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)

JADUKATA-RAKTI RIVER IMPROVEMENT PROJECT

Draft Final
December 1993

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

Canadian International Development Agency

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)

72

JADUKATA-RAKTI RIVER IMPROVEMENT PROJECT

Draft Final
December 1993

NOT FOR CIRCULATION
PRELIMINARY DRAFT
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

Canadian International Development Agency

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
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DTW	deep tube well
EIA	environmental impact assessment
EIRR	economic internal rate of return
EMP	Environmental Management Plan
EPWAPDA	East Pakistan Water and Power Development Agency
FAP	Flood Action Plan
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 Planning Organization
NGO	non-governmental organization
NHC	Northwest Hydraulic Consultants
NPV	net present value
PD	person-day
PWD	Public Works Department
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 this project is to reduce damage to agricultural land from pre-monsoon flash floods, improve post-monsoon drainage, facilitate navigation and quarrying and to reduce sedimentation in Tangua Haor, a key wetland site and "mother" fishery.

The project area contains plentiful natural resources but is situated in a morphologically unstable location that is subjected to high intensity floods and large sediment inflows. The centre of activity for this initiative is on the Jadukata River, which is the main influence on flow patterns in the Patnai, Upper Baulai, Nandia and Rakti Rivers. The river is currently in the process of shifting across its alluvial fan into the Maharram channel to the west. Two key wetland sites (Tangua Haor and Gurmar Haor), as well as valuable fisheries habitat and agricultural land are threatened by rapid sedimentation from this channel shift.

The Jadukata River is also the centre of activity in another sense. It is a major source of sand and stone for the construction industry in the region. In 1992 it was estimated that roughly 500,000 m^3 of aggregates was quarried from the river and over 85 million taka was introduced into the local economy from this work. However, the Rakti River, which is the main navigation route for boats transporting this material has become silted up to the point where it is completely dry during the winter. Furthermore, due to this siltation, post-monsoon drainage is deteriorating and the net cultivable area is gradually declining.

The proposed initiative emphasizes developing a management plan for the project area so that hazards from flooding and erosion can be minimized, and economic activity can be improved. Given the unstable nature of alluvial fans, it will be impractical to attempt to make the entire fan area safe from flooding and/or erosion. However, the situation can be improved through monitoring, ongoing channel maintenance and local river training. Dredging 24 km of the Jadukata/Rakti River from Dulabpur to Fazlipur would have a high priority, as this would improve drainage and facilitate navigation. Consideration would also be given to limiting further flow diversion from the Jadukata River by constructing a submersible weir across the Maharram River to prevent bed load and early and pre-monsoon flows from entering Tangua Haor.

The project would be implemented by BWDB and the estimated cost of the project would be US$ 7 million.

a

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 prefeasibility 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 Kishorganj Seminar
Proceedings of the Narsingdi Seminar
Proceedings of the Habiganj Seminar
Proceedings of the Netrokona Seminar
Proceedings of the Sylhet Fisheries Seminar

Pre-feasibility Studies

Jadukata/Rakti River Improvement Project
Baulai Dredging
Mrigi River Drainage Improvement Project
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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

1.1 General Information

BWDB Division:	Sunamganj
District:	Sunamganj
Thana(s):	Tahirpur, Bishwamvarpur, Jamalganj and Sunamganj
MPO Planning Area:	23
Gross Area:	37,434 ha
Net Area:	30,322 ha

1.2 Scope and Methodology

This is a pre-feasibility study that was undertaken over a period of one month in early 1993. The study team consisted of a water resources engineer, a socio-economist, an agronomist, a fisheries specialist, and a wetland resources specialist. Additional analytical support was provided by an environmental specialist, river morphology specialist and an economist.

1.3 Data Base

Project analyses presented in this document was based mainly on secondary data supplemented by information obtained during field inspections and discussions with project area residents. Information and data sources used by the various analysts are as listed below.

Engineering analysis: Existing topographic maps, historic climatological and hydrological records, river and khal cross-sections surveyed by BWDB Morphology Directorate and by SWMC, BWDB reports, MPO Reports, personal field observations and interviews with beneficiaries, recommendations by BWDB officials and by local representatives.

***Agricultural analysis*:** Data published in the "Land Resources Appraisal for Agricultural Development in Bangladesh" (AEZ Reports) for soils information, data published by the Water Resources Planning Organization (WARPO) for agricultural inputs, data assembled through the "Agriculture Specialist Study" by NERP, interviews with individuals and groups of farmers in different areas and on each land type, and hydrological data developed by the hydrology and engineering sections of the NERP.

***Fisheries analysis*:** Topographic maps, BFRSS data, CIDA Inception Report, NERP Fisheries Specialist Study, field observations and local interviews, information provided by local representatives during field seminars held in Sylhet on June 26, 1992 and in Sunamganj on February 13, 1993.

Wetland analysis: Topographic maps, local revenue department records, personal field observations and interviews with local people, and the "Wetland Specialist Study" published by NERP.

Socio-economic analysis: Published BBS data on demographic features, education and agriculture; reports of the Directorate of Public Health and Engineering, and the NERP data base on Population and Human Development, personal field observation and field interviews with various cross-section of local people, the opinions and suggestions from various local level representatives including NGO personnel and the Honourable Members of the Parliament.

1.4 Report Layout

A description of the biophysical features of the project area is provided in Chapter 2. Chapter 3 describes the current status of development and resource management including a summary of the types of problems faced by people living in the area. Chapter 4 briefly reviews previous studies directed towards development of the water resources and Chapter 5 lists trends which are occurring and which will continue if no interventions are made. Chapter 6 reviews water resource development options which were considered and Chapter 7 provides an analysis of the best option. The annexes consist of detailed information to support the main body of the report.

2. BIOPHYSICAL DESCRIPTION

2.1 Location

The Jadukata-Rakti River Improvement Project covers a gross area of 37,434 ha in the northeast of Sunamganj district, between latitude 25°0′ and 25°12′ N, and longitude 91°23′ and 91°7′ E. The project area is bounded by the international boundary on the north, Surma River and Halir Haor on the south, Gagotia River, Karcher and Joalbhahga Haors on the east and Tangua Haor and Baulai River on the west (Figure 1).

2.2 Climate

There is no meteorological station in the project area. Sylhet is the nearest station. The climate of the project area based on data from this station is summarized in Table A.1. The climate of the project area is monsoon tropical with hot wet summers and cool dry winters. The highest temperature in Sylhet was recorded at 40.6 C in May and the lowest at 8.9 C in December and February. The lowest monthly temperature is in January when the mean is 18.7 C and the highest monthly temperature is in July when the mean is 28.8 C.

Rainfall distribution shows a general pattern of gradual increase from south to north. Average annual rainfall in the area ranges from about 5400 mm in the south near Durlabpur to about 6000 mm in the north near Saktiarkhola for the recorded year 1961-1990 (Figure 2). Mean monthly rainfall varies from 10 mm in January to 820 mm in June, and mean annual rainfall is 4096 mm. Potential evapotranspiration is lowest in December 102.64 mm/month and highest in March at 162.4 mm/month.

2.3 Land (Physiography)

2.3.1 General Description

The project area is bounded on the north by the Shillong Plateau/ Meghalaya Hills of India, an elevated block of Pre-Cambrian Basement rock which has been draped over by late Mesozic and Cenozoic sediments (primarily sandstone, siltstone and conglomerate). The plateau extends to an elevation of 2,000 m asl and up to 70 % of the land lies above El. 900 m. The south face of the plateau has been dissected by steep, V-shaped canyons that follow structurally controlled valleys. The southern escarpment of the plateau is bordered by the east-west trending Dauki Fault, which forms a distinct lineament separating the lowlands in Bangladesh from the mountains in India (Figure 3). This area has been the site of several major earthquakes including the great Assam earthquake of June 12, 1897 (estimated magnitude 8.7) and the Srimangal earthquake of July 8, 1918 (estimated magnitude 7.6).

The project area comprises two main physiographic features:

- alluvial fans formed by Jadukata River and Jhalukhali River on the north;

- flood basins and haors which merge in the floodplain of the Surma River on the south;

The alluvial fans have formed as a result of sediment deposition from the steep mountain streams as they exit from their canyons and spread over flatter unconfined low lands. The fans have an approximately conical shape and merge gradually into the low-lying floodplains to the south (Figure 3). The area of the fans amounts to approximately 23,900 ha or roughly 68% of the total project area. Several recent and ancient meandering channels radiate from the heads of the two fans. The sediments in these channels consists of boulders, cobbles and coarse sand near the fan heads but rapidly changes to coarse sand and very fine gravel within a few kilometres. This indicates virtually all of the coarser sediments are deposited near the fan head. The ongoing sediment deposition has modified the overall north to south drainage in the project area by causing a radial pattern from the two stream canyons.

The second major physiographic unit in the project area consists of low-lying flood basin and floodplain lands of the Sylhet Depression. Haors are one characteristic landform in this unit. These features are saucer shaped, seasonally flooded inter-fluvial depressions bounded by natural river levees around their perimeter. The largest haors in the project area include Matian Haor (6,577 ha), Shanir Haor (7,521 ha), Karchar Haor (5,598 ha),Joalbhanga Haor (4,625 ha) and Angurali Haor (2,631 ha). Other important haors adjacent to the project area include Tangua Haor on the northwest, Gurmar Haor on the west and Halir Haor on the south west (Figure 1). The haors are typically inundated to depths of 4 - 5 m during the monsoon season. However, during the winter, only the lowest beels remain flooded (Figure 4).

The origin of the haors is believed to be associated with the evolution of the Brahmaputra River channel. Morgan and McIntire indicated the earliest evidence of the Brahmaputra River consists of a series of large channel scars, which extend from near Mymensingh into the Sylhet Basin. One of these low flooded areas is Matian Haor. The main river apparently extended east beyond this location at one time and then swung southward into the ancient Bay of Bengal.

Figures 5 and 6 illustrate the distribution of land elevations in various portions of the project area. The north and northeastern areas are comparatively higher than the south and southeastern part. Average land elevation in the north along the left bank of the Jadukata River ranges 6.5 - 12.5 m PWD while in the right bank ranges 3.0 - 11.5 m PWD. Average land elevation in the remaining area ranges 1.0 - 8.0 m PWD.

The extreme low elevations of the land in this area have generally been attributed to ongoing regional subsidence brought about by tectonic movements (Johnson and Alam, 1991) or by compaction of unconsolidated sediments in the Sylhet Basin (Alam, 1989). This subsidence appears to have been approximately offset by ongoing sediment deposition, so that in the long-term at least, the land surface appears to remain approximately the same. There is insufficient data available at this time to estimate subsidence rates over project planning time scales. Although previous studies have reported rates of between 2 - 21 mm/year in the Sylhet-Mymensingh Basin, the basis for these figures appears very questionable. Crude estimates of subsidence rates in other parts of Bangladesh have ranged between 1 mm/year to 6 mm/year, corresponding to 0.02 m - 0.12 m over a 20 year time period.

2.3.2 Soils

The Jadukata-Rakti river improvement project area is covered mostly by the Young Piedmont Alluvial plain and partly by the Old Surma-Kushiyara floodplain.

The Young Piedmont Alluvial plain comprises the alluvial fans of the Shillong plateau and also the adjoining basins and basin depressions. The fan soils are poorly to imperfectly drained, strongly mottled brown, loamy sands to clay loams, poorly structured with strongly to very strongly acid reaction. The very poorly drained basin deposits comprise strongly reduced heavy clay lacking any sign of profile development.

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

2.4 Water (Hydrology)

2.4.1 Runoff Patterns

Hydrological conditions in the project area are governed by inflows from the Jadukata and Jhalukhali Rivers from the north and by backwater conditions from the Surma River from the south (Figure 1).

The Jadukata River originates in the Meghalaya Hills in India and enters Bangladesh at Lorerghar. The catchment area totals 2,513 km^2 and consists of steep uplands and hills. Approximately 60 % of the catchment lies above El. 900 m and the highest point reaches to El. 1925 m.

Within Bangladesh, the Jadukata River flows over its alluvial fan and follows a southerly course for 25 km to its confluence with the Surma River at Durlabpur. Between Lorerghar and Durlabpur, the Jadukata Rivers bifurcates three times. The first bifurcation occurs about 1 km south of Lorerghar where the Patnai takes off westward but it has silted up completely and does not carry any flow. Due to recent avulsion of the Jadukata River, a new channel has developed just north of the Patnai River, locally called Marharram River which is perennial. The Maharram River flows to the Patnai River in the west a few kilometer from its offtake. The second bifurcation occurs about 10 km downstream of Lorerghar where the Baulai takes off westward and the third is further 5 km downstream where the Nadia Gang takes off. The lower stretch of the river, south of Tahirpur, is called the Rakti.

The Jhalukhali River drains an area of 448 km^2 from the Meghalaya Hills east of the Jadukata basin. The Jhalukhali has constructed a large fan that extends to Nolagang on the east, Karchar Haor on the south and coalesces into the Jadukata fan on the west. The satellite photo in Figure 4 shows several old abandoned channels radiate from the head of the fan near the International border. During the flood season these channels may continue to carry a substantial portion of the river's discharge. A former main channel heads south-west immediately downstream of the fan head near the international boundary. This channel, called the Dhamalia River (locally called Gagotia River) flows towards the Jadukata River (Figure 7).

Discharge measurements on the Jadukata River and Jhalukhali River have only been started very recently (1989-90). Furthermore, obtaining reliable discharges at these sites has been complicated by the occurrence of upstream spills, rapid changes in discharges during flash floods, high velocities in the channels, ongoing channel shifts and unstable stage-discharge rating curves. These difficulties are inherent to unstable mountain rivers carrying high sediment loads and subject to very large inflows.

Figure 8 shows hydrographs from the two rivers during 1991. Actually observed minimum and maximum discharges on the Jadukata River at Lorerghar were 10.12 m^3/sec and 2,310 m^3/sec over the periods 1989-91. The estimated maximum daily discharge in 1991 was reported to reach 5,260 m^3/s and flows were estimated to exceed 4,000 m^3/s on four other occasions. These estimates were based on recorded water levels and extrapolation of stage-discharge rating curves. Although the values may be approximate, they illustrate the magnitude of the very high runoff generated in the Jadukata catchment.

On the Jhalukhali River at Muslimpur, observed discharges ranged from 2.19 m^3/sec (March) and 893 m^3/sec over the period 1990-1991.

Predictions of runoff from the Jadukata River and Jhalukhali River have been made by SWMC using the NAM rainfall-runoff model. However, since daily rainfall data are not available from India, it is difficult to apply this model to Meghalaya catchments. Therefore, the results are considered to be very preliminary and are mainly for qualitative interpretation. The predicted mean and extreme daily discharge for the Jadukata (catchment NE -48) and Jhalukhali (catchment NE -11) Rivers for the rainfall year 1986-91 are summarized in Table 2.1.

Predicted mean monthly flows are summarized in Table A.2. Recorded monthly water levels on the Jadukata River are summarized in Table A.3.

Figure 9 shows the pattern of water levels during 1992 at three locations around the project area — Durlabpur on the Surma River near the outfall of the Jadukata River, at Marala in Shanir Haor and at Lorerghat on the Jadukata River near the head of the fan. Between June and October the water levels were virtually the same at Durlabpur and Marala due to backwater from the Surma-Meghna River system. At this time most of the project area is inundated as a result of the

Table 2.1: Range in Discharges Estimated from NAM Model

River	Station	Range of Daily Discharge			Period (Years)
		Minimum	Mean	Maximum	
Jadukata	Lorerghar	2.0	511	5965	1986-91
Jhalukhali	Muslimpur	<1.0	145	1024	1986-91
Surma	Sylhet	2.6	548	2480	1964-89

Source: NERP

backwater conditions. Throughout the monsoon season the average water level at Lourerghat remained about 1 m higher than in Shanir Haor. However, during the three flash floods that occurred in 1992 the Jadukata River responded by rising 2 to 3.5 m while the levels in Shanir Haor remained virtually unaffected. In the post-monsoon season, the Surma River dropped at a faster rate than Shanir Haor, so that by February there was about 1 m of head between Marala and Durlabpur.

2.4.2 Flooding

The magnitude and extent of flooding in the project area is affected by two main factors:

- inflows from the Jadukata and Jhalukhali Rivers;
- backwater conditions in the Surma River.

In addition, two different types of floods need to be considered:

- pre-monsoon flash floods occurring from March to May, which damage boro rice;
- monsoon floods occurring between June and October and damaging aus and aman crops.

In some years, flash floods have also occurred in the post-monsoon season from October to December.

Figure 10 summarizes historic trends in maximum pre-monsoon and annual maximum water levels at Saktiarkhola on the Jadukata River and on the Surma River at Sunamganj. The time series do not show any noticeable trends over time. Table 2.2 lists estimated daily water levels

Table 2.2: Peak Water Levels for Various Return Periods (m PWD)

River	Station	Return periods			
		1:2	1:5	1:10	1:20
Pre-Monsoon Floods:					
Jadukata	Saktiarkhola	6.25	6.86	7.17	7.48
Surma	Sunamganj	6.52	7.18	7.45	7.64
Surma-Baulai	Sukdevpur	4.92	5.04	5.09	5.12
Annual (Monsoon) Floods:					
Jadukata	Saktiarkhola	9.23	9.49	9.60	9.65
Surma	Sunamganj	8.61	8.88	9.08	9.28
Surma-Baulai	Sukdevpur	7.40	7.76	7.91	8.01

Source: NERP

for various return periods during the pre-monsoon and monsoon season on the Jadukata River at Saktiarkhola (#131), Surma River at Sunamganj (#269) and Baulai River at Sukdevpur (#72 B). During the pre-monsoon season, peak water levels on the Jadukata may rise up to 1.8 m above the long-term mean May level. Based on stage-discharge rating curves, typical pre-monsoon discharges reach in the order of 300 m^3/s on the Jadukata River. In 1991 the highest pre-monsoon discharge on the Jhaluhali River at Muslimpur was reported to be 210 m^3/s. The drainage area of the Jhalukhali catchment is about 18 % of the Jadukata basin. Therefore, if the runoff was proportional to the drainage area, pre-monsoon floods of 700 m^3/s - 1,000 m^3/s could be expected on the Jadukata River. Additional hydrometric data will be required to improve estimates of pre-monsoon flood flows on both the Jadukata and Jhalukhali Rivers.

Peak water levels during the monsoon season are typically between 2.0 m - 2.6 m higher than corresponding pre-monsoon levels. Using recent discharge measurements and stage-discharge rating curves to estimate possible flood inflows results in estimates ranging between 2,500 m^3/s to over 5,000 m^3/s during extreme floods on the Jadukata River. For example, in the four month period from July - October 1991, the maximum daily discharge at Lurarhat was estimated to be 5,260 m^3/s, with flows exceeding 4,000 m^3/s on four separate occasions. In 1991 the Jhalukhali River at Muslimpur reached a maximum discharge of 893 m^3/s and exceeded 700 m^3/s on four occasions. To put the magnitude of these discharges in perspective, the highest discharges on the Surma River at Sylhet is only 2,800 m^3/s.

During the monsoon season, about 23,645 ha (78%) of the project area is inundated by floods having a 1:2 return period based on MPO flood depth categories. About 13,639 ha (46%) is flooded to depths exceeding 1.8 m (Table 2.3).

2.4.3 Drainage

The project area drains to the Surma River at Durlabpur through the Jadukata-Rakti River system in the south (Figure 1). Currently, the dry season discharge of the Jadukata River flow through the Nandia Gang which in turn flows to the Surma River through the Baulai River. Recent aggradation along the Rakti channel delays post-monsoon drainage from the completed haor projects, particularly Angurali, Karcher, Joalbhanga and Halir haors and a substantial area from the Bishwamvarpur thana. In addition, Dhamalia River dry season discharge, which used to flow through the Rakti, now also flows through the Nandia Gang. These combined dry season flows have increased water levels in the Nandia Gang-Baulai system which consequently delays post-monsoon drainage from Shanir Haor as well as projects located along both banks of the Baulai River.

Table 2.3: Area Flooded by Depth Category

Land Types	Flood Depth (meters)	Cultivable Area	
		(ha)	(%)
F0	0.0 - 0.3	6637	22
F1	0.3 - 0.9	4789	15
F2	0.9 - 1.8	5258	17
F3	> 1.8	13639	46
Total		30322	100

Source: MPO (WARPO)

Preliminary estimates show that about 6,100 ha (gross) does not drain by the last date of plantation (January 31). The lowest level at which crops were planted was estimated on the basis of discussions with area residents, area-elevation data for the various haors (Figures 5 and 6) and water balance computations (Table A.4). The analysis shows that lowest level at which crops were planted in Angurali, Shanir and Matian Haors ranges between 2 - 2.5 m PWD and between 3 - 3.5 m PWD in Karchar Haor and Joalbhanga Haor. By comparison, the water levels on the Surma River at Durlabpur during the last ten days of January range between 1.5 - 1.8 m PWD (Table A.5) and over 3.5 m on the Nandia Gang (Figure 9). The existing bed level of Rakti is also over 3.5 m PWD so that no drainage can be affected through this channel (Figures 11). These figures suggest that there is the potential to improve the drainage from the haors by the end of January if the Rakti channel can be improved.

2.4.4 Water Bodies

Open water bodies
About 78% (23,645 ha) of the project area is seasonally inundated to a depth of greater than 0.3 m. Approximately 1,716 ha (5.7 % of the project area) consists of permanent waterbodies (Table A.6). The larger permanent water bodies are listed in Table 2.4.

Closed water bodies
In addition to the open beels and khals there are 3748 used for fish stocking, bathing, washing etc. The ponds have a total area of about 290 ha (Table A.7).

2.4.5 Surface Water Availability

Surface water availability (80% dependable) for irrigation use for the month of January, February, and March could not be analyzed due to inadequate data. However, recent observed discharges show that both Jadukata and Jhalukhali Rivers are perennial and have minimum flows of 10 m^3/s and 2 m^3/s respectively during the critical month of March (refer to section 2.4.1).

Table 2.4: Major Water Bodies in Project Area
(beels unless otherwise specified)

Matian Haor	Shanir Haor	Angurali Haor	Karchar Haor	Joalbhanga Haor	Banuar Haor
Loveroar Baidar Golaghat Khupaura Matian Bara Singar	Boigani khal Pashbhanga Chapachatal Katkatia Bana Sonatala	Jamirtala Angurali Duba Aga Uligang Tin	Karcharghor Kursha Nadi Lairkaitta Kanu	Saphela Nainda Joalbhanga Baushi Chhunua	Palir

Table 2.5: Estimated Ground Water Recharge

Usable recharge (Mm^3)			Available recharge (Mm^3)		
STW	DSSTW	DTW	STW	DSSTW	DTW
1.33	20.52	82.28	0.58	11.26	45.80

Source: NWP (WARPO), 1991

2.4.6 Ground Water

MPO estimated usable ground water recharge within the project area is 82.28 Mm^3. About 45.8 Mm^3 is available within the depth range accessible by the force mode DTW technology. Suction mode STW technologies are not suitable due to aquifer constraints, but about 11.26 Mm3 available recharge could be withdrawn by deep-set STW (Table 2.4). About 68% of the total ground water resource potential is located in Bishwamvarpur thana (Table A.8).

2.5 Land/Water Interactions

2.5.1 River Instability and Siltation

Erosion and sedimentation in the project area are governed primarily by processes on the Jadukata and Jhalukhali alluvial fans. These fans are characterized by relatively sudden, irregular channel shifts that result in periodic abandonment of some channels and the creation of new channels across the fan surface. After this shift (termed an avulsion), the lands adjacent to the new channel will experience erosion as the channel widens to accommodate the high velocity flows. Large amounts of coarse sand will also be deposited overbank during subsequent floods. On large fans such as on the Jadukata, the zone of active deposition may extend over a width of several kilometres. Sand and finer sediments may also be deposited at the distal end of the fan and in low-lying flood basins and haors as a result of the inflows from the newly formed channels. Consequently, morphologic impacts can be felt a considerable distance from the site of the initial channel shift. It is often possible to diagnose and identify potential avulsions a few years before they occur. However, the long-term pattern of channel shifting on most fans is unpredictable.

It is expected that virtually all of the sediment inflows from the Jadukata/Jhalukhali catchments are deposited on the alluvial fans or in the low-lying haors in the project area. Surveys across Shanir Haor, Angurali Haor and Karchar Haor have been compared with 1:15,480 scale topographic maps surveyed in 1963 to assess overall rates of siltation on the lower ends of the fans. Preliminary estimates show the land in the vicinity of Shanir Haor, Angurali Haor and Karchar Haor has aggraded by 0.7 m on average, and as much as 1.5 m it some locations. This deposition represents a net aggradation of approximately 3.5 million m^3/year in the project area. Based on miscellaneous suspended sediment rating curves and comparisons with other nearby catchments, a crude estimate of annual suspended sediment loads was made for the Meghalaya streams (NERP Sediment Specialist Study, 1992). Tentative estimates were 4 million tonnes/year for the Jadukata and 1.8 million tonnes/year for the Jhakukhali River. These figures are expected to underestimate the actual total sediment inflows. For example, they do not include coarse sand and gravel which is transported as bed load. More reliable estimates of sediment inflows will require improved field measurements of discharge, suspended sediment concentration and bed load.

