on the east, the Meghalaya Hills on the north and the Kangsha River and Old Brahmaputra River on the west. The project covers a gross area of 320,000 ha and extends over the districts of Sunamganj, Netrokona, and Kishoreganj.

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* (Tangua Haor, Shanir Haor, Matian Haor, Pagner Haor, Sonomoral Haor, Dharmapasha-Rui Beel, and so on) that are bordered by natural levees from the complex maze of ancient and recent distributary channels that cross the basin.

Figure 2 shows a generalized contour map of the project area. The area has been sub-divided into three units on the basis of topography, drainage pattern and landforms. Figure 3 shows the overall distribution of land elevations. Elevations typically range between El. 3 - 8 m PWD, 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 El. 4 m and 50 % is below 5 m PWD.

2.1.3 Soils

The Geological Survey of Bangladesh (1990) describes the underlying sediments in the Central Basin as "paludal deposits of marshy clay and peat, often with thin beds of peat and clay interbedded with alluvial silts". Soils found on higher ridges and recent or older floodplain deposits typically consist of a grey, massive puddled top soil overlying a grey mottled clay to silty clay loam sub-soil with medium to strongly acid reaction. Poorly drained soils in the lower lying backbasins are typically grey to dark grey clay and have a prismatic or blocky structure and a medium to strong acid reaction. Very poorly drained basin soils, which remain saturated throughout the year, have a reduced colour and a near neutral reaction.

2.1.4 River Channels

The Surma/Nawa/Baulai/Ghorautra River system is one of the main drainage channel for the Northeast Region. Flows to the Central Basin include runoff from the Meghalaya Hills, flows from the Barak River, and flows from the Kangsha River system in the west.

The Surma River originates at the International Boundary near Amalshid where the Barak River bifurcates into the northward flowing Surma River and the south flowing Kushiyara River. The Surma River flows westwards for a distance of 150 km, to just past the town of Sunamganj. The "Old Surma River" channel (formerly the main branch of the Surma River) turns southwards near Sunamganj, and heads into the low-lying Central Sylhet Basin, eventually re-joining the Kushiyara River near the town of Ajmiriganj. By 1952 the Nawa/Baulai River was the main branch of the river and the Old Surma channel was a smaller distributary. A memo by BWDB dated May 8, 1963 reported:

> *"low flow of Surma does not join Meghna at Markuli but flows to Baulai River. The channel from near Sunamganj (Old Surma) to Markuli probably does not carry much of the flood flows of Surma."*

By 1992, the entrance to the Old Surma River was only about 40 m wide and 2 m deep in the dry season. The main flow route now is through the "Nawa River channel" and into the southward flowing Baulai River which drains off the Meghalaya Hills. Downstream of this point, the main channel is called "Baulai River". The river turns abruptly south and is joined on the west (right bank) by several major tributaries, including the Someswari, Ghulamkhali, Kangsha, and Mogra River. Downstream of the Mogra River junction, the channel widens appreciably and is called the "Ghorautra River". The Ghorautra River joins the Kushiyara/Kalni/Dhaleswari River system near the town of Dilapur to form the upper Meghna River.

The main distributary channels include:

- Piyain River channel, which splits off the Baulai River around Jamalganj and re-joins near the town of Kaliajuri;
- Bheramohona River channel, which connects the Old Surma River channel with the Baulai near Dhanpur;
- Gharabhanga River channel, which connects the Kalni River to the Baulai River.

In addition, 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.

2.1.5 Water Bodies

Open water bodies
The project area covers the central depression of the Northeast Region and includes many important permanent water bodies: Tangua Haor, Pashua Haor, Shanir Haor, Kaliagota Haor, Nawatona Haor, Chatal beel, Kachar beel, Derai beel, Bhanda beel, Baulai River, Dhanu River, Darain Gang, Mora Surma, Rakti River, and so on. About 8.4% (26,900 ha) of the project area is perennial beels, and about 2.9% (9,400 ha) of the area is rivers and channels.

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.

Closed Water bodies
In addition to the open beels and khals there are about 25,200 ponds, borrow pits, and ditches used for fish stocking and other household purposes. The ponds have a total area of about 2450 ha. Most of the ponds are inundated during the high monsoon floods, particularly in low areas.

2.2 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 ten BWDB rain gauges in, or around the periphery of, the project area. The locations of these rain gauges are given in Table A2, and the data for 1961-90 in Table A3 (Annex A).

The data show that annual rainfall increases from an average of 2,247 mm/year in the south to 5,539 mm/year in the north, or by 147% across the project area. This latitudinal increase is mainly attributable to the presence of the Shillong Plateau to the north (Figure 4).

A regional analysis of annual rainfalls (NERP, 1993a) 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. These trends have been reflected in increased floods and flooding in recent years, but it is not known whether they will continue into the future, level off, or be reversed. Climate modelling research being undertaken in the West suggests these trends, particularly that in variability of the annual rainfalls, will continue in the decades ahead.

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 (Bajitpur)	North (Sunamganj)
Dry	4	2
Pre-Monsoon	22	15
Monsoon	65	78
Post-Monsoon	9	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.

2.3 Hydrology

2.3.1 Runoff Patterns

Discharges on the Surma-Baulai River system are governed by inflows from the Barak River at Amalshid and from tributary streams draining the Meghalaya Hills, 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 available hydrometric stations in the project area. Daily discharges have been estimated by BWDB for the Surma River at Sylhet since 1964 and at Sunamganj since 1991. Some miscellaneous discharge measurements have also been collected on the Baulai River at Sukdevpur in 1992-1993. Daily water levels have been measured at Chhatak, Sunamganj, Sukdevpur, Kaliajuri, Itna and Dilapur, in some cases since the 1950's. (Table A.3).

Water balance studies indicate the mean discharge increases by a factor of six between Sylhet and its junction with the Upper Meghna River near Durlapur (Table 2.3). These results illustrate the contribution from the tributaries draining the Meghalaya Hills (Chela River, Jhalukhali River, Jadukata River) and from the Kangsha River system.

Figures 6 and 7 show the range in daily water levels and discharges for various years at Sylhet, Sunamganj and Sukdevpur. These hydrographs illustrate the annual pattern of flash flooding during the pre-monsoon season, a longer term flood rise during the monsoon (often with several sharp flood peaks), flood recession and drainage during the post-monsoon season and very low runoff during the dry season.

The seasonal distribution of runoff at Sylhet (the only station with long-term discharge records near the project) is summarized in Table 2.4.

Table 2.3: Runoff Along Surma/Baulai River

Location	Mean Annual Discharge (m^3/s)
Surma River at Sylhet	563
Surma R. above Baulai R. junction	1,646
Baulai R. above Dhanu R. junction	2,879
Ghorautra River	3,267

Table 2.4: Seasonal Distribution of Runoff

Season	At Sylhet	
	Discharge m^3/s	% of Annual Runoff
Pre-monsoon	399	11.9
Monsoon	1,263	75.0
Post-Monsoon	395	11.7
Dry Season	23	1.4
Year	563	100

2.3.2 Flooding

Three types of floods occur in the project area:

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

Winter floods, which occur between December and February, are caused by winter storms in the out-lying 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 depths and for durations beyond their tolerance. As a result, the crops (usually *boro* rice at various early stages) is 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.

The monsoon season floods are large and normally last from July to October. The monsoon season floods are a combination of flood inflow from external rivers, seasonal rainfall, and lack of drainage due to backwater effect of the Upper Meghna River. Agriculture damage from these floods tends to be less since farmers either leave their land fallow during this time or they plant flood tolerant low yielding deepwater *aman* rice.

Figure 8 shows trends in the maximum daily discharge during the pre-monsoon and monsoon seasons at Sylhet. Figures 9 and 10 show a time series of maximum water levels during the pre-monsoon and monsoon seasons. There are no obvious trends towards increasing peak discharges or water levels at stations downstream of Sylhet over the last 20 years, although there has been some large floods recently. Unusual conditions were experienced at Sunamganj on the Surma River during the 1950's and 1960's, when pre-monsoon flood levels appear to have increased by 2-3 m over an eight year period. This may have been related to the partial abandonment of the Old Surma branch and increased flow diversion into the Nawa River channel. One notable feature of the plots at Kaliajuri is that the lowest annual water level has risen by about 0.6 m on average during the period between 1964 - 1990. Peak pre-monsoon water levels have fluctuated over a three metre range during the period of record while the range in annual maximums is about two metres. Since the late 1970's, the peak pre-monsoon level is between 1 - 2.5 m lower than the annual maximum level.

Tables A.7 and A.8 summarize estimates of frequencies and magnitudes of flood levels during the pre-monsoon and monsoon seasons along the Surma/Baulai River system. Additional background information on the method of flood frequency analysis is contained in *Surface Water Resources of Northeastern Region, NERP, 1993.* These results were used to construct a longitudinal profile of pre-monsoon and monsoon flood levels between Dilapur at the junction with the Meghna River and Chhatak on the Surma River. The water surface profile of pre-monsoon floods is relatively flat between Dilapur and Kaliajuri, then steepens noticeably through the Nawa River reach up to Sunamganj. The gradient flattens out again between Sunamganj and Chhatak, suggesting the levels at Chhatak are partially backwater controlled.

Figure 5 shows average pre-monsoon flood levels at sites throughout the project area. The map illustrates that there is a strong gradient from the Kalni River system and the streams draining the Surma/Baulai Inter-Basin towards the Baulai River system. For example, the average pre-monsoon flood level at Ajmiriganj on the Kalni River is 0.66 m higher than the corresponding level at Itna on the Baulai River and the water level at Markuli is 1.9 m higher than the level at Kaliajuri.

Preliminary estimates of the extent of flooding under existing conditions are summarized in Table 2.5. During the monsoon season, approximately 238,600 ha (91%) of the net cultivable area is inundated, with 128,700 ha (54%) flooded in excess of 1.8 m during a 1:2 year flood.

Table 2.5: Area Flooded During a 1:2 Year Monsoon Flood

Flood Condition	Non Flooded	Flooded Area (ha)			
		0.3 m to 0.9 m	0.9 m to 1.8 m	> 1.8 m	Total
Monsoon	22,397	41,309	68,534	128,743	238,586

2.3.3 Drainage

Drainage patterns throughout the project area follow the land gradient, sloping from north to south, and from either side of the project towards the central Surma-Baulai channel. Consequently, distributary channels from the Surma River all behave as spill channels, diverting water out of the Surma system into the Central Basin lowlands. Historically, most of the flows from the eastern distributary channels drained into the Kushiyara/Kalni River system between Markuli and Ajmiriganj and thence to the Lower Meghna. However, increasing water levels during the post-monsoon season have reduced the river's drainage capacity. 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 Darain Nadi and Old Surma River which discharges into the Baulai River at Dhanpur (Figure 5). However, since the Darain Nadi and the Old Surma channels are too small to convey these discharges, the drainage from the entire basin is delayed.

Runoff from the upper Baulai River, Someswari River, Kangsha River and Dhanu/Mogra River drains in a south and easterly direction into the Baulai River system. The gradient of these tributary streams all flatten out appreciably as they approach the low-lying Central Basin lands. The streams connect with the Baulai River through a complex maze of distributary channels. Various people have reported that post-monsoon drainage congestion occurs along these tributaries as a result of sedimentation at their outfalls and increasing water levels on the Baulai River. These opinions are difficult to confirm, since there are few hydrometric stations in the affected area. In the last few years water levels have risen by approximately 1.5 m during the months of January and February at Mohanganj. However, this is believed to be caused by construction of cross dams that have been built to retain water for irrigation. Additional site inspections and surveys will be required to identify local drainage congestion problems in the project area.

2.4 River Stability and Sedimentation

The following comments summarize preliminary findings about sedimentation processes and channel morphology along the Surma/Baulai River system. Additional information and data is summarized in Annex A3. Figures 11 and 12 show channel shift maps between 1952 and 1990. These maps are intended to illustrate overall channel pattern changes (such as loop cuts) that have occurred along the river over the last 40 years. Figure 13 shows a satellite photo of the Baulai

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River near Kaliajuri. Figure 14 shows a longitudinal profile of the Surma/Baulai River as well as average monsoon flood levels at key locations. Figure 15 shows variations in bankfull hydraulic geometry along the river, as determined from 1991 SWMC cross sections.

The Surma River flows in a "transport reach" between Amalshid and Chhatak. The river has established a stable sand-bed channel that can accommodate a mean annual flood at most locations without spilling its banks. There has been some enlargement of the channel over the last 20 years, probably in response to higher discharges that have been experienced recently. The river does not have a particularly high sediment transport capacity and is transporting in the order of 1.2 million tonnes/year of bed material and roughly 4 million tonnes/year of fine sand/silt in suspension.

Downstream of the Old Surma River offtake, the river flows through the Central Basin lowlands and experiences backwater from the Meghna River throughout the monsoon season. As a result, flow spills out of bank and the channel becomes deeply submerged in the vast lake of the flood basin. During these conditions the channel carries only a small fraction (in the order of one third to one half) of the total river discharge and the channel's capacity to transport sediment becomes substantially reduced. Therefore, this lower reach becomes a natural sedimentation zone during the monsoon.

The Nawa and Baulai River reaches are relatively recently formed in comparison to the Upper Surma River and have been adjusting to the higher discharges caused by the diversion of flow from the Old Surma River channel. After this shift occurred, the Nawa and Baulai Rivers appear to have degraded and enlarged their channels to accommodate the increased discharges. The Baulai River has maintained a relatively small channel cross section in comparison to the Nawa channel. This is probably due to two main factors: (1) the nature of the bank materials along the Baulai River (cohesive), and (2) because so much of the inflows from the Surma/Nawa River spill overbank during high flows, so that the river's "dominant" or "channel-forming" discharge is relatively low.

The available survey data suggests channel aggradation has occurred along the Baulai River downstream of Sukdevpur since the early 1980's. To-date, much of the sedimentation occurs in the form of natural levees, crevasse splays and overbank spills. Therefore, the rate of accretion is relatively low.

Recent loop cuts by BIWTA have shortened and straightened the lower Baulai River by about 23 km. This work has caused the river to flow in an artificially straightened alignment. The loop cuts appear to have been constructed by excavating narrow pilot channels across the neck of each meander. However, the new channels have not enlarged to the river's natural width, probably as a result of cohesive sediments in the floodplain. This appears to have created several local constrictions, particularly near Kaliajuri and in the 15 km reach upstream of Sukdevpur.

Past morphologic changes have also affected many of the major tributary channels that join the Baulai River. For example, upstream channel shifts on the Someswari River and Kangsha River system have reduced inflows to these channels. With reduced discharges, the lower branches of the Someswari and Kangsha River have less capacity to flush fine sediment through them, and appear to be gradually infilling. A similar situation may be occurring on the Piyain River, since the offtake from the Surma River has gradually silted-in. As a result, there has been reports of increased siltation problems and drainage congestion at several of the submersible embankment projects adjacent to these channels.

As mentioned previously, ongoing channel shifts and morphologic changes on the Kangsha River have resulted in increased flows through the Ghulamkhali River. This is increasing the morphologic activity of the channel in the reach where it approaches the low-lying Central Basin. Consequently, more frequent channel shifting and instability has been reported on this distributary, which is adversely affecting drainage patterns and navigation along the west side of the Baulai River.

3. SETTLEMENT, DEVELOPMENT, AND RESOURCE MANAGEMENT

3.1 Human Resources

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)	260,984
Homesteads	5,060
Beels	26,900
Ponds	2,450
Channels	9,390
Hills	0
Fallow[1]	11,200
Infrastructure[2]	4,310

[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 as villages along the levees of the rivers. In places where land elevation is higher, especially in the northeastern part of the project, homesteads are also constructed in the fields. Densely populated areas are found around the thana headquarters, marketing centres, and river banks. Generally settlements are sparsely scattered in the fields. Settlements are extremely sparse in the south-western low-lying haor areas where land elevation is very low.

Flood Damage to Housing
Generally, homesteads located on higher lands are not damaged by floods. Damage to homesteads in the north eastern part is generally caused by pre-and early monsoon flash floods. Damage to homesteads as a result of monsoon flooding is common in the low-lying haor areas in the southwest. Many villages in this area have been badly damaged and reportedly some have been completely eroded by monsoon wave action.

Coping Strategies
Homestead platforms are raised to one meter or more to avoid monsoon flooding. However, within villages in the low-lying haor areas, homesteads are raised up to three to five metres to avoid flooding. Necessary measures are taken to protect erosion of the homesteads against monsoon wave action. Seasonal protection walls are constructed around the homesteads using soil, bamboo, and locally available grasses. Flood waters from monsoon flash floods in the eastern area usually recede from homesteads within a week or so. But monsoon flood waters stay in the low-lying haor areas for a period of about five to six months from about late May. If there is severe flooding, villagers generally make platforms inside their houses and shift their belongings to these platforms. In these flood situations the poor suffer the most.

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	16.5	15.6	13.4	45.7	2.1	6.7	100.0
Female	17.4	16.5	12.1	47.1	1.6	5.3	100.0
Total	16.9	16.1	12.8	46.4	1.8	6.0	100.0

Source: BBS, 1981 Population Census

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be about 1,368,700 of whom 670,600 are female. The gender ratio is calculated to be 103.7 (males to 100 females). The total number of households are estimated to be 226,700 within 1,880 villages. The population increased by 18.83% between 1981 and 1991.

The cohort distribution for males is: 32.1% are below 10 years of age, 45.7% are between 15 and 54 years of age, and 6.7% are above 60 years of age. The corresponding distribution for females is 33.9%, 47.1%, and 5.3% (see Table 3.2).

The average population density is 427 persons per km^2, with density ranging from a maximum of 718 persons per km^2 in Bishwamvarpur to 260 persons per km^2 in Kaliajuri thana. The average household size in the area is estimated to be 6.0 persons.

3.1.3 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 1981 census, the literacy of the population at 5 years of age and above varied from 11.1% in Nikli thana to 22.7% in Netrokona Sadar thana. The corresponding figures for females were 7.0% and 13.5% respectively for the same thanas. The rate appears to have slightly increased during the last 10 years. According to the 1991 census, the literacy rate for all people of Netrokona district is recorded as 18.09% for both male and female, while for Kishoreganj district it is 16.42%.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 14.5% in Madan thana to 22.2% in Sullha thana. Attendance for females in this age cohort in these two thanas varies from 12.2% to 19.9% respectively. Attendance for all youths between the ages of five and 24 is 12.4% and 18.3% for these thanas while the corresponding attendance for females is 8.8% and 14.5%.

The situation is worse for the rural poor. They can not afford to send their children to school. Moreover, many villages, especially in low-lying haor areas of Sunamganj and Netrokona district, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 5.6% for Sunamganj district, 4.3 for Netrokona district, and 4.1 for Kishoreganj district (BANBEIS, 1990).

Access to Health Services

The district headquarters of Sunamganj, Netrokona and Kishoreganj have hospital facilities at their headquarters. Similarly, 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. The situation is worst for the people of the haor areas of Sunamganj, Netrokona and Kishoreganj districts. According to the Directorate General of Health Services (1992), one hospital bed is meant for 6,625 people in Sunamganj district, and nearly 6,000 people for both Netrokona and Kishoreganj districts. Immunization coverage of children below two years of age is generally high for the project area, except Kaliajuri and Itna thanas. The rate varies from 18% in Barhatta 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 Sunamganj, DPHE[1] reports the availability of one working tube well for 181 persons. For Netrokona and Kishoreganj districts, these figures are 108 and 122 respectively. In 1990, 80% of the households had access to potable water in each of the three districts of the project area. It is noted that most tube wells are located in the houses of the rich. This results in the poor having 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 banana leaves. During monsoon months, the haor people generally defecate in running water. Sanitary latrines are uncommon in the village environment, except for the very well-off and educated families.

3.1.4 Employment and Wage Rates

Village employment opportunities are mainly limited to agricultural activities. The major crop in the area is boro in the low-lying haor areas and t.aman in the higher lands. Employment for men mainly consists of transplanting which occurs between July and August and harvesting which occurs in late November and December for t.aman. There are two peak periods for employment for boro cultivation: transplanting in January-February, and harvesting in mid-April to mid-May. Well-off farmers employ seasonal labourers during the winter months for boro cultivation, especially in the low-lying haor areas.

[1] DPHE, 1991-92

The wage rates for male agricultural labourers vary from Tk 30 to 45 per day (with or without a meal) during peak agricultural months. During the months when there is little agriculture work, the daily wage rate varies from Tk 20 to 30. Employment scope reduces significantly during the monsoon months for the poor of the haor areas of Sunamganj and Netrokona districts. However, it is reported that during monsoon months, many labourers (20-50 from a village) migrate to Companiganj, Tahirpur (Fazilpur) and Chhatak thanas to work on sand and stone carrying activities. They are usually involved in transporting these materials from the quarries to various storing and construction centres throughout Sunamganj and Sylhet districts. Some poor also get employment in boat plying during the monsoon months, especially in the haor areas. Self-employment of the poor in catching fish during the monsoon season is also important in the haor flood plain areas. The average daily income from these activities varies from Tk 50 to Tk 100.

During months when employment opportunities in agriculture are limited, some poor people also migrate to the various district headquarters within the project area to work as rickshaw pullers, as construction workers, or sometimes in household activities. Employment opportunities for women are limited in the area. A few women are reported to be employed as seasonal labourers, especially with large farmers of the haor areas. A limited number of women migrate to the district headquarters to perform household work.

Migration to outside countries, particularly Great Britain, is common in Golapganj, Biswanath, Balaganj and Jagannathpur thanas. There is little out-migration from the other thanas of the project area.

There is some in-migration into the project area, mainly from Mymensingh, Comilla, Faridpur, Manikganj and Pabna. They come to the project area and stay seasonally to work on harvesting of boro crops and earth work. Seasonal migration of fishing labourers into the project area also takes place from Brahmanbaria district and Bhairab bazar thana during winter months to catch fish in the jalmohals.

3.1.5 Land Ownership Pattern

Nearly 46.7% of the households are landless (with cultivable land less than 0.2 ha). Among the landless, about 2.8% have no homesteads of their own. If the definition of landless includes landholdings of up to 0.4 ha, the proportion of households included increases by 10%. 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 22.9%, 21.0%, and 9.5% respectively.

Nearly 19% of the project area is not available for cultivation including deeper wetlands, reed lands, and community pastures. The price of agricultural land varies from Tk 2,000 to Tk 60,000 per ker (0.12 ha) depending on the demand and quality of the land and the intensity with which it can be cropped.

3.1.6 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 for local varieties is that one-half of the produce is retained by the land owners but they provide no inputs. For HYV rice, 50% of the input costs are generally shared by land owners. The leasing out of land in kind (chukti) is

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declining in the area. However, leasing out of land with advance cash (Rangjama) is widely practised in the haor areas. The usual rate for such arrangements varies from Tk 600 to Tk 1000 per ker (0.12 ha) and this is paid in advance to the land owner for one year. Landless people have very little access to land under this tenurial arrangement as they cannot advance the cash and buy agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area. Most of the important jalmohals of the haor areas are located here and competition over the fish resource is increasing. There are mainly two types of fishermen, traditional and non-traditional, who catch fish to generate an income. Traditional fishermen live on fishing and have been engaged in the profession for many generations. The jalmohals are generally leased out to them through their cooperatives. There are an estimated 4,000 to 6,000 traditional fisherman households in the project area. Additional information on fishing practices is given in Section 3.5.

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 their catch. Such non-traditional fishermen are increasing and nearly 25-30% of the households, especially from the deeply flooded haor area, are reportedly engaged in catching fish.

3.1.8 Situation of Women

Women's role is 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, including activities like gathering wild fruits, vegetables, and collecting fuel. Village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, par-boiling and storing of rice. Many women work on homestead gardens and raise poultry/ducks in addition to other household work.

3.2 Water Resources Development

3.2.1 Flood Control & Drainage

There are 17 existing water development projects in the project area (Figure XX). The total gross area of these projects is about 98,304 ha and the net cultivable area is 86,773 ha. Fifteen of these projects are located on the right bank of the Baulai River; two projects, Pagner Haor and Udgal Beel Projects, are located on the left bank. These two projects have a gross area of about 24,975 ha with an estimated net cultivable area of about 21,865 ha.

The existing schemes are all submersible embankment projects which provide pre-monsoon flood protection to boro crops. Ten of the projects are completed, five have only embankments, and three projects have ongoing construction activities. The total length of embankments of these projects is 646 km. Nine out of the 17 projects are planned to be rehabilitated and upgraded under the System Rehabilitation Project (Credit No 2099/BD), with IDA and EEC financing (Table 3.3). In addition, EIP and NERP have identified three projects. The gross area of these proposed projects is about 33,680 ha and the net cultivable area is about 28,000 ha. (Table 3.3).

Table 3.3: Existing and Proposed Projects

Name of Project	Area (ha)		Embankment (km)	Structures (no)	Remarks
	Gross	Net			
EXISTING PROJECTS Karcher Haor	7770	6600	39	2 nos: completed	Completed under SRP
Angurali Haor	2529	2430	19	1 no: completed	Completed
Shanir Haor	7010	6677	48	1 no: completed	Completed under SRP
Joalbhanga Haor	4370	3660	16	not completed	Ongoing
Matian Haor	6368	6310	46	1 no: completed	Completed under SRP
Gurmar Haor	5360	5000	45	Nil	Completed
Sonamoral Haor	3725	3160	52	Nil	Completed
Mohalia Haor	1356	1200	15	Nil	Not compl. under SRP
Halir Haor	7325	6680	53	2 nos: completed	Completed under SRP
Dhankunia Haor	1780	1619	25	1 no: completed	Completed under SRP
Joydhona Haor	1330	1214	12	Nil	Not compl. under SRP
Chandrasonarthal Haor	4450	4046	42	Nil	Not compl. under SRP
Haijda Embankment	9716	8097	60	12 nos: completed	Completed.
Nawatona Khal	3120	2145	23	1 no: completed	Completed
Kalner Haor	7120	6070	52	partly (2 nos) constructed	Not compl. under SRP
Pagner Haor	19075	17165	65	2 nos onging	Ongoing
Udgal Beel	5900	4700	34	7 nos. Partly completed	Ongoing
Sub-Total: (Existing)	**98304**	**86773**	**646**		
PROPOSED PROJECT Dharmapasha-Rui Beel	20500	17024	50	10 nos	Proposed (NERP)
Updakhali Project	5960	4890	25	7 nos	Proposed (NERP)
Singuar Beel	7220	6150	27		Proposed (EIP)
Sub-Total: (proposed)	**33680**	**28064**	**102**		
Total:	**131984**	**114834**	**748**		

Flooding and drainage conditions at the existing projects have worsened over recent years. Reportedly, water levels in the northern rivers, particularly the Upper Baulai, Jadukata-Rakti, Someswai, and Kangsha Rivers, have risen due to sedimentation. Now submersible embankments are frequently breached and post-monsoon drainage is delayed. SRP have proposed that submersible embankments be raised to counteract increased water levels. The proposed Baulai River Improvement Project (Chapter 5) would improve the flood and drainage conditions at the existing water resource projects and possibly make raising of existing embankments (646 km) unnecessary.

3.3 Agriculture

Agricultural data collection and analysis of the Baulai River project was undertaken by dividing the area into 3 catchments for generating data on flooding conditions. Water level data at designated locations in each of the catchments were established along with the development of area elevation curves. These data were analyzed for computing approximate areas under different land types. These areas will need to be refined at the feasibility study stage. Water does not drain out from about 18,550 ha of cultivated land till the end of January.

Crop production practices in the project are guided by agro-climatic conditions, especially the hydrologic regime. Present cropping patterns indicate the outcome of farmers' efforts to adjust crop production practices with the hydrologic regime. The area flooded in excess of 1.8 m (F3 land) constitutes 46 percent of the cultivated area; another 29 percent is flooded between 0.9 to 1.8 m (F2 land). Most of these areas are flooded early in the pre-monsoon season and remain wet for a part of the rabi season. Dominance of such a semi-aquatic environment during most part of the year, has led to the emergence of rice as the single most dominant crop on these land types. Local boro is the only crop grown in most of the F3 land, initially on static water after the recession of flood water. Irrigation is provided at a later stage wherever water is available; elsewhere farmers have to depend on pre-monsoon rains. About 18,550 ha under F3 land remains fallow throughout the year as water does not drain out from these areas till the end of January at which time it is too late to transplant boro seedlings because of the threat of pre-monsoon floods.

Local varieties of broadcast aman (b aman) is the dominant crop on F2 land. Most of this is grown as a single crop except a minor area where the recession of flood water in the post-monsoon season permits growing of rabi crops in the winter. Depending on irrigation facilities and the start 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 cultivated area on F2 land.

Flooding and drainage congestion do not constrain crop production practices on higher elevations. Rice based multiple cropping is practised in F0 and F1 land with a higher proportion of high yielding varieties on F0 land. In these areas, local and high yielding varieties of aus rice and local and high yielding varieties of transplanted aman rice are grown in the first and second kharif seasons respectively.

Present cropping patterns and crop production in the project area are presented in Tables 3.4 and 3.5.

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Table 3.4: Present Cropping Patterns

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					52698	70	0	0	52698
fallow-l boro					0	0	96562	80	96562
fallow-hyv boro	0	0	0	0	3764	5	2414	2	6178
b aus-fallow-rabi	0	0	4538	10	3764	5	0	0	8302
b aus-lt aman	3924	20	15882	35	0	0	0	0	19806
b aus-lt aman-potato	981	5	0	0	0	0	0	0	981
b aus-lt aman-rabi	1962	10	6807	15	0	0	0	0	8769
b aus-hyv aman	2551	13	0	0	0	0	0	0	2551
b aus-hyv aman-rabi	588	3	0	0	0	0	0	0	588
hyv aus-rabi	1962	10	2269	5	0	0	0	0	4231
hyv aus-lt aman	785	4	3176	7	0	0	0	0	3961
hyv aus-hyv aman	1766	9	907	2	0	0	0	0	2673
lt aman-fallow	1570	8	1815	4	0	0	0	0	3385
lt aman-rabi	1766	9	6807	15	0	0	0	0	8572
hyv aman-wheat	785	4	0	0	0	0	0	0	785
hyv aman-potato	0	0	1361	3	0	0	0	0	1361
hyv aman-rabi	981	5	1815	4	0	0	0	0	2796
b aman-rabi	0	0	0	0	11292	15	0	0	11292
b aman-hyv boro	0	0	0	0	3764	5	0	0	3764
Total	**19622**		**45377**		**75283**		**120702**		**260984**

Note: Areas in hectares

Table 3.5: Present Crop Production

Crop	Damaged free area			Damaged Area			Total Prod.
	Area	Yield	Prod.	Area	Yield	Prod.	
b aus	38498	1.25	48122	2500	1.05	2625	50747
hyv aus	10866	3.75	40747	0	0	0	40747
b aman	55255	1.75	96696	12500	1.45	18125	114821
lt aman	36975	2.15	79496	8500	1.75	14875	94371
hyv aman	9255	3.95	36559	1500	3.55	5325	41884
l boro	68762	2.25	154714	27800	1.45	40310	195024
hyv boro	5442	4.55	24763	4500	2.75	12375	37138
Paddy	225052		481096	57300		93635	574731
wheat	785	2.05	1609				
potato	2342	12	28109				
pulses	6682	0.85	5680				
oilseeds	22276	0.75	16707				
spices	2227	2.25	5012				
vegetables	13365	8.75	116943				

Note: Areas in hectares; yield and production in metric tonnes

Storage and marketing facilities are very limited and most farmers sell their agricultural produce in the village market immediately after harvest when prices are normally low. Remoteness and inaccessibility of the area prevents farmers from getting a good price for their produce and they are compelled to sell at low prices. Often they have to buy back rice at a later date for family consumption at a higher price. It is estimated that only 10 to 20 percent of the production actually enters commercial markets. Private traders handle most of this.

Homesteads are an integral part of the farming system providing fruits, vegetables, fuel, and building materials. The type of vegetation varies with the size and location of the homestead. Trees (mango, betel nut, bamboo, banana, and so on) are common on higher homesteads. Vegetable gardens adjacent to the homestead are also common in these locations. Lower homesteads have fewer trees and are often exposed to the risk of erosion by wave action. Most of the vegetables consumed by the family are produced in the kitchen garden, adjacent to the homestead.

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3.4 Fisheries

3.4.1 Floodplain Fisheries

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

Most of the open permanent water bodies are leased out through open auctions which give the leaseholder fishing rights usually for a period of one or three years. For beels, fish are harvested during the dry season, whereas for the rivers and channels harvesting continues throughout the whole year. During the last part of the monsoon season some leaseholders restrict access to their fisheries and this creates local conflict. There are other conflicts in the area, some between paddy farmers and leaseholders over the use of water during the dry season.

At present the Government is trying to resolve these conflicts by introducing a new system called the New Fisheries Management Policy (NFMP).

3.4.2 Species Present in the Area

It is estimated that about 90 species inhibit the project area. The main species of the area are listed in Table 3.6.

3.4.3 Duar Fishery

During the dry season young fish overwinter in the river duars and 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 about 165 duars in the project area (95 for big Cat Fish, 8 for Pangas, 39 for Major Carp, and 23 for Chital).

Table 3.6: Major Fish in the Baulai Area

Large Fish	Small Fish
Catla, Rui, Mrigel, Air, Gonia, Boal, Rita, Pangas, Chital, Gazar, K.Baush, Shoal, Mohashoal, 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.

3.4.4 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 early monsoon, when the early flash floods or rain water inundate new areas with higher nutrients and a favourable environment (temperature, gradually shallow region, suitable water velocity, soil texture, and so on). Most of the small fish including Pabda, Foli, Koi, Magur, and Lati are usually localized breeders and swim only a short distance for spawning.

Table 3.7: Present Estimated Fish Production

Water body	Area (ha)	Prod Rate (kg)	Total prod (mt)
Beel	26900	525	14122
F. plain	228022	44	10033
Pond	2450	800	1960
River	9390	200	1878
Total			**27993**

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 migratory fish like giant fresh water prawn (M. rosenbergii) and Ilish (Hilsa ilisha) are also widespread in the rivers and floodplains of the south western part of the project area. Prawn fry are migrating towards the floodplains from the sea for grazing, while Ilish are mainly migrating for spawning.

3.4.5 Production trend

Fish production in the project area has reportedly declined by about 25% over the last five years. Present fish production for the area is estimated at about 28,000 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.
- broodfish exploitation.
- increased fish disease.
- construction of embankments and regulators on fish migratory routes.
- increased irrigation and insecticide use.
- increased agricultural area encroaching into water bodies

3.4.6 Fishing Practice

Open water fisheries resources are important: they contribute about 93% of the total fish catch (floodplain 50.5%, beel 35.8%, river 6.7%) while the closed water fisheries only contribute 7%. Subsistence fishing occurs mainly during the monsoon season and large scale beel fishing takes place from December to March.

Installation of katha along river banks is common to attract fish; usually hizal, koroch, jarul, jam, and shewra are used. Various types of nets and gear (ber jal, kona jal, phash jal, bhesal jal, thela jal, uther jal, hooks, and line, and so on) are commonly used for fishing in this area.

3.4.7 Present Fisheries Resource Development

A small portion of the 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 are four tonnes. The ice plant has a capability of 10 tonnes/day. The plant exported 262 tonnes of fish during 1992.

BFDC Fish Marketing Centre, Dabor

The centre was opened in May 1991 and has a capacity of about 50 tonnes/day for cold storage and about 20 tonnes of ice per day. The centre is not operating at its capacity.

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

3.5 Navigation

Water transport through the Meghna/Baulai/Surma River system is an important transport route for the Northeast Region. Many villages depend solely on water transport, particularly during the monsoon season when large areas are deeply flooded. The dominance of water transport in the project area is illustrated in Table 3.9, which summarizes yearly inflows and outflows of commodities by transport sector.

Table 3.8: BIWTA Route Classification

Route	LAD (m)	Season
I	3.6-3.9	Perennial
II	2.1-2.4	Perennial
III	1.5-1.8	Perennial
IV	< 1.5	Seasonal

Note: LAD - Least Available Depth

Figure 17 shows the major navigation routes through the project area. The various routes have been classified by IWT according to their "Least Available Depth" (LAD) using the criteria listed in Table 3.8 (BIWTMAS, 1988).

Major navigation routes are described below.

Bhairab to Companiganj:
This important 230 km long Class II route connects Bhairab Bazar on the Meghna River with Mitamine, Itna, Kaliajuri, Gajaria, Sachna, Jamalganj, Sunamganj, Doara Bazar, Chhatak and continues on along the Upper Surma River to Sylhet and eventually up to Companiganj. Modern IWT vessels travel along this route almost year round, (except February and March) up to Chhatak and country boats can go upstream to Companiganj, even in the dry season. The route is used for transport of sand, boulders, and stone aggregate that is quarried from the mountainous tributary streams draining off the Meghalaya Hills. It is also used for trade between India and Bangladesh; for example, limestone products from India are shipped out of Chhatak.

A profile of the river centreline from BIWTA's 1992 sounding surveys is shown in Figure 18. In 1992, there were six locations where shoals reduced the LAD to below 2.1 m. The total volume of material in these shoals amounts to approximately 120,000 m^3. In order to maintain a Class I channel (LAD of 3.6 m), over 5 million m^3 of shoals would have to be removed, which is not possible with present BIWTA resources.

Daky-Kanchanpur Khal
This route follows a khal between the Surma and Kushiyara River. Boats from Chamraghat, Mitamine, and Itna are able to travel to Rashidganj, Kakailchhao and Ajmiriganj through the khal. The lowest draft on this route reaches around 1.5 m.

Dhanpur-Beramona Khal
This is another route connecting the Surma and Kushiyara Rivers. The khal remains navigable year round. The lowest draft in the khal is around 1.2 m. Often a cross dam is constructed to retain high water from the Kushiyara River.

Chamraghat-Shamarchar
The route follows the Narasunda and Dhanu Rivers, Dhonpur-Beramona Khal, and the Old Surma River. The route remains navigable up to Beri near Shamarchar. By the beginning of winter, water levels drop to about one metre, and from Shamarchar to Kallayanpur, water depths drop to 0.3 m and boats can not ply for one to two months.

Chamraghat - Goaldighi
The route is only 25 km in length from Chamraghat to Goaldighi along the Ghorautra and Gharabhanga Rivers. The Gharabhanga connects the Ghorautra and Baulai Rivers. In December, the confluence of the Gharabhanga and Baulai dries up due to siltation, and no boats can enter.

Chamraghat - Kishoreganj
This route is about 35 km along the Narasunda River. The route is navigable year round from Chamraghat to its junction with the Ghorautra River. The route to Kishoreganj is almost dry during the winter season. As a result, boats can only travel along this route for three or four months in a year.

Gajaria-Fazilpur
This route connects the Baulai River with the Abbua and Jadukata Rivers. Large vessels can ply up to Fazilpur.

Table 3.9: Yearly Inflow and Outflow of Major Commodities

Name of the Market	Total Volume (Tons)	Mode of Transport			
		Mode - 1 Country Boats	Mode - 2 IWT Vessels	Mode - 3 Road Transport	Mode - 4 Rail Transport
Inflow of Major Commodities					
Jamalganj	2817564	1136030	1681534	-	-
Sunamganj	354820	334631	1975	18213	47
Chhatak	2409036	2387067	2520	17005	2444
Companiganj	2271079	2270694	-	385	-
Chamraghat	97495	86441	-	11054	-
Mohanganj	145013	92039	85	51618	1269
Total	**8,095,007**	**6,306,901**	**1,686,114**	**98,275**	**3,713**
Outflow of Major Commodities					
Jamalganj	**2795252**	**133914**	**2644444**	**16893**	
Sunamganj	**354820**	**14763**	**318425**	**21631**	
Chhatak	**2257086**	**108519**	**1943805**	**204761**	
Companiganj	**2271079**	**2268482**	-	**2597**	
Chamraghat	**97428**	**14154**	-	**83274**	
Mohanganj	**139151**	**86136**	-	**29773**	**23249**
Total	**7,914,816**	**2,625,968**	**4,906,674**	**358,929**	**23,249**

Source: Water Transport Study, NERP, September 1993.

BIWTA's Masterplan (BIWTMAS, 1988) observed that "*deterioration of Bangladeshi waterways' navigability over the past decades has taken place and will continue in the northeast divisions tributaries and connectors*". This deterioration has been attributed to several factors, including siltation of distributary channel offtakes and changes to the river's low flow regime.

3.6 Summary of Problems and People's Perceptions

General

Local people's perception 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 might solve these problems. These were collected through personal interviews, group discussions, and meetings with various cross-sections of people during the relatively short field work in the project area. Also, opinion and suggestions were sought in a series of four seminars which were held at the district headquarters in Sunamganj, Netrokona, Sylhet, and Kishoreganj. Participants at the seminars included the Honourable Members of Parliament, District and Thana level officials, Union Parishad Chairmen, representatives from village level organizations, and NGOs. The problems and suggestions from these seminars are described below.

Problems

Flooding and drainage congestion are described as the major problems of the project area. Pre-monsoon flash flooding is referred to as a serious and widespread problem. This flooding mainly damages rice crops. Boro is affected almost every year and is damaged fully or partly in many haors and beels by pre-monsoon flash floods in April and May. These flash floods generally enter the project area through channels and tributaries from the major river systems of the Surma, Kushiyara, and Baulai. Sometimes, there is over bank spill and the low-lying boro fields are inundated. The situation is sometimes further aggravated by intensive rainfall. Damage has occurred regularly in recent years. The major entry points of these flood waters are: the Dhopa Khal, Madhabpur Khal, Mora Surma River, and Piyain River from the Surma-Baulai River system, and Kangsha River, Someswari River, Chalti gang, and Jadukata River. Sometimes flood waters over spill the banks of the Kushiyara River down to Sherpur and near Ajmiriganj, and the Baulai River down to Lepsa bazar. There are two major internal rivers which overspill their banks and inundate boro fields: the Mora Surma River and Piyain River.

Aus and the seed beds of t.aman are also damaged by pre- and early monsoon flash floods in the north-eastern part of the basin. T.aman is affected in these areas during June to September by monsoon floods overspilling mainly the banks of the Surma and Kushiyara Rivers, and their tributaries. The flood waters generally last for seven to ten days in the upper areas and there are three to four such occurrences reported in every monsoon period.

Drainage congestion is reported to be the second most important problem. Due to the silting up of the Surma-Baulai and Kushiyara River systems as well as the smaller internal rivers and channels, water can not be drained out in time to start boro cultivation. This delays the transplanting of boro (local and HYV) and makes the crops more vulnerable to damage by pre-monsoon flash floods. This reduces the net cultivable area.

Damage to homesteads by monsoon waves is also a serious problem, especially in the villages of Kaliajuri, Itna, Sulla, Derai and Jamalganj thanas. Many villages in these thanas are being rapidly eroded by monsoon waves.

Fishermen considered that fishing by dewatering jalmohals was a major cause of decreasing fish production. They also stated that roads and embankments in the flood plains obstructed the movement of fish and reduced fish production. Concern was expressed about fish migration in the project area from the Kushiyara and the Surma-Baulai Rivers as a result of closure or constructing sluice gates on the various channels and smaller rivers. They were also concerned about the loss of fish habitats and large scale deforestation in the flood plains.

Fishermen of Chhatak and Dowarabazar thanas expressed their concerns about the industrial pollution in the Surma River from the Chhatak Cement and Pulp Factories. They stated that this pollution may have a negative impact on fish production in the area.

People also expressed their concern about boat and launch movement along the Baulai River and between the haors and rivers. They stated that if navigation was not improved at critical points, for example at Paindamukh, Piyain outfall at Lepsa, and on various internal rivers, there would be a tendency to cut embankments during the early monsoon months. Due to the silting up of the Baulai River at various locations, navigation, particularly during the dry season, has become more difficult.

Suggestions

Numerous suggestions were put forward by local people. However, some suggestions are meant for very small and localised issues. The most common are:

- Dredge the Surma and Baulai Rivers to provide rapid drainage of flash flood waters as well as for improved navigation.
- Re-excavate the Old Surma, Piyain, Darain, upper Baulai, Jadukata, Someswari, and Kangsha Rivers for improved pre-monsoon and post-monsoon drainage.
- Improve the banks of the Surma and Baulai Rivers to stop overspilling of pre-monsoon flash flood waters into the haor areas at various locations.
- Control pollution of the Surma River water caused by Chhatak industrial waste.
- Stop intrusion of flash flood waters into Kaliagota Haor through Kalkolia khal at Alipur.
- Construct a sluice gate on the Piyain River at Lepsa and include provisions for navigation and fish movement.
- Re-open the Bheramohona River near Ajmiriganj and provide a sluice gate with provision for navigation.
- On a priority basis, protect the most vulnerable villages of Kaliajuri, Itna, Derai, Tahirpur, Jamalganj, and Sulla thanas from monsoon wave erosion.
- Allow poor and subsistence fishermen to catch fish in the flood plain.
- 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. Tangua beel and Kaliajuri area should be considered as possible candidates.

- Provide adequate provisions for navigation so that embankment construction does not impede the waterways.

3.6.1 Local Initiatives

Local people stated that it is their traditional practice to organize themselves to counteract crisis which arise as a result of flash floods and drainage congestion. The main activity is to construct dams on various localised canals to stop pre-monsoon flash floods entering the agricultural areas. A cross dam is constructed almost every year by local farmers in Kolkalia khal of Kaliagota haor to stop the entry of pre-monsoon flash floods.

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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.

Net population growth
About 1.8% per year. This 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 would be 2,669,700 and by the year 2015 the population would be 3,482,580.

Morphologic Change
The Baulai River appears to be a depositional zone, with sediment aggradation occurring during the monsoon season when the river slopes are very flat and sediment flushing occurring during pre-monsoon flash floods when river gradients and channel velocities are highest. Much of this sediment deposition appears to be occurring overbank and in distributary channels that join the main channel.

If no action is taken, it is expected that additional sediment deposition will occur at the mouth of the Someswari, Kangsha and Piyain Rivers, since the flows carried by these channels has been reduced by upstream morphologic changes. These "dying channels" will gradually fill-in, with the shoals causing reduced depths for navigation and greater drainage congestion than at the present time.

Although recent efforts have been made to close spill channels on the right bank of the Kalni, there is a strong flow gradient during pre-monsoon flash floods from the Kalni River into the Baulai River through the network of inter-connecting khals and channels in the Central Basin. This suggests there should be a tendency for increased spills from the Kalni River into the Baulai River, at least during pre-monsoon flood conditions.

Future rates of siltation will depend on the magnitude of the sediment inflows and discharges from the Surma River and its tributaries. These inflows could be affected by three external factors including:

- 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.

The historic trend of increasing rainfall and increasing variability of rainfall over the period 1901-1991 was described in Section 2.2 of this report. It is not certain whether these trends will continue in the future, level off or be reversed. However, global climate modelling research suggests the trends, particularly that in the variability of rainfall, will continue in the decades ahead.

At present virtually all of the Barak River inflows pass down the Kushiyara River during the dry season. Therefore, any further changes at the bifurcation are not likely to reduce low flows any more on the Surma/Baulai.

India has recognized the potential for constructing a major dam on the Barak River at Tipaimukh gorge for many years. In recent years a proposal has been advanced for a multi-purpose project that would provide hydro-power and flood control. Construction was proposed to start by 1993 but has been delayed pending resolution of various issues including the effects on flow regulation on Bangladesh. Additional comments on this project are provided in the Northeast Regional Water Management Plan, Draft Final, September 1993.

Preliminary simulations of the project with 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 the flow regulation will result in lower discharges between June and September, and higher flow volumes between October and May. However, due to the magnitude of the tributary inflows downstream of Sylhet, the impact of this flow regulation will be relatively minor on the Baulai River.

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 increased flow could delay drainage which could make portions of the project area become non-cultivable. Increased post-monsoon and dry season flows would provide benefits for navigation and irrigation. To-date, the information available from the Joint River Commission provides only a minimal description of the Tipaimukh project. Additional information will be needed to improve estimates of future impacts. However, the preliminary calculations completed so far, serve to illustrate that Tipaimukh Dam could significantly alter the hydrologic regime and could produce both positive and negative impacts to the region.

Food grain production growth

Current trends in agricultural production would continue if the problem created by silt deposited in the Baulai River is not cleared through dredging. Preliminary analysis of the water level data indicates that drainage congestion would further impact an additional area of over 6,000 ha, bringing the total area suffering from drainage congestion to 24,700 ha on F3 land. It would not be possible to grow any crops in these areas in absence of drainage improvements through dredging of the Baulai River. The magnitude of flash floods are expected to increase. Damage to local and high yielding varieties of boro rice at the reproductive phase would increase. A marginal expansion of irrigation facilities would take place due to limited dry season water availability. This would facilitate an expansion of high yielding varieties of boro area that would continue to be damaged by pre-monsoon floods. But before making these investments, farmers are expected to apply their judgements in selecting the sites with the least possibility of flood damage.

Flash floods would continue to damage local varieties of aus and deep water aman rice. In fact the extent of damage would increase if the magnitude of flash flood increases.

Local varieties of transplanted aman rice are expected to be replaced by high yielding varieties of transplanted aman on F0 land types. But the extent of area affected by drainage congestion on F1 land would 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 with no river improvement project are presented in Tables 4.1 and 4.2.

Table 4.1: Cropping Patterns under Future Without-Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					52698	70	6035	5	58733
fallow-l boro					0	0	78456	65	78456
fallow-hyv boro	0	0	0	0	7528	10	6035	5	13563
b aus-fallow-rabi	0	0	4538	10	3764	5	0	0	8302
b aus-lt aman	2551	13	15882	35	0	0	0	0	18433
b aus-lt aman-potato	981	5	0	0	0	0	0	0	981
b aus-lt aman-rabi	1962	10	6807	15	0	0	0	0	8769
b aus-hyv aman	3924	20	0	0	0	0	0	0	3924
b aus-hyv aman-rabi	588	3	0	0	0	0	0	0	588
hyv aus-rabi	1962	10	2269	5	0	0	0	0	4231
hyv aus-lt aman	785	4	3176	7	0	0	0	0	3961
hyv aus-hyv aman	1766	9	907	2	0	0	0	0	2673
lt aman-fallow	196	1	1815	4	0	0	0	0	2011
lt aman-rabi	2158	11	6807	15	0	0	0	0	8965
hyv aman-wheat	785	4	0	0	0	0	0	0	785
hyv aman-potato	0	0	1361	3	0	0	0	0	1361
hyv aman-rabi	1962	10	1815	4	0	0	0	0	3777
b aman-rabi	0	0	0	0	7528	10	0	0	7528
b aman-hyv boro	0	0	0	0	3764	5	0	0	3764
Total	**19622**		**45377**		**75283**		**120702**		**260984**

Note: Areas in hectares

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Table 4.2: Crop Production Under Future Without-Project Condition

Crop	Damage free area			Damaged Area			Total Prod.
	Area	Yield	Prod.	Area	Yield	Prod.	
b aus	38498	1.25	48122	2500	1.05	2625	50747
hyv aus	10866	3.75	40747	0	0	0	40747
b aman	57526	1.75	100670	12500	1.45	18125	118795
lt aman	34620	2.15	74433	8500	1.75	14875	89308
hyv aman	11610	3.95	45860	1500	3.55	5325	51185
l boro	42956	2.25	96652	35500	1.45	51475	148127
hyv boro	11828	4.55	53815	5500	2.75	15125	68940
Paddy	207903		460299	66000		107550	567849
wheat	785	2.05	1609				
potato	2342	12	28109				
pulses	6324	0.85	5375				
oilseeds	21080	0.75	15810				
spices	2108	2.25	4743				
vegetables	12648	8.75	110670				

Note: Areas in hectares; yield and production in metric tonnes

5. PROPOSED RIVER IMPROVEMENT PROJECT

5.1 Rationale

The rationale for carrying out channel improvements along the Baulai River and its distributaries is that these activities are necessary for the long-term maintenance of the river channel system and for ensuring the operation of infrastructure in the surrounding area. Channel maintenance measures are also less likely to produce other undesirable impacts in comparison to other structural works that have been used in the past, such as flood embankments.