In recent years, the project area has been subjected to extremely high runoff and sediment inflows, frequent flooding by channel spills and overbank flows, recurring channel instability and bank erosion and sand deposition over widespread areas. The most significant channel change in the project area involves the avulsion of the Jadukata River into the westward flowing Marharram channel near the head of the fan. Evolution of this avulsion was assessed using historic maps and satellite imagery. Figure 7 summarizes recent channel changes in the project area. In 1956 and 1974 the Maharram channel appears to have been an abandoned and partially silted-in spill channel. Although flow may have been carried during the monsoon season, it was dry during the winter months. LANDSAT imagery in 1984 show the channel had opened up and was capturing part of the Jadukata River's dry season flows. By 1988 the river was a major perennial channel which was building a shallow delta into the northern end of Matian Haor. In 1990 the channel shifted southward and extended the delta further westward into the haor. There is insufficient data available to determine the present distribution of flows between the Jadukata and Marharram River channels. Test runs using the MIKE 11 hydrodynamic model indicated very high spill down the Maharram River channel into Matian and Tangua Haors. However, additional surveys and callibration work are required to provide estimates suitable for design purposes.

A second avulsion site on the Jadukata River is situated near Fazilpur where a former channel heads off south eastwards into the Rakti River (Figure 7). This avulsion was initiated some time before 1956. Future morphologic changes on the fan could easily cause this channel to be re-activated. If this happened, inflows of sediment and water would increase into Angurali Haor and would decrease in Shanir Haor.

A third avulsion site occurs at the northeast corner of Shanir Haor, where the river bifurcates into the Baulai River and Nandia Gang (Figure 7). In 1956 the main flow from Jadukata River turned westward into the Baulai River and passed around the northern edge of Shanir Haor. At that time the Rakti and Nandia channels mainly carried overflows from the Jadukata River and spills from the Jhalukhali River (through the Dhamalia and Gatgotia channels). Over the last decade the upper portion of the Baulai River has aggraded which has forced more of the flow to pass down the Rakti River channel. Consequently, sediment from the Jadukata River has been deposited in the middle and lower reaches of the Rakti channel, causing it to become partially infilled. The aggradation in the Rakti River extends for about 12 km from its outfall and has caused the river to dry-up during the winter months.

2.5.2 Impacts of Sedimentation

The ongoing channel shift from the Jadukata River into the Maharram channel has reduced the cultivable area along the newly formed active channel zone due to bank erosion and overbank sand deposition. Tangua Haor, which has been identified as a "mother" fishery site, is now receiving more sediment than in the past and is gradually silting up. Continued expansion of the Maharram channel will lead to deltaic sedimentation in these haors and loss of valuable fisheries habitat. Increased dry season flows in the Maharram River increases water levels in the Patnai

River and delays post-monsoon drainage from Matian Haor and also from the unprotected to the north. Furthermore, this siltation adversely affects post-monsoon drainage which also contributes to the gradual decline in net cultivable area.

Aggradation at the Baulai/Rakti bifurcation (north east corner of Shanir Haor) has contributed to bank erosion and breaching of the submersible embankments along the Baulai and Rakti Rivers. Consequently, embankment breaching and sand deposition in Shanir Haor has become a regular feature in recent years. This aggradation also blocks navigation along the Rakti, Nandia Gang and Baulai Rivers during the dry season.

In summary, channel instability and sedimentation has led to intensified flooding and bank erosion, increasing frequency of embankment breaching and sand deposition on cultivable areas, drainage congestion and impaired navigation due to channel aggradation and reduced fisheries habitat due to infilling of haors and beels.

2.5.3 Crop Damage

Crops are damaged by floods, drainage congestion, hailstorms, cyclones and pests. Data on damage due to floods and drainage congestion were collected during field visits to the project area and then cross checked using results from a hydrologic analysis of water levels and frequencies.

Crops are damaged in the Jadukata-Rakti inter-basin area in the pre-monsoon and monsoon seasons due to flash floods and drainage congestion. Crops damaged in the pre-monsoon season include local and high yielding varieties of boro rice in the reproductive phase and local varieties of broadcast aman in early vegetative growth phase. The crops are submerged when water levels rise suddenly following rains in the catchment. The extent of damage depends on the growth stage of the crop and the duration of submergence. Farmers are sometimes able to collect the partially matured panicles from underneath water in a flooded field. However, at a considerably reduced yield. Local varieties of broadcast aman seedlings are damaged when they are submerged before the plants have acquired the ability to elongate with the rising flood levels.

Crops damaged in the monsoon season include local and high yielding varieties of transplanted aman rice. The damage take place mostly at the vegetative growth stage that hampers tillering, ultimately bringing down their yield levels. The crops are also damaged due to slow drainage in the post-monsoon season. This delayed drainage also imposes restrictions on production of rabi crops.

2.6 Wetlands, Swamp Forest and Reed Swamps

2.6.1 Natural Wetlands

There are six important wetlands situated within this project. Each of these wetlands consist of several perennial beels. The wetlands are: Matian Haor complex, Banuar Haor complex, Shanir Haor complex, Angurali Haor complex, Karchar Haor complex and Joalbhanga Haor complex. The total area of perennial water bodies (beels) in these wetlands is about 1,720 ha.

Water depths may reach as much as 7 m in the wetlands during the monsoon season. Although the wetlands are located very close to each other, they differ somewhat in their ecological characteristics. Matian and Banuar Haors are very deep and situated side by side. They have very little floating vegetation inside the haor proper, but contain dense submerged vegetation. On the northeast side of Matian Haor there are two patches of reed lands and on the northwest there is a tract of upland reserved forest. Angurali and Karchar Haor are flatter and shallower, which provides very good habitat for submerged and rooted floating plants. The most dominant plant species are Hydrilla verticillata, Aponogeton sp., Vallisnaria spiralis and Nymphaea sp. Other important species are Limnophila, Trapa, Ottelia, and Potamogeton.

The characteristics of Shanir Haor and Joalbhanga Haor are similar, both having vast moderately shallow areas with dense submerged and rooted floating plants and some very deep pockets virtually lacking any vegetation. The dominant species in Shanir Haor is Echinochloa colonum (*parua*), this single species covers more than 100 ha of land in the monsoon.

Resident waterfowl concentrations are high in these wetlands. Migratory bird population is also fairly high. The world's largest actively breeding population of Pallas's Fish Eagle (IUCN Red Data Book) is present in this area. The area between the water and the reeds provides very good habitat for smaller mammals such as fishing cats, otters and rats. Both Common Otter, Lutra lutra and Smooth Indian Otter, Lutra perspicillata are present.

The two most important wetlands of the entire Northeast Region, Tangua Haor and Pashua beel are located on the western boundary of the project.

2.6.2 Swamp Forest Trees

There are more than ten different swamp forest tracts in the project ranging from 10 ha to a few trees. These are the last remaining trees from the vast forests which covered the area in earlier times. Individuals of species like Barringtonia acutangula (*hizal*) and Pongamia pinnata (*koroch*) can be found in homestead groves.

2.6.3 Reed Swamp

There are six patches of reed swamps within the project (Sunamganj Forest Range) with the status of acquired forest class. The names and sizes of these reed lands are given in Table 2.6.

The main species in these reed swamps is Phragmites karka (*khagra*), associated with Saccharum spontaneum (*khag*). The latter species generally prefer to grow on more elevated ground. Other grass species present are Vetiveria zizanioides (*binna*), Arundo donax (*baranol*), Sclerostachya fusca (*ekor*) and some Hemarthria protensa (*chilla*). Other than grasses, some woody shrubs and climbers are very common including Ficus heterophylla, Lippia javanica, Asparagus recemosus and Asclepias.

The swamps can only support smaller mammals such as fishing cats, jackal, Smooth Coated Otters and Bandicot Rats. There is a high concentration of both resident and migratory bird populations as there is less human disturbance in these sites than in other areas. Resident birds make nests in the reeds including the Little Grebe, Little Cormorant, Bittern, Egret, Openbill Stork, Purple Swamphen, Pheasant-tailed Jacana and Common Moorhen. These lands also support many smaller birds such as the Bush Chat.

22

2.7 Upland Forest

There are four small tract of upland reserved forest in the project, name and area of these lands are given in Table 2.6. An approximate location map of these forests are also presented in Figure 13. The main species of these forest are Dipterocarpus sp.(*garjan*), Artocarpus chaplasha (*chapalish*), Bombax ceiba (*simiul*), and artificially planted teak Tectona grandis (*sagun*). Resident larger mammals are rare although some time they come from India by crossing the border.

Table 2.6: Upland Forest and Reed Area

Name of Reed Swamps	Approx. Area (ha)
Laurgarh	496.76
Dipchor	354.47
Karaigarh Ban San Mahal	607.29
Karchar Haor Ban Mahal	202.43
Das-sena Ban Mahal	404.86
Ekratia Purangaon Ban Mahal	809.72
Total for the Project	2,875.53

Upland reserved Forest	Approx. Area (ha)
Maheshkhola	867
Dlergaon	725
Laurgarh	1450
Sunamganj Sadar	450
Total for this Project *	**3,492**

Source: Forestry Master Plan.

* Some area is out side the project but difficult to demarcate.

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)	30322
Homesteads	750
Beels	1716
Ponds	290
Channels	167
Hills	-
Fallow[1]	4064
Infrastructure[2]	125

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

Settlements
Settlements within the project area are mainly found in the form of villages along the levees of the rivers and along road sides. Where land levels are higher, especially in Bishwamvarpur thana, homesteads are constructed in the fields. Settlements are extremely sparse in the 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. Homesteads situated in the north-eastern part of the project area are damaged by pre- monsoon and early monsoon flash floods. Damage to homesteads as a result of monsoon flooding is common in the haor areas where homesteads are frequently eroded as a result of wave action.

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

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 202,485 (1991) of whom 99,150 are female. The gender ratio is calculated to be 104 (males to 100 females). The total households, are estimated to be 33,692 within 325 villages. The population increased by 23.2 between 1981 and 1991.

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	16.4	15.3	13.4	46.6	2.0	6.3	100.0
Female	17.3	16.2	12.2	47.5	1.4	5.0	100.0
Total	16.9	15.7	15.7	47.1	1.7	5.6	100.0

Source: BBS, 1981 Population Census

The cohort distribution for males is as follows: 31.7% are below 10 years of age, 46.6% are between 15 and 54 years of age, and 6.3% are above 60 years of age. The corresponding distribution for females is 33.5%, 47.5%, and 5.% (Table 3.2).

The average population density is 412 persons per km^2, with densities ranging from a maximum of 713 persons per km^2 in Bishwamvarpur thana to 382 persons per km^2 in Jamalganj 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
According to the 1981 census, the literacy of the population at 5 years of age and above varied from 14.0% in Bishwamvarpur thana to 17.7% in Sunamganj Sadar thana. The corresponding figures for females were 8.5% and 11.2% respectively for the same thanas. The rate appears to have slightly increased over the last 10 years. According to the 1991 census, the literacy rate for all people of Sunamganj district is 17.2% for both male and female.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 16.6% in Tahirpur thana to 19.1% in Sunamganj Sadar thana. Attendance for females in this age cohort in these two thanas varies from 14.3% to 16.7% respectively. Attendance for all youths between the ages of five and 24 is 13.1% and 16.4% for these thanas while the corresponding attendance for females is 9.8% and 12.6%.

The situation is worse for the rural poor. They can not afford to send their children to school. Moreover, many villages, especially in Bishwamvarpur and Tahirpur thanas, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 5.6 for Sunamganj district (BANBEIS, 1990).

Access to Health Services
The district headquarters of Sunamganj has a hospital, and all thanas have hospital facilities located at their headquarters. Access to health services is generally limited for rural villagers and is out of reach of the poor. According to the Directorate General of Health Services (1992),

there is one hospital for every 176,910 persons, one hospital bed for every 6,626 persons and one doctor for every 24,234 persons in the district of Sunamganj. Immunization coverage of children below two years of age is high for the project area. The rate varies from 47% in Tahirpur thana to 60% in Bishwamvarpur 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. In 1990, 82% of the households had access to potable water in the district. It is noted that most tube wells are located in the houses of the rich. This results in the poor having very limited access to potable water.

Sanitation
Specific information on sanitation facilities are not available at the project level. During field reconnaissance, it was noted that open space defecation is a common practice in the rural villages, particularly for males. Women generally use kutcha latrines or defecate at a fixed spot which is protected by bamboo mats or 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 project area is *boro* in the low-lying haor areas and *t.aman* in the higher lands of Bishwamvarpur thana. 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*. Employment during *boro* cultivation has two peaks of transplantation in January-February and harvesting during mid-April to mid-May. Seasonal employment is available with well-off farmers, especially in the haor areas during winter months for boro cultivation.

The wage rates for male agricultural labourers vary from Tk 30 to 45 with two meals per day during peak agricultural months. During months when there is no agriculture work, the daily wage rate varies from Tk 20 to 30. Employment scope reduces significantly during monsoon months for the poor of the haor areas of Sunamganj district. 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 the district. Some poor also get employment in boat plying during monsoon months, especially in haor areas. Self-employment of the poor in catching fish during monsoon months is also important in haor flood plains. 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 districts headquarters of Sunamganj and Sylhet to work as rickshaw pullers, as construction workers, or sometimes in household activities. Employment opportunities for women are limited in the area. However, a few women are reported to be employed as seasonal

---

[1] DPHE, 1991-92

labourers, especially with large farmers of the haor areas. A few poor women are employed for the Rural Maintenance Program of CARE, and some women also migrate to Sylhet and Sunamganj towns to perform household works. But their numbers are very limited. Many villages have no such migrant woman labourers.

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

3.1.5 Land Ownership Pattern

Land ownership is extremely skewed in the project area. More than 45% of the households are landless (with cultivable land less than 0.2 ha). Among the landless, about 2.0% have no homesteads of their own. If the definition of landless includes landholdings up to 0.4 ha, the proportion of households included increases by 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 25.6%, 20.3%, and 8.6% respectively.

The project area has a substantial amount of land not available for cultivation. These include deeper wetlands, reed lands and community pastures. The price of agricultural land varies from Tk 5,000 to Tk 15,000 per ker (0.12 ha) depending on the 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 of the area generally share out their lands to tenants for operation. The share cropping system is that one-half of the produce is retained by the land owners but they provide no inputs. For HYV rice, 50% input costs are shared by land owners. The leasing out of land in kind (chukti) is declining in the area. However, leasing out of land with advance cash (rangjama) is practised widely in the project area. The usual rate for such arrangements varies from Tk 500 to Tk 1,000 per ker (0.12 ha) and this is paid in advance to the land owner for one season. Landless people have very little access to land under this tenurial arrangement due to their inability to provide the cash after which they must still purchase agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area and competition over the fish resource is increasing every year. There are mainly two types of fishermen--traditional and non-traditional, who catch fish for generating an income. Traditional fishermen live on fishing and have been engaged in the profession since generations. The jalmohals are generally leased out to them through their cooperatives. However, the rich among them, act as the financiers and appropriate most of the profit from the catch while the poor catch fish on a regular basis and sell out for their survival. They also work as fishing labourers. There are an estimated 1,000 to 1,500 traditional fisherman households in the project area. Additional information on fishing practices is given in Section 3.5.1.

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

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

3.1.8 Situation of Women

Women's role is agricultural production is important, especially in the post harvesting activities. Their contribution, however, tends to be devalued and under reported. Though women generally do not work in the field, some poor women are reported to be working outside their homes, mainly for the Road Maintenance Program of CARE and activities such as gathering wild fruits, and vegetables and collecting fuel. Some poor women of Bishwamvarpur thana work in their nearby fields to grow *rabi* crops and winter vegetables. The village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, per-boiling and storing of rice. Most women prefer working on homestead gardening and raising poultry/ducks in addition to other common household works.

3.1.9 People's Perception

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 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, opinions and suggestions were sought in a one-day seminar held at the district headquarters of Sunamganj with the Honourable Members of the Parliament, District and Thana level officials, Union Parishad Chairman, representatives from village level organizations and NGOs. These are described below.

Problems
Flooding and drainage congestion are described as the major problems of the project area. Pre-monsoon flash flooding is considered to be a serious problem and widespread all over the area. This flooding mainly damages rice crops. *Boro* is affected almost every year and damaged fully or partly in the Haors and beels of the project area by pre-monsoon flash floods between April and May. The flash floods generally enter into the area through various channels from the Jadukata and Rakti Rivers, and inundate the low-lying boro fields. The situation is further aggravated by water logging as a result of intensive rainfall during this period. In recent years, increased spills down the Maharram River channel causes damage to rice fields on the west side of the Jadukata River fan.

Aus and seed beds of *t. aman* are also damaged by pre-monsoon and early monsoon flash floods in the north and eastern part of the project area. T.aman is affected in these areas by monsoon floods during June to September by over land flow and sometimes, by overspilling of the

Maharram River banks. The flood water generally last for three to five days in the upper areas and there are three to five such occurrences reported in every monsoon period.

Drainage congestion is reported to be the second most important problem of the area, especially in the low-lying haor areas. People report that in recent years, low-lying lands can not be drained out in time to start boro cultivation due to siltation on the Jadukata-Rakti River system as well as the internal smaller rivers and channels. This delays the transplantation of *boro* (local and HYV) and makes transplantation very difficult in some locations.

People also expressed their needs for year-round navigation through the Jadukata-Rakti River to carry on the stone/sand collection and transportation activities from the upstream quarry up to Durlavpur along the Surma River.

Damage to homesteads by monsoon wave action is also described as a serious problem, especially in the villages around Shanir, Matian and Tangua haors. Many villages of these areas are eroding fast by monsoon wave action and their existence is reportedly threatened to a large extent.

Lack of water for winter irrigation in the boro fields is also described as a problem by the upland farmers of the project area.

Poor fishermen stated that the prohibition of open water fishing by powerful jalmohal leasees was a major problem for them. Local fishermen are found to take more care of a leased jalmohal to ensure the sustainability of their resources. Fishermen considered fishing by de-watering jalmohals was a major cause of decreasing fish production. They also stated that roads and embankments in the flood plains obstructed easy movement of fish and reduced fish production. Concern was expressed about fish migration in the project area from the Rakti, Nandia and other rivers as a result of closure of the various channels. They were also found concerned about the loss of fish habitats and large scale deforestation in the flood plains.

Suggestions

The most common suggestions put forward by local people were:

- Re-excavate the Jadukata-Rakti Rivers for quick drainage of flash flood waters as well as for year-round navigation from the Surma River up to the quarry upstream of Fazilpur.

- Dredge the Surma River to drain more rapidly the upstream flood waters, especially during pre-monsoon period.

- Re-excavate the Baulai River from Fazilpur to Paikertala to improve navigation and availability of winter irrigation water.

- Improve the banks of the Jadukata-Rakti Rivers to stop overspilling of pre-monsoon flash flood waters into the haor areas.

- Stop pre-monsoon flow of flood waters through the Maharram River by constructing a permanent dam across the river.

- Provide permanent embankments on the south side of Matian Haor and the north side of Shanir Haor.
- Provide sluice gates at Minajuri, Bhadertek and Gazaria.
- Construct protective walls to defend the most vulnerable villages of the area from erosion caused by monsoon wave action.
- Construct permanent roads/embankments in place of submersible embankment.
- Lease jalmohal only to local fishermen.
- Allow poor and subsistence fishermen to catch fish on the floodplain.
- Conserve enough fish habitat for the normal production of fish. To assist in this, plant water resistant trees, such as *hizol* and *koroch* on the higher floodplains and river banks.
- Identify the duars in the area and protect them as fish shelters.
- Select a few suitable jalmohals, for fish sanctuary and preserve them for increased fish production.
- Stop overfishing of jalmohals as well as fishing by complete de-watering them.
- Preserve Tangua Haor as a fish sanctuary and wetland site.
- Keep enough provision for navigation while developing river banks to stop overspilling in order to check the tendency of cutting embankments. Such provision is also necessary for any submersible embankment in the flood plain to allow early monsoon navigation.

3.1.10 Local Initiatives

In recent years local people have constructed a low cross-dam out of sand and gravel across the Maharram River to reduce spills from the Jadukata River into the newly forming avulsion channel. The purpose of this work is to protect the *boro* crop downstream of the channel bifurcation from pre-monsoon flooding and to reduce water levels on the Patnai River during the dry season. The cross-dam has been constructed every year by locals since the avulsion on the Jadukata River started. Since the structure is constructed of local bed materials it is not able to withstand high velocity flows or overtopping. Therefore, although it might be able to slightly delay the occurrence of flooding in some years, it will not have much impact during high flow conditions.

People stated that it is their traditional practice to organize local people to counteract crisis which arise as a result of flash floods and drainage congestions. The main activity is to construct dams on various localised canals to stop the intrusion of pre-monsoon flash floods to save the boro crop. They would also assemble to re-excavate canals for quick drainage. This is generally done on a voluntarily basis by the villagers around a particular canal which is threatening their property. More recently the Union Parishad also allotted rice/wheat for this purpose.

3.2 Water Resources Development

3.2.1 Flood Control & Drainage

The existing water development infrastructure in the project area is shown on Figure 12. The main infrastructure relates to the submersible embankment projects on Shanir Haor, Angurali Haor, Karchar Haor Joalbhanga Haor and Matian Haor. In each case, the purpose of these projects was to protect the *boro* crop against pre-monsoon flash floods.

Shanir Haor Project
According to local farmers, about 19 km of low embankments and an eight vent regulator were constructed at Shanir Haor by the larger landowners during the 1920's. When the regulator became inoperable, a cross dam was constructed in the channel each year. In 1976, BWDB took over the project, incorporating it into the Haor Development Program of Sunamganj Division. Between 1976-77 and 1979-80 embankments were constructed under FFW. Between 1980-81 and 1985-86, a six vent regulator was constructed under IDA credit. Since completion, BWDB has been maintaining the embankments under FFW. The existing project infrastructure includes 48 km of submersible embankments, 9 km of compartmental bunds, and one six-vent flushing cum drainage regulator.

Following project completion, *boro* cultivation increased significantly. However, recent observations indicate the project is not providing the expected benefits. In recent years the project has experienced recurring drainage congestion, sand deposition and embankment breaching. Furthermore, the public have had to resort to frequent cutting of the embankments to let water into and out of the project.

Angurali Haor Project
The project was identified by BWDB in 1980 and an Early Implementation Project (EIP) Appraisal Mission recommended that it be included in their 1981 program. Construction started in 1982 and was completed in 1987. Approximately 19 km of submersible embankments and one two-vent regulator were constructed.

Frequent breaches to the embankment occur along the northern side of the project due to flash floods and high velocity overbank spills. As a result, large volumes of sand are being deposited on agricultural land inside the project. Nevertheless, the project appears to be having a positive impact on food production. Boro areas have increased in the central and southern project region while they have decreased in the north of the project due to recurring breaches in the embankment at Michakhali and Goddamara.

Karcher Haor Project
This is one of the older projects in the Sunamganj area, implemented by the East Pakistan Irrigation Ministry in 1967-68. Existing physical components include 39 km of submersible embankments, one four-vent flushing/drainage sluice and one irrigation inlet.

The project has not achieved its full objectives for numerous reasons. The embankment breaches at several locations in the northeast corner every year. This allows large amounts of sand to be deposited on the agricultural land. The regulator is operational but the wooden fallboard need to be replaced by vertical lift steel gates. The irrigation inlet has silted up completely and will be difficult to make operational because of the rates of siltation at this location.

Joalbhanga Haor Project
In 1990 an EIP appraisal mission recommended inclusion of the project in the 1991-1992 EIP program. Embankment upgrading and construction of the regulators, pipe sluices and irrigation inlets were proposed to begin in 1992. The proposed infrastructure includes 16 km of submersible embankments, three flushing/drainage regulators and a substantial number of irrigation inlets. The project is being executed under the Dutch-Swedish technical assistance programme and is planned to be completed in 1994.

Matian Haor Project
The project was originally constructed by local authorities through a FFW program. It was then handed over to BWDB in 1976 as a part of the Haor Development Program. BWDB started upgrading the embankments in 1977 and the work was completed in 1979. A regulator was completed in 1985 with IDA financing. Since project completion, the embankments have been maintained by BWDB with FFW wheat allocations. The project has been included in the Systems Rehabilitation Project with IDA and EEC financing.

Flood control infrastructure includes 46 km of submersible embankments and one four-vent drainage/flushing regulator. The project has had a positive impact on agriculture by providing a more secure environment for boro paddy. However, the progressive channel avulsion from the Jadukata River into the Maharram channel is adversely affecting the agricultural production in the project. If this avulsion continues to develop, bank erosion, intensity of flooding and overbank sand deposition will increase in magnitude in this project. Furthermore, it should be noted that:

- there are no drainage structure on the recently extended Chilani-Lakshimipur submersible embankment and as a result the area does not drain;
- existing drainage structure is not adequate and requires additional drainage/flushing structure around Ratansree village;
- wooden stop-log gates are not operational and could be replaced by the vertical lift steel gates; and,
- there are public cuts for navigation. Hence boat transfer facilities could be introduced in the new regulators.

3.2.2 Irrigation

Surface Water
Present surface water irrigation coverage is about 8,822 ha by LLPs and traditional modes (AST, 1991). There are 163 LLP's of various discharge capacities (113 equivalent to 57 litres/sec) operating which irrigate an area of 1,934 ha. The majority of the surface water irrigated area is mainly concentrated in Bishwamvarpur, Tahirpur and Sunamganj thanas (Table A.9).

Ground Water
Present groundwater abstraction for irrigation use is not significant. According to AST (1991) there are 19 shallow tube wells and one deep tube well in the project area. Reported ground water irrigated area is 191 ha of which 171 ha is by shallow tube well, and 20 ha is from deep

tube wells. Ground water abstraction is about 1.2 Mm^3 based on MPO estimated ground water irrigation duty. According to AST information, ground water irrigation is mainly concentrates in Bishwamvarpur thana (Table A.9).