5.2 Objectives

- to improve the drainage capacity of key tributary and distributary channels (Someswari, Kangsha, Piyain, Old Surma Rivers) in order to reduce the post-monsoon drainage congestion that is plaguing the existing submersible embankment projects adjacent to the rivers;
- to reduce pre-monsoon flood levels and post-monsoon levels on the Baulai/Nawa River by increasing the channel's cross sectional area at local constrictions; and
- to improve navigation along the Surma/Baulai and its distributaries by increasing depths during the dry season through dredging and/or local river training.

5.3 Scope of Channel Improvement Work

5.3.1 Baulai/Nawa River

There are several locations where the Baulai River's channel width and cross sectional area are constricted. At some of these locations, the constrictions developed after pilot loop cuts failed to enlarge and establish a normal "regime" width. Furthermore, portions of the river have not widened appreciably after the shift from the Old Surma channel diverted more water into the Baulai system. The reason for the slow adjustment is probably the presence of erosion resistant cohesive sediments and peat in the channel banks. Therefore, one option that should be considered, is to enlarge these local constrictions by widening the cross section. This would assist the channel to develop a more stable regime by hastening adjustments that are already developing. Based on the limited cross section data, it appears a "target" bankfull width would be around 200 m and a corresponding cross sectional area would be around 1,600 m^2.

Major shoals also develop at "crossings" between bends, mid-channel bars in expansions, and some point bars. The aim for channel improvements in these reaches should probably be to maintaining a useable navigation channel rather than attempting to deepen the entire cross section. This is because inspite of the sediment deposition that has been occurring, these sections have been able to maintain a relatively large cross sectional area by progressive channel widening.

Table 5.1: Proposed Improvement Works on Baulai Channel

Reach	Km	Proposed Works	Benefits
Below Sukdevpur - Nawa River	245-260	Channel excavation and local widening	Reduction in pre-monsoon water levels
Former loop cut upstream of Kaliajuri	270-272	Channel excavation and local widening	Reduction in pre-monsoon water levels
Baulai/Nawa/Surma	165-350	Local channel excavation at shoals and bars	Improved navigation between Bhairab and Chhatak

Note: Channel distances (km) measured from start of Surma River at Amalshid
Refer to Figures 11 and 12 for reach locations.

Table 5.1 and Figure 19 illustrate the locations where channel excavation could prove beneficial. Most effort is focused at former loop cuts such as upstream of Kaliajuri and near Sukdevpur.

Dredging for navigation would be carried out at local obstructions between Chhatak and the Ghorautra River junction, with initial efforts made to ensure a Class II channel could be maintained. Based on 1992 IWT sounding charts, there were seven locations over a 130 km reach of river requiring dredging. The total amount of material that needed to be removed amounted to approximately 120,000 m^3. A review of charts from earlier years showed there has been considerable year to year variation in the location and quantity of shoals on the river.

For preliminary planning purposes it has been assumed that 7 million m^3 of material would be excavated from the Baulai River system. This includes 6.7 million m^3 for improving the channel capacity and 0.3 million m^3 for improving the navigation channel.

The impacts on water levels from channel excavation depend on:

- the discharge of the Surma/Baulai 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 greatly reduced. Therefore, channel improvements should <u>not</u> 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. The main goal of the proposed works would be to reduce water levels during the pre-monsoon and post-monsoon seasons.

For any specific flow condition considered, the impacts of channel excavation are governed primarily by the increase in the channel's cross sectional area and the total volume of material removed from the channel. However, the local hydraulic conditions, 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, dredging in wide, lower gradient reaches has much less impact on upstream water levels than dredging in narrow reaches with relatively steeper slopes. It is important to identify local hydraulic controls such as "crossings" or constrictions. Therefore, detailed surveys and hydrographic information are required in order to make reliable assessments of impacts. With available cross sections spaced between 9 km - 18 km apart, only very preliminary estimates can be made at this time.

Initial calculations with the Mike-11 hydrodynamic model indicated that there is relatively little hydraulic impact from excavating material downstream of Kaliajuri. This is because the gradient below Kaliajuri is very low so that the change in water level is very insensitive to the amount of material excavated from the channel. Additional test backwater calculations suggested that channel improvements in the 15 km reach between Sukdevpur and the lower Nawa River (km 245 to km 260 on Figure 19) had a substantially greater impact on upstream water levels. Backwater computations were repeated using various dredge cut geometries and bed levels to assess the sensitivity of the water level changes to the proposed improvements. It was found that excavating 5.8 million m^3 could lower water levels by up to 0.8 m in the Nawa River and by 0.7 m at Sunamganj (at a discharge of 2,000 m^3/s at Sunamganj).

Water level changes of this magnitude during the pre-monsoon flood season would benefit several existing submersible embankment projects including Pagner Haor, Halir Haor, Joal Bhanga Haor, Shanir Haor, Karchar Haor, and Dhankunia Haor and so on. However, more precise estimates of expected impacts will have to be made after additional cross section surveys and hydrometric data becomes available and more refined model simulations are carried out. Furthermore, the cumulative impacts of other developments will have to be considered.

5.3.2 Drainage Improvement of Distributary Channels

The floodplain of the Baulai River is laced with a maze of channels that connect with major tributary rivers such as the Someswari River, Kangsha River, and Mogra River. Other channels serve to inter-connect khals and distributaries that drain the vast low-lying Central Basin. Past morphologic changes have affected the upstream supply of water and sediment to these channels. The lower reaches of the Someswari River, Kangsha River, and Piyain River appear to have silted-in after upstream flow diversions reduced their capacity to flush fine sediment that has been deposited during the monsoon season when the channels are deeply flooded. The Patnai-Baulai River system appears to be receiving increased flow from an avulsion on the Jadukata River. This will induce channel widening and degradation on the upper reaches of the Patnai River, with the sediments deposited further downstream, probably near the junction with the main Baulai River. As this avulsion progresses, it will divert more water and sediment into the Upper Baulai River and further increase the requirements for channel improvements in this area.

Major channel re-excavation work is needed along the distributary channels to improve drainage and navigation within the project area. A list of potential drainage improvement works on these channels is summarized in Table 5.2. The approximate extent of the channel improvements is shown on Figure 20. Longitudinal profiles showing approximate ground elevations along the channels are summarized in Figures 21-24.

The proposed work includes improving 175 km of channels. This includes 24 km on the Jadukata-Rakti River and 42 km along the Old Surma River, which has already been described in separate NERP pre-feasibility studies ("*Jadukata-Rakti Improvement Project*" and "*Surma-Kushiyara-Baulai Basin Project*"). These components have been included in this report to provide a complete package of drainage improvement works throughout the Central Basin.

The work would involve re-excavating channels to provide a uniform minimum available depth during the dry season, widening the channels if necessary to increase their conveyance and straightening reaches with highly sinuous channels to allow greater discharge capacity. Preliminary excavation quantities for each channel are summarized in Table B.2 (Annex B). In most cases no detailed surveys of the channels were available. Therefore, volume estimates have been made on the basis of site inspections. Detailed hydrographic surveys will be required along each channel during feasibility investigations.

**Table 5.2: Proposed Improvement Works
Tributary Channels**

River	Section	Proposed Works	Benefits
1. Jadukata-Rakti	Outfall of Rakti into Surma at Durlabpur to Fazilpur (24.0 km).	Deepening of the channel by dredging combined with manual re-excavation to increase the flow capacity of the river.	1. Restoration of BIWTA Class II navigation route up to Fazilpur. 2. Reduction in the pre-monsoon flood levels. 3. Earlier post-monsoon drainage.
2. Patnai-Baulai	Outfall of Baulai into Nawa to the confluence with Ghasia River (25.0 km).	Deepening of the channel by dredging combined with manual re-excavation to increase the flow capacity of the river.	1. Reduction in the pre-monsoon flood levels. 2. Earlier post-monsoon drainage. 3. Improved local boat navigation.
3. Someswari	Outfall of Someswari into Baulai at Sukdevpur to Joysree (16.0 km).	Removal of localized sand bars and re-opening of the silted channel section.	1. Reduction in the pre-monsoon flood levels along the re-excavated section. 2. Improved pre-monsoon and post-monsoon drainage from the Kangsha River basin.. 3. Improved local boat navigation.
4. Kangsha	Outfall of Kangsha into Baulai to Mohanganj (38.0 km).	Dredging of bed and enlarging of the channel section along the 10 km lower reach. Re-excavation of silted sections downstream of Mohanganj.	1. Reduction in the pre-monsoon flood levels along the re-excavated section. 2. Improved pre-monsoon and post-monsoon drainage from the Kangsha River basin. 3. Improved local boat navigation.
5. Piyain	From Lipsa to Bhatipara (30 km).	Dredging of localized silted sections.	1. Improved local navigation.
6. Old Surma	Dhanpur to the confluence with Kalni (42.0 km).	Channel dredging and loop cuts.	1. Reduction in the pre-monsoon flood levels. 2. Earlier post-monsoon drainage. 3. Improved navigation.

There appears to be little scope for using river training structures such as spurs as a general alternative to channel re-excavation along the distributaries. However, structures may prove useful in specific applications and should be considered further during feasibility investigations.

It should be noted that the proposed work on the Piyain River is primarily intended for navigation improvement, not pre-monsoon flood control since the lands adjacent to this channel are very low.

Table 5.3: 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

5.4 Dredging Considerations

5.4.1 Dredger Capacity

The proposed works would require a substantial increase in the capacity of the dredge fleet in the Northeast Region. This might require private sector involvement and/or procurement of new higher capacity equipment. For example, BWDB currently has eleven 18 inch suction cutterhead dredgers. The dredges can pump 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 (4,000-5000 feet). Assuming one operated 12 hours/day and 20 days per month, the expected production from a single dredge is in the order of 50,000-60,000 m^3/month.

The status of BIWTA's dredge fleet was reviewed in their *Bangladesh Inland Water Transport Masterplan* (BIWTMAS), 1988. In this 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 5.3.

Annual production has averaged 2.5 million m^3/year, ranging between 1.8 million and 3.5 million. An annual dredging performance of 4.5 million m^3/year was considered to be the maximum medium term target (by 1994/95) within reach of the present BIWTA organization. It was stated that this increased production could be achieved primarily by increasing the dredging time from 16 hours/day to 24 hours/day and by increasing the deployment time from 27 weeks/year to 35 weeks/year.

Guidelines published by the US Army Corp of Engineers indicate potential solid output rates of around 5,000 m^3/day for an 18 inch cutter suction dredger 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 past BIWTA rates.

An upper limit for a single 18 inch dredger operating between September and March is probably around 700,000 m^3/season. A production target of 2.5 million m^3/year might be achievable with four dredgers (260 m^3/hr x 16 hr/day x 150 days/year x 4 dredges). This implies it would require at least 12 dredger-years of effort (three years by four dredgers) to excavate 7 million m^3 of material from the river. A comparable effort would be required to complete the work on the six drainage channels, with each channel requiring 2-3 dredger-years of work.

5.4.2 Dredge Spoil Disposal

Careful consideration would have to be given to the problem of disposing of the dredge spoil in an acceptable manner. If the spoil was simply dumped back in the river, then some of the benefits of the work could be lost. Furthermore, if adequate disposal methods were not followed, it could produce undesirable impacts to fisheries habitat and agricultural land. Formulation of a dredge disposal plan will require a considerable amount of site specific information which is not available at this time. Furthermore, previous experience gained from the Dredged Material Research Program, (US Army Corps of Engineers) has shown :

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

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

- the quantity of the dredge material;
- its grain size and organic content;
- its degree of contamination and its toxicity;
- soil permeability and the depth to the water table at the disposal site.
- land-use in the vicinity of the site and public acceptance of spoil disposal; and
- presence of critical habitat or wetlands.

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

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

The NERP initiative, "*Flood and Erosion-Affected Villages, Development Project (FEAVDEP)*" has considered using dredge spoil as a resource to construct new village platforms above the level of the monsoon flood in the deeply flooded Central Sylhet Basin. The aim of this project is to raise and enlarge homesteads belonging to families that are vulnerable to flooding and erosion. The most affected victims would be resettled onto new homestead platforms. A typical new village was planned to contain 130 households (700 persons). It was also assumed that the platforms would be constructed up to 5 m above the surrounding floodplain land and each platform would occupy around 2.6 ha for households and 0.65 ha for public land. Therefore, each village platform would require roughly 189,000 m^3 of fill material. This volume corresponds approximately to three months operation from an existing BWDB dredger.

If 2.5 million m^3/year of dredging was carried out over 20 km of the Baulai River, then village platforms could be constructed at a rate of 10 per year. This calculation 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 totalling around 7 million m^3, it is conceivable that 27 new village platforms, which could contain 3,300 households and 17,700 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. If the overall channel length of the dredged reach was 20 km, this implies the villages could be spaced around 1.7 km apart, on average. A review of topographic maps and satellite photos was made to provide a crude estimate of the number of existing villages located in the potential spoil disposal zone (a 20 km long, 1.5 km wide strip on each bank of the river). It was found there were 18 villages on the left bank and 17 on the right bank, excluding major towns. Therefore, the proposed work could approximately double the number of village sites along this reach of the river. In reality, the dredge spoil could be used in many different ways: to create new village sites on khas land or land used for agriculture, to raise existing village platforms (assuming the residents were interested) or to extend existing villages.

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.

5.5 Expected Benefits

The primary benefits of the project relate to agriculture, water transport, and fisheries. The project will not affect water levels during the monsoon season. However, improving the channels' discharge capacity will reduce water levels and flood damage during the pre-monsoon season. The works would also improve drainage during the post-monsoon season by allowing faster drainage. However, an analysis of post-monsoon water level data reveals that it would not be possible to drain out water from the total project area till the end of January. The area remaining out of cultivation could be reduced from 24,700 ha under the "future without project" condition to roughly 9,000 ha under the "future with project" condition. This implies an additional 15,700 ha could potentially be brought under cultivation through drainage improvements.

The benefit of these improvements would mainly be derived in agriculture through increased crop production. Farmers would be able to harvest local and high yielding varieties of boro rice before the onset of the monsoon. Damage presently suffered by these crops from pre-monsoon floods would be reduced and delayed flooding would induce farmers to replace some of the local varieties of *boro* rice by high yielding varieties. However, it will not be possible to eliminate flood damage from the entire area. As a result, it has been assumed that damage to local and high yielding varieties of *boro* rice would continue, but at a reduced scale. The area expected to suffer from flood damage even with the improvements, has been estimated from the post-project water level data.

Drainage improvements in the post-monsoon season would make the land available for cultivation early in the *rabi* season, facilitating timely plantation of *rabi* crops. As a result, the area under *rabi* crop production is expected to increase after the channel improvements were completed. Farmers are expected to utilize the residual soil moisture by growing *rabi* crops. This would include fodder crops to meet the requirement of cattle feed.

Estimated cropping patterns and crop production under the "future with project" condition are presented in Table 5.4 and 5.5, respectively.

The proposed channel improvements would also benefit water transportation, which is now being significantly restricted during much of the year (November - April). These benefits would be greatest along the tributary and distributary channels which are virtually unusable during the dry season.

Re-excavation of infilled distributary channels would also benefit fisheries by allowing better access to spawning areas during fish migration.

Use of the dredge spoil for raising and constructing village platforms could improve the living conditions for local residents along the river.

Table 5.4: Cropping Patterns for With-Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					26349	35	12070	10	38419
fallow-l boro					0	0	72421	60	72421
fallow-hyv boro	0	0	0	0	3764	5	24140	20	27905
b aus-rabi	0	0	4538	10	3764	5	0	0	8302
b aus-lt aman	2551	13	15882	35	0	0	0	0	18433
b aus-lt aman-potato	981	5	0	0	0	0	0	0	981
b aus-lt aman-rabi	1962	10	6807	15	0	0	0	0	8769
b aus-hyv aman	3924	20	0	0	0	0	0	0	3924
b aus-hyv aman-rabi	588	3	0	0	0	0	0	0	588
hyv aus-rabi	1962	10	2269	5	0	0	0	0	4231
hyv aus-lt aman	785	4	3176	7	0	0	0	0	3961
hyv aus-hyv aman	1766	9	907	2	0	0	0	0	2673
lt aman-fallow	196	1	1815	4	0	0	0	0	2011
lt aman-rabi	2158	11	6807	15	0	0	0	0	8965
hyv aman-wheat	785	4	0	0	0	0	0	0	785
hyv aman-potato	0	0	1361	3	0	0	0	0	1361
hyv aman-rabi	1962	10	1815	4	0	0	0	0	3777
b aman-rabi	0	0	0	0	37642	50	0	0	37642
b aman-hyv boro	0	0	0	0	3764	5	0	0	3764
Total	19622		45377		75283		120702		260984

Note: Areas in hectares

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Table 5.5: Crop Production for With-Project Condition

Crop	Damage free area			Damaged Area			Total Prod.
	Area	Yield	Prod.	Area	Yield	Prod.	
b aus	38498	1.25	48122	2500	1.05	2625	50747
hyv aus	10866	3.75	40747	0	0	0	40747
b aman	67325	1.75	117819	12500	1.45	18125	135944
lt aman	34620	2.15	74433	8500	1.75	14875	89308
hyv aman	11610	3.95	45860	1500	3.55	5325	51185
l boro	44621	2.25	100398	27800	1.45	40310	140708
hyv boro	27169	4.55	123618	4500	2.75	12375	135993
Paddy	234708		550996	57300		93635	644631
wheat	784	2.05	1609				
potato	2342	12	28109				
pulses	18069	0.85	15358				
oilseeds	25296	0.75	18972				
spices	3613	2.25	8130				
vegetables	14455	8.75	126481				
fodder	10841						

Note: Areas in hectares; yield and production in metric tonnes

5.6 Project Operation and Maintenance

It is proposed that a single Project Operation Unit (POU) be formed for the purpose of operating and maintaining the project. The POU should include a hydraulic engineer, an agronomist, a fisheries specialist and representatives of local bodies in various capacities and various field monitors.

Three types of operations need to be considered for this project:

- Initial project development dredging and channel re-excavation work;
- Ongoing channel maintenance;

- Periodic unscheduled channel maintenance due to occasional extreme floods or unusual events such as rapid channel shifting.

Operations during development dredging would involve implementing the channel improvement program and the dredge spoil disposal program.

Periodic (possibly every one to three years) channel maintenance dredging and channel re-sectioning would be required to ensure the distributaries are not re-filled with sediment. Requirements for maintenance dredging would have to be established by regular monitoring through the POU. At this stage, the effort required to maintain the channels is not known.

5.7 Organization and Management

During the early part of the feasibility study process, a client group would need to be organized to oversee project development. The client group would be composed of representatives from the local communities and would include relevant thana-level technical officers. The group would ensure that the problems of the area are clearly understood and adequately reflected in the feasibility work and that the technical solutions being proposed address the problems in an acceptable manner. They would be continually briefed as the feasibility work was carried out and would need to confirm the conclusions of the exercise. They would also be informed as to details of designs being proposed by BWDB design engineers which designs, in the end, would require their approval. The groups would also monitor the construction program which would be carried out by BWDB.

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 be under the Sylhet and Mymensingh circles. Construction supervision would be carried out by sub-divisional field staff.

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.

5.8 Cost Estimates

Total project costs are estimated at about Tk 1,485 million. A break down of the costs by component is shown in Table 5.6. The costs include a Pilot Project component, which is described further in Chapter 6. Costs of work carried out under the main project have been adjusted to include any work completed under the Pilot Project. The basis of the estimates and a breakdown by each river channel is provided in Annex B.

Future dredging costs have been estimated assuming a unit cost of 80 Taka/m^3. 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 200,000/ha.

5.9 Project Phasing

It is proposed that a pilot project be conducted during year one and two to test channel improvement concepts and to develop methods for disposing of the spoil and using it for constructing village platforms. Additional feasibility studies will be completed during this period, including preparation of an Environmental Impact Assessment.

The schedule for the main development dredging work will be finalized during completion of the Pilot Dredging and feasibility studies. At this time, it appears the main channel excavation would require at least three seasons of dredging effort and a similar length of time for the distributary channels. The actual time required to complete the work could vary significantly depending on the equipment that was available.

Table 5.6 Project Cost Summary

Item	Cost (Taka ,000)
Main Channel Excavation	560,000
Land Acquisition	44,000
Distributary Channel Excavation	325,200
Land Acquisition Distributary Channels	49,600
Base Cost	978,800
Physical Contingencies	254,488
Subtotal	1,233,288
Pilot Project	66,550
Study Costs	184,993
TOTAL	1,484,831

Notes:

1. *Physical Contingencies are 25% of Base Costs.*
2. *Study costs are 15 % of the sub-total and include the costs of an EIA and preparation of an Environmental Management Plan.*
3. *Costs of works on Jadukata-Rakti and Old Surma River channels are not included as these have been outlined in other NERP pre-feasibility reports.*

5.10 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)*
- *Kalni-Kushiyara River Improvement Project (NERP)*
- *Water Transport Study (NERP)*
- *Bangladesh Inland Water Transport Masterplan (BIWTMAS)*

5.11 Impacts

5.11.1 Biophysical

The intent of the project is to rehabilitate the river by initiating a program of channel maintenance dredging. The work has become necessary as a result of ongoing channel changes and impacts from past developments on the river. The aim of the work is to restore the drainage characteristics of the main distributary channel and to assist the main channel to establish a more stable configuration. As a result, the principal biophysical impacts of the maintenance work are expected to be beneficial. In particular, the work should be compatible with fisheries interests over the long-term, since it will allow easier fish migration through the distributary channels.

5.11.2 Social

The project will improve the environment of the local people living along the river. The work will allow for easier transport of goods and people between communities throughout the project area. Construction of new homesteads and villages from the dredge spoil will allow those most affected by flooding and erosion to improve their situation.

5.12 Costs - Benefits

It is considered that the objectives of this project are necessary, desirable, and of high priority. To achieve these objectives, technical options were evaluated and chosen, based in part, on cost-effectiveness. Given the ongoing hydrologic and morphologic changes occurring throughout the project area and the uncertainties in estimating impacts of localized works on the affected area and expected benefits, it was decided that computations of economic benefits and rates of return from the proposed works would not be meaningful at this time. This assessment, including impacts on agriculture, water transport and fisheries, should be carried out as part of feasibility investigations.

5.13 Multi-Criteria Analysis

The qualitative criteria shown in Table 5.7 are scored on an 11 level scale of -5 to +5. 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.

Table 5.7: Multi-Criteria Analysis

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Ecological Character	+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

6. PILOT PROJECT

6.1 Rationale

Pilot-scale dredging is an appropriate means for developing technical solutions and for demonstrating the feasibility of larger scale river improvement operations. At this time there is little prototype experience available to assess the effectiveness of dredging operations, or to evaluate 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.

6.2 Objectives

The objectives of the Pilot Dredging Project are:

- to carry out selective channel improvements on the distributary channels by dredging. The work is intended to be the first stage in a more comprehensive project to improve drainage in the project area;

- to develop, test and demonstrate measures for disposal of dredge spoil, including assessing its potential use for creating new village platforms; and

- to develop methodologies and experience for administering, training personnel and managing a dredging program.

6.3 Project Description

The pilot project would be carried out over a two year period. The work would include initial planning and identification of project limits and project goals, establishment of a monitoring program to assess project impacts, developing a dredging program and a dredge spoil disposal plan, executing the pilot project and evaluating the results of the work.

It is expected that the work would focus on a single distributary channel which is experiencing drainage congestion and reduced navigation due to siltation. For example, the lower reaches of the Someswari River near its junction with the Baulai River, would make an appropriate Pilot Project test site. However, the final selection of the site would require additional field inspections and discussions with local residents.

The following brief comments illustrate the kinds of issues that would be addressed during the study.

Initial Planning
Meetings would be held with BWDB and BIWTA to discuss the project concept, exchange information and formulate plans for activities over the year. The availability of dredging equipment over the next two years would be assessed. Reconnaissance surveys would be made to define the extent of channel improvements that would be feasible on a single distributary channel. Public presentations would be made, and opinions would be solicited on appropriate sites for dredging and disposal.

Preparation of Dredging Plan
A pre-project dredging plan would be prepared in consultation with BWDB, BIWTA and local authorities. During this time, the extent of dredging and quantity of material to be removed would be estimated. A detailed plan for disposing and stockpiling the spoil would be prepared and a monitoring plan for assessing dredging effectiveness and impacts of spoil disposal operations would be made. Detailed surveys in the proposed test reach and land surveys at the disposal sites would be prepared.

Dredging
The disposal sites would have to be cleared and works would have to be installed for retaining the spoil. Dredging would be carried out over a period of five months (say November to March). It is expected that in the order of 250,000 m^3 of material could be excavated by a single dredge over a five month operating season. This implies a dredge would be able to complete a 30 m wide, 1.6 m deep dredge cut over a 5 km reach in a single season. The actual dredging would probably be concentrated on removing local high spots rather than continuous excavation. Furthermore, some manual excavation might be carried out, particularly if loop cuts or channel re-locations were made.

For the purposes of this study it is assumed a total of 500,000 m^3 of material would be removed over the duration of the Pilot Project. This would provide sufficient spoil for at least two village platforms (assuming 130 homesteads/village). This could allow some alternate concepts for spoil disposal to be tested and compared. For example, one disposal site could be located in a former beel or loop cut while the second site might be located on the floodplain.

Monitoring
Monitoring would be carried out over the two years of pilot dredging. Hydrographic surveys would be made in the dredged reach during the monsoon and post-monsoon season to assess the bed level changes. Surveys and monitoring would also be made on land to observe the fate of the spoil during the monsoon season, particularly erosion by wave action and currents. Environmental impacts from dredging and dredge disposal operations would be monitored. In addition, the response of the local community to the work would also be observed.