3.3 Other Infrastructure

The project area does not have any Roads and Highway Department regional highways nor any feeder roads. There are about 41 km of village roads which connect all the thana centers. Most of these roads are not accessible during the monsoon season due to flooding. The roads are damaged annually, with an average damage rate estimated at about 15% of the capital cost.

3.4 Agriculture

Crop production practices in the project area are dictated by the region's hydrological regime. Land flooded in excess of 1.8 m (F3 land type) constitutes 45% of the cultivated area. Most of this land is flooded early in the pre-monsoon season and continues to remain wet for a part of the *rabi* season. The dominance of this semi-aquatic environment during much of the year has led to the emergence of rice as the single most important crop. Local *boro* is the only crop grown on most of the F3 land Initially it is planted into standing water which remains after the flood waters recede. Irrigation is then provided later wherever it is available. Elsewhere, farmers have to depend on pre-monsoon rains. High yielding varieties of *boro* rice are grown in very limited areas depending on the availability of irrigation.

About 17% of the project area is flooded between 0.9 to 1.8 m (F2 land type). As with the F3 land type, the F2 land is also flooded early in the monsoon and continues to remain wet until well into the rabi season. Local varieties of broadcast *aman* are the dominant crop in F2 land. Most of this is grown as single crop except in minor areas where flood water recedes earlier in the post-monsoon season and permits rabi crops to be grown in the winter. Where post-monsoon drainage is slow, rabi crops can usually not be grown. Depending on the availability of irrigation and the time when flooding is initiated, high yielding varieties of *boro* rice can be grown. It is then mostly as a single crop and partly in sequence with transplanted deep water *aman* rice.

About 38% of the cultivated area is flooded up to 0.9 m (F0 and F1 land types) where rice based multiple cropping is practiced. These include local varieties of *aus* in the first *kharif* season and local and high yielding varieties of transplanted *aman* rice in the second *kharif* season. Growing potato and high yielding wheat varieties depends on when the preceding crop is harvested. *Rabi* crops which are grown in the winter with residual soil moisture and in sequence with rice include various pulses, oilseeds, spices and vegetables. The most common cropping patterns whic are presently found on the various land types in the project area are presented in Table 3.3.

The agricultural production system is closely linked with farm family needs as well as storage and marketing facilities. Most farmers sell their agricultural produce in the village market immediately after harvest when prices normally are low. Lack of storage facilities and need for getting some cash compel them to do this. As a result, they must buy the same products for family consumption at higher prices on a later date. It is estimated that only 20 to 25 percent of the production actually enters commercial markets. Private traders handle most of this amount.

Table 3.3: Present Cropping Patterns in Jadukata-Rakti Basin

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					3944	75	682	5	4625
fallow-l boro					0		12275	90	12275
fallow-hyv boro	0				526	10	682	5	1208
b aus-potato	398	6							398
b aus-rabi	796	12	479	10					1275
b aus-lt aman	1194	18	2395	50					3589
b aus-lt aman-potato	265	4							265
b aus-lt aman-rabi			239	5					239
b aus-hyv aman	664	10							664
lt aman-fallow	465	7	479	10					943
lt aman-potato	332	5							332
lt aman-rabi	863	13	958	20					1820
hyv aman-fallow	664	10							663
hyv aman-potato	199	3							199
hyv aman-rabi	796	12	239	5					1036
b aman-rabi	0		0		789	15			788
Total	6636		4789		5258		13639		30322

Note: All areas in Hectares

Homesteads are an integral part of the farming system. Homestead vegetation varies depending on the size of the homestead area and vulnerability to flooding. Trees such as mango, betel nut, bamboo, banana etc. commonly provide fruit, fuel, and building materials. Homesteads vulnerable to flooding have fewer trees. Most of the vegetables consumed by the family are produced in the kitchen garden, adjacent to the homestead.

Present levels of input use in Jadukata-Rakti basin is low in local varieties and moderate in high yielding varieties of crops. Yield level of crops vary depending on the level of input use and flood vulnerability. As a result, yield data for damaged and damage-free conditions were collected. Crop production data have been also generated separately for damage-free and damaged areas. Results from these analyses are presented in Table 3.4.

Table 3.4: Present Crop Production in Jadukata-Rakti Basin

Crop	Damage free area			Damaged Area			Total Production
	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)	
b aus	6431	1.25	8039	0	1.05	0	8038
b aman	4414	1.75	7725	1000	1.45	1450	9174
lt aman	7190	2.15	15458	0	1.75	0	15458
hyv aman	2562	3.95	10120	0	3.55	0	10120
l boro	3400	2.25	7650	8875	1.75	15531	23181
hyv boro	458	4.55	2083	750	3.25	2438	4520
Total Rice			51074			19419	70493
potato	1194	12	14334				
pulses	774	0.85	658				
oilseeds	2580	0.75	1935				
spices	258	2.25	580				
vegetables	1548	9.75	15093				

3.5 Fisheries

3.5.1 Floodplain fishery

About 60 important permanent beels exist within the project area. The most important for fish reproduction are listed in Table 3.5. Beels serve as important overwintering refuges for these species. During the monsoon season, water from the Jadukata, Patnai, Nainda, Baulai, Surma, Jalukhali, Rakti/Abbua River flow in through open khals, breached dykes, and by overtopping of the rivers banks. Most of the beels are interlinked with each other by narrow channels and fish can move freely between rivers, channels, beels, and floodplain.

Most of the large fisheries are leased by a few rich influential persons for a period, usually of three years. They people generally reside outside the area and appropriate the profits from the catch. This system deprives local fishermen of access to the fisheries resources. Neither is there much opportunity to serve as labourers for the final catch since fishermen from outside areas are generally hired for this purpose.

Conflicts and tension are common over the issue of fishing the jalmohals in the area, particularly between farmers and fishermen. The jalmohal lessees construct and maintain water retention dams on the beels drainage canals which prevents timely *boro* cultivation in the peripheral zones of the beels. On the other hand, annual beel fishing in mid-winter is a common practice in the area — this involves completely draining the beels to maximize the catch at a time when farmers most need the water for irrigation. Neither of these practices are in the interests of the farmers.

It was reported that lessees do not permit fishing by either traditional or non-traditional fishermen in the vicinity of the jalmohals even during the monsoon months. This assertion was not cross-checked but it is in agreement with another study in the area (Minken, 1992). The extent of the jalmohal lessees' control over the area needs to be verified more closely during feasibility since this will have a significant bearing on the operability of any proposed intervention.

Table 3.5: Important Fish Breeding Sites

Matian Haor	Shanir Haor	Angurali Haor
Bara Beel Palair Beel Banuar Haor Baider Beel Golaghat	Sonatala Beel Chapti Beel Bankoi Beel Bara Beel	Tin Beel Aga Uligang Beel Jamirtala Beel

Karchar Haor	Joal Bhanga Haor	
Chatal Beel Kurcha Nadi Laiyarkirta Beel	Nainda Beel Chhenua Beel	

3.5.2 Species present in the area

Of the 155 species identified in the region, about 65-70 species inhabit the project area. The most common of these species are listed in Table 3.6.

Table 3.6: Major Fish Species

BARAMACH	CHOTOMACH
Catla, Rui, Mrigel, Kalibaus, Ghonia, Boal, Air, Bagair, Ghagot, Rita, Ghagla, Chital, Gazar, Shoal, Pangas, Mohashoal, Ilish.	Singi, Magur, Gang Magur, Koi, Kholisha, Lati, Cheng, Garua, Tengra, Gulsha, Bajori, Bheda, Fali, Napit, Darkina, Mola, Chata, Dhela, Chela, Tit puti, Puti, Sarputi, Kani pabda, Pabda, Chanda, Boicha, Tatkini, Kanipona, Baashpata, Batashi, Bacha, Rani, Chapila, Keski, Laso, Tara baim, Baim, Gutum, Cirka, Kaikka, Shilon, Poa, Ek Tuitta, Chanda, Golda chingri, Icha .

3.5.3 Duar fishery

Duars, which are an indispensable part of a typical floodplain fishery, act as a refuge for the larger mother fish during the winter season. These fish then migrate to a suitable spawning ground for breeding when water levels begin to rise. There are 23 major duars in the adjacent Surma, Abbua and Rakti Rivers (Table A.10). After errosion occurred near Katakhali village in the Jadukata River in 1988, a new duar was created which now acts as a natural sanctuary for larger size fish.

3.5.4 Sources of fish and breeding

It is generally understood that early rain, thunder, flooding, temperature, grassy or rocky land influence spawning of freshwater fish. If conditions are favourable, during the flooding time, fish migrate from beels to adjacent grassy areas, to the rivers, and vice-versa. Migrations are usually contranatent at that time and in most cases, fish will tend to move from the river up to the khal, to the beel and adjacent floodplain. Except for major carp, Pangus and Illish, most of the species breed more or less everywhere in the area. Localized breeding migration can be seen for Boal, Ghonia, Sarputi, Pabda, Fali, Koi, Singi, Magur, Puti, Chanda, Tengra, Gulsha, Kholisha, Along, Bheda, Laso, Lati, Shoal, Gazar and some other smaller varieties fish.

Important sites for fish breeding are summarized in Table 3.5. Existence of permanent water bodies with shallow floodplains and reeds makes an area suitable for fish breeding. Within the project area, species composition of capture fishery is dominated by miscellaneous species (60-70%) followed by carps (20-30%) and catfish (5-10%), except for the river duars and some deeper beels.

There are currently four "Mother Fisheries" identified in the region of which Tangua Haor mother fishery (as well as carp breeding ground) is located adjacent to the project. This site exerts a controlling influence on fish abundance over the entire floodplain of the area.

The giant freshwater prawn (M. rogenbergii) is also available in the rivers and floodplain of the Matian haor, Shanir haor, Joal Bhanga haor and Karchar haor. It is highly valuable species for export. Adults migrate downstream to spawn in estuaries and the sea. Juveniles move back into rivers to grow and mature.

Ilish (Hilsa ilisha) is also available in the Baulai, Surma, and Rakti rivers in the project. The adults migrate from the sea far up rivers to spawn.

3.5.5 Production trends

Fish production in the project area has apparently declined by 25-30% over the last 5 years. While no verifiable estimates of overall fish production are available for the project area, the estimated production is 2,000 metric tonnes per year (Table 3.7).

Table 3.7: Present Fish Production

Regime	Area (ha)	Production (kg/ha)	Total Production (mt)
Beel	1716	410	704
Floodplain	23686	44	1042
River/channel	167	175	29
Pond	290	800	232
Total	25859		2007

Source: BFRSS

According to NERP analysts, fish abundance is directly related to the level and duration of flooding, and access to the flood lands. The fish production in the project area has been declining. The identified causes of the fish decline are outlined below:

- Siltation of beels. Beel area has been reduced by about 60-70% in the Chalti haor and northern Matian Haor area by the Jadukata avulsion into Maharam River. Both the depth of water and water hectare-months are declining (Pasahaul and Amtali Beel have already been damaged). High rates of sedimentation are also affecting the extent of habitat at the eastern side of Karchar Haor.

- Construction of sluice gates and closures of khals (Matian Haor project, Shanir Haor project, Karchar Haor project, Joal Bhanga project and Angurali Haor project) have restricted fish migration to and from the floodplain, which reduces fish resources in the area.

- Reduction of fish population due to over-fishing and loss of fish habitat.

- Reduction of reproductive stock due to indiscriminate use of some fishing gear in the duars (kona jal, current jal, jam jal).

- Increased fish mortality due to fish diseases caused by water pollution in the beels, particularly during the months of December and January.

- Lack of proper extension services for pond owners to develop culture-based fish farming in existing flood free ponds.

- Reduction of fish habitat by encroachment of agriculture into beels.

3.5.6 Fishing practice

Floodplain

Open water fisheries are the major source of fish in the area (floodplain 46%, beels 42%, ponds 10% and Channels 2%). Subsistence fishing occurs mainly during the flooding period and large-scale beel fishing occurs from November to February. In most cases, beel fishing is done on an annual basis.

Installation of *katha* along rivers is common; usually *hizal, koroch* and *jarul* tree branches are used. *Kathas* are installed in the months of August and September when the water recedes from the floodplain.

Closed Water
Pond fish culture is more difficult here than in other parts of the country because most ponds are located in flood prone areas. Where pond fish culture is practiced, pond owners release an uncounted number of fingerlings into their ponds (various species caught in the wild) without undertaking basic fisheries management activities such as predatory fish eradication or regular application of feed and fertilizer. Monitoring the growth and health of the fish is also not carried out on a regular basis. The fish produced under this minimal management process are usually harvested during the dry season. It should be noted that many ponds adjoining homestead lands provide domestic water supply for a wide variety of activities (bathing, washing clothes and dishes, occasionally watering homestead vegetable plots, and so on) which also adversely affects pond fish culture.

3.6 Navigation

Commercial navigation between the Surma River and Fazilpur on Jadukata River is important for transporting aggregates and stone materials to market. The Jadukata River is a major source of stone and sand for the construction industry in the region. The aggregate is mined from gravel bars near the Indian border and transported by small two man boats to Fazilpur where it is stored. There are said to be 50 cargo boats having capacities of 150-200 tonnes, as well as hundreds of country boats moving the materials from Fazilpur to points south. Their normal route is to travel via the Rakti River to Durlabpur on the Surma River or sometimes to ship directly from Fazilpur to Dhaka.

In 1992 it was estimated that roughly 70,000 m^3 of coarse sand and 30,000 m^3 of stone was being shipped down the Jadukata/Rakti River each month. During field trips in December, in the order of 5,000 to 6,000 barki boats were working on the river. This activity was said to go on year-round although its intensity was reported to decrease during times of extreme low water or high water. Assuming the level of work was maintained for five months of the year, approximately 500,000 m^3 of aggregate was quarried from the river in 1992. Interviews with locals indicated boatmen were being paid 150 taka per trip to transport the stone. This corresponds to a total monthly income of 17,400,000 Taka or a seasonal income of roughly 87 million Taka introduced into the local economy. It appears anyone can collect sediment from the Jadukata River by barki boat, however, all of the stone must be sold to one of the contractors at Fazilpur. It was reported there is an Association of contractors, which pays a lease fee to mine the river.

Due to the ongoing sedimentation processes on the Jadukata fan, the Rakti River, which is the main navigation route for aggregates, has become silted up to the point where it is completely dry during the winter months. Sedimentation has also restricted navigation on the Nandia Gang, particularly in the reach near Beheli. This sediment deposition is now constraining the production of stone materials from the project area and limits the number of months that operations can be carried out.

3.7 Wetland Resources Utilization and Management

The most important use of natural wetlands products in this area is thatching material. The utilization of this material is in several different ways; for making structures to protect homesteads from wave erosion; for making roofs and panels for houses; and for making mats. However, it is mainly used in the deeply flooded areas. Various types of grasses are used. The species used for protecting the homesteads is Hemarthria protensa (*chilla*). The species used for other purposes are Vetiveria zizanioides (*binna*), Sclerostachya fusca (*ikor*), Phragmites karka (*khagra*) and Clinogyne dichotoma (*murta*). These species generally grow on the border of perennial beels with the result that it is very difficult to estimate the area on which they grow. It is estimated, however, that the area which these plants cover is not less than 500 ha and the estimated yield is about Tk 150 per ha per year. Therefore, the gross estimated total value is at least Tk 75,000 per year and creates about 1000 pd per year (assuming 2 pd per ha).

A second important use of wetland products is fodder. People living in the deeply flooded areas are fully dependent on these materials for fodder since during the monsoon water inundates grazing land. People living in the more shallowly flooded area also depend on these materials for green fodder. Plants such as Nymphaea sp. (*shapla*), Nymphoides sp. (*chandmela*) and other grasses are commonly used. These grasses grow mostly on F3 land which remains fallow in summer. Quantification of the real economic value of this product is very difficult since people collect the grass as they need it. The estimated value of this material is therefore made based on its replacement value. There are about 12,000 ha of these varieties of grasses growing in the project area. Assuming an estimated value for fodder of Tk 40 pr ha, the total value amounts to Tk 0.48 million per year. The estimated employment used for gathering the fodder is about 12,000 pd per year.

Reeds are used as a raw material for the production of pulp and paper. The wetland plants used for this are Phragmites karka (*khagra*) and Saccharum spontaneum (*khag*). The Sylhet Pulp and Paper Mill was established to produce pulp from these materials. Productivity of the reedlands inside the project area are very low, approximately 4,500 tonnes. However, reeds have good economic value; at a price of Tk 200-250 per tonne, the estimated value of the reeds in the project area is somewhere between Tk 1 and 1.5 million per year. At least 4 pd/ha are required for harvesting and drying this material. Hence, the employment associated with this activity amounts to about 11,500 pd per year.

Another important use of these resources is fuel wood. Due to the high scarcity of fuel wood around the homesteads, people are becoming increasingly dependant on swamp products. Swamp forest trees are highly valued as fuel in the wetland areas. Saplings of these species are suffering badly due to this demand.

Other uses of the wetlands are:

- Food material. Poor peoples depend on this food source in periods of scarcity. The rhizome of Aponogeton are used mostly. Floral stalks of water lily Nymphaea sp. and seeds of water chestnut Trapa maximowiczii are also used. Water chestnut seeds also have some market value, with roasted peeled seeds selling for up to Tk 10/kg.

- Bio-fertilizer, from various weeds of the wetland.

80

- Medicinal plants, mostly from Polygonum sp (*kukra*) and many others.

These common property resources are of some importance to the poor, who are the most likely to engage in wetland gathering, to eat wetland food in times of scarcity, to depend on income from wetland products, and so on. Fodder and building materials tend to be collected by men, and food and medicinal materials tend to be collected by women.

4. PREVIOUS STUDIES

4.1 Early Implementation Projects (EIP), BWDB

EIP carried out studies on Angurali Haor and Joal Bhanga Hoar. An EIP mission recommended a submersible embankment project be implemented on Angurali Haor in their 1981 program. The project was subsequently evaluated in 1988 and reported on in the Fourth Evaluation of EIP Projects, Engineering Study Phase 2, Netherlands Technical Assistance Program.

In 1990, an EIP appraisal mission recommended inclusion of a submersible embankment project around Joal Bhanga Haor in the 1991-92 EIP program. The expected date of completion of this work is in 1994.

4.3 Systems Rehabilitation Project (SRP), BWDB

The Systems Rehabilitation Project is in the process of completing feasibility studies to rehabilitate ten existing haor development projects in the north east region. The project is co-financed by IDA, EEC and the Government of the Netherlands in association with the World Food Programme. The work is directed towards rehabilitation of existing structures within the haors, and no new initiatives were investigated. SRP projects falling within the scope of this current investigation include Shanir Haor Project, Matian Haor Project and Karchar Haor Project. Results from field surveys, borehole data and hydrological information collected during the course of SRP's investigations have been utilized in this study.

4.3 Jadukata-Rakti-Baulai Dredging Programme

In 1992, a parliamentary committee was formed by the Government of Bangladesh, headed by local MP Mr. Nazir Hossain to consider options for improving navigation along the Rakti River by dredging. Subsequently, a river survey was initiated by BIWTA. No report has yet been published. BWDB Sunamganj WD Division also proposed the project to the Superintending Engineer, Sylhet BWDB Circle for its implementation.

82

5. WITHOUT-PROJECT TRENDS (NULL OPTION)

The purpose of this chapter is to characterize the future of the project area, assuming no new interventions are carried out. This chapter provides a "future without project" scenario. Comparisons of conditions "with" and "without" interventions are summarized in Chapter 7. The time frame considered in this analysis extends to the year 2015.

The main trends that can be identified are as follows:

Net population growth
The population of the project area is estimated to be 243,100 by the year 2000 and 317,800 in the year 2015. This assumes the population growth rate will decrease from the rate of 2.2% experienced over the last 10 years to 1.8% per year by 2015.

River course changes
In the short-term, it is expected that the avulsion from the Jadukata River into the Maharram River channel will continue to develop, producing greater flooding and higher sedimentation rates on the west side of the Jadukata Fan and in Matian and Tangua Haor. This should produce greater flooding and longer periods of inundation on the upper reaches of the Baulai River system. Reduced flows down the Jadukata River will lessen the intensity of flash flooding around Shanir Haor and Karchar Haor. This may diminish the rate of siltation inside these haors. However, the reduced flows will also reduce these channel's capacity to remain self-scouring. Therefore, it is expected that the Rakti and Nandia Gang channels will tend to decrease in size and become shallower over time.

In the longer term, it is likely that new patterns of instability will be initiated on the fans. For example, as sediment aggradation continues along the Maharram channel and Matian Haor there will be a greater tendency for the flows to spill back down the Jadukata/Rakti River channel. Since this channel will have shrunk in size during the previous period, it will not be large enough to accommodate the new increased discharges. Consequently, the flows could spill out and re-activate other old channels or even develop completely new routes across the fan.

Food grain production growth
Current trends in agricultural production will continue in the absence of any intervention in the Jadukata-Rakti basin area. There will be no change in area under different land types except for the fact that some areas which are currently of an F3 land type will be raised because of sediment deposition. The area flooded by less than 0.3 m is extremely limited so an expansion of high yielding varieties of aman is not likely. Local varieties of transplanted *aman* will also be restricted to the limited area classified as an F1 land type. Local *boro* will continue to be dominant in F3 lands. Continued siltation may lead to replacing some local *boro* rice by *b aman* as the irrigation water supply will be reduced in the dry season.

Marginal expansion of irrigation facilities may occur but will be limited by the availability of water in the dry season. Any increase in irrigated area will facilitate expansion of high yielding varieties of *boro*. The high yielding varieties of *boro* rice will continue to be exposed to damage from pre-monsoon floods.

Anticipated future cropping patterns, assuming no intervention in the Jadukata-Rakti basin, are presented in Tables 5.1.

Table 5.1: Cropping Patterns under Future Without Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					3944	75	2046	15	5989
fallow-l boro							11593	85	11593
fallow-hyv boro					789	15			789
b aus-potato	398	6							398
b aus-rabi	796	12	479	10					1275
b aus-lt aman	863	13	2395	50					3257
b aus-lt aman-potato	265	4							265
b aus-lt aman-rabi			239	5					239
b aus-hyv aman	995	15							995
lt aman-fallow	332	5	479	10					811
lt aman-potato	332	5							332
lt aman-rabi	863	13	958	20					1820
hyv aman-fallow	664	10							664
hyv aman-potato	199	3							199
hyv aman-rabi	929	14	239	5					1168
b aman-rabi					526	10			526
Total	6636		4789		5258		13639		30322

Note: All areas are in hectares

Analysis of the historical data shows the yield level of individual varieties have not changed over time. Changes in production have come about mainly from shifts in variety. Without any change in the flood regime, the level of input use is not expected to change and damage to different crops will continue. Damage to local and high yielding varieties of transplanted *aman* from drainage congestion, especially in F1 land type, will continue.

Crop production under future without project conditions are presented in Table 5.2.

Table 5.2: Crop Production Under Future Without Project condition

Crop	Damage free area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)	
b aus	6431	1.25	8039		1.05		8039
b aman	5515	1.75	9652	1000	1.45	1450	11102
lt aman	6725	2.15	14459		1.75		14459
hyv aman	3027	3.95	11955		3.55		11955
l boro	2718	2.25	6116	8875	1.75	15531	21647
hyv boro	488	4.55	2224	300	3.25	975	3198
Total Rice			52443			17956	70400
potato	1194	12	14334				
pulses	754	0.85	641				
oilseeds	2515	0.75	1886				
spices	251	2.25	566				
vegetables	1509	9.75	14712				

Openwater fisheries production

With increased siltation in supposedly key "Mother Fisheries" sites, such as Tangua Haor, one would expect that fisheries production will decrease over time. On the other hand, interventions to improve fisheries management could increase fish production. Therefore, the magnitude of future changes is difficult to predict. In this analysis it has been assumed that the "future without project" production will remain the same as the present level.

84

6. WATER RESOURCES INFRASTRUCTURE DEVELOPMENT OPTIONS

6.1 Summary of Problems

Critical problems within the area have been highlighted in earlier sections of this report. Most problems occur as a result of the project area's physical setting in a morphologically unstable area that is subject to high intensity floods and large sediment inflows. The main problems that have been addressed in subsequent sections of this report are as follows:

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

- Substantial portions of the project area are subject to high velocity spills, bank erosion and overbank sediment deposition due to recurring instability on the Jadukata and Jhalukhali alluvial fans. Channel instability and sedimentation has significantly reduced the effectiveness of the existing haor development projects in the area. These developments, such as Shanir Haor Project, Angurali Haor Project and Karchar Haor project have not withstood the flash flooding and channel erosion that is associated with alluvial fans.

- Sediment aggradation along the Rakti and Baulai Rivers is obstructing navigation and between Durlabpur on Surma River and Fazilpur and limiting the duration of commercial stone quarrying operations on the Jadukata River.

- Two key wetland sites (Tangua Haor and Gurmar Haor), as well vulnerable fisheries habitat and agricultural land are threatened by the channel avulsion of Jadukata River into the Maharram River.

6.2 Water Resources Development Options

Past experience has shown that it is difficult to provide permanent engineering solutions to control channel instability and flooding on alluvial fans. Measures for controlling alluvial fans have included some or all of the following elements:

- Reduce the sediment supply through land management practices in the catchments upstream of the fan.

- Construct debris basins or "sabo dams" at the head of the fan to trap the sediment before it is deposited on the lower fan.

- Construct embankments to channelize the flow and increase its capacity to transport the incoming sediment.

- Construct river training works such as spurs or closure dykes to control the river alignment and to guide spills away from critical infrastructure, and

- Carry out maintenance dredging to increase the channel's discharge capacity.