Evaluation
The overall performance of the dredging operations would be assessed at the end of the two years, as well as the effectiveness of the disposal scheme and the impacts of the work, including impacts on fisheries, wetlands, agricultural land use and social impacts. The aim of this work would be to provide an assessment of the sustainability of the work, particularly concerning the need for future ongoing maintenance dredging in the reach and the long-term stability of the spoil.

6.4 Cost Estimate

Total costs for a two year pilot dredging program on a single drainage channel would be Tk 66.55 million. A break-down of the costs are summarized in Table 6.1.

Table 6.1: Pilot Project Costs

Item	Costs Tk ,000
Excavation	40,000
Land	1,240
Base Cost	41,240
Contingencies	10,310
Study Costs	15,000
Total	66,550

7.0 OUTSTANDING ISSUES

1. The magnitude of water level impacts in the haor areas adjacent to the river from channel improvements on the Baulai-Surma River 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 water level measurements in the haor areas will be required and additional hydrodynamic model development and verification will be required.

2. Additional monitoring and sediment data collection is required to provide reliable estimates of maintenance dredging requirements.

3. The location and characteristics of the most appropriate sites for disposing dredge spoil needs to be defined.

4. If dredge spoil was used for village platforms, the existing population density could be doubled along the river. The methodology for assessing social impacts, and for carrying out resettlement and ensuring social and economic viability of the villages would need to be addressed.

5. Execution of this project would require a major upgrading of the existing dredger fleet. The possibility of involving the private sector in dredging operations should be explored further.

REFERENCES

1. Bangladesh Inland Water Transport Master Plan (BIWTMAS), Draft Final Report, November 1988.

2. National Dredging Scheme, Phase 1, Water Resource Planning Organization (WARPO), May, 1992.

3. Petersen, Margaret "*River Engineering*", Prentice-Hall, 1986, 580pp.

4. U.S. Army Corps of Engineers, EM 1110-2-5025, "*Dredging and Dredged Material Disposal*", 1983.

ANNEX A

ENGINEERING DATA AND ANALYSIS

ANNEX A: ENGINEERING DATA AND ANALYSIS

Climatic Data

Weather stations near the project area are listed in Table A1. The climate of the project area as a whole, is best represented by data for Sylhet, located east of the project area. Data for the 1957-1991 observation period are given in Table A2.

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 4,202 mm. Mean monthly rainfalls range from 10.4 mm in January to 903 mm in June, and monthly minimum and maximum rainfalls have ranged from 0 mm in November through April to as much as 1,387 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.

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Table A1: Baulai River Improvement Project
Climate Stations

Station No.	Name of Station	Type of Observations	Latitude	Longitude	Since
R-063	Durgapur	R	25°07.0'N	90°40.5'E	1902
R-068	Jaria Janjail	R	24°58.0'N	90°40.8'E	1962
R-123	Netrakona	R/E	24°53.0'N	90°43.0'E	1902
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-071	Kishoreganj	R	24°26.0'N	90°47.5'E	1902
R-112	Itna	R	24°00.9'N	91°07.1'E	1962
R-061	Bajitpur	R	24°10.6'N	90°52.0'E	1962

Table A2: Meteorological Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (°C)													
Max	25.1	27.2	30.6	31.0	30.7	30.5	30.5	31.3	31.0	30.5	28.9	26.0	31.3
Min	12.4	14.2	18.0	21.1	22.7	24.5	25.1	25.1	24.7	22.4	17.9	13.9	12.4
Mean	18.9	20.8	24.4	25.8	26.7	27.8	27.9	28.3	27.7	26.6	23.5	20.1	24.9
Humidity (%)	73	65	66	76	82	88	88	88	88	84	77	75	79
Sunshine (hr/day)	8.3	8.4	8.0	6.8	6.2	3.9	3.6	4.7	4.7	7.4	8.5	8.3	6.4
Wind speed (kph)	2.1	7.3	8.5	8.8	7.3	7.3	7.3	7.3	6.9	6.9	6.9	6.9	7.3
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	1550.6
Rainfall (mm)													
Mean monthly:													
Durgapur	4.0	13.9	39.0	165.5	432.6	699.3	832.2	612.4	572.0	230.2	15.5	12.4	3598.8
Jaria Janjail	5.4	15.8	38.5	162.8	391.4	668.2	752.7	547.8	507.2	190.1	18.5	8.7	3348.8
Netrakona	6.4	17.5	45.9	169.5	375.8	621.9	565.7	462.0	407.6	213.3	27.1	11.0	2971.2
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	3602.6
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	5362.5
Sunamganj	6.4	26.2	82.3	287.4	547.8	1059.6	1402.2	1088.3	734.1	263.9	23.3	10.6	5538.6
Sylhet	10.4	31.2	119.0	378.2	548.2	902.6	803.7	621.6	512.8	233.6	36.8	11.5	4202.0
Kishoreganj	5.7	15.5	49.1	152.5	338.1	418.4	401.2	396.8	303.5	162.7	20.1	9.3	2269.6
Itna	10.3	21.4	67.8	235.3	480.9	575.3	658.6	486.9	489.3	196.8	33.3	9.3	3355.6
Bajitpur	5.8	23.8	41.3	151.8	343.9	435.4	401.5	342.8	277.1	170.0	29.9	6.8	2246.9

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Hydrological Data

The hydrological regime of the Surma/Baulai River is governed by:

- external flows from the Barak River in India
- tributaries from the Meghalaya Hills (Dauki, Dhalai Gang, Chela, Jhalukhali, Jadukata Rivers);
- 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 only a few miscellaneous discharges available downstream of Sunamganj. 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.

The location of key hydrometric stations, along with the type of observations that have been carried out are listed in Table A.3.

Table A3: Baulai-Surma River Hydrometric Stations

Station No.	Name of Station	Type of Observations	Latitude	Longitude	Available Records
266	Kanairghat	S,Q	25°00.00'N	92°15.55'E	1952
267	Sylhet	S,Q	24°53.24'N	91°52.26'E	1938
268	Chhatak	S,Q	25°02.15'N	91°39.93'E	1949
269	Sunamganj	S	25°04.53'N	91°24.84'E	1949
72B	Sukdevpur	S	24°52.76'N	91°09.94'E	1982
72	Kaliajuri	S	24°41.30'N	91°07.33'E	1945
73	Itna	S	24°31.83'N	91°05.63'E	1964
74	Dilapur	S	24°11.22'N	90°58.59'E	1964

Table A4: Range of Daily Water Levels and Discharges on Surma River at Sylhet, 1964-1989

	Water Level (m PWD)	Discharge (m^3/s)
Minimum	1.99	2.60
Mean	6.30	548.30
Maximum	11.94	2480.00

Table A5: Mean Monthly Water Levels and Discharges, Surma River at Sylhet, (267)

Month	Water Level (m PWD)			Discharge (m^3/s)		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	2.64	4.94	8.13	31.6	238.1	677.6
May	4.85	6.98	8.96	107.8	489.9	933.3
June	6.18	9.18	10.79	318.9	1109.3	1829.3
July	9.28	10.30	10.95	1038.9	1471.3	1918.7
Aug	8.98	9.93	10.76	825.9	1322.8	1667.1
Sept	7.87	9.37	10.47	554.0	1074.7	1447.2
Oct	6.30	7.81	9.82	211.6	614.5	1302.4
Nov	4.09	5.15	7.18	19.6	130.2	406.6
Dec	2.95	3.62	5.01	6.6	32.9	123.5
Jan	2.36	2.73	3.14	4.5	11.9	33.0
Feb	2.07	2.47	3.34	4.2	7.8	22.8
Mar	2.03	2.84	4.65	3.9	36.2	193.4

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Table A6: Range of Daily Water Levels on Surma-Baulai River

	Sunamganj 269	Sukdevpur 72B	Kaliajuri 72	Itna 73
	Water Level (m PWD)	Water Level (m PWD)	Water Level (m PWD)	Water Level (m PWD)
Min	1.34	0.80	0.98	1.20
Mean	5.23	4.44	4.66	4.39
Max	9.46	8.08	8.99	8.69

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-7 and A-8.

Table A7: Flood Discharges, Surma River at Sylhet

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual	2,051	2,251	2,339	2,400	2,416	2,456	2,486
Pre-Monsoon	853	1,155	1,281	1,366	1,387	1,440	1,478

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

Table A.8: Frequency and Magnitude of Water Levels on Surma/Baulai River

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual Floods:							
Sunamganj	8.56	8.83	9.03	9.23	9.30	9.51	9.73
Sukdevpur	7.44	7.80	7.95	8.05	8.07	8.14	8.19
Kaliajuri	7.26	7.69	7.94	8.16	8.22	8.41	8.58
Itna	7.14	7.53	7.75	7.93	7.98	8.12	8.25
Dilapur	6.81	7.24	7.57	7.64	7.69	7.82	7.93
Pre-Monsoon Floods (April 1 - May 15)							
Sunamganj	6.47	7.13	7.40	7.59	7.63	7.74	7.82
Sukdevpur	4.96	5.08	5.11	5.16	5.17	5.19	5.20
Kaliajuri	3.82	4.45	4.81	5.11	5.20	5.45	5.68
Itna	3.43	4.00	4.35	4.67	4.77	5.06	5.33
Dilapur	2.94	3.28	3.48	3.65	3.70	3.84	3.96

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

Morphologic Information

The Surma/Baulai River system has been sub-divided into six reaches:

Upper Surma River (Amalshid to Chhatak)
Lower Surma River (Chhatak to Old Surma River offtake)
Nawa River (Old Surma River offtake to Baulai River junction)
Baulai River (from Baulai River junction to Kaliajuri)
Lower Baulai River (Kaliajuri to start of Ghorautra River)
Ghorautra River to junction with upper Meghna River

Table A9 summarizes the main geomorphic features in each reach.

Evolution

The Rennell's survey of 1768 shows the Surma River was the direct continuation of the Barak River. The Surma River was shown to be very close to its present alignment between Amalshid and Sunamganj. Near Sunamganj, the river turned abruptly south until it joined the Kalni/Kushiyara River near the town of Ajmiriganj. This course, between Sunamganj and Ajmiriganj is now called the "Old Surma River". Rennell's maps also showed several distributary channels branching from the Surma River in the vicinity of Sylhet/Chhatak which flowed southwards to join the Kalni/Kushiyara River system.

Maps prepared from 1952 air photos show the Surma River split into two main branches downstream of Sunamganj:

- the Old Surma River channel;
- the Nawa/Baulai River which flowed westwards and then south until joining the Meghna River near the town of Dilapur.

By the early 1960's, and possibly considerably earlier, the Nawa Channel was the main active branch of the Surma River. For example, a BWDB memo dated May 8, 1963 stated:

> *"low flow of Surma does not join Meghna at Markuli but flows to Baulai River. The channel from near Sunamganj (Old Surma) to Markuli probably does not carry much of the flow of Surma".*

Channel Morphology

Between Amalshid and Chhatak, the Surma River flows in a single, irregularly meandering sand-bed channel that frequently deflects off bedrock and other inerodible deposits. The channel has an average top width of 172 m and a mean depth of 8.6 m at bankfull stage. The river becomes noticeably wider downstream of Chhatak, with an average top width of 250 m and a mean depth of 10.2 m (Figure 35). During most water level conditions there are no bars exposed and no islands. The river narrows again in the Nawa Reach, downstream of the Old Surma River offtake. This channel has been relatively recently formed and may still be adjusting to the higher flows that have been occurring with the gradual closure of the Old Surma channel.

Table A.9: Morphologic Characteristics of Surma/Baulai River

Reach	Physiographic Unit	Channel Pattern	Bars	Islands	Vertical Stability	Lateral Stability	Bed Material D_{65} (mm) D_{50} (mm) D_{35} (mm)	Bank Material	Sinuosity (Lc/Lv)	Slope(m/km) Average Pre-monsoon Monsoon	Bankfull Dimensions Top Width Mean Depth Area
Amalshid - Chhatak	Surma/Kushiyara Floodplain	Single Channel Irregular meanders	Point Bars	Absent	Stable	Minor erosion due to progressive meander migration	0.23 0.20 0.16	Stiff Clay Silty Clay	1.51	0.040 0.040 0.050	172 8.6 1480
Chhatak - Old Surma River	Central Basin	Single Channel Sinuous meanders	Absent	Absent	Slow Aggradation	Stable	0.18 0.16 0.13	Silty Clay Organic Clay	1.58	0.005 0.005 0.026	250 10.2 2550
Old Surma River - Baulai River	Meghalaya Basin	Single Channel Irregular/Sinuous	Absent	Few	Slow Aggradation	Minor widening,	0.10 0.095 0.08	Clay, Organic Clay and Peat	1.24	0.008 0.030 0.014	177 11.0 1947
Baulai River Junction - Kaliajuri	Central Basin	Split Channel Irregular/Straight	Absent	Occasion al	Degrading	Cutoffs, irregular shifts	0.11 0.10 0.086	Clay and Peat	1.27	0.008 0.028 0.014	149 7.1 1058
Kaliajuri - Ghorautra River	Central Basin	Split Channel Irregular Meanders	Absent	Occasion al		Cutoffs, irregular shifts	0.11 0.10 0.086	Silty Clay Peat	1.64	0.008 0.010 0.006	246 6.1 1500
Ghorautra River - Meghna River	Central Basin	Single Channel Irregular Sinuous	Point bars	Occasion al	Degrading	Cutoffs, irregular shifts	0.11 0.10 0.086	Silty Clay, Peat	1.47	0.008 0.010 0.006	300 8.7 2600

It appears most of the sand from the Meghalaya is being deposited on the fan surfaces and in the haor areas north of the river.

The Baulai reach, like the Nawa reach appears to be still adjusting to the westward shift of the main Surma River. The river becomes progressively smaller in this reach, having a top width of 149 m and a mean depth of 7.1 m at bankfull stage. The bed profile also flattens out appreciably and the river contains frequent mid-channel shoals and bars. These bars are mainly found in the straight "cross-overs" or "riffles" that occur between bends. Shoals also occur in split channels where loop cuts have been carried out since the flow is now divided between two channels.

Prior to recent loop cutting, the Baulai River flowed in a single irregularly meandering channel. After completion of loop cuts in the 1980's, the river had a straight, anastomosed channel pattern with flow often splitting around large mid-channel islands. This pattern appears to be unstable and the river is just beginning to adjust to its altered regime. The top of the river banks are typically 3 - 4 m below the level of a typical monsoon flood, so the channel is deeply flooded and not confined by natural levees.

The channel enlarges substantially in the Ghorautra reach and displays a single tortuously meandering sand-bed channel. The river has huge point bars that are exposed at low water. The increase in channel size is not due to the additional flow from the Mogra/Dhanu River, as this contribution is quite minor. It is more likely that the river is flowing through a paleo-channel, which was formed by in the past by much greater flows, either from the Brahmaputra River or the combined Surma/Kalni River.

The bed material in the Surma/Baulai River consists of fine to medium sand, with median sizes ranging from 0.25 mm to 0.085 mm. There is a noticeable decline in the grain size along the river, with the sediments in the Baulai River having a median size of only about 0.1 mm. There are virtually no sediments finer than 0.063 mm in the channel bed, which indicates that finer silt sizes are transported through the channel as "wash load".

Hydraulics

Figure 14 shows a longitudinal profile of the Surma/Baulai River, including the thalweg level, left and right bank levels and the mean annual flood at the available hydrometric stations. Both the water surface profile and the bed profile show a characteristic concave shape, indicating their slope decreases in a downstream direction. The longitudinal profile also indicates that the top of bank coincides very closely to the mean annual flood level over the reach from Amalshid to the Old Surma River offtake. The corresponding bankfull discharge was estimated to be around 2,100 m^3/s at Sylhet and 3,350 m^3/s near Chhatak.

Downstream of the Old Surma River offtake, the top of bank becomes progressively lower so that by Kaliajuri it is nearly 5 m below the mean annual flood level during the monsoon. In the Baulai Reach, the cross sectional area at bankfull stage averages only 1,058 m^2, which is about 40% of the value in the reach near Chhatak. The bankfull capacity was estimated to be approximately 1,000 m^3/s using uniform flow calculations. This is less than the river's long-term mean discharge. Furthermore, even when water levels are 3 m above bankfull stage, the channel's discharge capacity is still less than 2000 m^3/s, which in the order of one third to one half of the typical monthly discharges in this reach during the monsoon season. These results illustrate that during the monsoon season, the channel conveyance becomes less important than the floodplain conveyance, with the in-channel flows being "drowned out" by the huge inundated lake of the Central Basin.

Navigation

The following BIWTA navigation charts were utilized in the investigation:

Table A.10: Sounding Charts on Surma/Baulai River

Year	Navigation Charts
1963	S57 A-H
1977/78	S186 A-H, 193 A-K
1983	S238 B-O
1992	S444 A-K

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

Bed EL. = LLW - Depth

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

Table A.11 summarizes the location and extent of shoals on the river, as determined from 1992 sounding charts. Only shoals that obstruct or encroach into the Class II navigation channel have been identified.

Table A.11: Location of Shoals

Location	Distance Along River (km)		Depth at LLW (m)	Shoal Length (m)	Shoal Volume (m^3)
	from Bhairab	from Amalshid			
Dilapur	25	379	0.3	600	60,000
Silundia	104	297	1.5	660	13,000
Kaliajuri	110.5	290	1.5	200	7,700
Sukdevpur	140.3	2592	1.8	300	5,800
Naingaon	227.6	177	1.5	70	8,900
Chhatak	238.4	166	1.5	300	26,500

ANNEX B

ENGINEERING COST ANALYSIS

ANNEX B: VOLUME AND COST ESTIMATES

Table B1: Dredging of Baulai-Surma River Channel

Item	Quantity	Unit	Rate (Tk)	Amount (Tk '1000)
1. Enlarging of channel section from Kaliajuri to Nawa River, 22 km				
Channel Excavation	7,000,000	m^3	80.00	560,000.
Land Acquisition	220	ha	200,000.00	44,000.

Table B2: Dredging of Tributary Rivers

Item	Quantity	Unit	Rate (Tk)	Amount (Tk '1000)
1. Jadukata-Rakti River, 24.0 km[1]				
Earthwork	2,300,000	m^3	80.00	184,000
Land Acquisition	48.0	ha	200,000	9,600
2. Patnai-Baulai River, 25.0 km				
Earthwork	1,125,000	m^3	80.00	90,000
Land Acquisition	50.0	ha	200,000	10,000
3. Someswari River, 16.0 km				
Earthwork	960,000	m^3	80.00	76,800
Land Acquisition	48.0	ha	200,000	9,600
4. Kangsha River, 38 km				
Earthwork	1,520,000	m^3	80.00	121,600
Land Acquisition	96.0	ha	200,000	19,200
5. Piyain River 30.0 km				
Earthwork	960,000	m^3	80.00	76,800
Land Acquisition	60.0	ha	200,000	12,000
6. Old Surma River 42.0 km[2]				
Earthwork	1,260,000	m^3	80.00	100,800
Land Acquisition	126.0	ha	200,000	25,200
Total Earthwork:		8,125,000 m^3		650,000
Total Land Acquisition:		428 ha		85,600

Notes: 1. *Included in the proposed Jadukata-Rakti River Improvement Project (FAP-6, December 1993)*

2. *Included in the proposed Surma-Kushiyara-Baulai Basin Project (FAP-6, December 1993).*

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

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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/EIA 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 5.3, "Slope of Channel Improvement Work" and Section 5.4, "Project Operation".

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:

Local community: As described in Section 3.6, "People's Perception".

C.2.4 Bounding (Step 4)

Physical:

Gross area: 320,300 ha.
Impacted (net) area: 261,000 ha.

Temporal:

Pilot Project: Two years, as described in Section 6.0.

Channel Excavation: Minimum of three years after completion of Pilot Project, see Section 5.9, "Project Phasing".

Maintenance Operations: 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 reverse cumulative impacts from previous embankment projects and from other morphologic changes to restore drainage conditions. However, long-term impacts of spoil disposal operations needs to be assessed during feasibility studies.

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

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C.2.5 Field Investigations (Step 5)

Field investigations were limited to seven - ten days of informal reconnaissance by a multi-disciplinary team.

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 5.4.2 and 5.11.

C.2.7 Quantify and Value Impacts (Step 7)

Adverse impacts will be quantified during feasibility studies.

C.2.8 Environmental Management Plan (Step 8)

At a pre-feasibility level, this section focuses on "identification of broad management options and major constraints" (p. 28, ISPAN, 1992).

Mitigation and enhancement. Measures should be incorporated as/when needed. Documented in Section 5.4.2.

Compensation. Measures should be incorporated as/when needed.

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.

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

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.

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, resettlement, 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	Extreme deposition after major floods		-	-				-			

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ANNEX D

FIGURES

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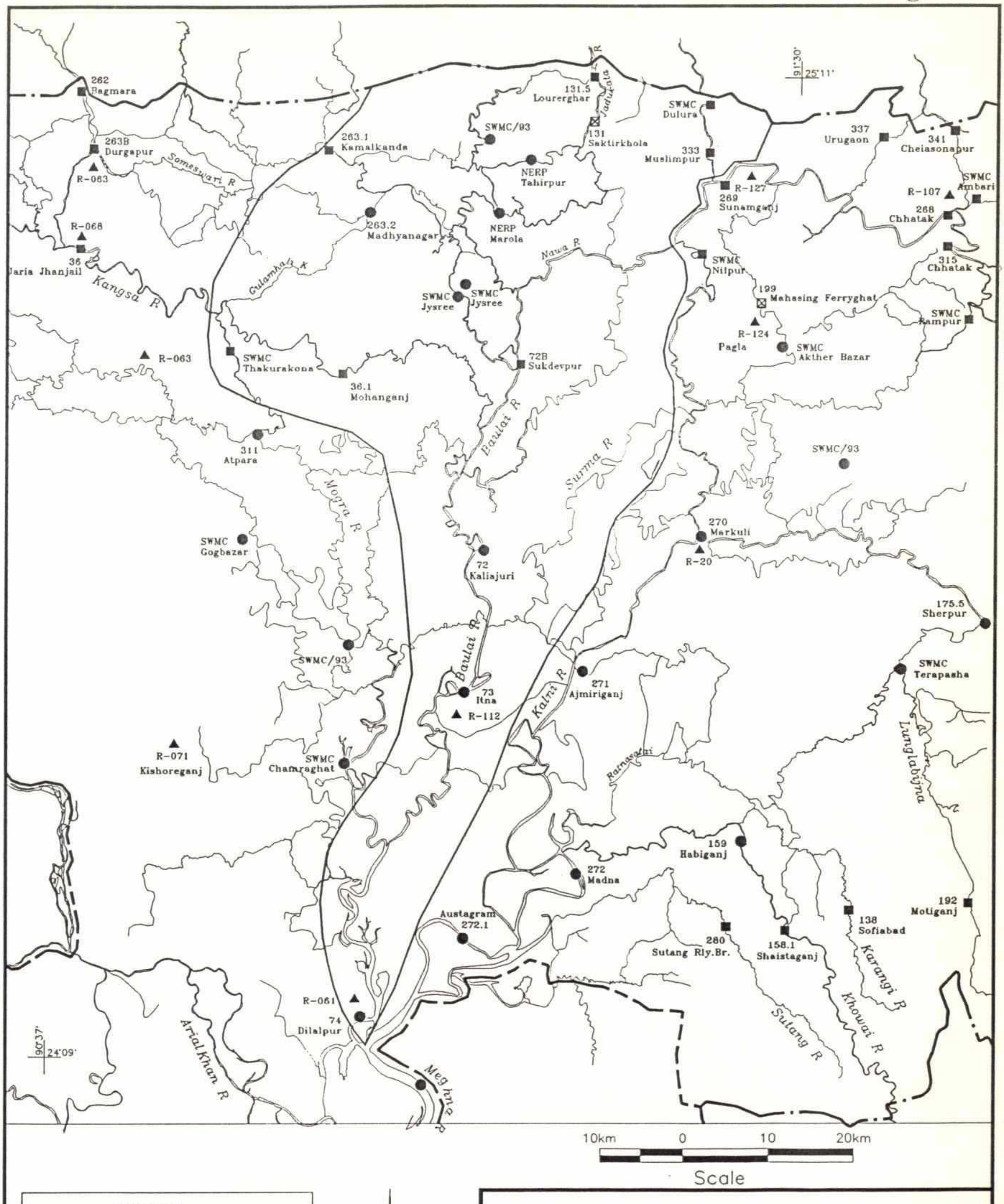
Figure 1



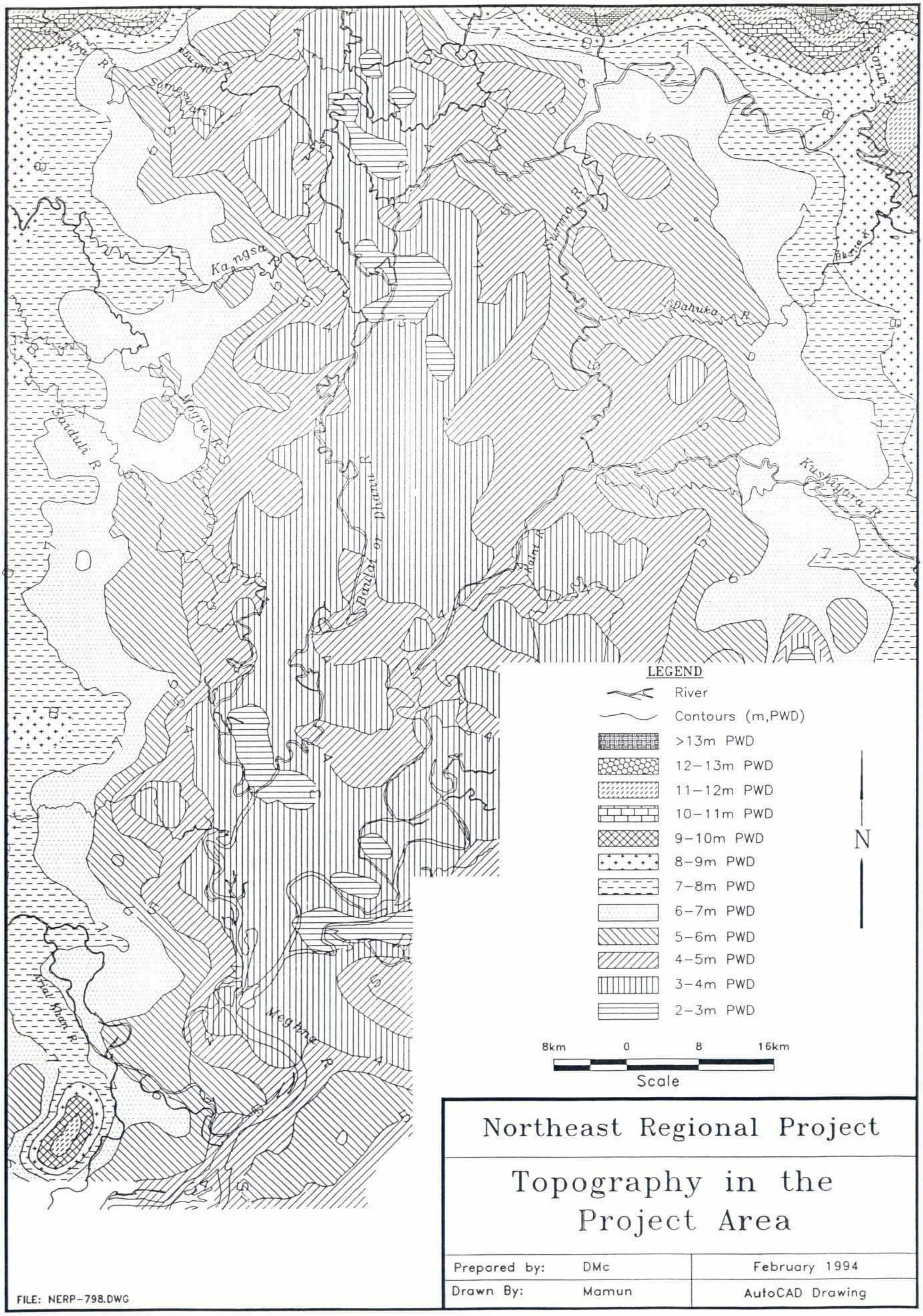
FILE: NERP-260.DWG

Northeast Regional Project

Baulai River Improvement project

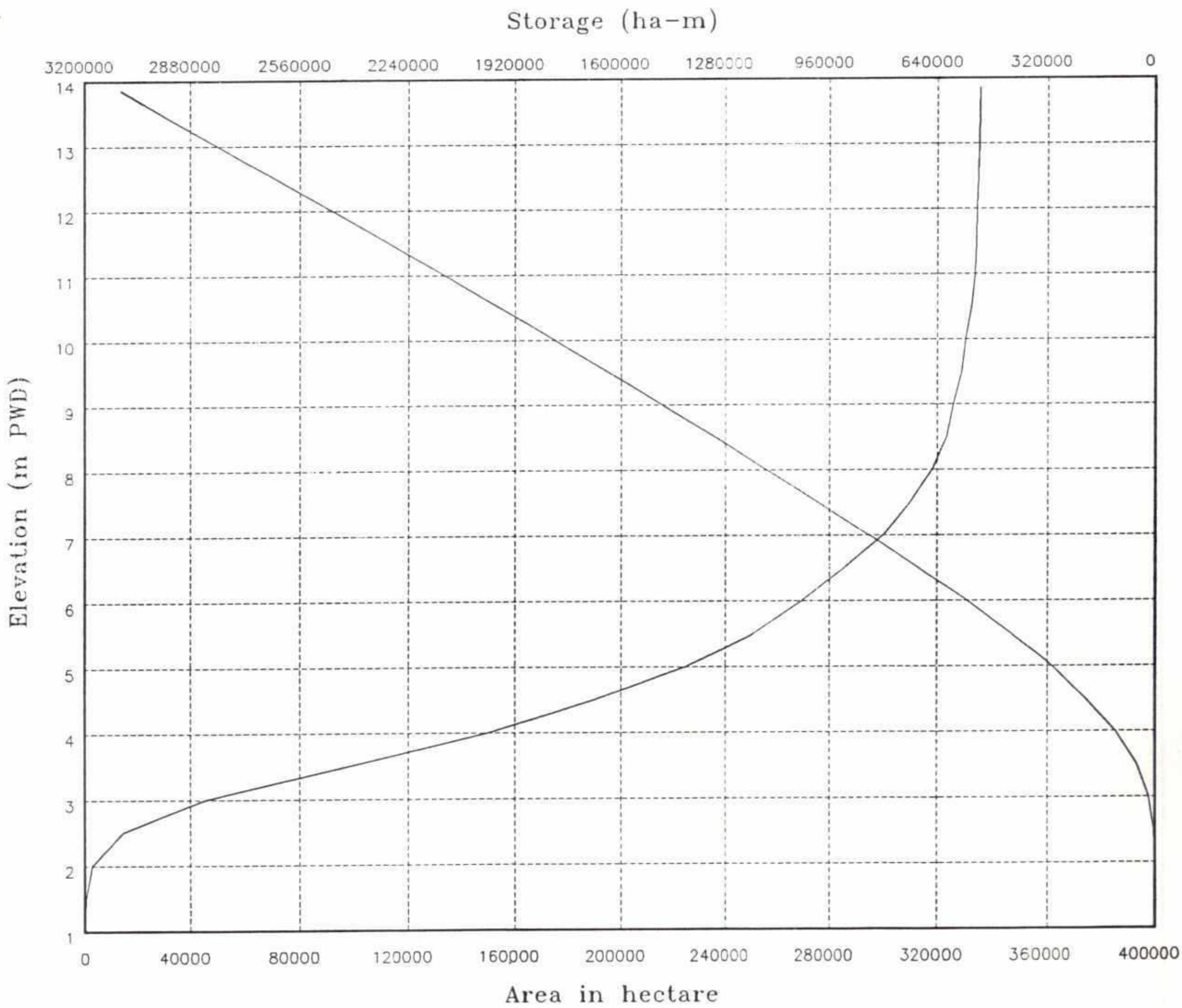
Prepared by: H.Werszko	February 1994
Drawn by: Sk. Jalal	AutoCAD Drawing

Figure 2



Someswari
Kangsa R
Mogra R
Saiduli R
Baulai or Dhanu R
Surma R
Dahuka R
Kalni R
Kushiyara R
Meghna R
Arial Khan R
LEGEND
River
Contours (m,PWD)
>13m PWD
12-13m PWD
11-12m PWD
10-11m PWD
9-10m PWD
8-9m PWD
7-8m PWD
6-7m PWD
5-6m PWD
4-5m PWD
3-4m PWD
2-3m PWD
N
8km
0
8
16km
Scale
Northeast Regional Project
Topography in the Project Area
Prepared by: DMc
February 1994
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-798.DWG

Figure 3



Northeast Regional Project

Area-Elevation Distribution in the Project Area

Prepared by:	Nasim	February 1994
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-803.DWG

Figure 4

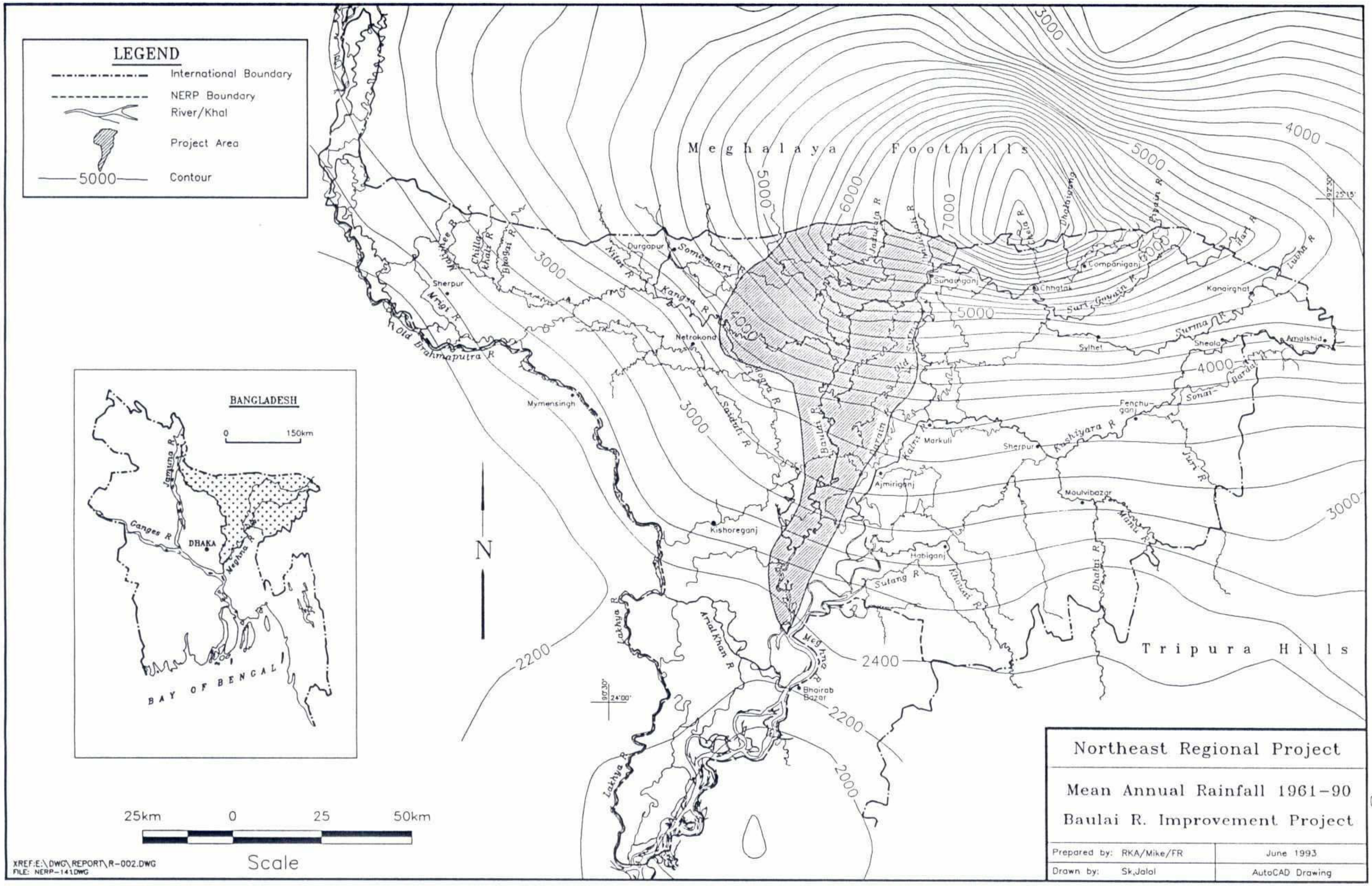
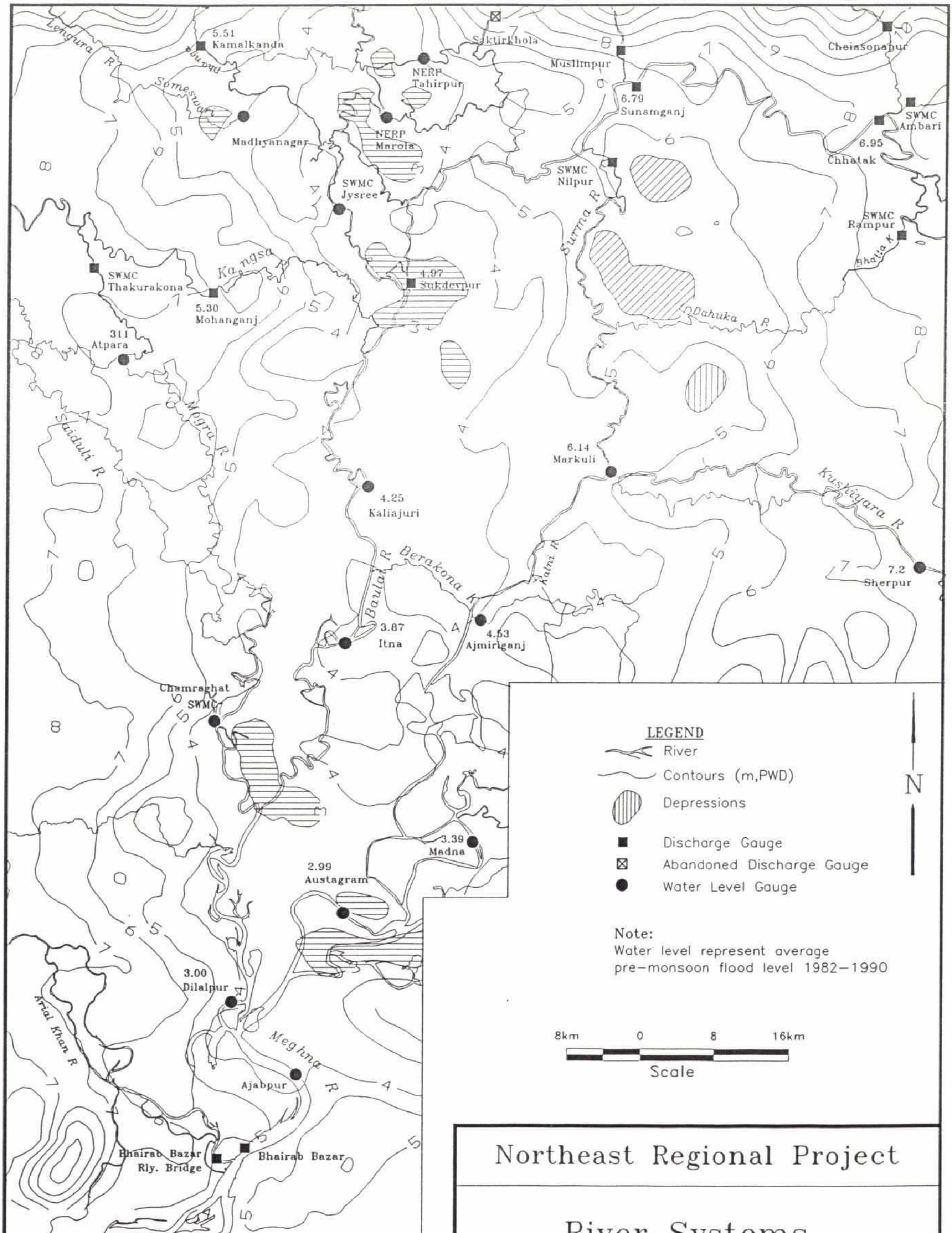

LEGEND
International Boundary
NERP Boundary
River/Khal
Project Area
5000 Contour
Meghalaya Foothills
Tripura Hills
BANGLADESH
0 150km
DHAKA
BAY OF BENGAL
Ganges R
Jamuna R
Meghna R
Sylhet
Sunamganj
Netrokona
Mymensingh
Kishoreganj
Habiganj
Moulvibazar
Sherpur
Durgapur
Bhairab Bazar
Ajmiriganj
Markuli
Fenchuganj
Chhatak
Companiganj
Kanairghat
Amalshid
Sheola
Someswari
Kangsa R
Surma R
Kushiyara R
Baulai R
Old Brahmaputra R
Lakhya R
Arial Khan R
Manu R
Dhalai R
Khowai R
Sutang R
Juri R
Mogra R
Saiduli R
Nitai R
Bhogai R
Malijhee R
Mrigi R
Jadukata R
Piyain R
Luba R
Hari R
Dhalaiganj
Chella R
Sonai
Bardal R
25km 0 25 50km
Scale
XREF:E:\DWG\REPORT\R-002.DWG
FILE: NERP-141DWG
7000
6000
5000
4000
3000
2400
2200
2000
Northeast Regional Project
Mean Annual Rainfall 1961–90
Baulai R. Improvement Project
Prepared by: RKA/Mike/FR
June 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

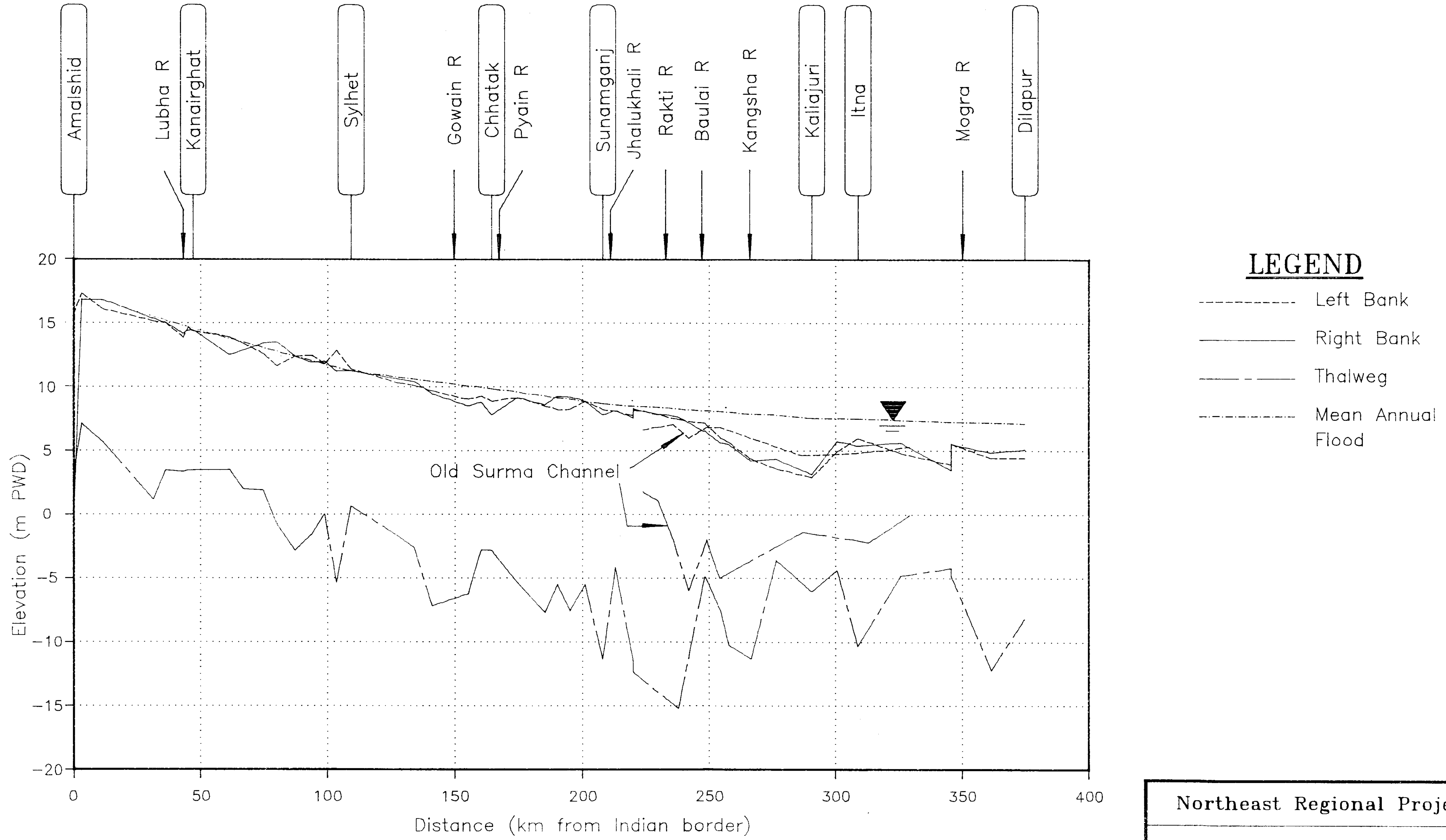
Figure 5



Lengura R
5.51
Kamalkanda
Somesuari
Madhyanagar
NERP
Tahirpur
NERP
Marola
SWMC
Jysree
Saktirkhola
Muslimpur
6.79
Sunamganj
Cheiasonapur
SWMC
Ambari
6.95
Chhatak
SWMC
Nilpur
Surma R
SWMC
Rampur
Bhatia K
Dahuka R
SWMC
Thakurakona
Kangsa
5.30
Mohanganj
4.97
Sukdevpur
311
Atpara
Mogra R
Shiduli R
6.14
Markuli
Kushiyara R
4.25
Kaliajuri
Baulai R
Berakona R
Kalni R
7.2
Sherpur
3.87
Itna
4.53
Ajmiriganj
Chamraghat
SWMC
3.39
Madna
2.99
Austagram
3.00
Dilalpur
Arial Khan R
Meghna R
Ajabpur
Bhairab Bazar
Rly. Bridge
Bhairab Bazar
LEGEND
River
Contours (m,PWD)
Depressions
Discharge Gauge
Abandoned Discharge Gauge
Water Level Gauge
Note:
Water level represent average pre-monsoon flood level 1982-1990
N
8km
0
8
16km
Scale
Northeast Regional Project
River Systems
Prepared by: DMc
February 1994
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-799.DWG