Not all of these measures are suitable for this area. Virtually all of the sediment supply is produced in India, so there is no opportunity to reduce sediment inflows through land management practices. Furthermore, there are no suitable sites in Bangladesh for constructing debris basins on the Jadukata or Jhalukhali Rivers. Constructing high flood embankments to channelize the fans would initiate major morphologic impacts throughout the region and along the Surma River, would be extremely expensive, and would involve very high maintenance costs. Therefore, the option of confining the Jadukata River or Jhalukhali River by high embankments was not considered further in this investigation. This leaves only river training and dredging as viable options for the project area.

6.3 Control of Jadukata River Avulsion Hazard

At present, the progressive avulsion of the Jadukata River into the Maharram River channel at the head of the fan threatens to induce major changes to the project area. This shift, if completed, will affect the hydrological regime, pattern of land-use and agricultural production and ecological characteristics of the entire project area. Options for controlling this progressive shift are summarized below.

1. Full Closure of Maharram River
The object of this work would be to block off the Maharram channel and return all of the flow back down the Jadukata River channel. This would reduce flooding and sediment inflows on the western side of the fan and would stop sedimentation in Matian Haor and Tangua Haor. However, both pre-monsoon and monsoon flood flows would increase in the central portions of the fan, particularly around Shanir Haor and Angurali Haor. Furthermore, a major change to the flow distribution could trigger other avulsions on the Jadukata, particularly in the vicinity of Fazilpur or at the Baulai/Rakti bifurcation. This could increase hazards to infrastructure and agriculture on a substantial portion of the fan which would not be socially acceptable or desirable. As a result, this option was not considered further.

2. Partial Closure of Maharram River
During the last few years, local people have constructed a low sill from sand and gravel across the Maharram River during the dry season. The purpose of this work is to delay spills down the channel so that their crops can be harvested before the pre-monsoon floods. Due to the temporary nature of the works and the high flows that can occur, only a very limited degree of protection is achieved. Nevertheless, the work is considered by the locals to be worthwhile.

Based on these observations, it is proposed to extend this concept further by constructing a more permanent and more effective partial closure on the Maharram River. The objective would be to reduce pre-monsoon floods and to control spills during the monsoon season down the Maharram River channel. Therefore, further progress of the avulsion would be halted but the channel could still act as a flood relief channel during the monsoon season. This would improve conditions on the central portions of the fan (Shanir Haor, Angurali Haor).

Various options were considered for controlling spills on the Maharram channel. A low stone weir could be constructed across the channel, with its sill elevation set to a suitable pre-monsoon flood level. Once overtopped, the structure would be subject to high velocities and scour at the downstream toe. Therefore, a long launching apron would be required to prevent undermining. Geotechnical problems such as piping under the structure would have to be addressed properly during the design stage.

Other options for achieving a partial closure include installing a permeable dyke across the channel to trap sediment. This could involve placing a dense network of bamboo "porcupines" or "jacks" across the channel to reduce velocities and trap debris. As the bed aggraded, the flow down the channel would be restricted. Problems with this option include the fact that the structures would probably have to be re-built several times over a number of years before they became effective. Furthermore, it would be difficult to regulate the amount of flow spilling down the channel during the monsoon season.

The concept of providing a partial closure on the Maharram River using a submersible stone weir was adopted in Chapter 7 as the most appropriate means for controlling the Jadukata River avulsion.

6.4 Dredging Rakti River

Re-excavating the Rakti River over a distance of 24 km from its outfall into the Surma River to just above Fazilpur, would re-open a major drainage channel down the middle of the project area. This would improve drainage from Angurali Haor, Shanir Haor, Halir Haor and Joal Bhanga Haor. This re-excavation would also improve navigation between Durlabpur and Fazilpur and allow increased movement of stone materials down the Jadukata River. The work would require an initial dredging program to deepen the channel and periodic maintenance dredging to prevent the channel from deteriorating back to its present state. A preliminary concept for a this dredging project is described further in Chapter 7 of this report.

6.5 Jadukata Left Bank Development (unprotected area)

BWDB proposed development project in the currently unprotected area (gross 7,860 ha) bounded by the international boundary on the north, Karcher Haor Project on the south, Jhalukhali River on the east and Jadukata River on the west (Figure 1). This proposed project area was identified by the BWDB, Sylhet Circle as Chalti Haor Project (Draft Thematic Study, NERP 1992). The project area is mainly flooded by the Dhamalia and Jhalukhali Rivers. Flooding is further aggravated by backwater from the Surma River.

During field visits, it appeared that pre-monsoon and monsoon floods do not have severe adverse impacts on the unprotected area. However, local people reported that siltation in the channel bed of the Rakti and Jhalukhali Rivers tends to cause overbank spills from these rivers. Construction of embankments on this portion of the alluvial fan would be risky since it might enhance further channel avulsions and instability. Moreover, the unprotected area does not appear to be affected adversely by seasonal floods. Furthermore, the proposed dredging on the Jadukata-Rakti River may also improve the drainage conditions in this area. Therefore, no further development is proposed at this time.

7. PROPOSED JADUKATA-RAKTI RIVER IMPROVEMENT PROJECT

7.1 Rationale

This plan provides for improved post-monsoon drainage, pre-monsoon flood protection and improved navigation round the year. The proposed works focus on improving the drainage capacity of the project area by restoring a former major drain that has filled-in as a result of ongoing channel aggradation and instability on the Jadukata fan. Improving post-monsoon drainage will restore the cultivable area in the project area to previous levels by draining an additional gross area of about 6,100 ha. Year round navigation will provide an opportunity to significantly increase the amount of stone quarried from the Jadukata River.

The proposed control works near the head of the Maharram River channel will increasing the stability of the project area by controlling further shifting from the Jadukata River. This will improve the security of *boro* crops from pre-monsoon flash floods in a gross area of 3,930 ha. Pre-monsoon protection will also reduce sedimentation in Tangua Haor, a key wetland and "mother" fishery site.

7.2 Objectives

The objectives of the project are:

- to reduce flood damage to *boro* crops;
- to improve post-monsoon drainage in the centre of the project area;
- to provide year round navigation between Durlabpur and Fazilpur;
- to reduce sedimentation in key wetland areas; and
- to facilitate expansion of stone quarrying operations in the region.

7.3 Description

The project components are:

- 24 km of channel dredging along the Rakti River; and
- one stone weir near the head of the Maharram Channel.

The location of the proposed works is shown in Figure 13.

7.3.1 Rakti River Dredging

It is proposed to dredge the Jadukata-Rakti River for a length of about 24 km, from its outfall at Durlabpur up to Fazilpur. Figure 11 shows a centreline profile of the existing channel (surveyed by NERP in 1993) and the proposed navigation channel. Preliminary design bed elevations at various locations along the channel are shown in Table 7.1.

Table 7.1: Design Bed Elevations

Locations	Section (km)	Bed Level (m PWD)
Jadukata-Rakti River		
Durlabpur	0.0	-1.10
Nandia Gang Offtake	12.3	0.12
Fazilpur	24.0	1.01

The required length of dredging from Durlabpur to Nainda Gang junction is 12.36 km. In this reach, Rakti has been provided with a minimum bed width of 63 m and an average bed slope of 8 cm/km. The proposed dredged level at Durlabpur is El. -1.1 m PWD.

The length of dredging between Nandia Gang junction and Fazilpur is 11.14 km. The proposed navigation channel in this reach has a bed width of 84 m and a bed slope of 8 cm/km. The channel is intended to provide a minimum depth of 2.1 m in the dry season, which corresponds to a BIWTA Class II navigation channel. The volume of excavation required to achieve this design sections is estimated to be about 2.3 million m^3.

It is expected that most of the excavation will be carried out using hydraulic pipeline cutterhead dredges. Current BIWTA dredges are reported to operate at average daily production rates of between 1,200 to 1,800 m^3/day. These values represent total production rates of 500,000 m^3/year, assuming the dredgers operate 250 days per year. However, modern dredge plants should be capable of substantially higher production rates. For example, guidelines used by the US Army Corps of Engineers indicate solid output rates of around 5,000 m^3/day for a dredger with an 18 inch diameter suction pipe, operating in water depths of 7 m and pumping over distances of approximately 1 km (U S Army Corps of Engineers, EM 1110-2-5025, Dredging and Dredged Material Disposal, 1983). Therefore, the initial dredging program would have to be carried out over a period of at least two years. Consideration should be given for using the dredge spoil to develop new homestead platforms along the right bank of the Rakti River.

Mechanical or manual excavation methods will have to be used along the upper reaches of the Rakti/Jadukata River.

It should be recognized that periodic maintenance dredging will be required to prevent the channel from filling in again. It is difficult to quantify these maintenance requirements at this time. However, it is notable that the channel apparently remained open during the period 1963 to 1984 before major channel changes started on the fan. Careful monitoring will be required to assess future infilling rates.

7.3.2 Impact of Dredging

The dredged channel will provide a major north-south drain running down the middle of the project area. A preliminary analysis was made to assess the impacts of this channel on water levels in the area. This involved comparing recorded winter water levels at Durlabpur, Marala, and Tahirpur and then adjusting these levels after dredging by assuming a low water slope and projecting water levels along the channels (Annex A12 and A13). Based on these crude estimates, it is expected that water levels could be lowered by as much as 1.5 m in the dry season near the Nandia/Rakti junction close to Fazilpur. This channel would provide drainage for the immediate area around the Rakti and Jadukata Rivers,including Angurali Haor, Karcher Haor, Joalbhanga Haor, Shanir Haor and the unprotected land between the Rakti River and Halir Haor.

Due to this lowering, water levels at Nandia Gang junction will be almost the same as at Marala during the dry season. This means that water from the Rakti will not drain through the Nandia Gang. The proposed rehabilitation programme of Shanir Haor under SRP provides two drainage structures along the Rakti River. As a result, drainage from Shanir Haor will continue to flow west, into the Baulai River.

There is a concern that the Nandia Gang may be fill-in due to reduction in discharge during the dry season. It is possible that all the east-west cross channels would fill-in over the long-term. A likely scenario is that eventually there will be two main drains running north-south; the Rakti channel in the east and the Baulai channel in the west.

Due to the proposed dredging, it may also happen that small country boats might have difficulties to travel from Fazilpur up to Lorergrah at the head of the fan due to higher slope that is produced. Some channel degradation will also be induced upstream of the dredged channel due to this increased slope. This will increase the rate of infilling along the dredged channel during the first years after the project is completed and may affect the maintenance requirements for the project. This aspect needs to be taken into consideration during feasibility studies.

7.3.3 Pre-monsoon Flood Protection

Partial Closure of Maharram Channel by Stone Weir

The unprotected area of Maharram River extends over a gross area of 7,554 ha and is bounded by the Jadukata River on the east, the International boundary on the north, the Baulai River on the south and Matian and Tangua Haors on the west.

Control of spills from the Jadukata River into the Maharram channel during the pre-monsoon season will be achieved by means of a low stone weir. This weir will be situated near the head of the Maharram River channel just downstream of the Jadukata/Maharram bifurcation. Considerable attention will have to be given to locating the structure so it can not be by-passed during flash flooding. Based on field inspections and a review of satellite imagery, the total width of the structure is estimated to be around 300 m.

Recent topographic data in the vicinity of the Maharram channel are not available. Therefore, only a conceptual layout of the structure can be made at this time. This is adequate for estimating approximate costs at a pre-feasibility level analysis. However, detailed site surveys and hydraulic studies will be needed to make engineering designs during feasibility studies.

Figure 14 shows one concept of a stone weir with a concrete retaining wall to reduce the possibility of failure by piping. It is assumed that the flow will be critical over the weir during extreme pre-monsoon flood conditions and early stages of the monsoon season. However, during peak monsoon floods the structure will be drowned out by downstream backwater conditions. In order to withstand the high velocities and turbulence, the structure will require heavy stone protection and flat slopes on its downstream side. Preliminary computations were made using guidelines for rockfill dams (Olivier, H. "Through and Overflow Rockfill Dams", Proc. Institution of Civil Engineers, March 1967). Based on this criteria, a suitable design would require side slopes of 1:12 on its downstream side 650 mm diameter rock to withstand 2.5 m of overtopping. In addition, a launching apron would be required downstream of the toe to prevent undermining by scour. The preliminary concept in Figure 14 shows a 10 m wide, 1,500 mm thick stone apron included for this purpose.

In this analysis, the crest elevation of the weir was set at the 1:10 year pre-monsoon flood level. Therefore, no spills would occur down the Maharram channel until a 1:10 flood was exceeded. Impacts of the proposed structure will be very sensitive to the level of protection that is provided. Establishing the most appropriate design crest level will have to be carried out during feasibility investigations.

7.3.4 Expected Benefits

The benefits expected from the project relate to agriculture, commercial stone quarrying and navigation, and protection fisheries and wetlands habitat.

As a result of dredging, the net cultivable area of the existing projects will be increased to its original level under damage free condition and pre-monsoon flood control infrastructures will protect boro crops from the unprotected areas (Table 7.2)

Protection from floods in the pre-monsoon season will enable farmers to harvest local and high yielding varieties of boro rices. This will reduce the damage presently suffered by these crops. As a result, yield levels are expected to increase at least to the level other farmers are obtaining under damage-free condition. This may induce farmers to replace some of the local *boro* by high yielding varieties of *boro* rice. Protection from flash floods in the pre-monsoon season will also reduce damage to local varieties of broadcast *aman*.

There will be no change in monsoon season flooding conditions after implementation of the project. Therefore, cropping patterns will remain similar to those under the "future without" project condition. The major impact of the project will be increased yield of crops that are presently damaged by pre-monsoon floods.

Drainage improvements in the post-monsoon season will make more land available for cultivation early in the *rabi* season. Farmers are expected to respond by growing more *rabi* crops and the area under *rabi* crop cultivation is expected to increase.

Table 7.2: Pre-monsoon Benefitted Area

Location	Benefitted Cultivable Area (ha)
Shanir Haor	1100
Matian Haor	1720
Karchar Haor	876
Joalbhanga Haor	400
Angurali Haor	500
Maharram Area	3525
Unprotected Area (Rakti-Halir Haor)	1500
Total	**9621**

Note: These figures do not reflect cultivable land acquired for infrastructure. Production impacts of land acquisition are documented in the Evaluation section.

Cropping patterns under "future with" project condition are presented in Table 7.3.

Protection from pre-monsoon floods will reduce the damage presently suffered by local and high yielding varieties of *boro* rice, increasing yield level of these crops. Yield level of b *aman* is also expected to increase by averting damage presently suffered from floods in the pre-monsoon season. Future crop production with partial flood protection is presented in Table 7.4.

Table 7.3: Cropping Patterns with Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					2629	50	682	5	3311
fallow-l boro							12275	90	12275
fallow-hyv boro					1052	20	682	5	1734
b aus-potato	398	6							398
b aus-rabi	796	12	479	10					1275
b aus-lt aman	863	13	2395	50					3257
b aus-lt aman-potato	265	4							265
b aus-lt aman-rabi			239	5					239
b aus-hyv aman	995	15							995
lt aman-fallow	332	5	479	10					811
lt aman-potato	332	5	0						332
lt aman-rabi	863	13	958	20					1820
hyv aman-fallow	664	10	0						664
hyv aman-potato	199	3	0						199
hyv aman-rabi	929	14	239	5					1168
b aman-rabi					1577	30			1577
Total	6636		4789		5258		13639		30322

Note: All areas are in hectares

Table 7.4: Future Crop Production with Project Condition

Crop	Damage free area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)	
b aus	6431	1.25	8039	0	1.05	0	8039
b aman	4888	1.75	8555	0	1.45	0	8554
lt aman	6725	2.15	14459	0	1.75	0	14459
hyv aman	3027	3.95	11955	0	3.55	0	11955
l boro	12275	2.25	27619	0	1.75	0	27619
hyv boro	1734	4.55	7888	0	3.25	0	7888
Total Rice			78514				78514
potato	1194	12	14334				
pulses	912.2	0.85	775.3				
oilseeds	3041	0.75	2280				
spices	304	2.25	684				
vegetables	1824	9.75	17784				

7.3.5 Mitigation Measures Incorporated

The project would not have any negative impacts on fisheries and wetland habitats.

7.4 Project Operation and Maintenance

Under this development plan, operating requirements would be minimal. Monitoring and periodic maintenance dredging will be required along the Jadukata-Rakti River. This may involve returning at approximately 3 - 5 year intervals to monitor infilling of the channel and re-excavate local shoals and reaches that have infilled. Periodic channel maintenance will be required at the stone weir on the Maharram river to assure effective pre-monsoon flood protection. In addition, other ongoing channel maintenance should be carried out along the Jadukata and Jhalukhali Rivers to reduce adverse impacts from future channel shifts and instability on these fans. The objective of this maintenance work would be to intervene early on using relatively small scale measures, before serious river stability problems develop.

An Environmental Management Plan, detailing actions necessary to achieve acceptable environmental impacts, will need to be prepared and costed as part of the feasibility study.

7.5 Organization and Management

During the early part of the feasibility study process, a client group would need to be organized to oversee project development. These client groups would be composed of representatives from the local farming community, fishing community, and would include relevant thana-level technical officers. The groups 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 designs, preparation of tenders, pre-qualification of contractors, contract awards and construction supervision. The general management of BWDB activities would be under the Executive Engineer stationed in Sunamganj. Construction supervision would be carried out by sub-divisional field staff.

The Department of Agricultural Extension (DAE) is responsible for the provision of extension services to the farmers within the project.

In summary, the organization and management of this project has a high dependency on central government for key inputs. The extent to which project targets are realized will be determined by how effectively it serves people's needs and how actively the local community participates in all stages of project development.

Bangladesh Rural Development Board (BRDB) is responsible for assisting with command area development through farmers' training and by organizing farmers into cooperatives which will then have access to short term crop production loans. Medium term credits are available to these cooperatives from all nationalized banks.

The supply of all agricultural inputs has been deregulated and the distribution placed into the hands of the private sector.

7.6 Cost Estimates

Total project costs are Tk 275.4 million. A summary of total costs is presented in Table 7.5. Additional details are provided in Annex A, Table A.11.

The estimates of land requirements and physical works are based on preliminary designs and lay-out plans prepared using 1:15,480 scale topographic maps and historic hydrological data.

Land costs reflect the current prices obtained from field interviews: land which was single cropped was estimated at Tk 120,000/ha; land that could be double cropped was Tk 300,000/ha; and, land suitable for homesteads and gardens (including high ridges along the rivers) was Tk 500,000/ha. Earthwork costs are based on BWDB's Schedule of Rates for Sylhet, indexed to

June 1991 prices. Structure costs are based on parametric costs developed for the Region, also indexed to June 1991 prices in accordance with the FPCO Guidelines for Project Assessment.

7.7 Project Phasing and Disbursement Period

Three years are required to implement the project. One year (year zero) is required for completion of feasibility studies and conducting field surveys. Preparation of detail designs should be completed in year zero. Land acquisition should commence in year one, be implemented in phases preceding construction, and completed in year two. Construction of the stone weir should start in year one and be completed in the same year. Dredging should start in year one and be completed in year two. An itemized implementation schedule is shown in Table 7.6.

Table 7.5 Capital Cost Summary

Item	('000 Tk)
Structures	28,000
Embankments	-
Dredging	184,000
Bridges	-
Buildings	-
Land Acquisition	4,800
BASE COST	191,600
Physical Contingencies (25%)	47,900
SUBTOTAL	239,500
Study Costs[1] (15% of Subtotal)	39,900
TOTAL	**275,400**
Net Area (ha)	30,322
Unit Cost (Tk/ha)	9,083

[1]Includes preparation of EIA and Environmental Management Plan.

Table 7.6 Implementation Schedule

Activity	Year (% Completion)				
	0	1	2	3	4
Preconstruction Activities					
Feasibility Study	100				
Engineering Investigation	100				
Detail Designs	100				
Land Acquisition		50	50		
Construction Activities					
Dredging of Channels		40	60		
Construction of Structures		100			

7.8 Evaluation

7.8.1 Environmental

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

Land Use
Land use changes are summarized in Table 7.7. A total of 48 ha of land (about 0.16% of the project gross area) will be required for storing dredged material. This land is planned to be used for new homestead developments.

Table 7.7: Changes in Land Use

Use	Change in area (ha)
Cultivated	-
Homesteads	-
Beels	-
Ponds	-
Channels	-
Hills	-
Fallow[1]	-
Infrastructure[2]	-48

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

Agriculture
The annual cereal production is expected to increase by about 8,116 tonnes, from 70,401 tonnes (FWO) to 78,517 tonnes (FW) as a result of the project, an increase of about 11%.

The cereal production increase implies a per person increase in cereal availability from 607 FWO) to 677 (FW) gm per person per day, an increase of +11% (Table 7.8), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice. Current Bangladesh average consumption is 440 gm per person per day.

Non-cereal production is expected to increase by 1,828 tonnes, from 23,080 tonnes (FWO) to 24,908 tonnes (FW), an increase of +8%. This results from a 1,051 ha increase in area cultivated for non-cereals (from 6,224 ha to 7,275 ha). This will increase the availability of non-cereals from 199 to 215 grams per person per day (Table 7.8).

Openwater fisheries production
The project is expected to impact on fisheries in three ways: it will facilitate migration, increase the depth of the Rakti River and consequently increase the dry season wetted surface area, and reduce the rate of siltation in Tangua Haor. The project will not impede fish access to the floodplain or back channel areas.

Re-excavation of the Jadukata-Rakti River channel will facilitate fish migration throughout the year. Currently, fish movement along the Rakti is prevented during the winter months due to channel siltation. The increase in depth of the Rakti River will have a positive impact on fisheries production since it will improve the overwintering habitat and provide better migration routes. This combined effect will increase the channel fisheries from its present level of 29 tonnes to 42 tonnes.

The project is expected to have a positive impact on spawning because rates of siltation in Tangua Haor will be reduced due to the construction of the weir across the Maharram River. In addition, the water linkage between the Surma River and the Tangua Haor will also improved due to the re-excavation of the Jadukata-Rakti River. This benefit could not be evaluated due to inadequate information.

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

Table 7.8: Indicators of Food Availability (grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	913	885	667	607
Non-Cereals	302	281	215	199
Fish	23	20	15	15

Impacts on open water fisheries production were assessed using a simplified model that represents the major system processes. These factors include migration, overwintering habitat extent, wet season habitat, habitat quality and spawning habitat. The basis for this model is summarized in Annex D. The estimated magnitude and sign of the expected impacts are summarized in Table 7.9.

In summary, the project is expected to have a positive impact on fisheries, providing a net increase of 13 tonnes per year. The projected per capita fish availability will be 15 grams per person per day in 2015 (Table 7.8).

Homestead flooding
Homestead flood damage would be reduced partially. Due to the lack of historical data on flood damage costs, a simple model was used to estimate future costs. There are about

Table 7.9: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ('000 kg)	Area (ha)	Area Equivalent	Production Impact ('000 kg)	Net Value ('000Tk)
Flood Plain	23686	1042	23686	23686	1042	0
Beel	1716	704	1716	1716	704	0
Channel /River	167	29	239	239	42	+810
Net Project	30322	1775			1788	+810

33,692 homesteads in the area, and the average plinth level is at about the 1:5 year flood level. About 30% of the homesteads are affected by flooding by 10-30 cm during a 1:10 to 1:20 year flood. It was estimated that roughly 3% would have some improvement as a result of the project. Based on this, the estimated annualized economic value from the reduced flood damage is Tk 0.42 million.

Wetland Habitats and Grazing Area

Impacts are difficult to quantify, but a general impression is given by Table 7.10, which shows the impact on:

- "Winter grazing area". Defined as F0, F1, and F2 lands that lie fallow in the dry season (winter) plus any perennially-fallow highlands. This land would have limited residual moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.
- "Winter wetland". Defined as F3 land that lies fallow in the dry season, plus any perennially-fallow lowland (F4), beel, and channel areas. This land would likely have considerable residual moisture and could support a range of wetland plant communities.
- "Summer wetland". Defined as F1, F2, and F3 land that lies fallow in the summer, plus perennially-fallow lowland (F4 area), beel, and perennial channel areas. This land would be inundated to >0.3 m and would support submerged, free-floating, rooted floating, and sedge/meadow plant communities.

The impact of the project will be to decrease the winter grazing area by 8%, decrease the winter wetland area by 26%, and increase the summer wetland area by 2%.

There would be no impact on swamp forest trees. Impacts on the reed swamp community would be very positive due to reduced sedimentation rates. The most important positive impact of this project would be the reduction of sedimentation in Tangua haor, which is a key wetland site in the region.

Table 7.10: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	**FW**	**Change**	**%**
sc/wf F0	2854	4033	1,179	
sc/wf F1	2874	3042	168	
sc/wf F2	3575	1274	-2,301	
Fallow Highland	2000	2000	0	
Total	11,303	10,349	-954	-8

Land Type	Winter Wetland			
sc/wf F3	1364	0	-1,364	
F4, Beel, Channel	3947	3947	0	
Total	5,311	3,947	-1,364	-26

Land Type	Summer Wetland			
wc/sf F1	0	0	0	
wc/sf F2	789	3821	3,032	
wc/sf F3	12277	9507	-2,770	
F4, Beel, Channel	3947	3947	0	
Total	17,013	17,275	262	2

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

Economic and employment impacts of the project on wetland plant and animal production can only be crudely estimated. Assuming an annual economic production of Tk 100 per hectare for both summer and winter wetland areas, gives a total annual loss of Tk 110 thousand per year. Assuming 1.0 pd /ha/yr for harvesting, the employment impact would be -1,120 pd/year.

Transportation/navigation
Navigation along the Rakti River will be improved significantly. The dredging will facilitate year round navigation for large boats (BIWTA class II vessels) up to Fazilpur. Assuming a longer period of operation during the dry season, quarrying of construction materials could be increased by approximately 350,000 m^3/year, from its present level of 500,000 m^3/year. The additional wages paid for quarrying and transport to Fazilpur corresponds to Tk 60 million. Generally, small two man barki boats are used for collecting and transporting the materials. The boats can carry about 0.8 m^3 of materials each trip. Based on this, the expanded production will create an additional employment opportunity of about 292,000 pd/yr for the landless people, assuming each boat can make 3 trips/day.

7.8.2 Social

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

Employment
There will be an overall increase in employment of 0.516 million person-days per year. This is composed of:

- an increase in owner-labour employment of +0.107 million pd/year, of which very roughly 20% is in post-harvest processing activities traditionally done by women of the household.

- an net increase in employment opportunities for landless people of +0.409 million pd/year, composed of changes in the following areas:

  - Agricultural hired labour: +0.114 million pd/year, of which about 10% is for post-harvest processing traditionally done by women hired for the purpose.

  - Fishing labour: +0.004 million pd/year; in addition to this, there would be a corresponding loss in support activities such as net-making and post-catch processing (mainly drying) much of which is done by women.

  - Wetland labour (gathering wetland products): -0.001 million pd/year. Fodder and building material is gathered mainly by men. Food, fuel, and medicine is gathered mainly by women.

  - Quarrying labour: +0.292 million pd/year; in addition to this, there would be corresponding increase in support activities such as boat-making, boat-repairing, small business centres for daily commodities etc.

Displacement impacts due to land use changes
There will be no displacement of homesteads due to the development of the project. Rather additional homesteads are planned to be developed with the spoil earth.

Conflicts
Improved drainage will encourage farmers to extend cultivation further into deeper part of the haor areas. This will bring them into conflict with fishermen who will find the fishing area reduced. This conflict will affect the way the regulator is operated and will have a direct bearing on the extent to which some of the crop production benefits are realized.

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

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This benefit accounts about 45% of the project and its distribution is somewhat *regressive*.

- Landless people gets direct benefit from quarrying of construction materials which is about 120% of the incremental net agricultural benefit or about 54% of the project. Strongly progressive.

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

Who loses?

- Families involved in gathering wetland products. These families are mainly landless and tend to be poor. *Regressive.*

Gender Equity
The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories <u>except</u> wetland gathering.

y8

Table 7.11 Qualitative Impact Scoring

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

Notes on Qualitative Impact Scoring

The qualitative criteria shown in Table 7.13 are scored on an 11 level scale of -5 to +5. Scoring of those criteria that are impacts (some are not, like "responds to public concerns") is shown in Table 7.11. 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.

7.8.3 Economic

The project has an economic rate of return of 26%, without quarrying of construction materials which compares well to the required rate of 12% as prescribed by government. It is a relatively low investment project, at Tk 275 million or Tk 9,083 per hectare, and it covers a large geographic area (37,434 ha gross). The rate of return, however, is quite sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 21%). The other sensitive variable is the timing of the benefits, and a delay in benefits by two years would reduce the ERR to 17%.

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

The agricultural benefits of the project are mainly due to increased yields by protecting crops from pre-monsoon floods, by facilitating early plantation through improved post-monsoon drainage and by conversion of some local *boro* to hyv *boro*. Average crop yields will increase as a result of reduced flood damage, and cropping intensity will increase by 10%. Non-cereal production will increase by 8%. Fish production was estimated to increase marginally.

However, the benefits to fisheries are underestimated in this analysis, since the impacts from protecting the "mother" fishery in Tangua Haor are not included. A small disbenefit would result from loss of food, shelter, and tree products that are currently harvested from the seasonal wetlands. A summary of salient data in provided in Table 7.12.

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

7.8.4 Summary Analysis

From a multi-criteria perspective (Table 7.13), the project is very attractive:

- Agricultural benefits derive entirely from increased rice production not at the expense fisheries and wetlands.
- Landless people gets large benefits from quarrying of construction materials.
- The net employment impact is highly positive because it is composed of a large gain in employment for owners and hired labours, landless people and fishing labours.
- A number of homesteads would be constructed for the landless people.

Other positive aspects of the project are:

- Rate of return is acceptable.
- Substantial increase in rice production.
- Substantial increase in non-cereal production.
- Protects mother fishery from sedimentation.
- Gender equity of impacts is somewhat progressive.
- Project responds to some public concerns.

The negative aspects of the project would be:

- Conflicts between farmers and fishermen would increase.
- The project has a high dependency on central government for implementation and for maintenance.

Table 7.13: Summary of Salient Data

Economic Rate of Return (ERR)	26			
Capital Investment (Tk million)	275			
Maximum O+M (Tk million / yr)	7			
Capital Investment (Tk/ha)	9,083			
Foreign Cost Component (%)	6			
Net Project Area (ha)	30,322			
Land Acquisition Required (ha)	48			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	49.77			
Cropping Intensity		1.4	1.4	1.4
Average Yield (tonnes/ha)		2.3	2.3	2.4
Average Gross Margins (Tk/ha)		11370	11415	12519
Owner Labour (md/ha)		114	113	113
Hired Labour (md/ha)		26	25	27
Irrigation (ha)		14983	13859	15670
Incremental Cereal Prod'n (' 000 tonnes / yr)	8			
Incremental Non-Cereal (' 000 tonnes / yr)	2			
Incremental Owner Labour (' 000 pd / yr)	107			
Incremental Hired Labour (' 000 pd / yr)	114			

FISHERIES IMPACTS		Flood plain	Channels	Spawning
Incremental Net Econ Output (Tk million / yr)	0.57		0.57	-
Impacted Area (ha)		-	72	-
Average Gross Margins (Tk/ha)		1540	12250	-
Remaining Production on Impacted Area, %		100%	100%	100%
Incremental Fish Production (tonnes / year)		-	+13	-
Incremental Labour ('000 pd / yr)	+4.4	-	+4.4	-

FLOOD DAMAGE BENEFITS				
Households Affected		1010		
Reduced Econ Damage Households (Tk M / yr)	0.42			
Roads/Embankments Affected -km		209		
Reduced Econ Damage Roads (Tk M / yr)	0			

OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	-0.001			
Wetland Incremental Labour ('000 pd / yr)	-1.1			
Acquired Cult & Homestead Lands, Incr Net Econ Output (Tk million / yr)	0			
Persons Displaced by Homestead Acquisition	0			

Note: ERR does not include benefits to quarrying.

Jadukata

Table 7.13: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	26*
EIRR, Increase Capital Costs by 20%	per cent	21
EIRR, Delay Benefits by Two Years	per cent	17
Net Present Value	Tk	147,489

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	8116	11
Incremental Non-Cereal Production	tonnes	1828	8
Incremental Fish Production	tonnes	13	1
Change in Floodplain Wetland/Fisheries Habitat	ha	0	-
Homesteads Displaced Due to Project Land Acquisition	homesteads	0	-
Homesteads Protected From Floods	homesteads	1010	-
Roads Protected From Floods	km	0	-
Owner Employment	million pd/yr	+.109	2.3
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	+0.409	13

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

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

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

ANNEX A

BACKGROUND DATA AND ANALYSIS

Climatic Data

TABLE A.1: METEOROLOGICAL DATA

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C) Max.	28.3	32.2	36.7	38.9	40.6	35.0	40.0	35.0	35.0	35.0	31.7	28.9
Min.	9.4	8.9	12.8	16.7	18.3	21.1	23.9	23.3	21.7	18.3	12.8	8.9
Mean	18.7	20.4	24.2	27.2	26.9	27.8	28.8	28.2	28.1	26.6	19.7	19.7
Humidity (%)	76.9	70.9	63.8	75.0	83.5	87.7	89.5	89.5	87.5	87.3	81.0	79.9
Sunshine (hr/day)	8.8	9.0	8.4	7.5	6.8	3.5	4.1	4.4	4.6	7.5	9.0	7.8
Wind speed (kph)	2.4	2.8	5.0	6.0	5.0	5.4	5.6	5.0	3.7	2.4	1.9	1.9
Evapotranspiration (mm/month)	105.6	124.4	162.4	157.1	153.4	124.9	125.0	130.6	121.5	128.4	114.5	102.6
Rainfall (mm) Mean monthly	9.2	36.5	101.4	397.1	514.0	916.5	747.2	555.0	282.2	198.7	53.7	30.2

Table A.2 : Mean Monthly Discharges (m3/sec)

Month	Gauge NE-48 JADUKATA			Gauge NE-11 JALUKHALI		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	75.9	137.0	265.8	21.8	55.1	118.8
May	130.0	395.0	684.3	50.4	145.3	239.5
June	287.3	925.4	1518.3	130.8	293.2	432.0
July	898.3	1428.9	1751.4	232.6	377.6	504.5
Aug	986.6	1355.4	2119.0	250.1	361.8	552.4
Sept	718.5	1189.4	1410.3	182.1	319.5	369.5
Oct	349.5	562.7	703.2	97.3	146.0	195.4
Nov	24.6	51.7	83.4	7.1	15.1	28.5
Dec	2.1	19.4	77.4	0.5	6.4	26.6
Jan	0.0	2.8	12.2	0.0	0.6	1.9
Feb	0.2	8.3	21.7	0.3	3.6	9.2
Mar	0.5	20.1	52.4	0.3	9.9	16.6

TABLE A.3 : Mean Monthly Water Levels (m PWD)

Month	Gauge 269 SURMA at Sunamganj			Gauge 728 BAULAI at Sukdevpur		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Apr	2.258	4.115	6.559	2.489	3.579	4.409
May	3.867	5.872	7.356	4.074	4.654	5.132
June	5.469	7.231	8.025	4.339	5.689	6.474
July	7.530	8.052	8.507	5.941	6.757	7.559
Aug	7.385	7.864	8.289	6.189	6.810	7.202
Sept	6.846	7.527	8.276	6.145	6.644	7.503
Oct	5.820	6.635	7.314	5.225	5.883	6.253
Nov	4.143	4.955	5.854	3.565	4.389	5.021
Dec	2.956	3.528	4.546	2.273	3.087	3.902
Jan	2.007	2.371	2.809	1.387	1.923	2.351
Feb	1.577	1.888	2.611	1.474	2.218	5.668
Mar	1.705	2.116	4.172	1.375	1.805	2.568

TABLE A.3 (Cont'd): Mean Monthly Water Levels (m PWD)

Month	Gauge 131 JADUKATA at Saktiarkhola		
	Minimum	Mean	Maximum
Apr	3.754	4.731	5.971
May	4.147	5.657	6.650
June	5.559	7.003	7.924
July	7.048	7.822	8.575
Aug	6.964	7.535	8.115
Sept	6.509	7.207	7.819
Oct	5.568	6.417	7.113
Nov	4.685	5.332	5.981
Dec	3.945	4.752	5.217
Jan	3.697	4.454	5.004
Feb	3.573	4.305	4.890
Mar	3.635	4.269	4.919

Table A.4 : Water Balance : Jadukata-Rakti River Improvement Project

Item	Unit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Rainfall	mm	16	38	145	473	569	1112	1058	702	517	210	40	11
Storage	ha-m	120	286	1091	3557	4279	8363	7957	5280	3888	1579	301	83
Data :													
ETO	mm	105.62	124.4	162.42	157.12	153.41	124.95	125.05	130.6	121.49	128.38	114.5	102.64
KC factor		1.2	1.25	1.25	1.2	1.1	1.1	0.95	1.1	1.1	1.1	1.1	1.15
Deep Percolation	mm	62	56	62	60	31	30	0	0	0	0	0	31
Losses :													
Boro, 6844 ha	ha-m	434	1064	1390	1290								
ETO (natural)	ha-m	72	84	110	106	104	85	85	88	82	87	78	69
Deep Percolation	ha-m	466	421	466	451	233	226	0	0	0	0	0	233
Total Loss :	ha-m	972	1570	1966	1848	337	310	85	88	82	87	78	303
Accum. Storage[1]	ha-m	-851	-1284	-875	1709	3942	8053	7873	5191	3806	1492	223	-220

[1]Note: Accumulated storage is total volume without drainage, Negative value means no storage.

TABLE A.5 : Mean Monthly Water Levels (m PWD)

Year	Gauge 269 SURMA at Sunamganj			Gauge 728 BAULAI at Sukdevpur		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum
JANUARY						
1987	2.07	1.46	2.57	1.95	1.36	2.43
1988	2.73	2.09	3.47	2.35	1.73	2.98
1989	2.08	1.68	2.61	1.72	1.36	2.18
1990	2.25	1.79	1.52	1.97	1.46	2.50
1991	2.88	2.26	3.70	2.61	1.98	3.33
FEBRUARY						
1987	1.67	1.42	1.85	1.51	1.29	1.76
1988	2.08	1.63	2.57	1.73	1.36	2.07
1989	1.69	1.41	1.99	1.26	0.95	1.61
1990	1.78	1.52	2.0	1.45	1.18	1.74
1991	2.09	1.73	2.31	1.85	1.54	2.03

Source: SWMC

Water Bodies in the Project Area

Table A.6 : Water Bodies in the Jadukata-Rakti River Project

Haor	Beel area (ha)	Haor	Beel area (ha)
Matian haor	664	Karchar haor	168
Shanir haor	475	Joalbhanga haor	114
Angurali haor	96	Moharram River Basin	200
TOTAL	**1716**		

Source: Inception report - Haor Development Project, CIDA, 1989.

Table A.7 : Closed Water Bodies in the Project Area

Thana	% of area under project	Total number of ponds	Combined pond area (ha)	Average pond size (ha)	Pond concentration (nos/km^2)
Tahirpur	50.0	1619	125	0.077	9.30
Bishwamvarpur	100	1552	120	0.077	11.75
Jamalganj	4.0	127	10	0.077	8.71
Sunamganj	9.0	450	35	0.077	8.47
Total		**3748**	**290**	**0.077**	

Source: BFRSS, 1986

Table A.8 : Groundwater analysis, 20m Pumping Limit from F0 Land
Jadukata-Rakti Rivers

Thana	Project Fraction	Useable GW by Technologies			Available GW by Technologies		
		(STW)	(DSSTW)	(DTW2)	(STW)	(DSSTW)	(DTW2)
Sunamganj	0.09	1.26	2.98	7.62	0.55	1.29	3.30
Tahirpur	0.50	0.00	5.30	22.45	0.00	2.51	10.65
Bishwamvarpur	1.00	0.00	11.80	50.90	0.00	7.23	31.19
Jamalganj	0.04	0.07	0.44	1.31	0.04	0.22	0.66
TOTAL		1.33	20.52	82.28	0.58	11.26	45.80

Source: MPO.

Table A.9 : Present Irrigation Use (1991)

Thana	Project Fraction	STW		DTW		LLP		Traditional mode (ha)
		No	(ha)	No	(ha)	No	(ha)	
Bishwamvarpur	1.00	19	161	1	20	92	768	2820
Jamalganj	0.04	-	-	-	-	3	45	323
Sunamganj	0.09	-	-	-	-	20	333	1763
Tahirpur	0.50	2	10	-	-	48	787	1984
TOTAL		**21**	**171**	**1**	**20**	**163**	**1933**	**6889**

Fisheries

TABLE A.10 DUARS AROUND THE PROJECT AREA

Name of duar	Approx. depth during dry season (m)	Baramaach occurred	Chotomaach occurred
River: SURMA			
Lalpurar duar	16-17	LC,C,MC	B,Ch,Ca,R
Ajkhalir duar	14-15	As above.	As above.
Puranlaxmansree	14-15	As above.	As above.
Paindar duar	10-12	As above.	As above.
Baburbazara duar	12-14	As above.	As above.
Amriar duar	15-16	As above.	As above.
Noagaoar duar	15-16	As above.	As above.
Jamlabazar duar	15-16		As above.
River: ABBUA & RAKTI			
Fatepurar duar	16-17	LC,C,MC	B,R,Ca,L
Behelir duar	9-10	C,LC,MC	As above.
Batenar duar	10-11	LC,C,MC	As above.
Badarpurar duar	8-9	As above.	As above.
Chamrarbarir duar	8-9	As above.	As above.
Barakurir duar	8-9	As above.	As above.
Ahmakkhalir duar	14-15	As above.	As above.
Sreepurar duar	7-8	As above.	As above.
Dhutomar duar	6-7	As above.	As above.
Fazilpurar duar	10-11	As above.	As above.
Anwarpurar duar	7-8	As above.	As above.
Alipurar duar	7-8	As above.	As above.
Lamar duar	7-8	As above.	As above.
Atlar duar	8-9	As above.	As above.
River: JADUKATA			
Katakhali	12-13	C,LC,MC	B,L,Ch,Ca

B:Bacha; C:Chital; Ca:Chapila; Ch:Chela; G:Golda Chingri; LC:Large catfish; MC:Major carp. (Source: NERP, 1992)

Stone Weir on Maharram River

The stone weir is intended to prevent pre-monsoon spills and flash floods from the Jadukata River down the Maharram River channel and damaging *boro* crops on the west side of the project area. These pre-monsoon floods typically occur in April or May. During the monsoon season, the water levels throughout the entire area in the vicinity of Matian Haor and Tangua Haor are controlled by backwater from the Baulai/Meghna River system. As a result, the slope along the Maharram River will be flatter during the monsoon season than in the pre-monsoon.

The stone weir must be designed so that it achieves flow control during pre-monsoon flash floods. The crest elevation needs to be set high enough so that frequently occurring flood events are prevented from passing down the channel. During very extreme pre-monsoon flash floods the weir will be overtopped, but the structure will throttle the spills so that the magnitude of the floods will be reduced. At the time of overtopping, the tailwater below the weir could be low, so that the structure needs to be designed to withstand the high velocities and turbulence associated with an overtopping rockfill embankment. During the monsoon flood season, the weir will be deeply submerged so that no flow control will be provided. During the monsoon season, the velocities over the structure will be substantially less than at the time of overtopping during the pre-monsoon season.

In this preliminary analysis it was assumed the weir crest was set 2.5 m above the existing bed level, at the 1:2 year pre-monsoon flood level. Flow over the structure was estimated using the broad crested weir equation:

$$q=2/3H\sqrt{2/3gH}$$

where H is the head over the weir and q is the unit discharge
The estimated hydraulic conditions at various pre-monsoon flows with and without the weir in-place are summarized in Table 11.

Table A.11 Pre-Monsoon Hydraulic Conditions at Weir

Return Period	Y m	H m	Discharge per unit width m^2/s	
			Without Weir	With Weir
2	2.5	0.0	3.2	0.0
5	3.14	0.64	4.65	0.9
10	3.47	0.97	5.5	1.63
50	4.08	1.58	7.19	3.39

Hydraulic conditions without the weir during pre-monsoon flows was estimated assuming uniform flow, with a channel gradient of 0.0003 and a Mannings roughness value of 0.025.

Preliminary estimates of stable stone size on overflow slopes was based on the experimental work by the British Hydromechanics Research Association (Oliver, H. *"Through and Overflow Rockfill Dams"*, Proceedings of the Institution of Civil Engineers, 36, March 1967, pp 433-471).

Oliver's formula in metric form can be written as follows:

$$q=0.2334D^{1.5}(W_s/W-1)^{1.667}/i^{1.167}$$

where **q** is the discharge per unit width, **D** is the stable rock size, $\mathbf{W_s}$ is the dry unit weight of the rock, W is the unit weight of water and ***i*** is the downstream slope of the weir.

For a 1:50 year pre-monsoon flood condition, q=3.4 m^2/s, a specific gravity of 2.6 and a slope of 1V:12H, the required stone size is 510 mm. However, the design parameters for the weir are sensitive to the crest level and water levels at the structure. Therefore, additional site information and hydraulic modelling analysis is required to optimize the weir design.

Dredging Program

The volumes of sediment that must be dredged to achieve various channel depths has been estimated on the basis of surveys carried out by NERP and BIWTA in 1992 and 1993. A longitudinal profile of the Rakti River was surveyed by NERP in November 1992 using an echo sounder and GPS positioning system. BIWTA surveyed the Rakti and Jadukata Rivers in early 1993 and have produced sounding charts of the channel bottom. To date, the sounding charts have not been tied to PWD datum. The BIWTA data can be adjusted to PWD datum approximately by comparing the two surveys. A mean bed elevation was determined from the sounding charts. The volume of dredging required was calculated for various new bed profiles from Durlabpur to Nandia Gang junction and Nandia Gang junction to Fazilpur (Table A.12). The channel bottom width was estimated from the BIWTA sounding charts.

Assumptions:

- The lowest water level at Durlabpur is 1.0 m PWD;
- The dredged bed slope will be 0.00008 (8 cm/km);

Table A.12 shows that between 1.23 - 3.57 million cubic metres of material needs to be dredged to provide bed levels of 0.0 m PWD to -2.0 m PWD. The table also shows that very little dredging is required between the Nandia junction and Fazilpur. The required bed elevation at Durlabpur to achieve a BIWTA class II navigation channel is -1.1 m PWD. The corresponding dredging volume is about 2.3 million cubic metres.

Impacts of dredging on water levels were estimated approximately using historic water level data from gauges at Durlabpur (junction of Rakti and Surma), Lorergarh and Marala (west side of Shanir Haor). It was found that for the purpose of this analysis, the water levels at Marala and Tahirpur were the same, so only Marala data was used. Furthermore, only 1992 water level data were used in this study. The hydrographs for these three gauges are shown in Figure 11.

Table A.12: Dredged Volume for Various Depths

Depth of Excavation mPWD	Area (m2)	Channel Width (m)	Volume (m3)
Durlabpur to Nandia Gang			
0.0	19,549	63.0	1,231,570
-1.0	30,905	63.0	1,947,000
-1.1	32,105	63.0	2,022,590
-2.0	42,901	63.0	2,702,790
Nandia Gang to Fazilpur			
0.0	0.0	84.0	0.0
-1.0	2,545	84.0	217,110
-1.1	3,002	84.0	252,200
-2.0	10,300	84.0	865,230
Total Rakti River Dredging			
0.0			1,231,570
-1.0			2,164,110
-1.1			2,274,790
-2.0			3,568,020

Water levels at Nandia Gang junction were calculated on the following assumed slopes and distances:

- slope on the Surma River is 0.00006 (6 cm\km);
- slope on all other rivers is 0.00008 (8 cm/km);
- distance between Marala and Nandia Gang junction is 22.3 km; and
- distance between Durlabpur and Nandia Gang junction is 12.36 km

The water level before dredging was estimated from the Marala gauge. Water levels after dredging were estimated from the Durlabpur gauge, adjusting for the anticipated hydraulic slope along the channel after excavation. During the monsoon season, the water levels at Nandia Gang junction will be very close to that at Marala. The preliminary analysis shows that during the months of January - February, it should be possible to drop the water level at the Nandia Gang junction by about 1.5 m. This suggests there would be little or no flow in the Nandia Gang during these months. Consequently, post-monsoon drainage will be faster which will facilitate early plantation of **boro** crop. Additional hydrodynamic model simulations should be carried out during feasibility studies to improve these estimates.