Figure 14

22



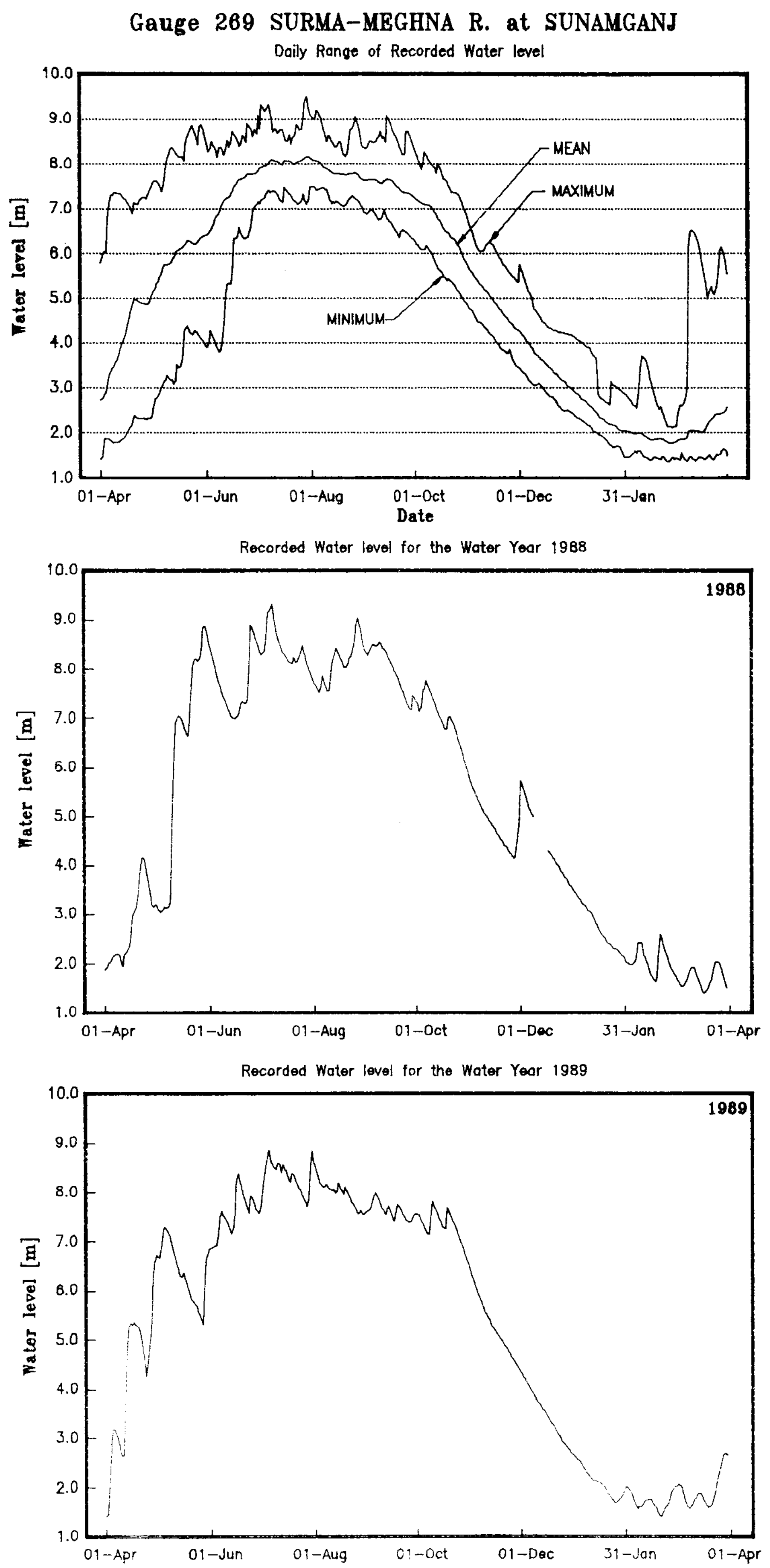
FILE: SURPRO.DWG

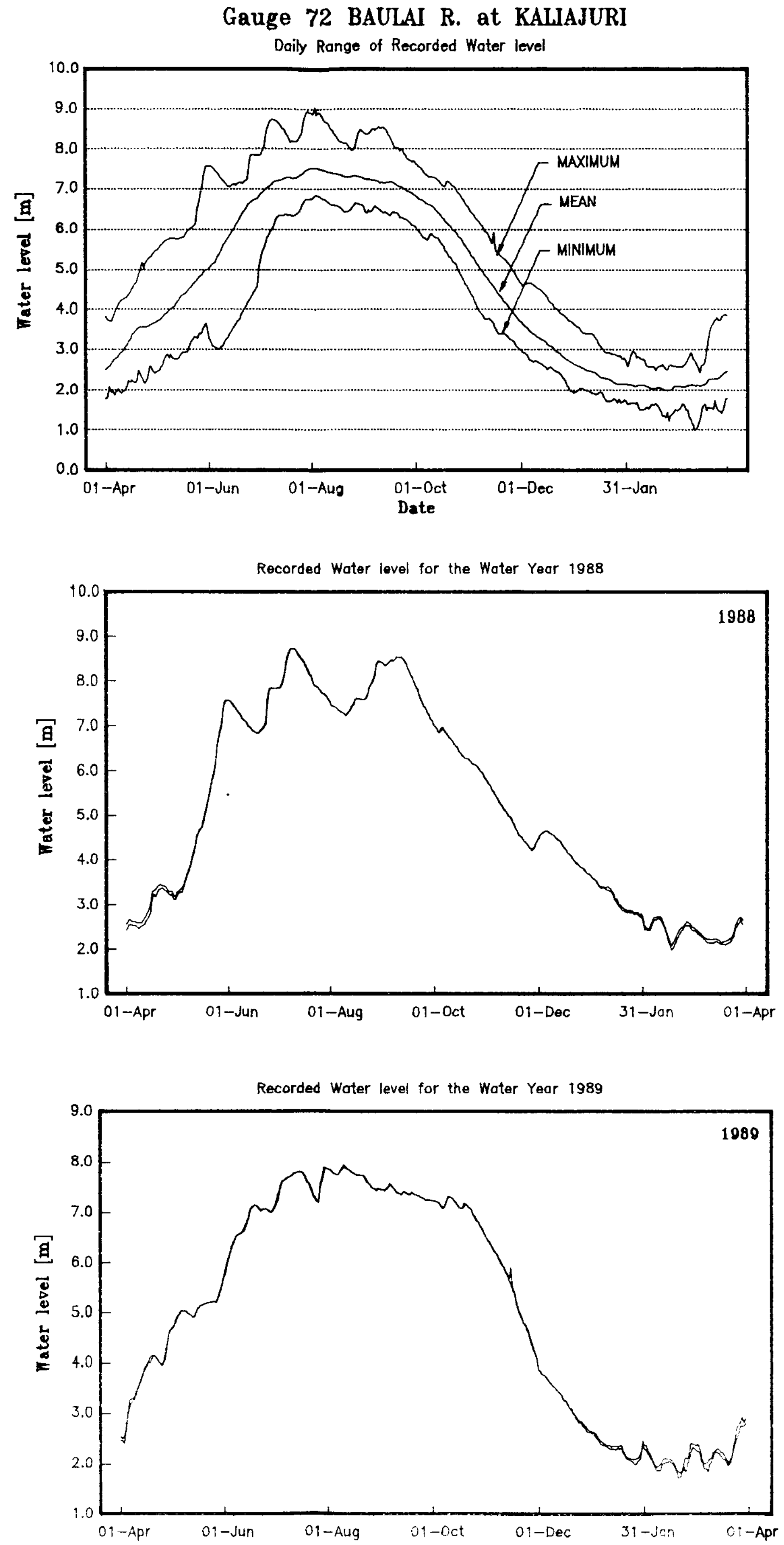
Northeast Regional Project

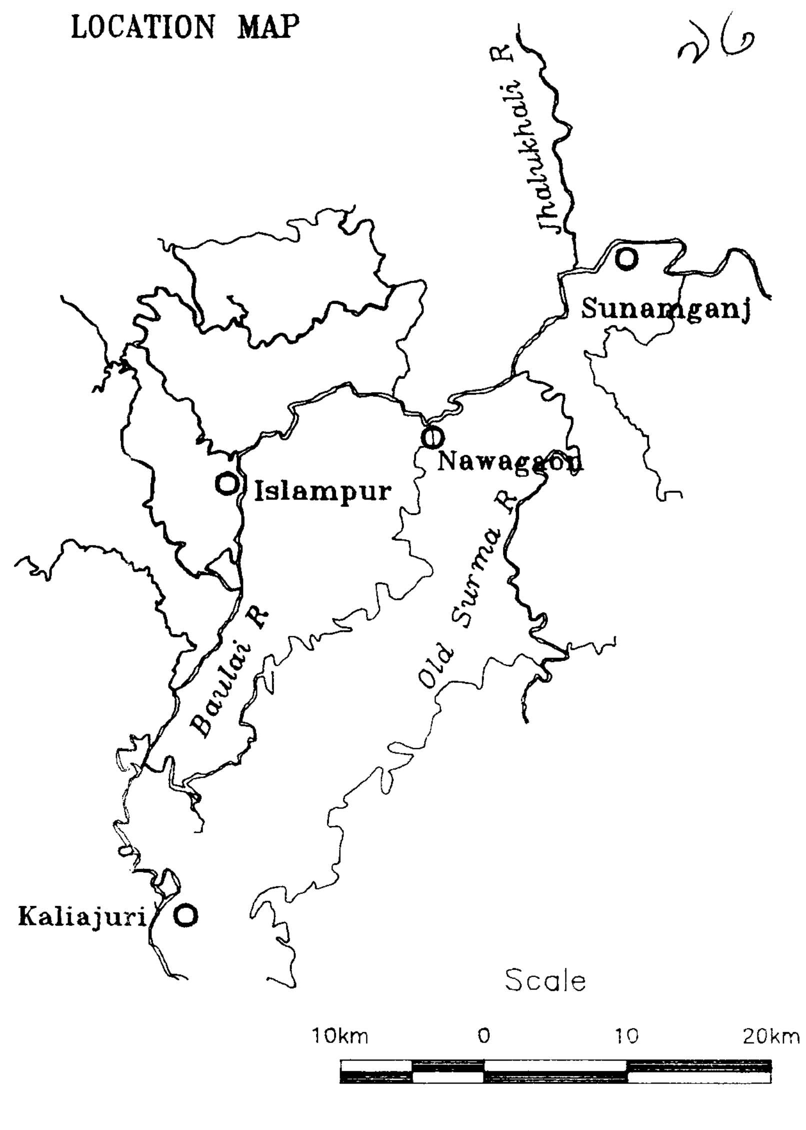
Surma River Profile

Prepared by: CHW | April [illegible]

Figure 6





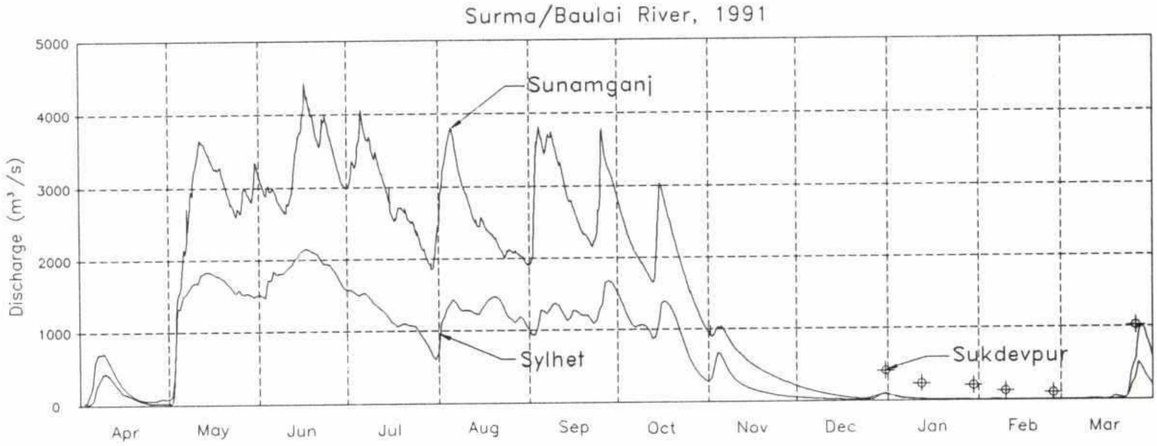


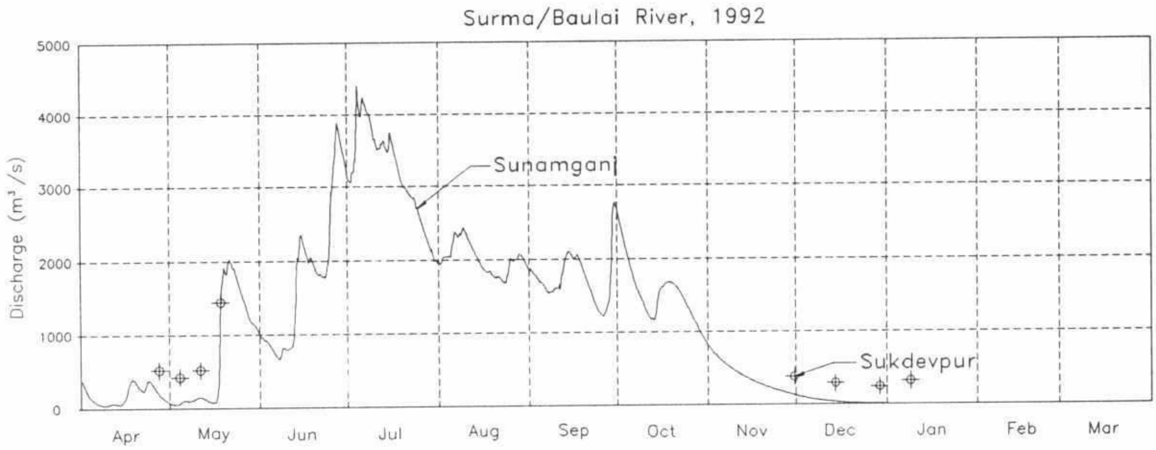
FILE: NERP-794.DWG

Northeast Regional Project

Hydrographs on Surma/Baulai River

Prepared by:	Nahid	February 1994
Drawn by:	Mamun	AutoCAD Drawing





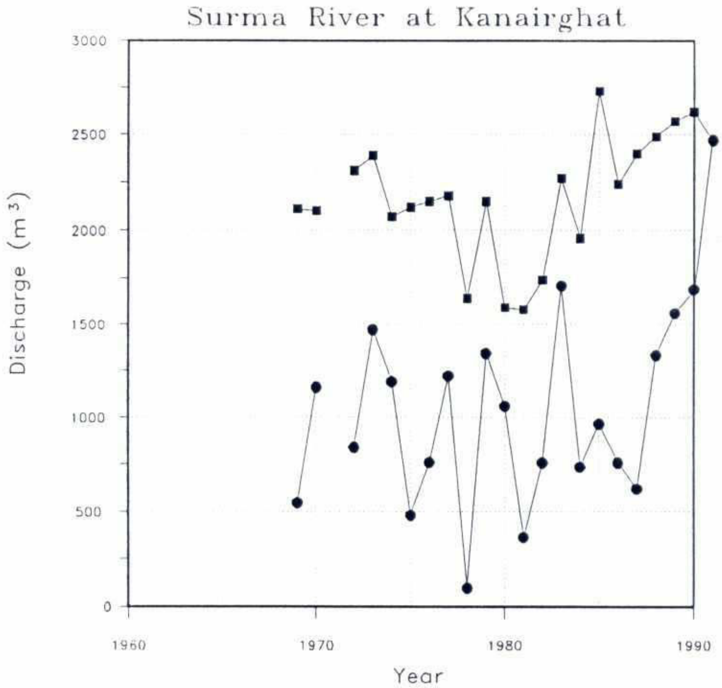
Note:

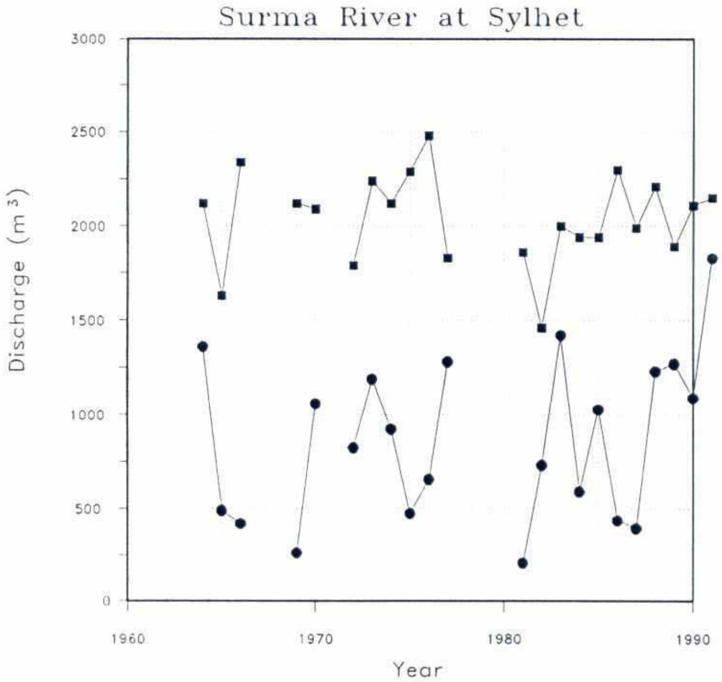
Discharges at Sukdevpur are miscellaneous measurements provided by SWMC.

Discharges at Sunamganj and Sylhet are from BWDB hydrometric records.

Northeast Regional Project	
Surma/Baulai River Discharge Hydrographs	
Prepared by: DMc	Feb 1994

FILE: q9192.DWG



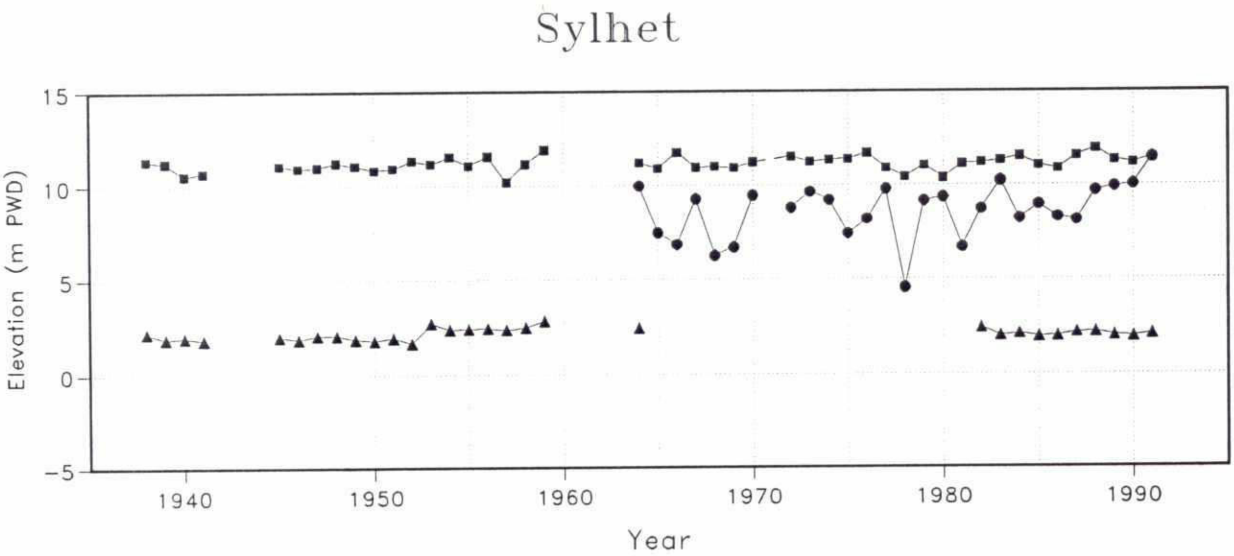


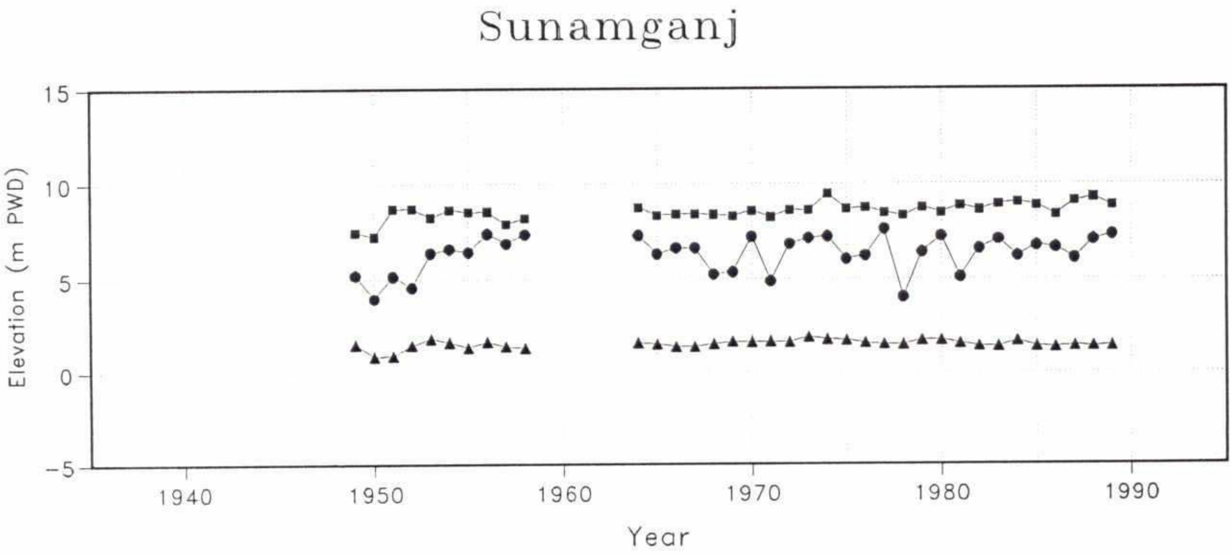
LEGEND

- ■ Maximum Annual
- ● Maximum Pre-Monsoon

FILE: dm-209.DWG

Northeast Regional Project	
Annual Discharges Surma River	
Prepared by: DMc	May 1993