Table A.13 : Estimated Capital and O & M Costs

Jadukata-Rakti River Project

Item of Works	Quantity	Unit	Unit Price	Capital Cost (m tk)	O & M % Capital Costs	O & M Costs (m tk)
Drainage Channel Re-excavation						
Manual Excavation	1150000	m^3	80.0 tk/m3	92.0	3	2.76
Dredging	1150000	m^3	80.0 tk/m3	92.0	3	2.76
Cross-Dam and Protective works						
Boulders	9250	m^3	255 tk/m3	2.4	2	0.05
Core wall (1:3:6)	225	m^3	1925 tk/m3	0.4		
Land Acquisition	48	ha	0.1 m tk/ha	4.8		-
Project Buildings	-		-	-	3	-
BASE COST:				191.6		5.6
Physical Contingency 25%				47.9		1.39
SUB_TOTAL:				239.5		6.96
Eng & Admin 15%				35.9		1.04
TOTAL:				275.4		8.0

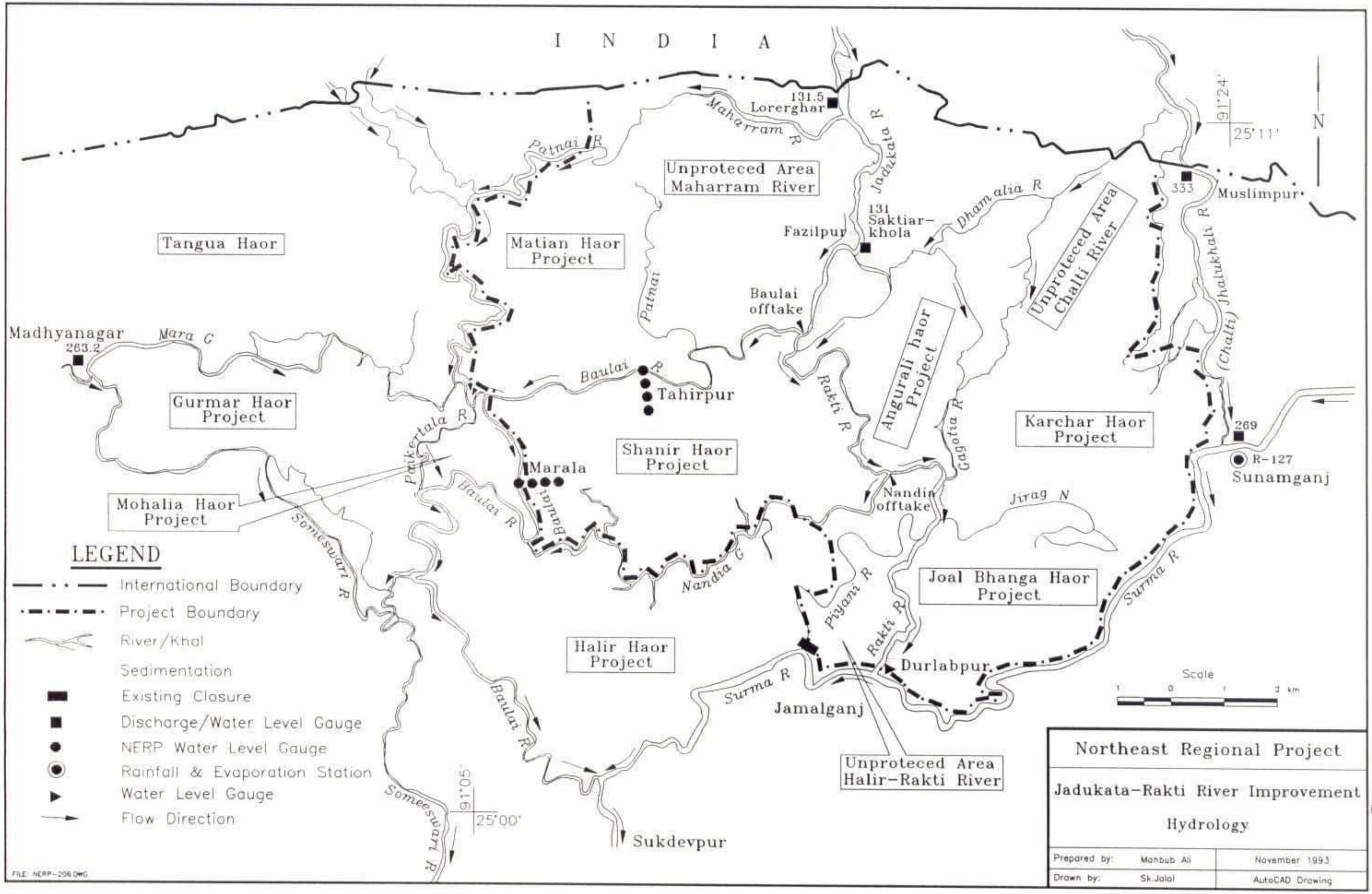
NET AREA (ha): 30,372
UNIT COST (tk/ha): 9,083

Source: NERP

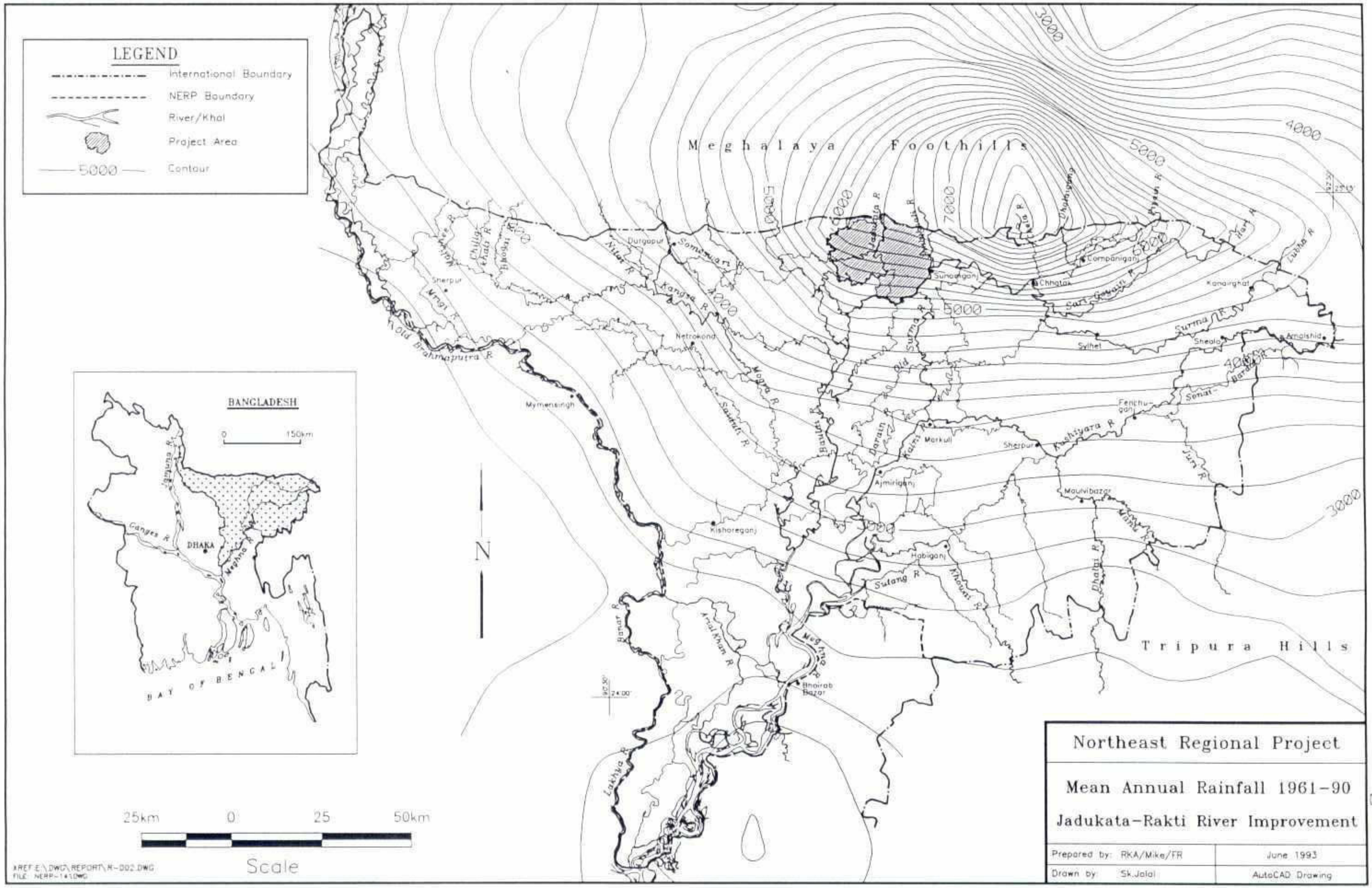
ANNEX B

FIGURES

Figure 1



I N D I A
N
91°24'
25°11'
91°05'
25°00'
Tangua Haor
Matian Haor Project
Unproteced Area Maharram River
Unproteced Area Chalti River
Angurali haor Project
Karchar Haor Project
Gurmar Haor Project
Shanir Haor Project
Mohalia Haor Project
Halir Haor Project
Joal Bhanga Haor Project
Unproteced Area Halir-Rakti River
Madhyanagar
263.2
131.5
Lorerghar
131
Saktiar-khola
Fazilpur
333
Muslimpur
269
R-127
Sunamganj
Baulai offtake
Nandir offtake
Tahirpur
Marala
Durlabpur
Jamalganj
Sukdevpur
Mara C
Patnai R
Patnai
Maharram R
Jadukata R
Dhamalia R
(Chalti) Jhalukhali R
Baulai R
Rakti R
Gagotia R
Jirag N
Paikertala R
Baulai
Nandia C
Piyani R
Surma R
Someswari R
Someeswari R
LEGEND
International Boundary
Project Boundary
River/Khal
Sedimentation
Existing Closure
Discharge/Water Level Gauge
NERP Water Level Gauge
Rainfall & Evaporation Station
Water Level Gauge
Flow Direction
Scale
1 0 1 2 km
Northeast Regional Project
Jadukata-Rakti River Improvement
Hydrology
Prepared by: Mahbub Ali
Drawn by: Sk.Jalal
November 1993
AutoCAD Drawing
FILE: NERP-206.DWG



LEGEND
International Boundary
NERP Boundary
River/Khal
Project Area
5000
Contour
Meghalaya Foothills
Tripura Hills
BANGLADESH
0
150km
DHAKA
Ganges R
Jamuna R
Meghna R
BAY OF BENGAL
N
25km
0
25
50km
Scale
Durgapur
Sherpur
Netrokona
Mymensingh
Kishoreganj
Sunamganj
Chhatak
Companiganj
Kanairghat
Sylhet
Sheola
Amalshid
Fenchuganj
Sherpur
Markuli
Ajmiriganj
Habiganj
Moulvibazar
Bhairab Bazar
Old Brahmaputra R
Someswari R
Kangsa R
Mogra R
Old Surma R
Surma R
Kushiyara R
Sari Gowain R
Piyain R
Jadukata R
Lubha R
Juri R
Manu R
Dhalai R
Khowai R
Sutang R
Meghna R
Banar R
Lakhya R
Arial Khan R
Baulai R
Dharam R
Sautuli R
3000
4000
5000
6000
7000
Northeast Regional Project
Mean Annual Rainfall 1961-90
Jadukata-Rakti River Improvement
Prepared by: RKA/Mike/FR
June 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 2

Jadukata River Jhalukhali River

Surma River

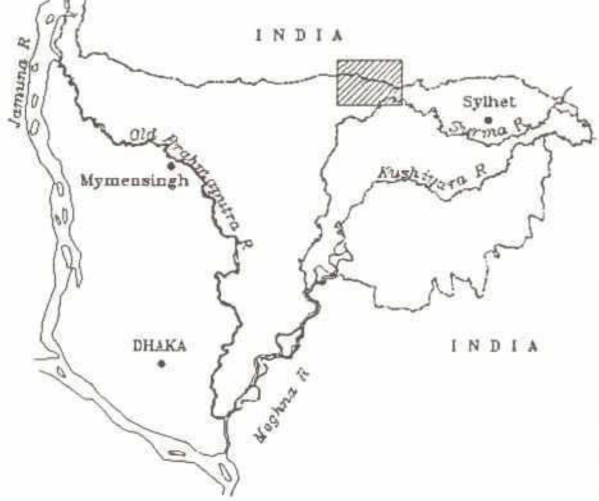
Scale

2 0 2 4 km

Approx.

N

Site Location



Northeast Regional Project

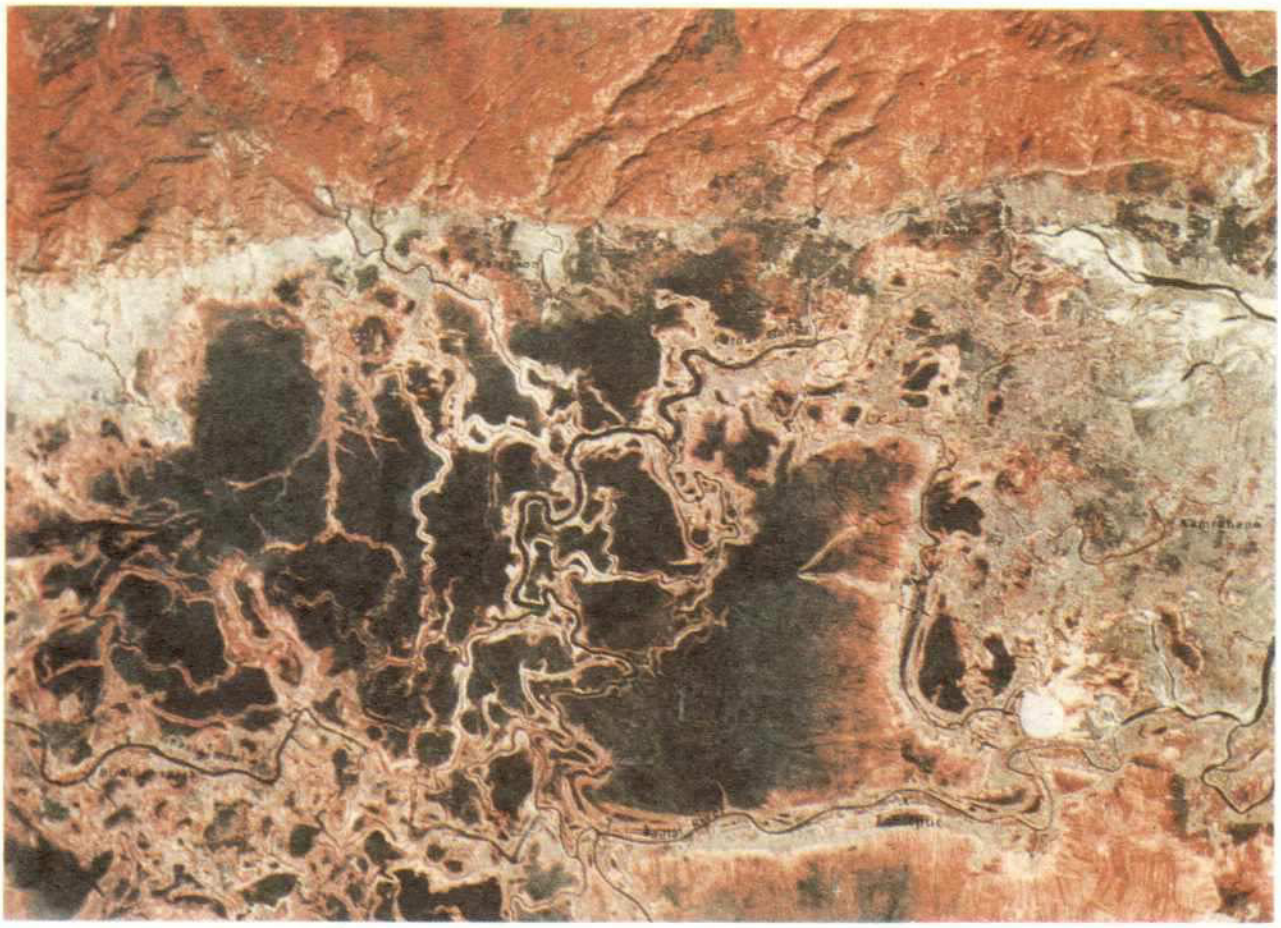
Jhalukhali River Alluvial Fan

Prepared by:	DMc	May 1993

FILE: Fig. 13.DWG

Figure 4

Jadukata River



Tanguar Haor   Bauli River   Matian Haor

Scale

2 0 2 4 km

Approx.

N

Site Location

Northeast Regional Project

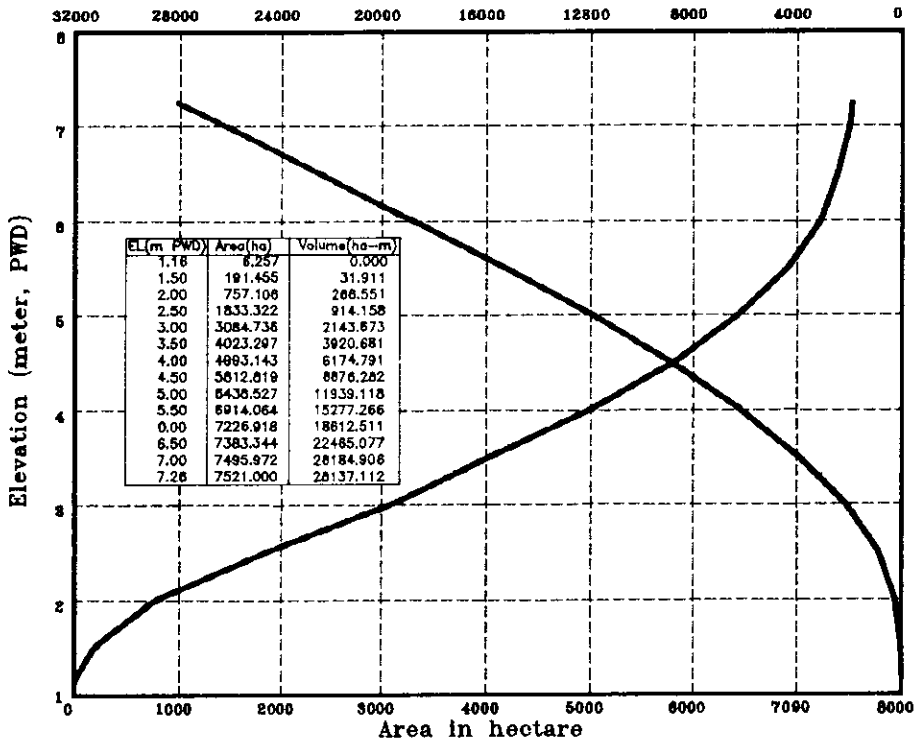
Meghalaya Basin Haors in Dry Season

Prepared by: DMc   May 1993

FILE: fig. 12.DWG

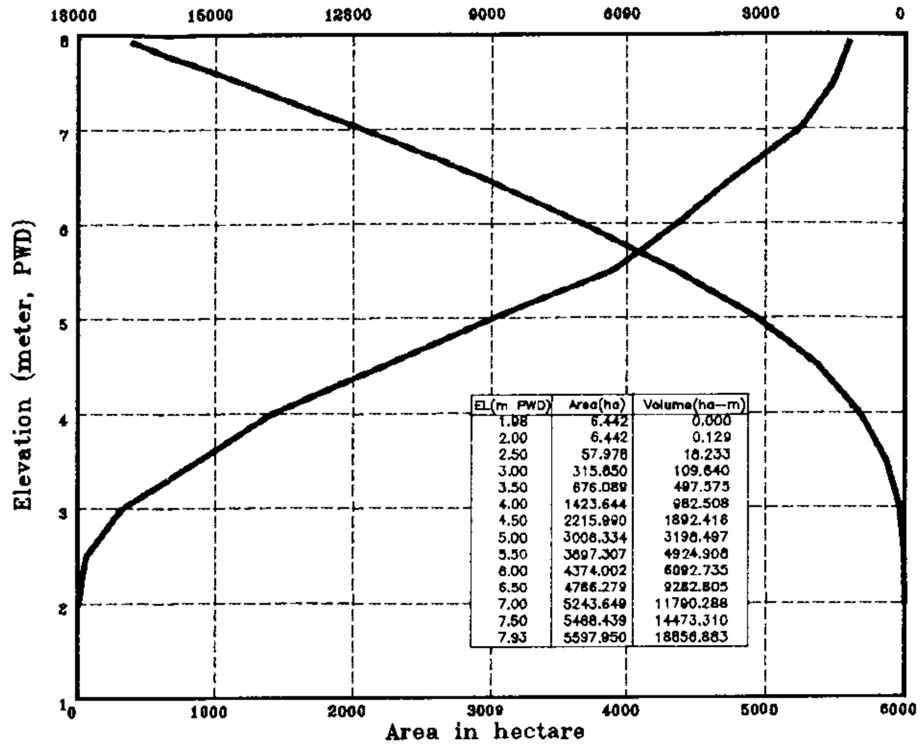
b>

Shanir Haor Project



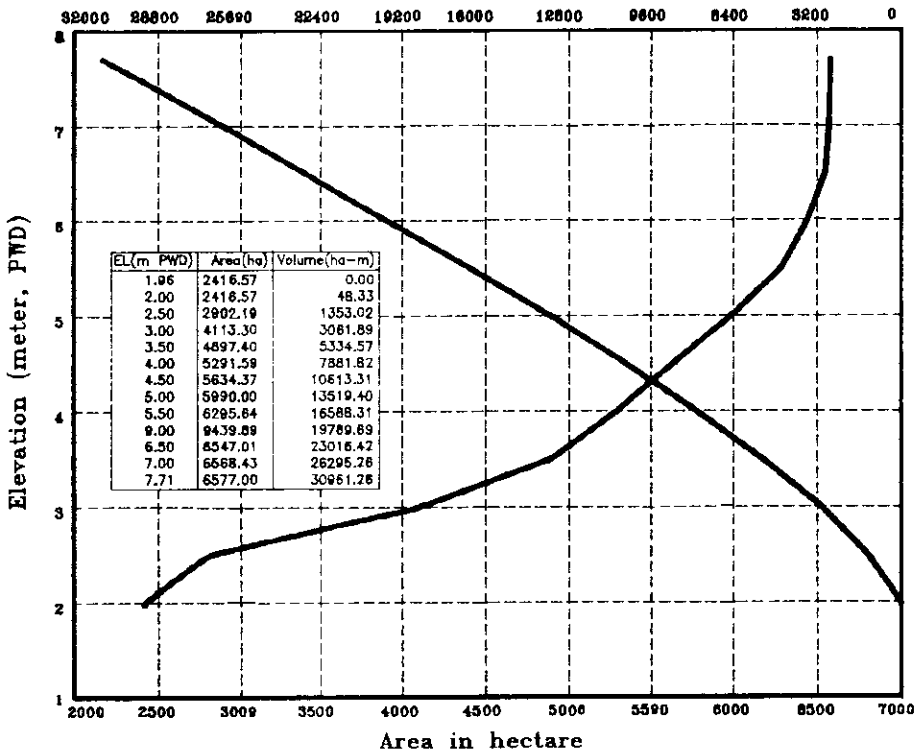
EL(m PWD)	Area(ha)	Volume(ha-m)
1.16	6.257	0.000
1.50	191.455	31.911
2.00	757.106	266.551
2.50	1833.322	914.158
3.00	3084.736	2143.673
3.50	4023.297	3920.681
4.00	4883.143	6174.791
4.50	5612.819	8876.282
5.00	6436.527	11939.118
5.50	6914.064	15277.266
0.00	7226.918	18812.511
6.50	7383.344	22465.077
7.00	7495.972	26184.906
7.26	7521.000	28137.112

Karchar Haor Project



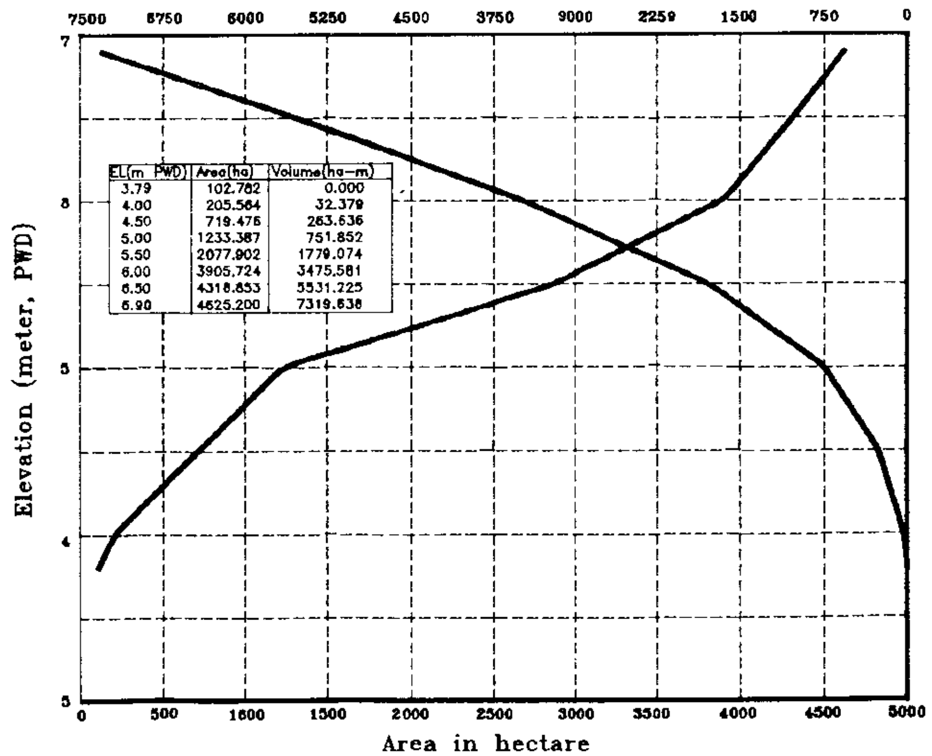
EL(m PWD)	Area(ha)	Volume(ha-m)
1.98	6.442	0.000
2.00	6.442	0.129
2.50	57.978	16.233
3.00	315.650	109.640
3.50	676.089	497.575
4.00	1423.644	982.508
4.50	2215.990	1892.416
5.00	3008.334	3196.497
5.50	3697.307	4924.908
6.00	4374.002	6092.735
6.50	4766.279	9282.805
7.00	5243.649	11790.288
7.50	5488.439	14473.310
7.93	5597.950	18856.883

Matian Haor Project



EL(m PWD)	Area(ha)	Volume(ha-m)
1.96	2416.57	0.00
2.00	2416.57	48.33
2.50	2902.19	1353.02
3.00	4113.30	3061.89
3.50	4897.40	5334.57
4.00	5291.59	7881.82
4.50	5634.37	10613.31
5.00	5990.00	13519.40
5.50	6295.64	16588.31
9.00	9439.89	19789.69
6.50	6547.01	23016.42
7.00	6568.43	26295.26
7.71	6577.00	30961.26