LEGEND

- ■ Maximum Annual
- ▲ Minimum Annual
- ● Maximum Pre-Monsoon

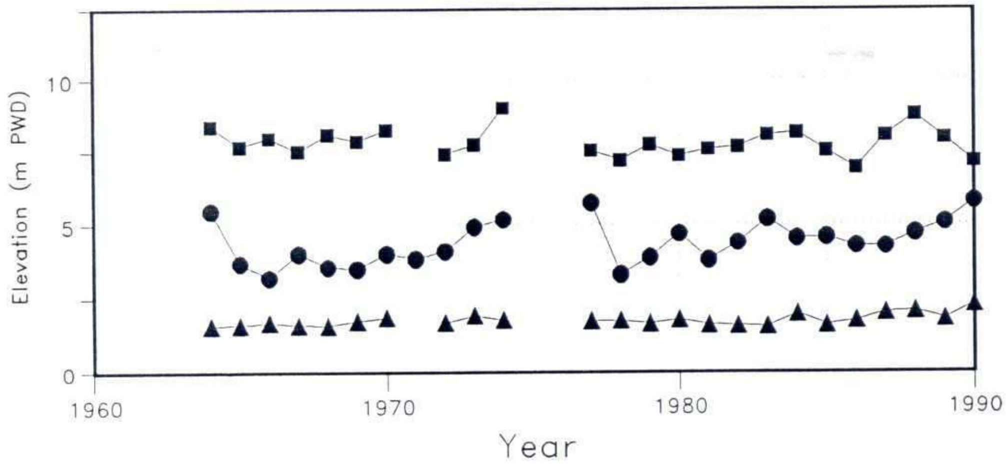
Northeast Regional Project

Water Levels
Surma River

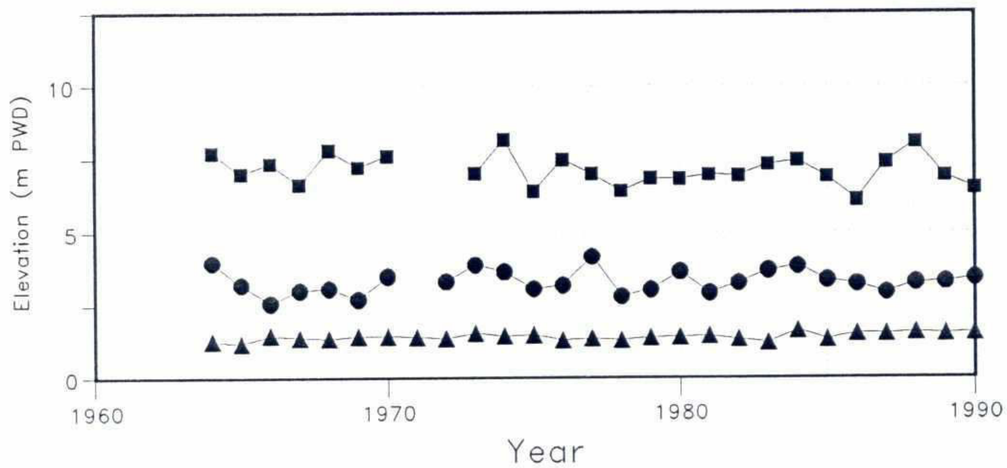
Prepared by: CHW | May 1993

FILE: DM204.DWG

Baulai River at Kaliajuri



Baulai River at Dilapur



LEGEND

- ■ Maximum Annual
- ▲ Minimum Annual
- ● Maximum Pre-Monsoon

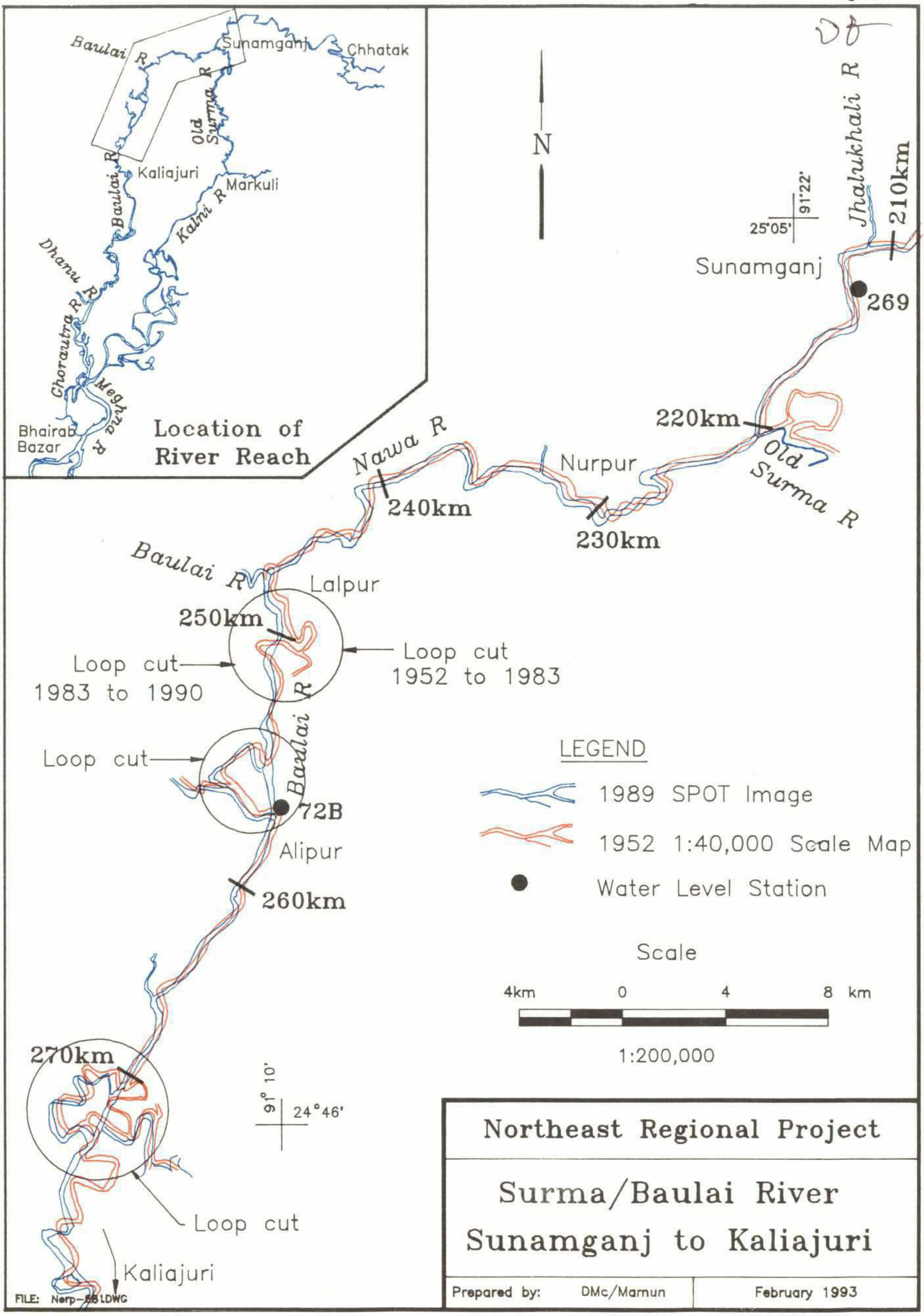
Northeast Regional Project

Annual Water Levels
Baulai River

Prepared by: DMc | May 1993

FILE: dm215.DWG

Figure 11

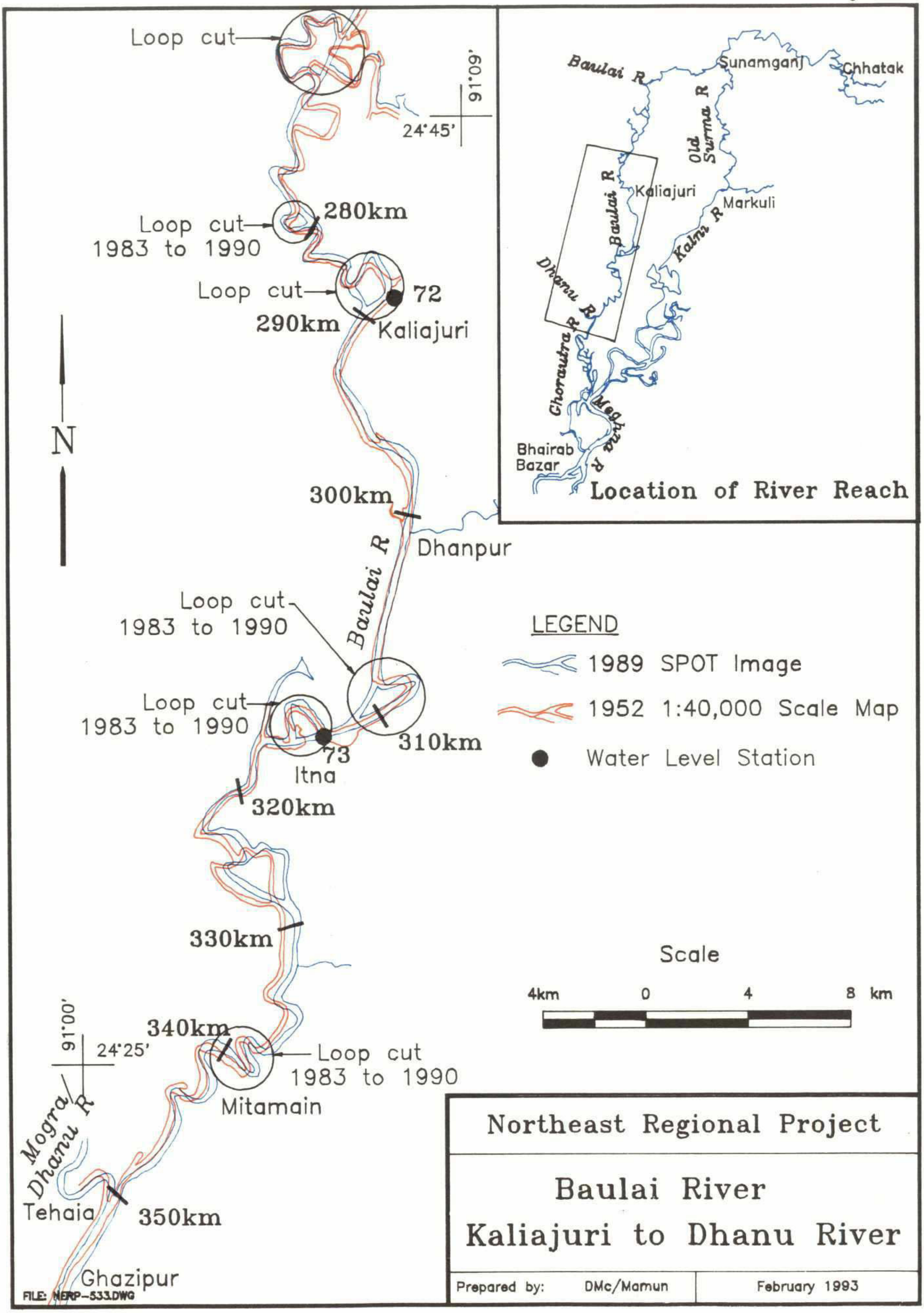


Northeast Regional Project

Surma/Baulai River Sunamganj to Kaliajuri

Prepared by:	DMc/Mamun	February 1993

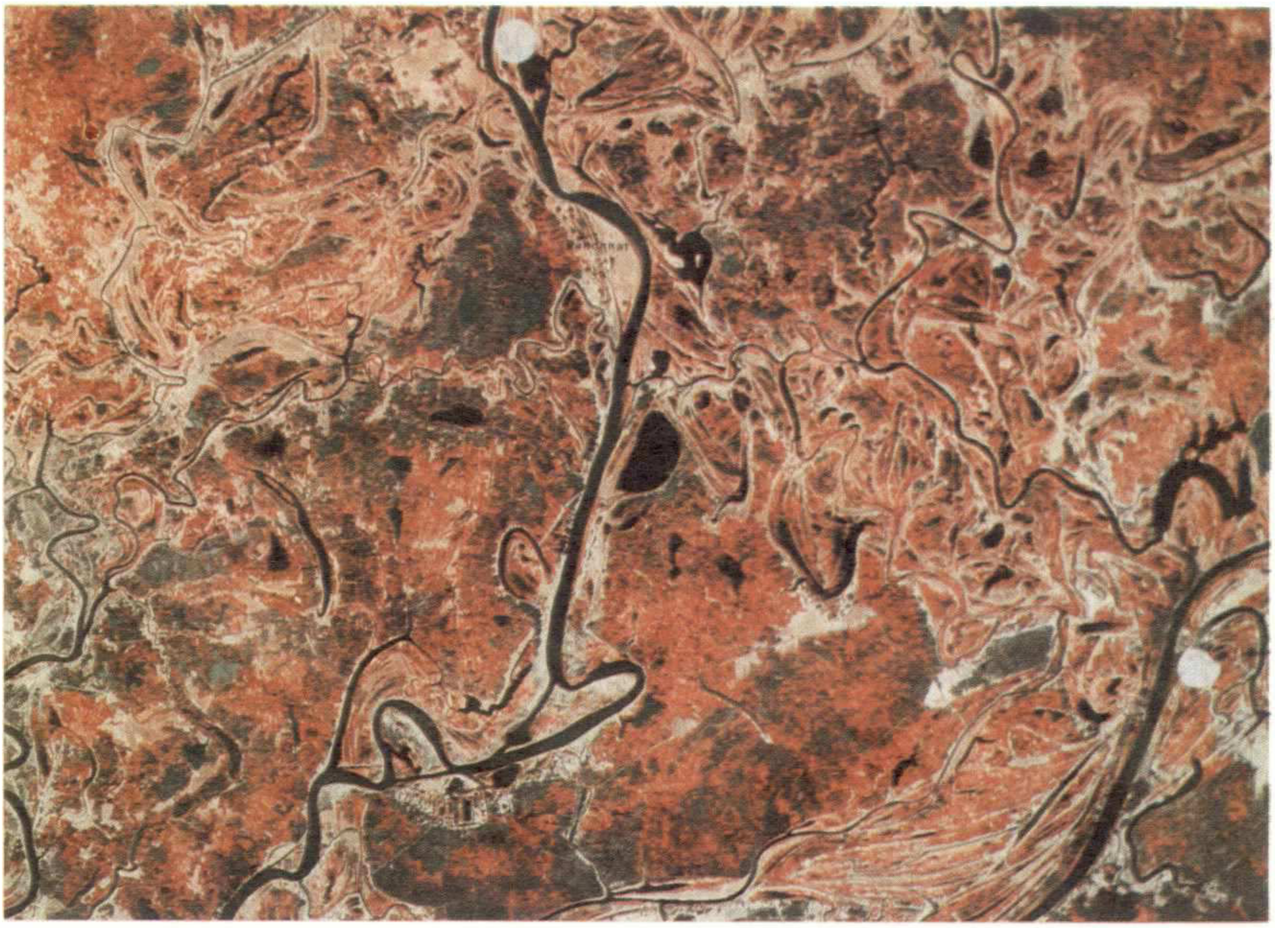
Figure 12



Northeast Regional Project

Baulai River
Kaliajuri to Dhanu River

Prepared by: DMc/Mamun	February 1993



Baulai River Kalni River

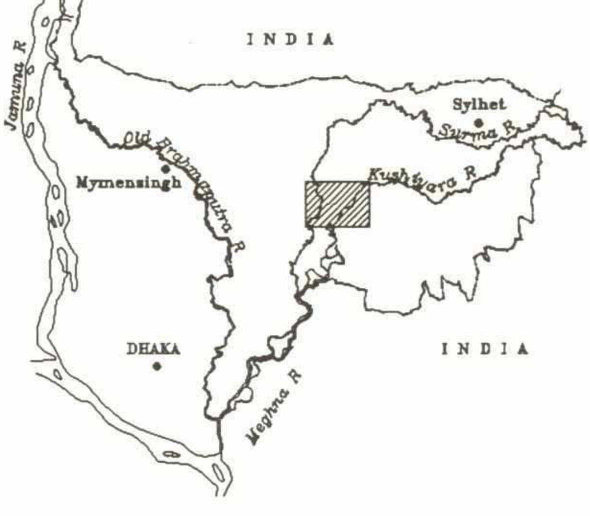
Scale

2 0 2 4 km

Approx.

N

Site Location

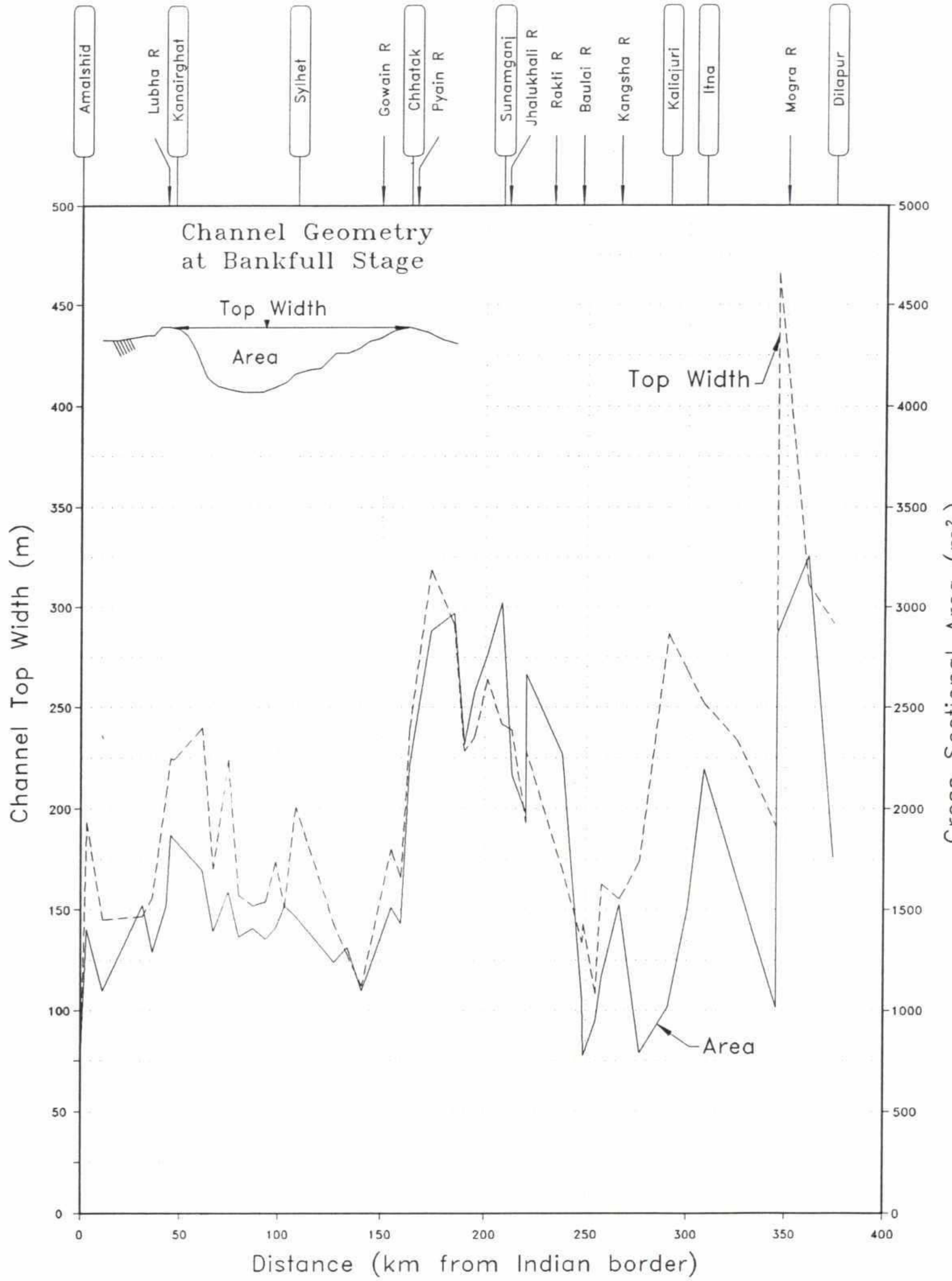


Northeast Regional Project

Channel Pattern on Flood Basin Lowlands

Prepared by: DMc | May 1993

FILE: dm188.DWG



Note:
1. Cross Sections
Surveyed by SWMC (1990).

Northeast Regional Project

Surma/Baulai River Channel Geometry

Prepared by: dm | May 1993

FILE: dm-217.DWG

Figure 16

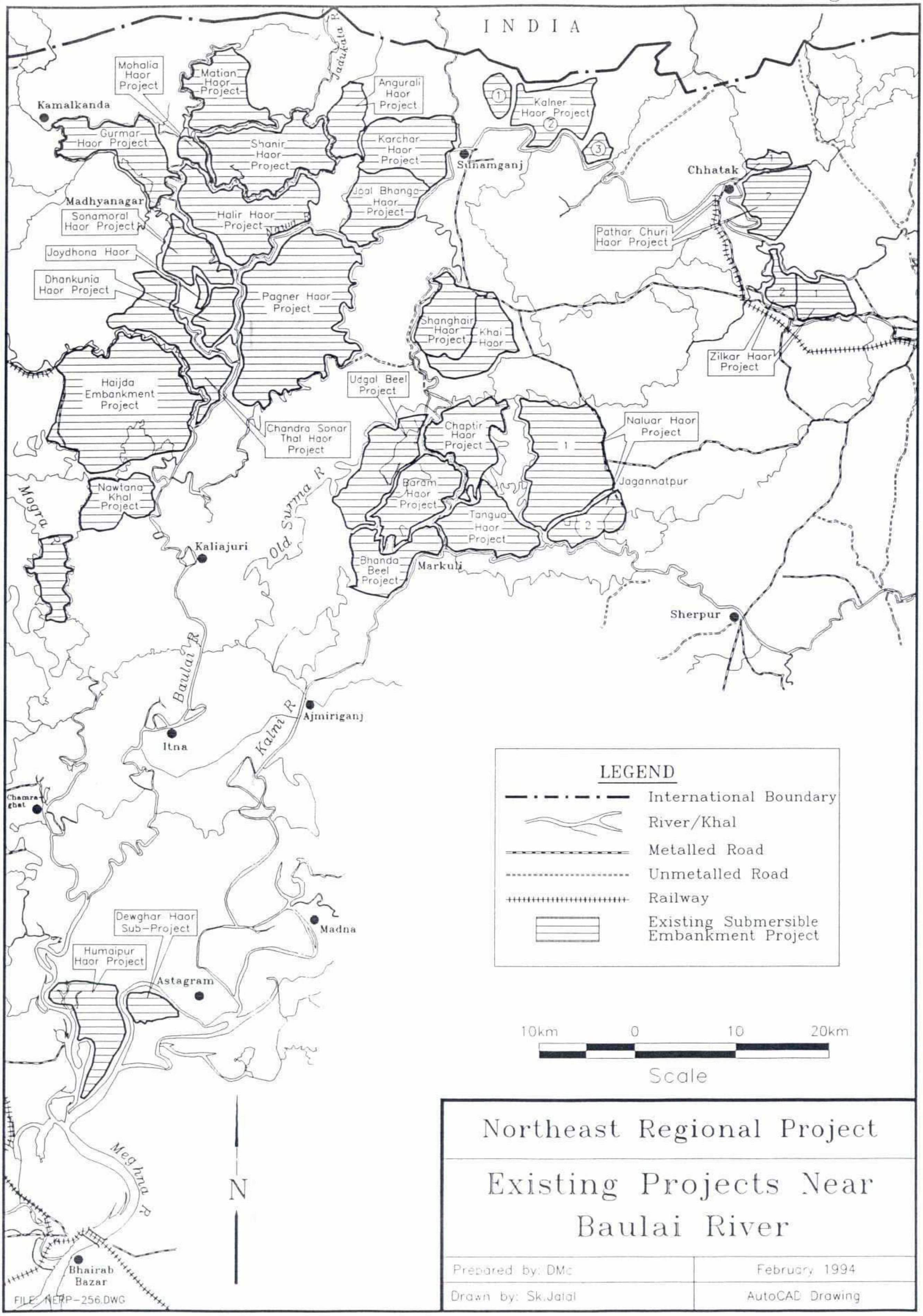
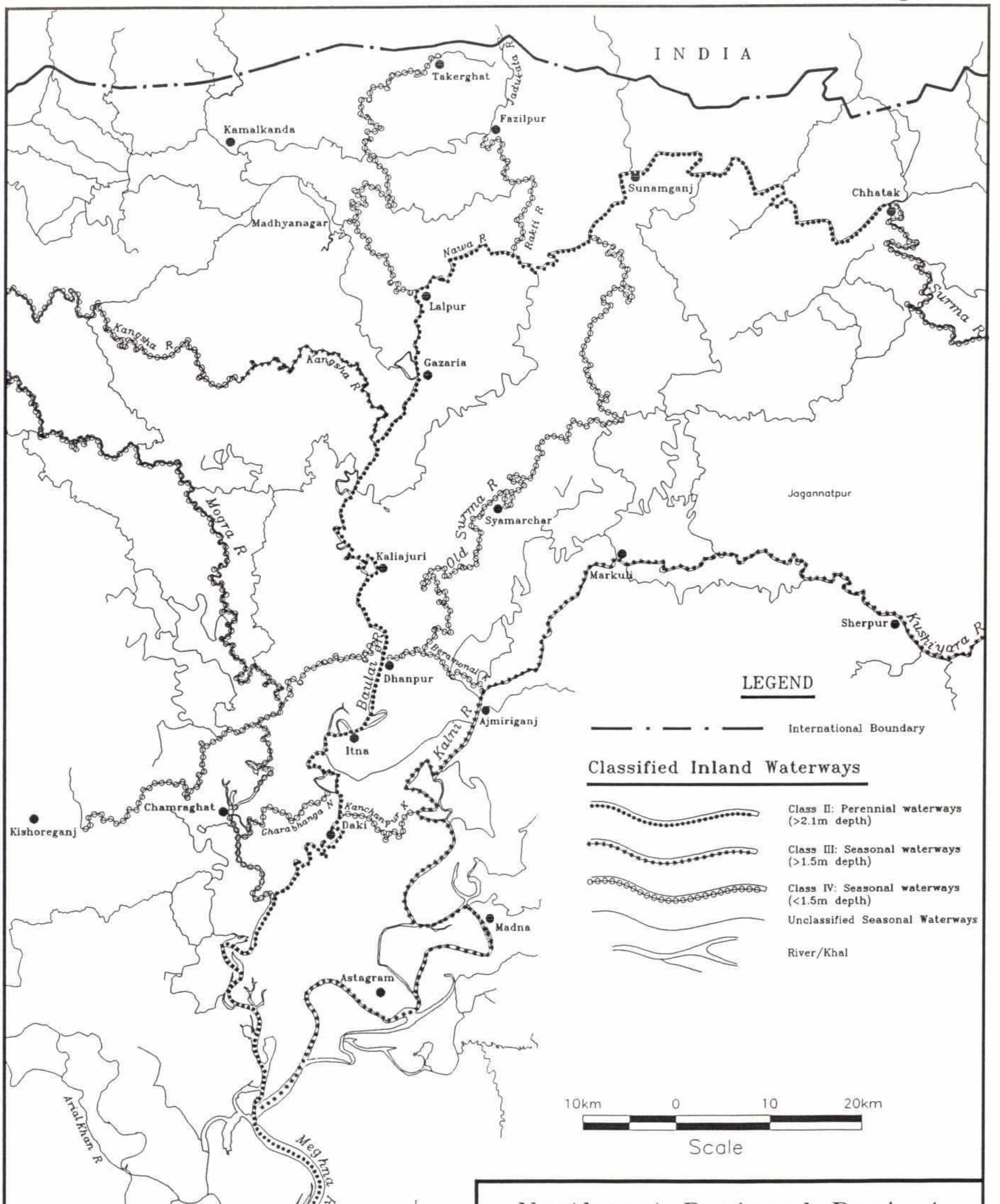

INDIA
Jadukata R
Mohalia Haor Project
Matian Haor Project
Angurali Haor Project
Kalner Haor Project
Kamalkanda
Gurmar Haor Project
Shanir Haor Project
Karchar Haor Project
Sunamganj
Chhatak
Madhyanagar
Sonamoral Haor Project
Halir Haor Project
Joal Bhanga Haor Project
Pathar Churi Haor Project
Joydhona Haor
Dhankunia Haor Project
Pagner Haor Project
Shanghair Haor Project
Khai Haor
Zilkar Haor Project
Haijda Embankment Project
Udgal Beel Project
Chandra Sonar Thal Haor Project
Chaptir Haor Project
Naluar Haor Project
Jagannatpur
Nawtana Khal Project
Baram Haor Project
Tangua Haor Project
Mogra R
Old Surma R
Kaliajuri
Bhanda Beel Project
Markuli
Sherpur
Baulai R
Ajmiriganj
Kalni R
Itna
Chamraghat
LEGEND
International Boundary
River/Khal
Metalled Road
Unmetalled Road
Railway
Existing Submersible Embankment Project
Dewghar Haor Sub-Project
Madna
Humaipur Haor Project
Astagram
10km 0 10 20km
Scale
N
Meghna R
Bhairab Bazar
FILE: NERP-256.DWG
Northeast Regional Project
Existing Projects Near Baulai River
Prepared by: DMc
February 1994
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 17



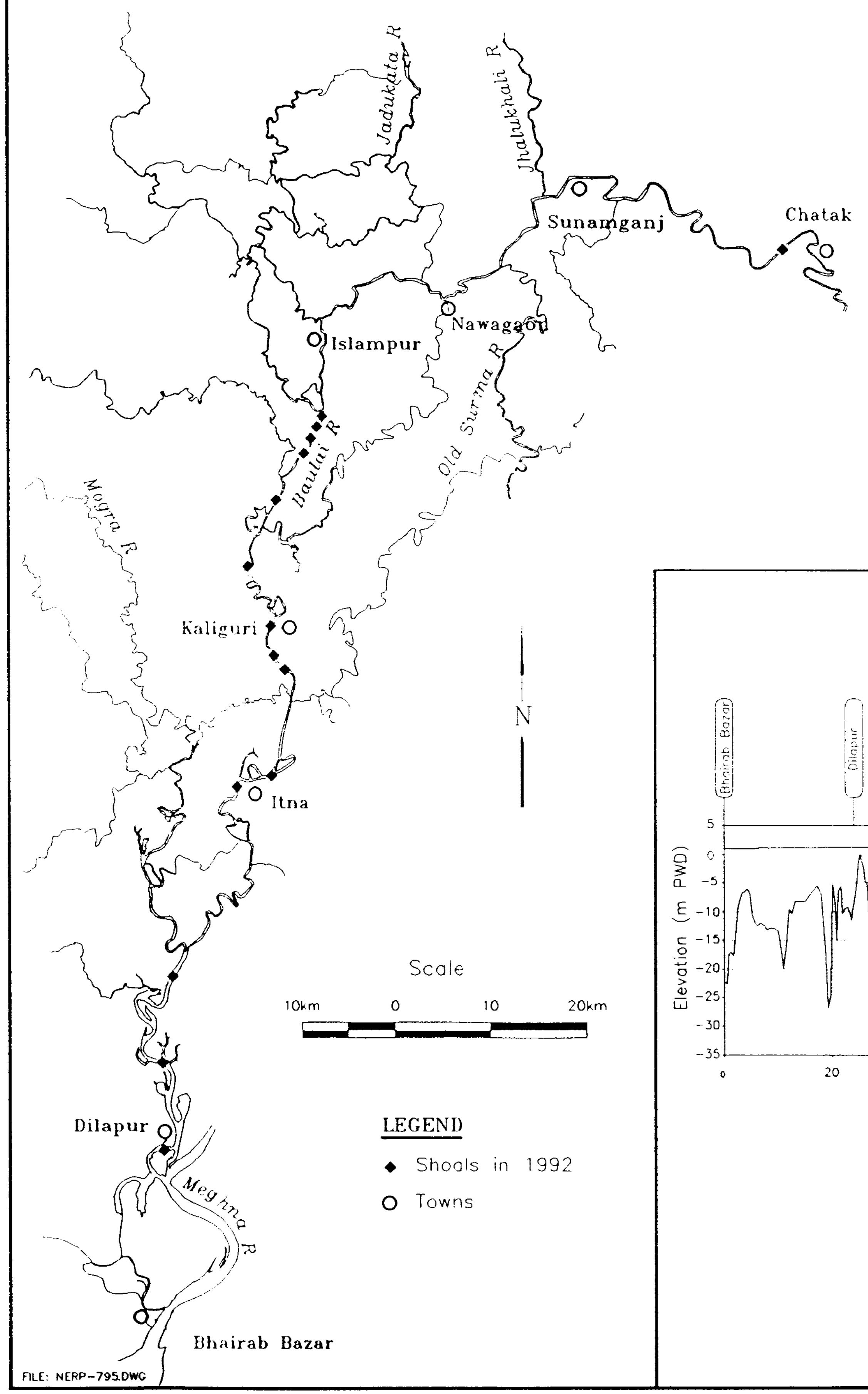
Northeast Regional Project

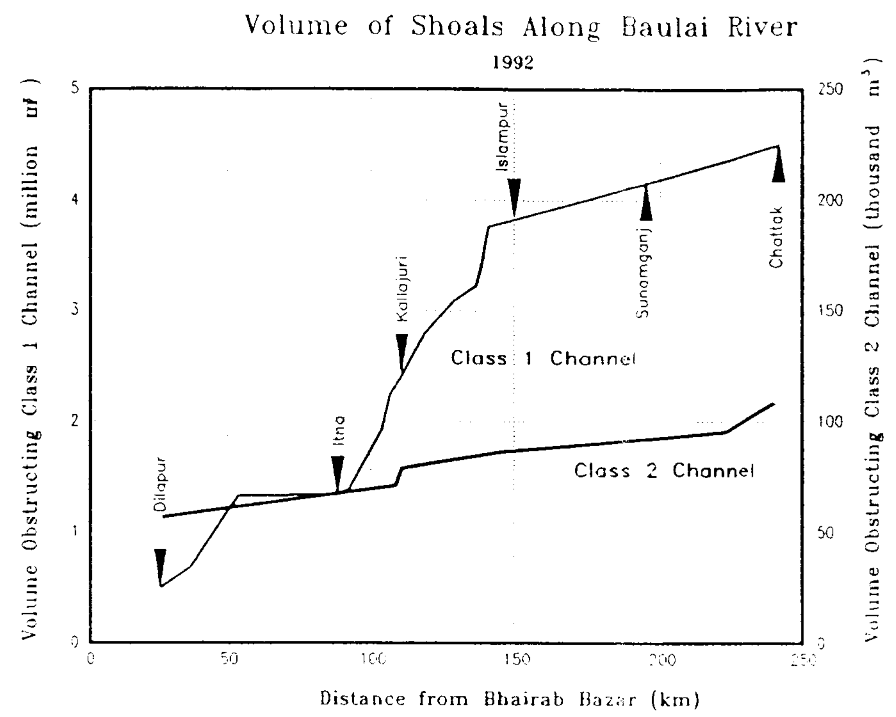
Navigation Routes Through the Project Area