Joal-Bhanga Haor Project



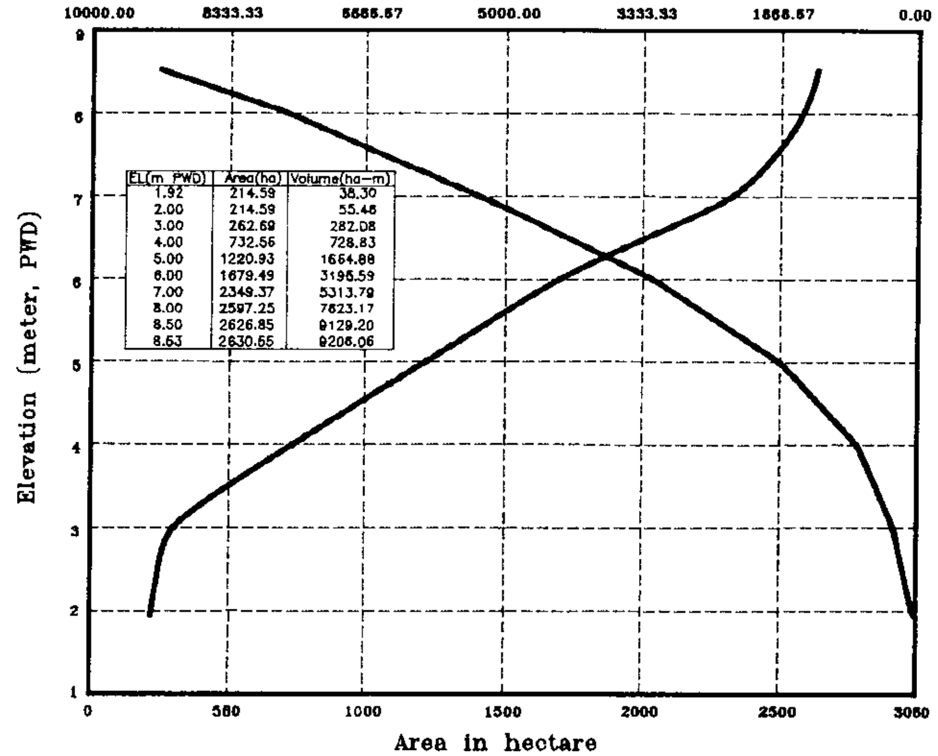
EL(m PWD)	Area(ha)	Volume(ha-m)
3.79	102.782	0.000
4.00	205.564	32.379
4.50	719.476	263.636
5.00	1233.387	751.852
5.50	2077.902	1779.074
6.00	3905.724	3475.581
6.50	4318.853	5531.225
6.90	4625.200	7319.638

Northeast Regional Project	
Area Elevation & Storage Volume Storage (ha-m)	
Prepared by: Nasim	December 1993
Drawn by: Mamun	AutoCAD Drawing

FILE: NERP-743.DWG

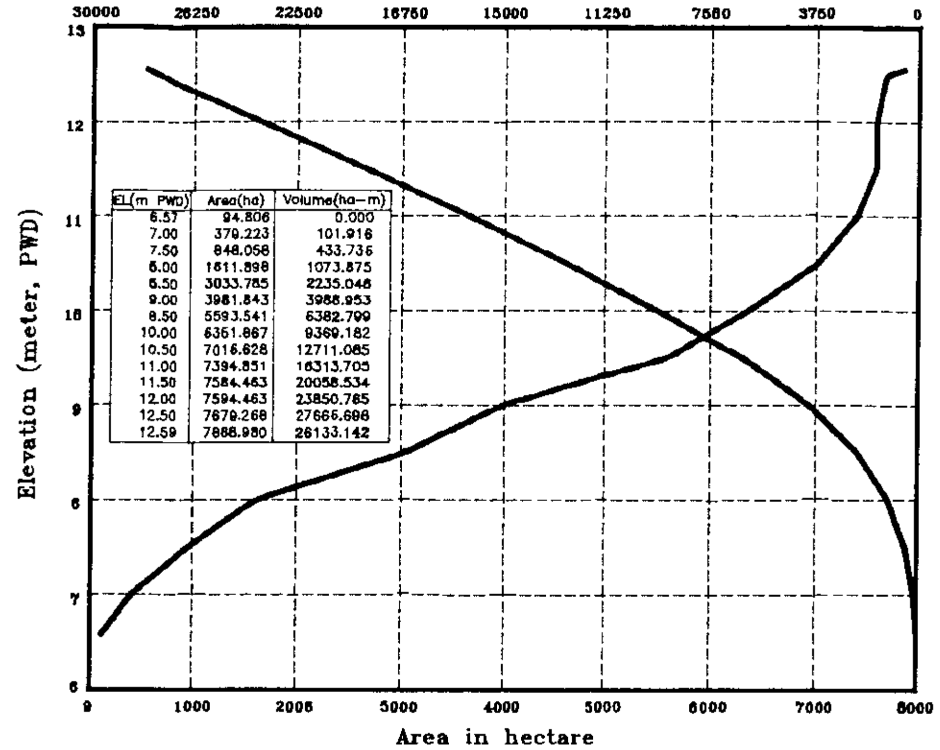
Figure 6

Angurali Haor Project



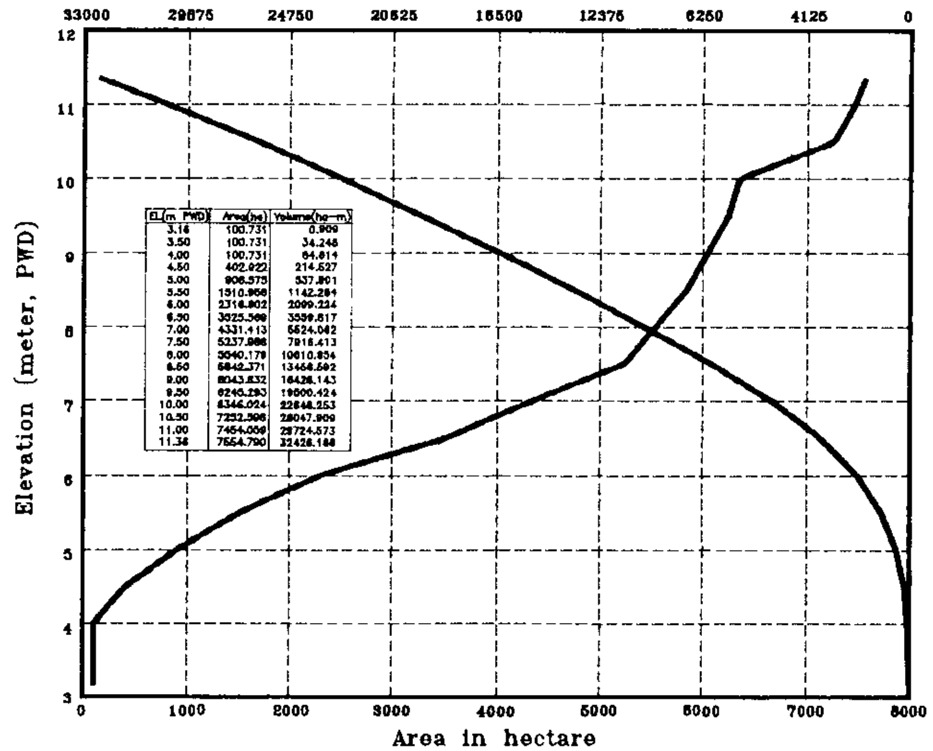
EL(m PWD)	Area(ha)	Volume(ha-m)
1.92	214.59	38.30
2.00	214.59	55.46
3.00	262.69	282.08
4.00	732.56	728.83
5.00	1220.93	1664.88
6.00	1679.49	3196.59
7.00	2349.37	5313.79
8.00	2597.25	7623.17
8.50	2626.85	8129.20
8.63	2630.65	8206.06

Chalti River Project



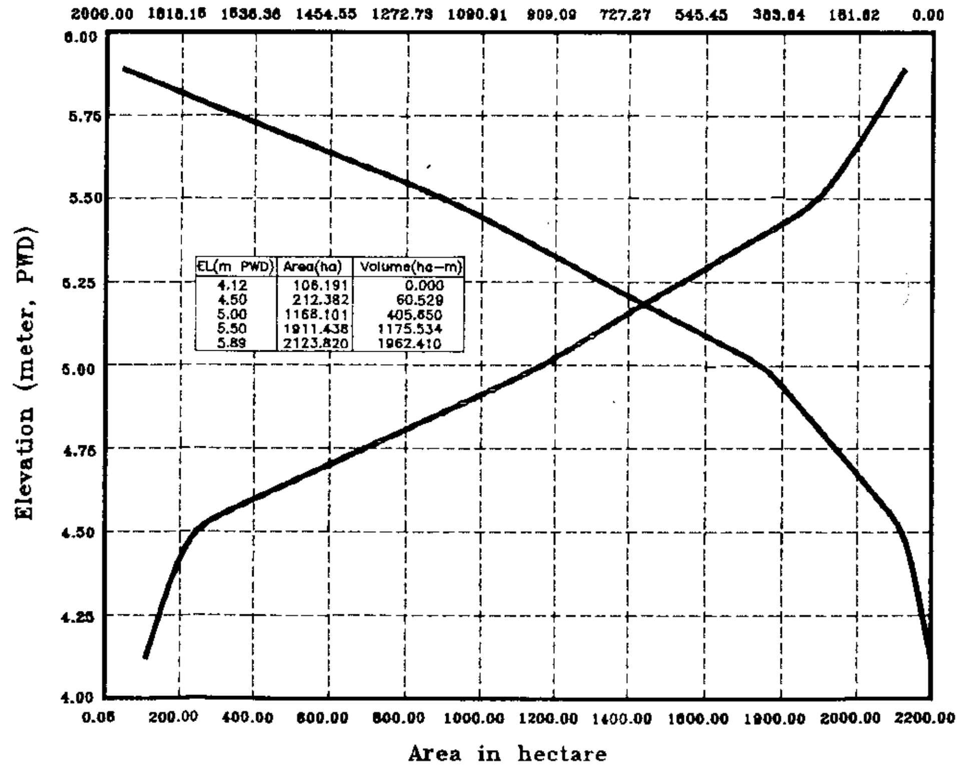
EL(m PWD)	Area(ha)	Volume(ha-m)
6.57	94.806	0.000
7.00	379.223	101.916
7.50	848.058	433.736
8.00	1611.898	1073.875
8.50	3033.785	2235.046
9.00	3981.843	3988.953
9.50	5593.541	6382.799
10.00	6361.867	9369.182
10.50	7016.628	12711.085
11.00	7394.851	16313.705
11.50	7584.463	20058.534
12.00	7594.463	23850.785
12.50	7679.268	27665.698
12.59	7888.980	28133.142

Maharram River Area



EL(m PWD)	Area(ha)	Volume(ha-m)
3.16	100.731	0.000
3.50	100.731	34.246
4.00	100.731	64.814
4.50	402.922	214.527
5.00	906.575	537.801
5.50	1510.966	1142.284
6.00	2316.802	2009.224
6.50	3025.369	3559.617
7.00	4331.413	5624.042
7.50	5237.986	7916.413
8.00	5640.179	10010.854
8.50	5842.371	13464.592
9.00	6043.832	16426.143
9.50	6240.293	19600.424
10.00	6346.024	22648.253
10.50	7252.596	26047.909
11.00	7454.009	28724.573
11.34	7654.790	32426.184

Area between Halir Haor and Rakti River

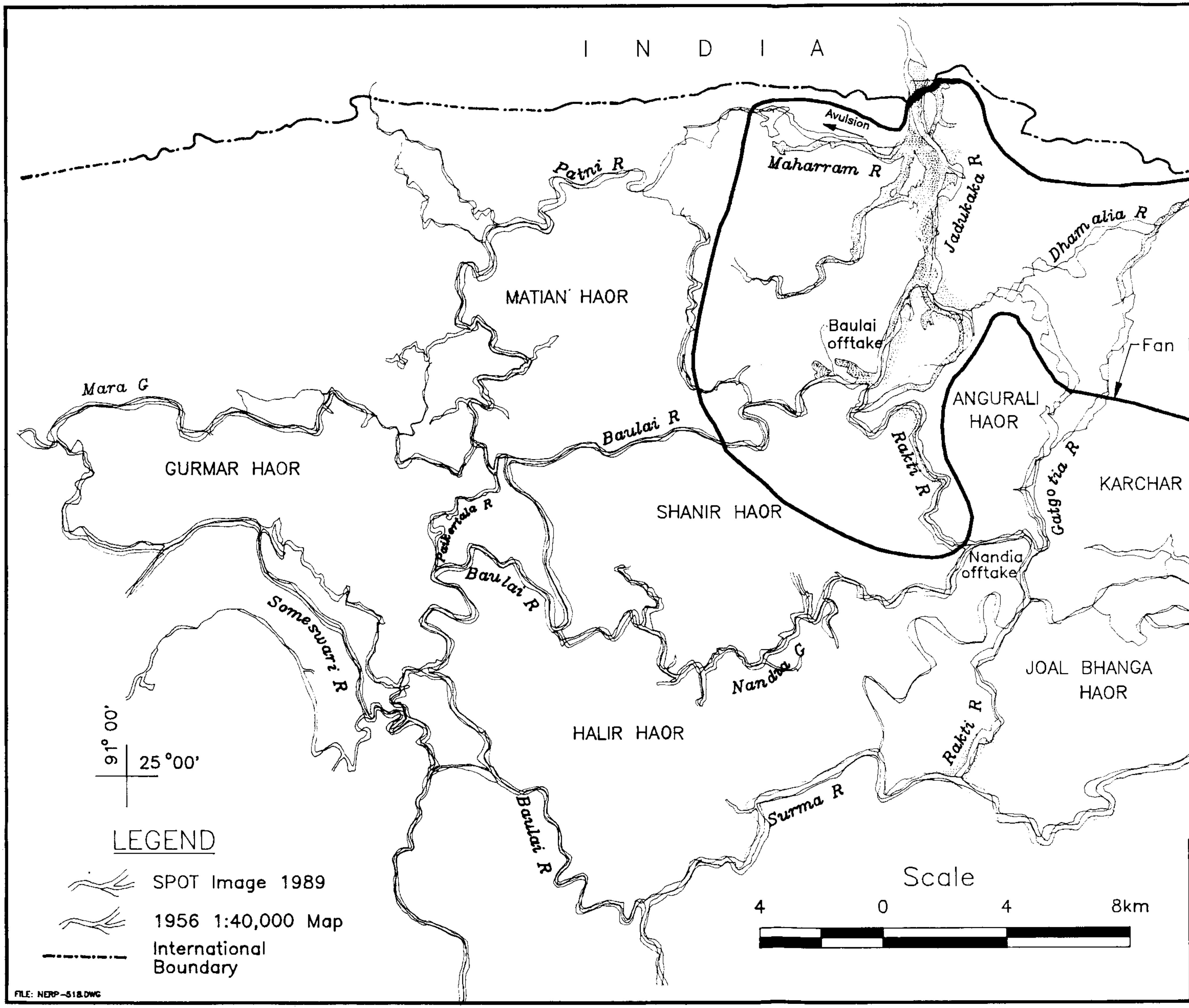


EL(m PWD)	Area(ha)	Volume(ha-m)
4.12	106.191	0.000
4.50	212.382	60.529
5.00	1168.101	405.650
5.50	1911.438	1175.534
5.89	2123.820	1962.410

Northeast Regional Project	
Area Elevation & Storage Volume Storage (ha-m)	
Prepared by: Nasim	December 1993
Drawn by: Mamun	AutoCAD Drawing

FILE: NERP-744.DWG

Figure 7

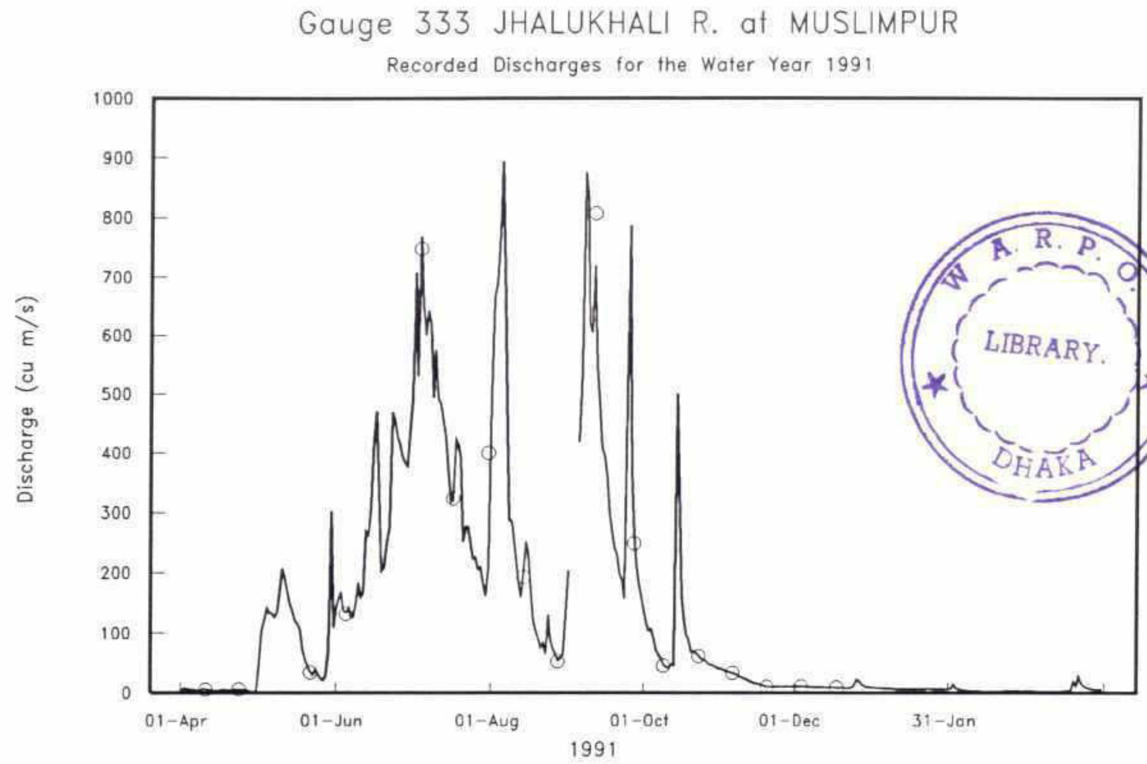


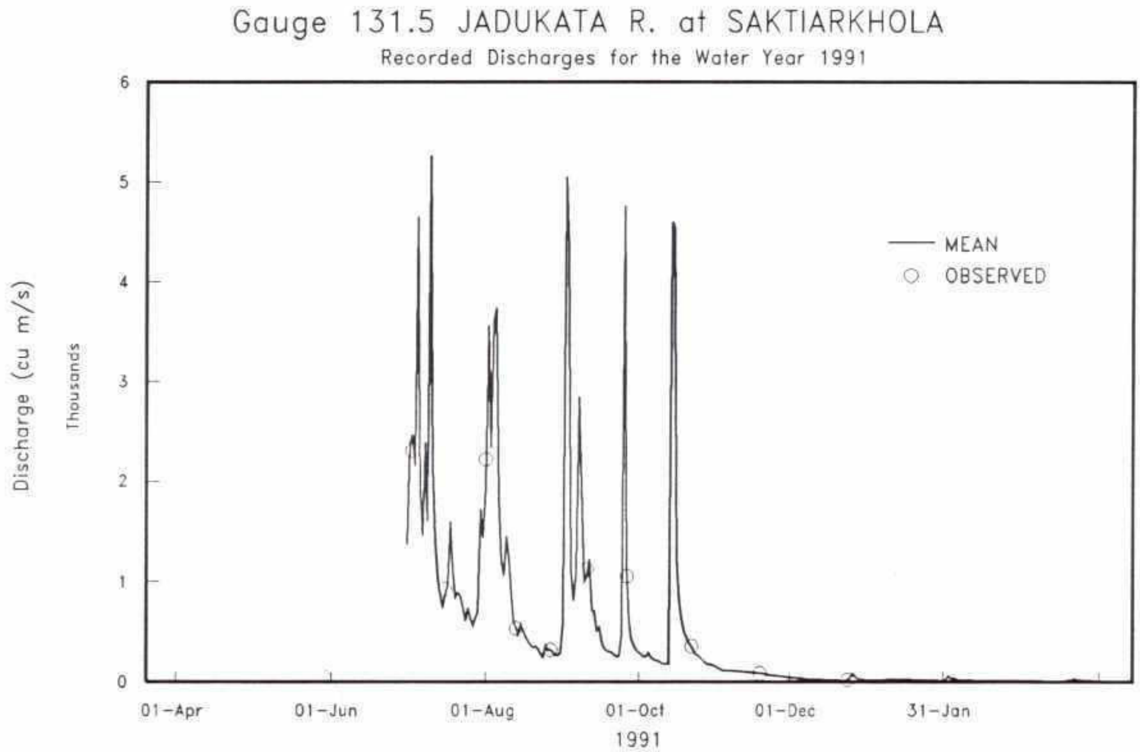
Northeast Regional Project

Changes on Alluvial Fans Jadukata & Jhalukhali River

Prepared by: Mamun | January 1993

Figure 8

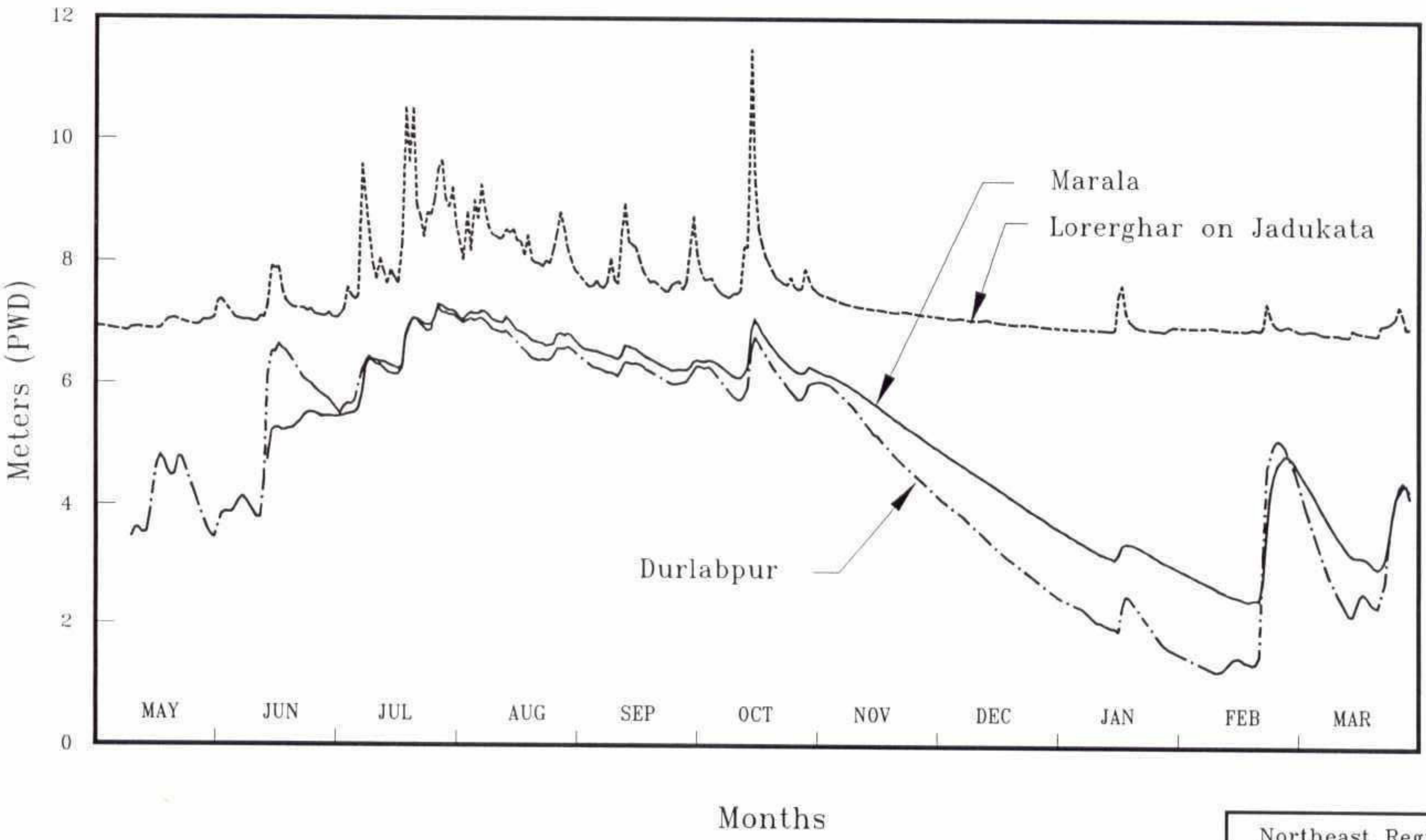




Northeast Regional Project			
Discharge Hydrographs on Meghalaya Streams			
Prepared by:	DMc/Nasid	December 1993	
Drawn By:	Mamun	AutoCAD Drawing	

FILE: NERP-746.DWG

Figure 9



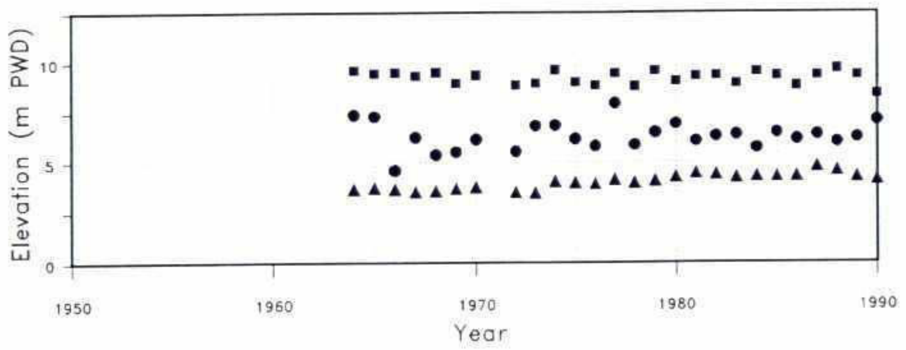
Northeast Regional Project

Water Level Around
Profile Area 1992

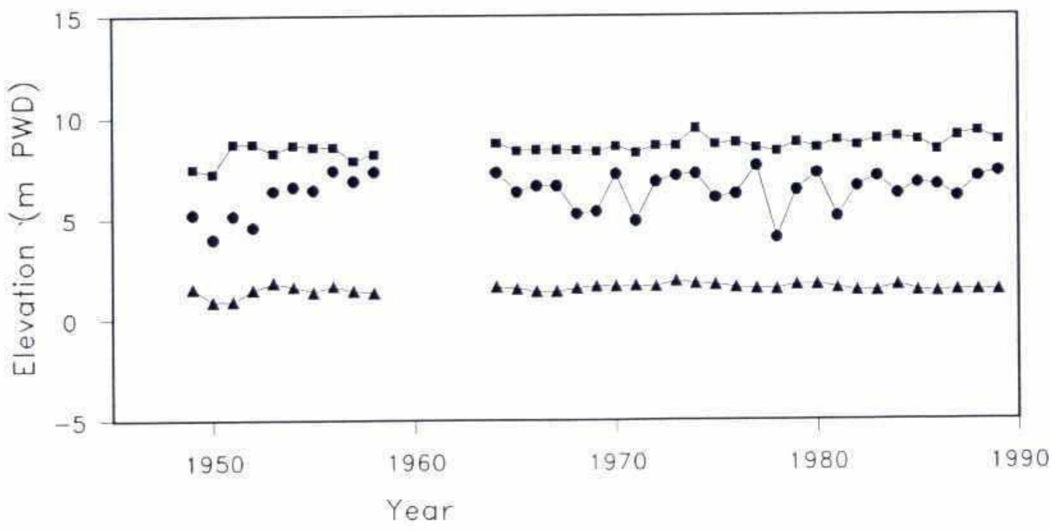
Prepared by:	CHW	November 1993	
Drawn by:	Mamun	AutoCAD Drawing	

FILE: NERP-704DWG

Jadukata River at Saktiarkhola



Surma River at Sunamganj



Legend

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

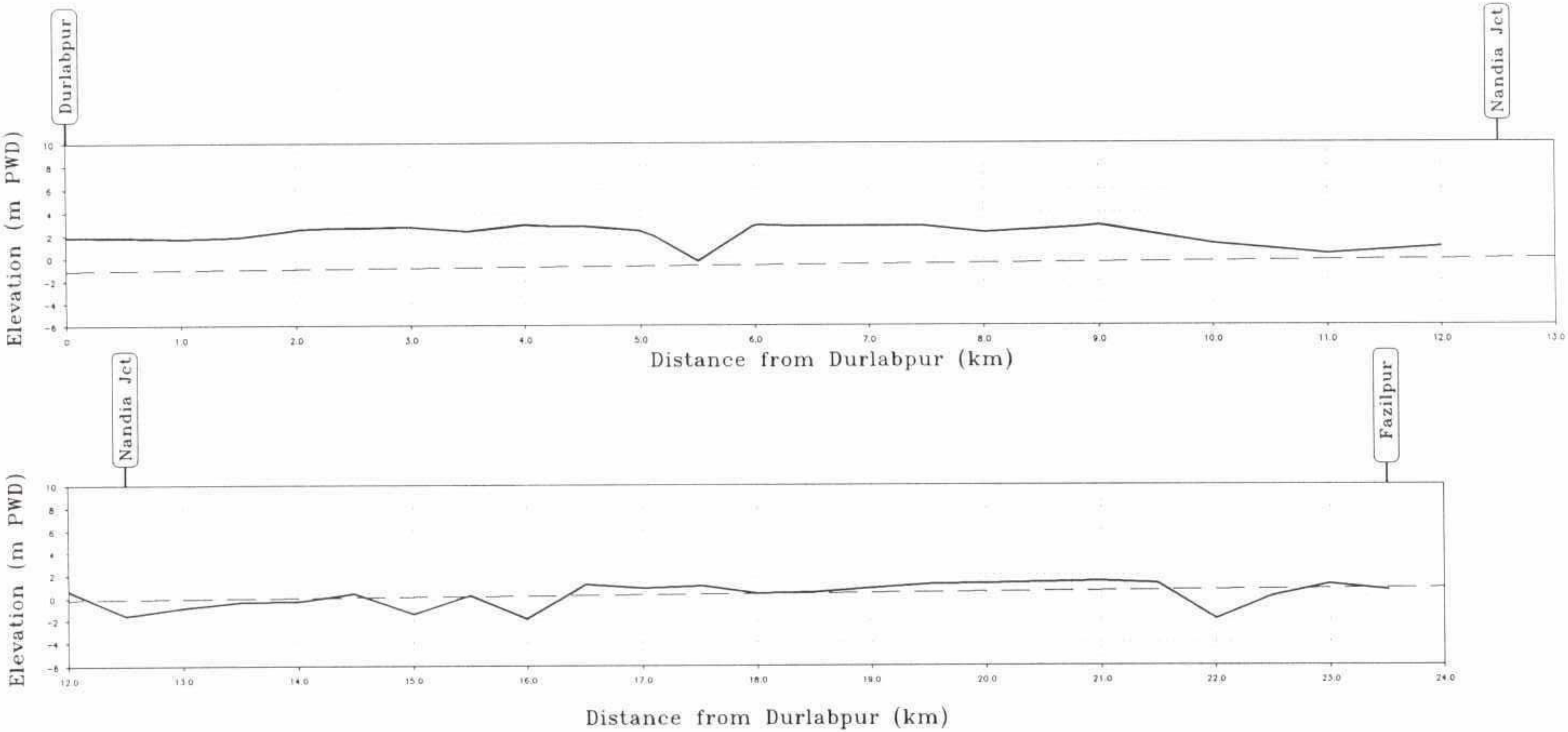
Northeast Regional Project

Historic Trends in Water Levels

Prepared by:	DMc	December 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-745.DWG

Figure 11



Legend

- — — — BIWTA Class II Channel
- ——— Existing Mean Bed

Northeast Regional Project		
Rakti River Bed Profile		
Prepared by:	CHW	November 1993
Drawn by:	Mamun	AutoCAD Drawing

FILE: NERP-709.DWG

Figure 12

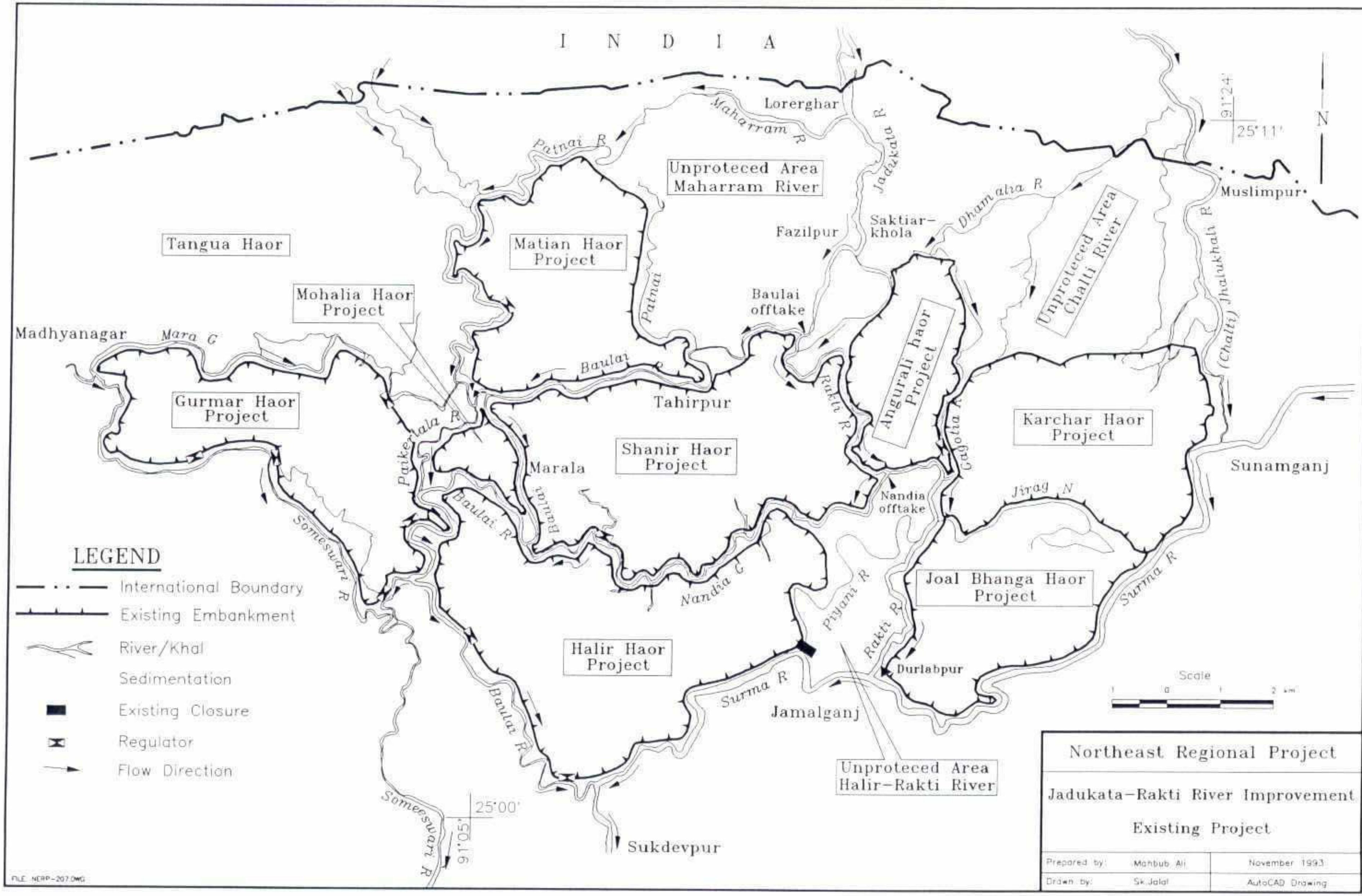

INDIA
N
91°24'
25°11'
Muslimpur
Lorerghar
Maharram R
Patnai R
Jadukata R
Unproteced Area Maharram River
Dhamalia R
Unproteced Area Chalti River
(Chalti) Jhalukhali R
Saktiar-khola
Fazilpur
Tangua Haor
Matian Haor Project
Patnai
Baulai offtake
Mohalia Haor Project
Madhyanagar
Mara G
Baulai
Tahirpur
Rakti R
Angurali haor Project
Gagotia R
Karchar Haor Project
Sunamganj
Gurmar Haor Project
Paikertala R
Marala
Shanir Haor Project
Nandia offtake
Jirag N
Baulai R
Baulai
Someswari R
Nandia G
Piyani R
Joal Bhanga Haor Project
Surma R
LEGEND
International Boundary
Existing Embankment
River/Khal
Sedimentation
Existing Closure
Regulator
Flow Direction
Halir Haor Project
Rakti R
Durlabpur
Scale
1 0 1 2 km
Surma R
Jamalganj
Baulai R
Unproteced Area Halir-Rakti River
Northeast Regional Project
Jadukata-Rakti River Improvement
Existing Project
Prepared by: Mahbub Ali
November 1993
Drawn by: Sk.Jalal
AutoCAD Drawing
Someeswari R
25°00'
91°05'
Sukdevpur
FILE NERP-207.DWG

Figure 13

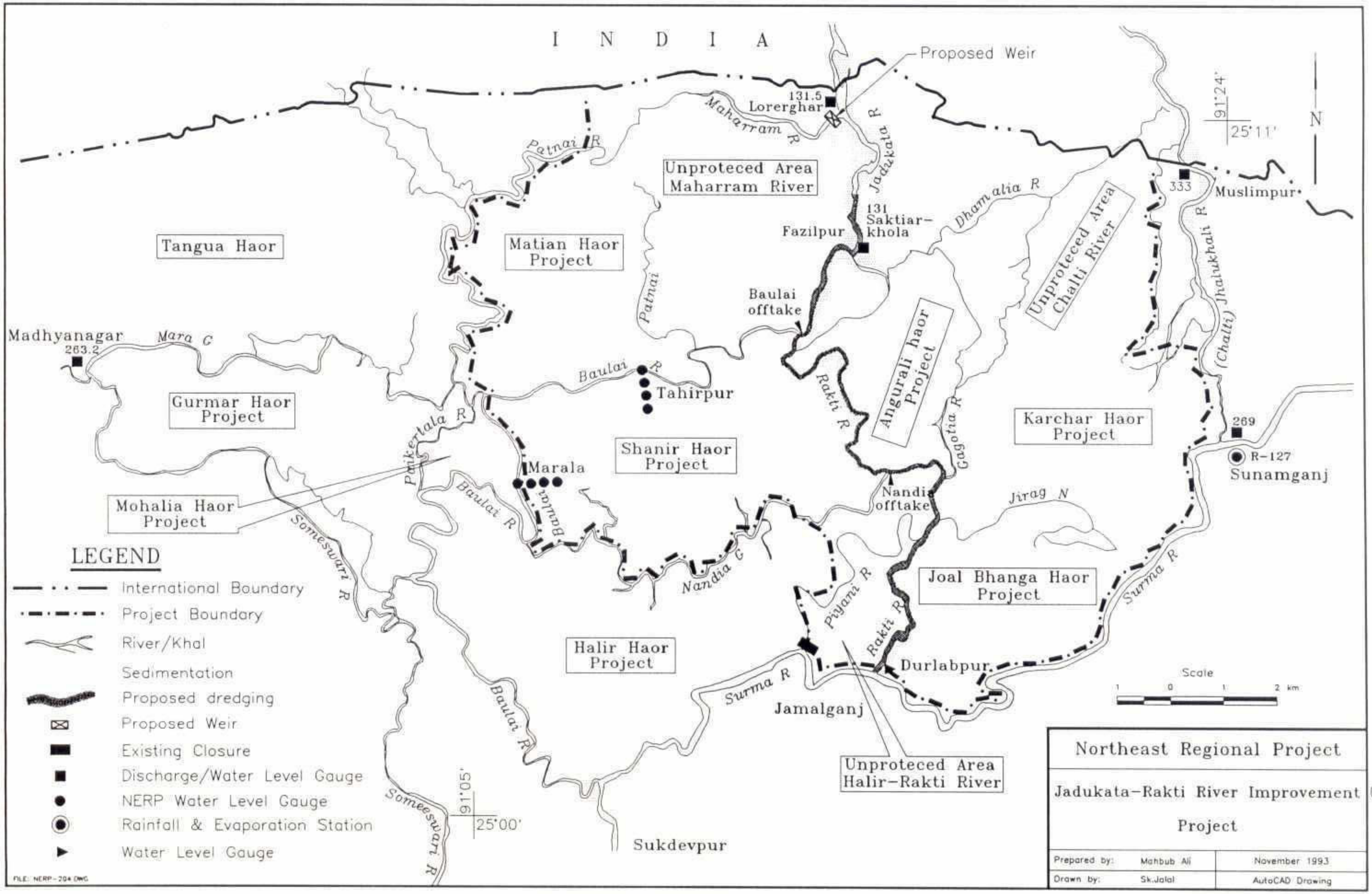
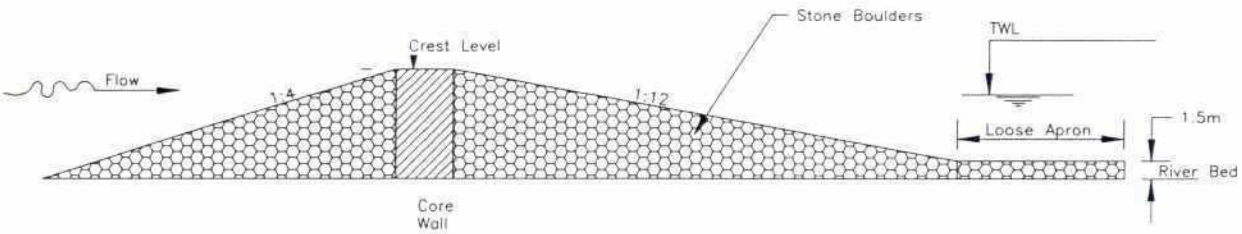

I N D I A
Proposed Weir
131.5
Lorerghar
Maharram R
Jadukata R
Unproteced Area
Maharram River
131
Saktiar-
khola
Fazilpur
Dham alia R
Unproteced Area
Chalti River
333
Muslimpur
91°24'
25°11'
N
Tangua Haor
Matian Haor
Project
Patnai R
Patnai
Baulai
offtake
Anguraili haor
Project
Jhalukhali R
(Chalti)
Madhyanagar
263.2
Mara G
Baulai R
Tahirpur
Rakti R
Gagotia R
Karchar Haor
Project
269
R-127
Sunamganj
Gurmar Haor
Project
Paikertala R
Marala
Shanir Haor
Project
Nandi
offtake
Jirag N
Mohalia Haor
Project
Baulai R
Baulai
Someswari R
Nandia G
Joal Bhanga Haor
Project
Surma R
Piyani R
Rakti R
Halir Haor
Project
Durlabpur
Surma R
Jamalganj
Scale
1 0 1 2 km
Baulai R
Unproteced Area
Halir-Rakti River
Someeswari R
91°05'
25°00'
Sukdevpur
LEGEND
International Boundary
Project Boundary
River/Khal
Sedimentation
Proposed dredging
Proposed Weir
Existing Closure
Discharge/Water Level Gauge
NERP Water Level Gauge
Rainfall & Evaporation Station
Water Level Gauge
FILE: NERP-204.DWG
Northeast Regional Project
Jadukata-Rakti River Improvement
Project
Prepared by: Mahbub Ali
November 1993
Drawn by: Sk.Jalal
AutoCAD Drawing

Figure 14



Typical Cross Section

Northeast Regional Project

Jadukata-Rakti River Improvement

Submersed Weir on Maharram River

Prepared by: Mahbub Ali	October 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-053.DWG

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

ANNEX C: INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

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

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

C.2 Alternative 1: Proposed Drainage Project

C.2.1 Project Design and Description (Step 1)

As in Section 7.3, Project Description.

C.2.2 Environmental Baseline Description (Step 2)

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

C.2.3 Scoping (Step 3)

Technical:

Literature review: Presented in Chapter 4, Previous Studies.

Local community: As described in Section 3.1.9, People's Perception.

C.2.4 Bounding (Step 4)

Physical:

Gross area: 37,434 ha.
Impacted (net) area: 30,322 ha.
Impacted area outside project: The project does not have any negative impact outside the project area.

Temporal:

Pre-construction: years 0 through year 3 (see Table 7.6).
Construction: year 1 through year 2 (see Table 7.6).
Operation: year 3 through year [?].
Abandonment: after year [?].

Cumulative impacts:

: With other floodplain infrastructure: This will be looked at in the context of the Regional Plan.
With pre-existing no-project trends. Described in Chapter 5.

C.2.5 Field Investigations (Step 5)

Field investigations primarily involved seven days in total, of informal reconnaissance by a multidisciplinary team. Physical surveys of the Rakti channel were made using a depth sounder and GPS survey system. Additional detailed monitoring has been carried out periodically between 1992-1993 in Shanir Haor and along the Baulai, Nandia Gang and Rakti Rivers as part of NERP's Project Monitoring Program (PMP).

C.2.6 Impact Assessment (Step 6)

At this level of detail, 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 7.8.

C.2.7 Quantify and Value Impacts (Step 7)

Quantification and evaluation of impacts is documented in Section 7.8.1 and Tables 7.12 through 7.14.

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. Documented in Section 7.8.1

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

- In-kind rather than cash compensation for households whose homestead land is taken.

- Compensation for persons other than landowners who are impacted negatively by land acquisition and construction/infrastructure-related land use changes. Example: project implementation could be made contingent upon successful resettlement of squatters displaced from embankment/structure sites under local initiative; local communities could work with NGOs to accomplish this.

Monitoring. There is a need to define monitoring needs and methodologies at regional, institutional (BWDB), and projects levels. This exercise should reflect (i) the need for greater people's participation in all project activities, which would include monitoring project function and opportunities for discussion with BWDB and (ii) the need for greater emphasis on operation and maintenance, of which monitoring can play an important role.

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.

Disaster management (contingency planning). Once the flood protection is operational, investment in agriculture will likely rise. This increases the total amount of farmers' assets that are at risk should an extreme flood event occur or the embankment fail for any reason. Currently in Bangladesh, these risks are borne by individual investors (in this case farmers). Unsustainable solutions (such as government subsidy of crop insurance) should be avoided however.

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. At a national or regional scale, there is a need to develop satisfactory reporting/accountability arrangements involving BWDB and DOE, probably through an Environmental Cell within BWDB linked to DOE. At the project level, the client committee and local BWDB staff should develop reporting/accountability arrangements satisfactory to themselves. 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.

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
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition										
		People's participation activities		+	+				+			
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)							+			
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal							+			
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving										
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving										
		Tube well installation: boring, distribution facilities, electrification										
	Abnormal	Suspension of construction before completion, construction delays		–	–				–			
		Incorrect construction practices or techniques										

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
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre-monsoon flood protection		+	+		+				+	
		Monsoon flood protection										
		Surface water irrigation		+			+					
		Ground water irrigation N/A										
		Drainage		+	?		+		+			
		Agriculture: operation of institutions, extension, credit, seed distribution, fertilizer and pesticide storage and use, farmer groups			?				+			
		Water management: activities of BWDB, subproject implementation committee, local water user groups, structure committees and guards		+					+			
	Abnormal (relative to FWO, not FW normal)	Pre-monsoon flooding (due to extreme event, infrastructure failure)	–	–	–	–	–		–		–	
		Monsoon flooding (due to extreme event, infrastructure failure)										
		Embankment overtopping		–								
		Under- and over-drainage	–	–				–	–			
		Improper operation (public cuts, mistiming of scheduled O&M events etc)										
		Riverbed aggradation/degradation										
Abandonment	Normal	Re-occupation of infrastructure sites										
		Reclamation of materials										
	Abnormal											

ANNEX D

FISHERIES MODEL

This annex briefly describes the model used to analyze fisheries impacts for the project.

The openwater fishery ecosystem is extremely complex. Impacts on production are assessed here using a highly simplified model. The limitations of the model mirror the limitations of the current understanding of and information about the system.

The major system processes about which some insight exists are:

- Migration access and timing. It seems to be accepted that:
  - a multiplicity of access points is desireable (i.e. that closing any or some channels is still deleterious,
  - the most important channels are those at the downstream end of the system (that with flood onset, fish mainly migrate upstream and onto the floodplain, and downstream out of the beels into the river), and
  - delay of flooding, as in partial flood control schemes, is highly disruptive

- Overwintering (dry season) habitat extent.

- Wet season habitat (floodplain grazing extent and duration). [It is expected that production also varies as a function of land type (F1, F2, F3) — probably such that shallower (F1, F2) land is more productive than deeper (F3) land — but as data to show this has been lacking it has been neglected from the model.]

- Habitat Quality. Habitat quality would include water quality, vegetation, and other conditions (presence of preferred types of substrate e.g. rocks, sand, brush). Water quality would appear to be most relevant during low volume/flow periods, and during the time of flood onset and recession when contaminants can disperse or accumulate.

- Spawning. Production outside the project area can also be impacted if habitats suitable for spawning within the project are adversely affected. It is believed that most of the region's fish production stems from spawning occurring in: mother fishery areas, which are those exhibiting extensive, well-interconnected, and varied habitats with good water quality; key beels; and river duars. Duars are somewhat a separate problem as they are located in rivers and larger channels, not on the floodplain.

The foregoing is represented quantitatively here as:

FWO production =

$$(R_0 * P_{RO}) + (B_0 * P_{BO}) + (W_0 * P_{WO})$$

FW production =

$$[M * Q * (R_1 * P_{RO})] + [M * Q * (B_1 * P_{BO})] + [M * (W_1 * P_{WO})]$$

Thus,

Impact = FW - FWO production =

$$\{ [(M * Q * R_1) - R_0] * P_{R0} \} +$$

$$\{ [(M * Q * B_1) - B_0] * P_{B0} \} +$$

$$\{ [(M * W_1) - W_0] * P_{W0} \}$$

where

sub-0 and sub-1 refer to FWO and FW respectively

R, B, and *W* are river/channel, beel, and floodplain (F1+F2+F3) areas, in ha

P is the unit FWO production in kg/ha for the respective habitats. Estimated regional average values are 175, 410, and 44 respectively.

M is the FW quality-weighted migration access remaining, relative to FWO conditions (range 0 to 1 for negative impacts, >1 for positive impacts)

Q is the FW acceptability of habitat/water quality relative to FWO conditions (range 0 to 1 for negative impacts; >1 for positive impacts).

A_M is the area of mother fishery and key beels affected times a factor (range 0 to 1 for negative impacts, >1 for positive impacts) reflecting the degree of degradation/enhancement

T is the estimated annual regional fish production attributable to spawning exported from mother fisheries/key beels (a constant of 50,000 tonnes, which is 50% of the total regional fish production of 100,000 tonnes)

A_T is the estimated regional mother fishery/key beel area (a constant of 100,000 ha).

Estimated values for this project are shown in Table D.1. Where standard values, established for the region or for a particular project type, are used, this is noted. Comments on project-specific values are also shown.

It is estimated that one person-day is required to capture one kilogram of fish on the flood plain.

Table D.1: Fisheries Parameters

Var	Value	Stnd value?	Comments
M	1	1	Fish migration routes will be improved with channel re-excavation and access to the Surma River will be retained.
Q	1	1	Water quality is expected to improve since water will not stagnate in the system.
R_0	167		
R_1	239		About 14 km channel will be re-excavated from its present bed level + 2.0 m PWD to - 1.1 m PWD.
B_0	1716		
B_1	1716		
W_0	23686		
W_1	23686		
P_{RO}	175	175	
P_{BO}	410	410	
P_{WO}	44	44	
A_M	—	100000	There is a "mother fishery" adjacent to the project area.