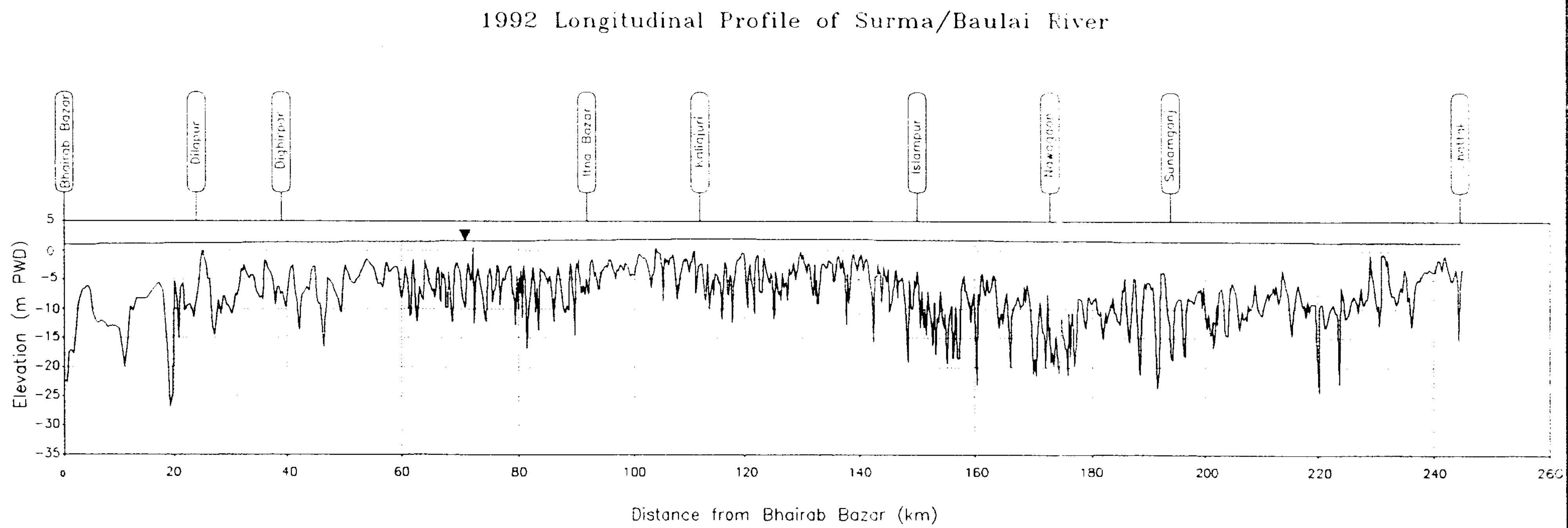
Prepared by: DMc/MA	February 1994
Drawn by: Sk.Jalal	AutoCAD Drawing

Figure 18

206







Note:
1. Bed levels from BIWTA navigation charts
2. Water level represents navigation Local Low Water
3. Class 1 Channel: L.A.D. > 3.6 m
4. Class 2 Channel: L.A.D 2.1 m - 2.4 m

Northeast Regional Project			
Baulai River Navigation Conditions			
Prepared by:	DMc	February 1994	
Drawn by:	Mamun	AutoCAD Drawing	

Figure 19

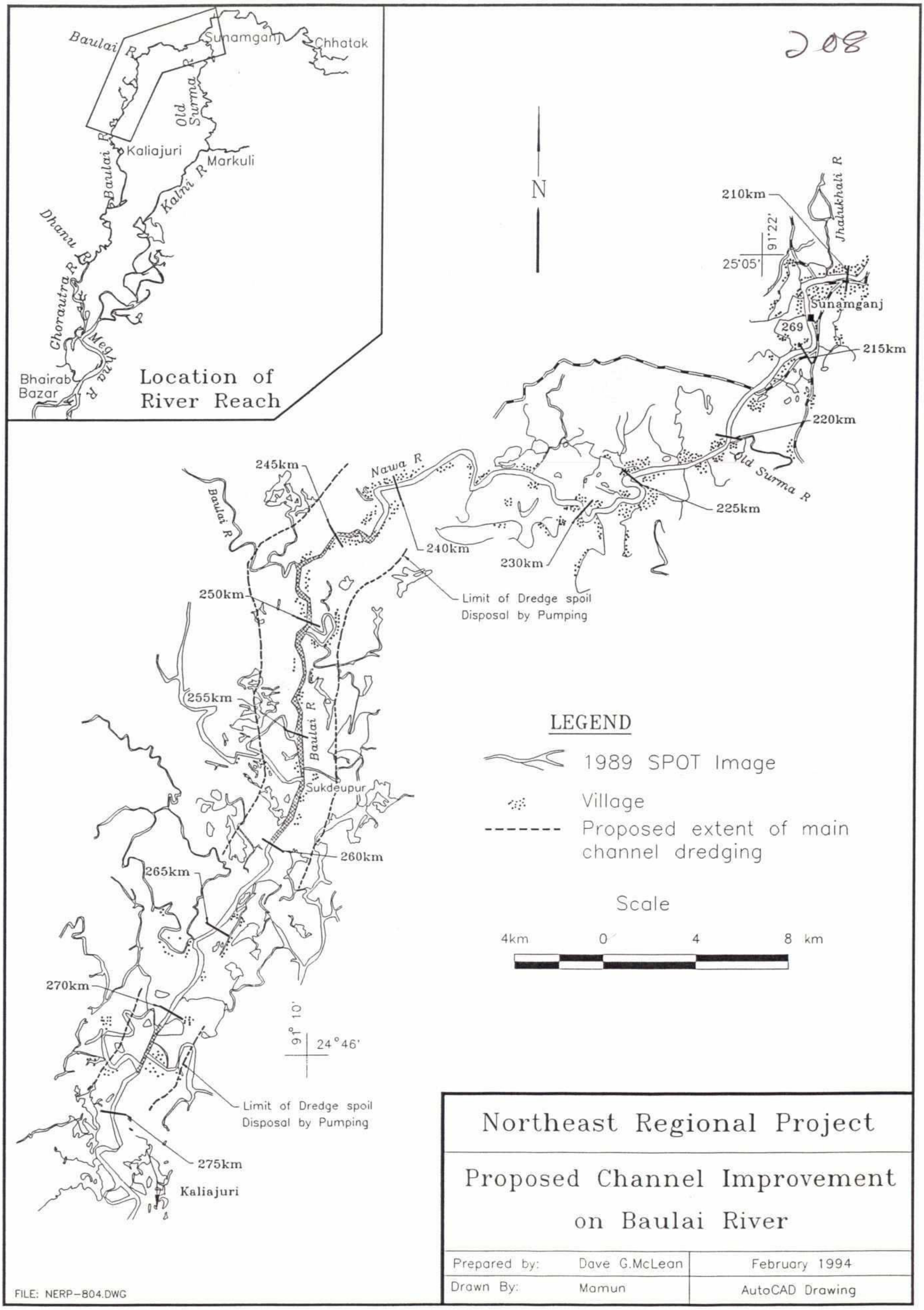

Baulai R
Sunamganj
Chhatak
Old Surma R
Kaliajuri
Markuli
Baulai R
Kalni R
Dhanu R
Chorautra R
Meghna R
Bhairab Bazar
Location of River Reach
N
210km
Jhalukhali R
91°22'
25°05'
Sunamganj
269
215km
220km
Old Surma R
225km
230km
240km
Nawa R
245km
Baulai R
250km
Limit of Dredge spoil Disposal by Pumping
255km
Baulai R
Sukdeupur
260km
265km
270km
91° 10'
24°46'
Limit of Dredge spoil Disposal by Pumping
275km
Kaliajuri
LEGEND
1989 SPOT Image
Village
Proposed extent of main channel dredging
Scale
4km 0 4 8 km
Northeast Regional Project
Proposed Channel Improvement on Baulai River
Prepared by: Dave G.McLean
February 1994
Drawn By: Mamun
AutoCAD Drawing
FILE: NERP-804.DWG

Figure 20

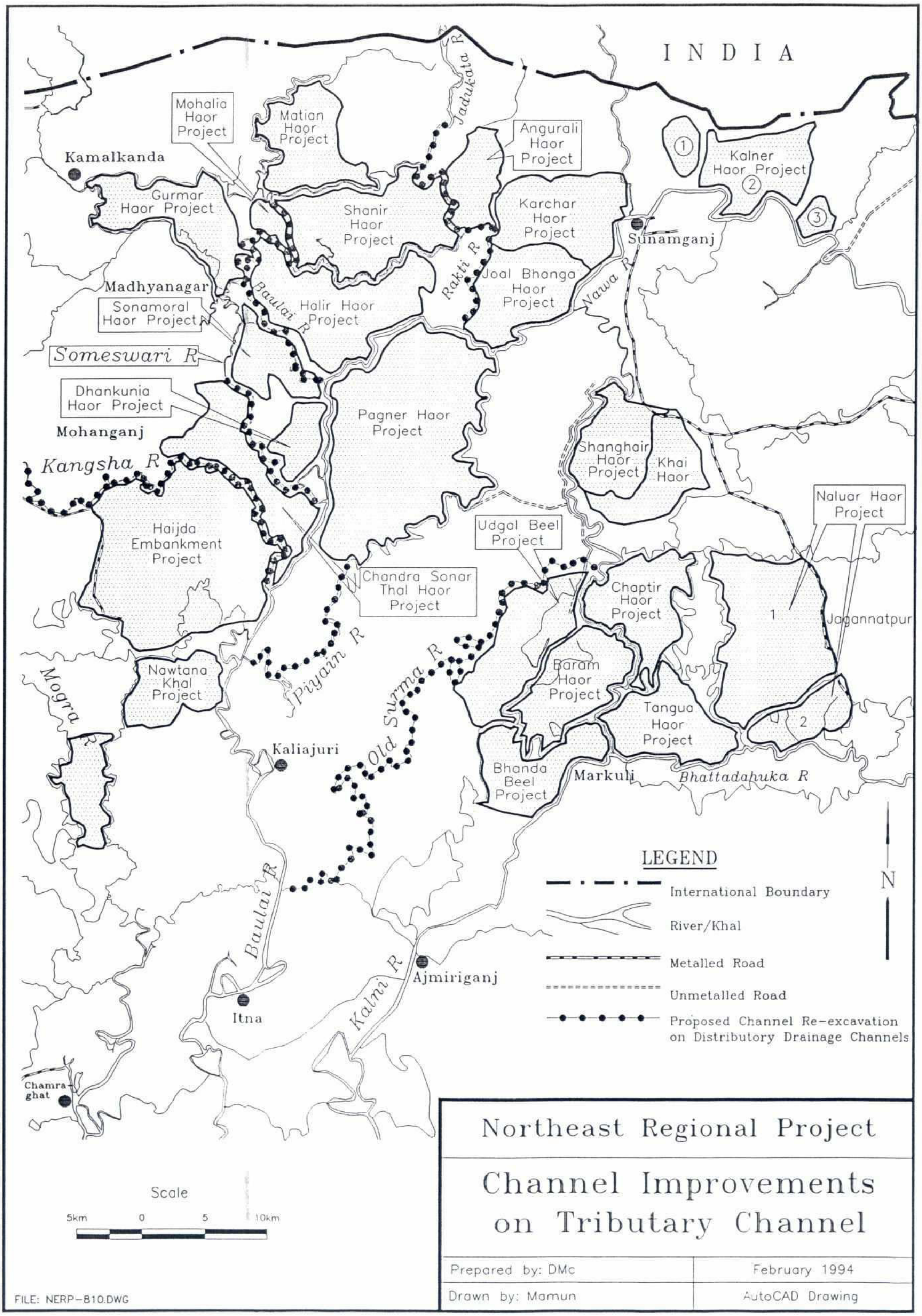
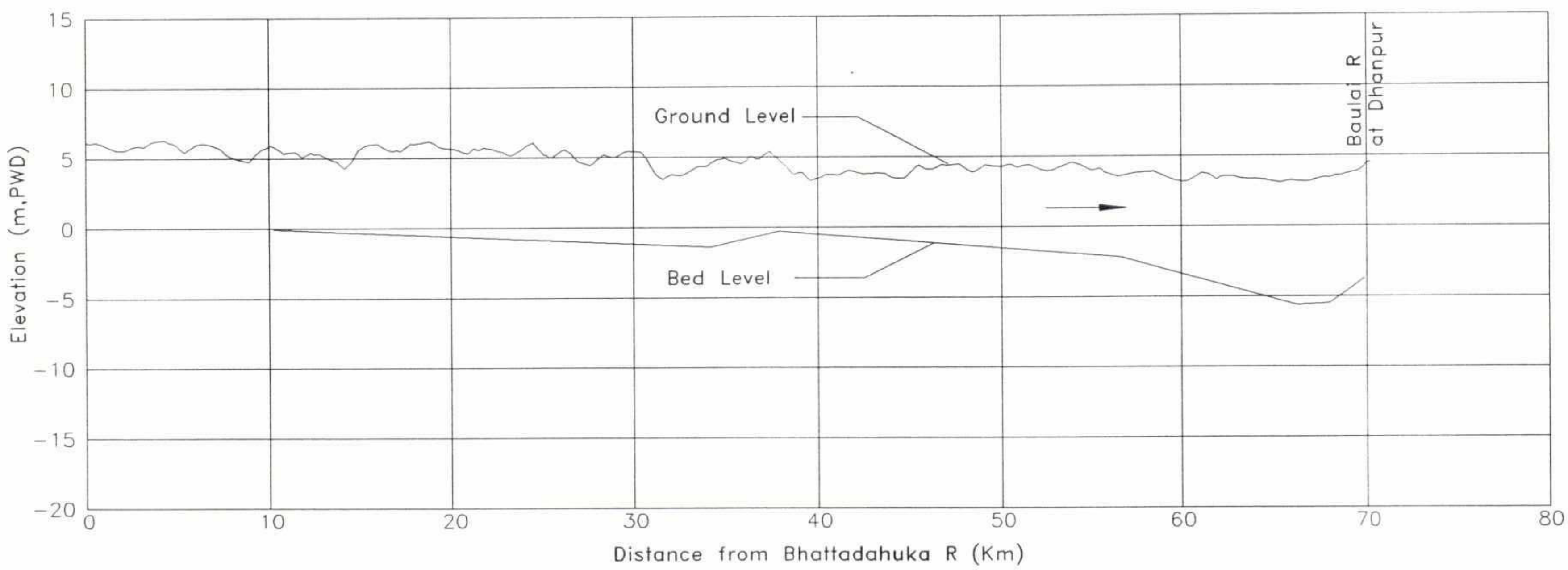

INDIA
Jadukata R
Mohalia Haor Project
Matian Haor Project
Angurali Haor Project
Kalner Haor Project
Kamalkanda
Gurmar Haor Project
Shanir Haor Project
Karchar Haor Project
Sunamganj
Madhyanagar
Sonamoral Haor Project
Baulai R
Halir Haor Project
Rakti R
Joal Bhanga Haor Project
Nawa R
Someswari R
Dhankunia Haor Project
Pagner Haor Project
Mohanganj
Kangsha R
Shanghair Haor Project
Khai Haor
Naluar Haor Project
Haijda Embankment Project
Udgal Beel Project
Chandra Sonar Thal Haor Project
Chaptir Haor Project
Jagannatpur
Piyain R
Old Surma R
Baram Haor Project
Nawtana Khal Project
Tangua Haor Project
Mogra R
Kaliajuri
Bhanda Beel Project
Markuli
Bhattadahuka R
LEGEND
International Boundary
River/Khal
Metalled Road
Unmetalled Road
Proposed Channel Re-excavation on Distributory Drainage Channels
N
Baulai R
Kalni R
Ajmiriganj
Itna
Chamra-ghat
Scale
5km 0 5 10km
FILE: NERP-810.DWG
Northeast Regional Project
Channel Improvements on Tributary Channel
Prepared by: DMc
February 1994
Drawn by: Mamun
AutoCAD Drawing

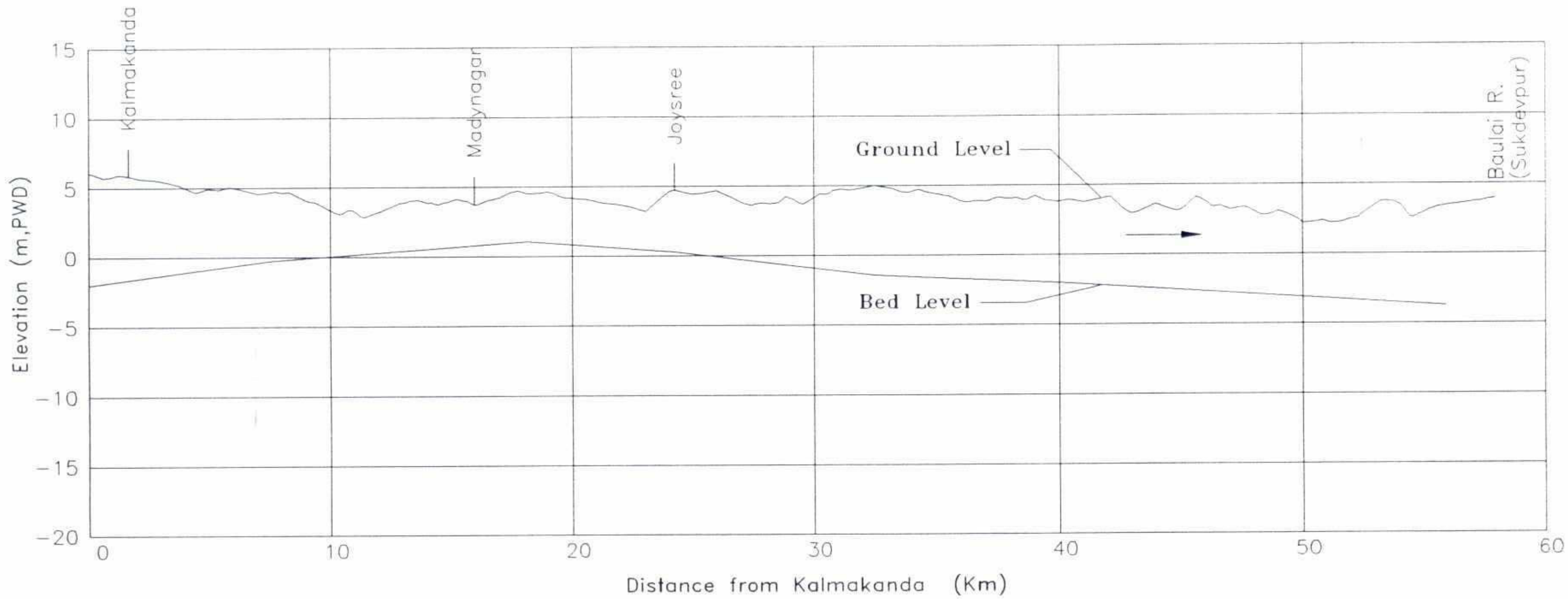
Figure 21



Note:
Ground elevations from 1Km MPO grid
Bed elevations from SWMC cross sections

Northeast Regional Project	
Old Surma River Ground Profile	
Prepared by: DMc	Feb 1994

FILE: os.DWG



Note:
Ground elevations from 1 Km MPO grid
Bed elevations from SWMC cross sections

Northeast Regional Project

Someswari River
Ground Profile

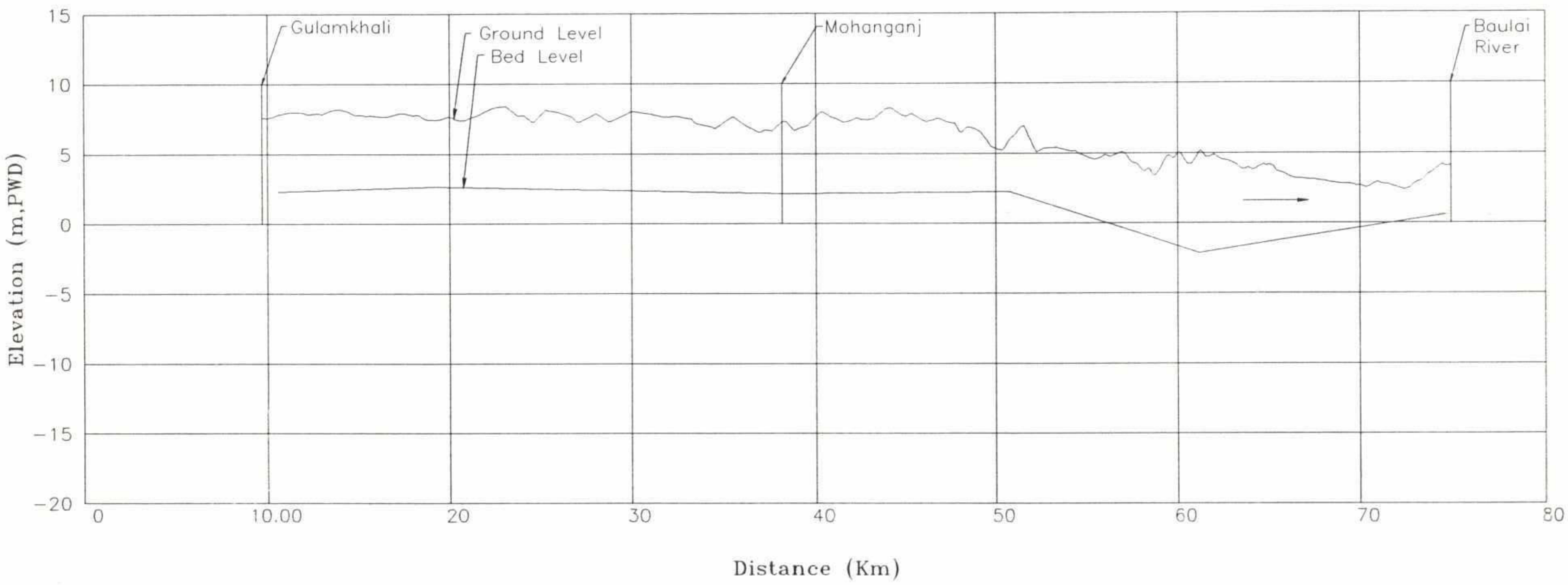
Prepared by: DMc | Feb 1994

FILE: somes.DWG

Figure 22

Figure 23

20b



FILE: NERP-812.DWG

Northeast Regional Project	
Kangsha River Ground Profile	
Prepared by: Awald	February 1994
Drawn by: Mamun	AutCAD Drawing

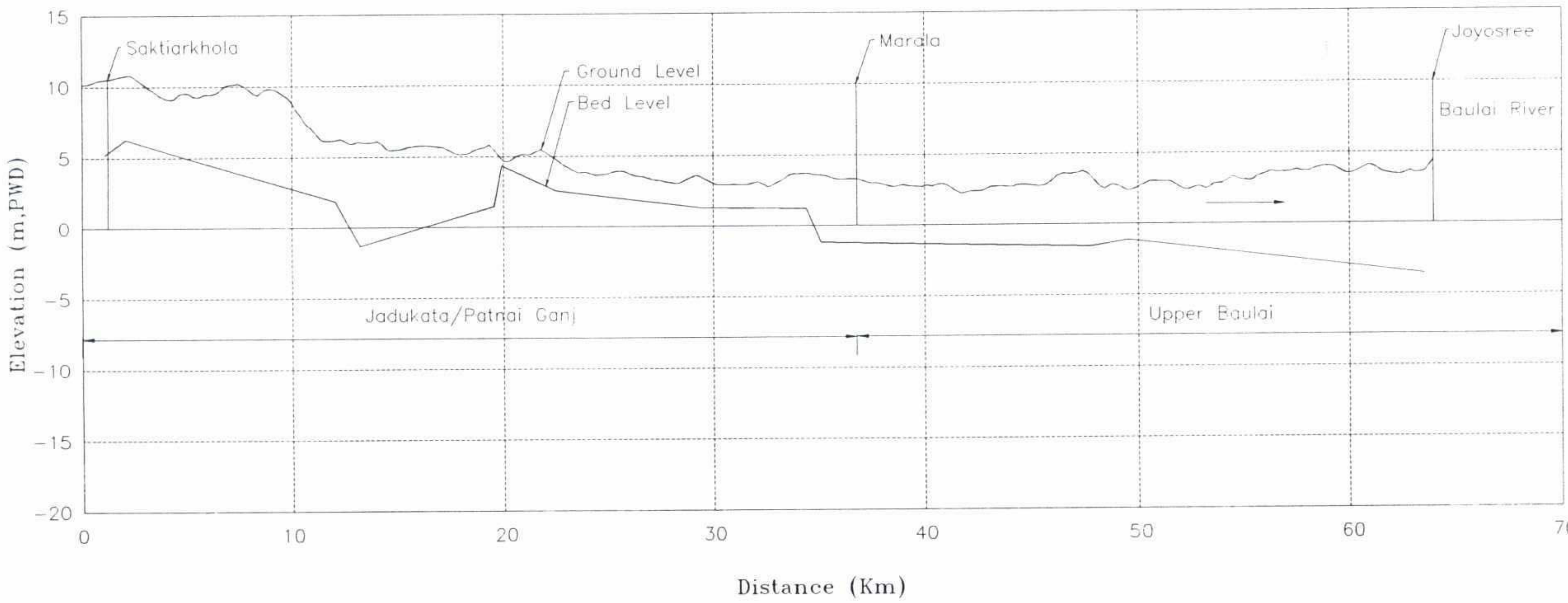


Figure 24

Northeast Regional Project

Patnaigang & Upper Baulai R
Ground Profile

Prepared by:	Awald	February 1994
Drawn by:	Mamun	AutCAD Drawing

FILE: NERP-811.DWG