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)

MRIGI RIVER DRAINAGE IMPROVEMENT PROJECT

November 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

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NOT FOR CIRCULATION
PRELIMINARY DRAFT
For Discussion Only.

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EXECUTIVE SUMMARY

The Mrigi River Drainage Improvement Project is located in Jamalpur and Sherpur Districts of Bangladesh and has a net area of 45,520 ha. The objective of the Project is to reduce agricultural damage resulting from drainage congestion without negatively affecting fisheries or navigation.

Rice based agriculture is the main economic output of the area and increased production is constrained because of inadequate pre- and post-monsoon drainage. On-going sediment deposition in the drainage system will result in increasing crop losses in the future, and will hamper navigation and river fish production. Production on land in adjacent areas to the north will also decline over time since sand coming from the upland hilly areas is deposited on agricultural land.

The proposed project includes:

- Re-excavating 28.2 km of the Mrigi River from Boysha Beel to Char Betmari;
- Rehabilitating the left bank of the Old Brahmaputra River from Nij Kharmarer
- Char to Gogra Kandi (35 km); and
- Enhancing fisheries in 10 ox-bow lakes by establishing nurseries and setting in-place a weed eradication program.

A 28 km reach of the Upper Mrigi River (from Matiphata to Boysha Beel) is being re-excavated in 1993 under the Canal Digging Program. This excavation combined with the proposed excavation will increase the inundated surface area by some 300 ha. By comparison, the improved drainage will reduce inundated beel areas by an estimated 15 ha. Therefore, the excavation should have a positive impact on fisheries production.

Rehabilitating the left bank of the Old Brahmaputra River should be carried out prior to channel excavation so that major siltation will not occur from Old Brahmaputra River flood overflows.

It should be noted that FAP-3.1 is proposing to embank the right bank of the Old Brahmaputra River as part of the Jamalpur Priority Project. FAP-25 assessed the impact of this scheme and found flood levels will be raised by up to 0.54 m at Jamalpur. Therefore, further raising and strengthening of the left bank embankment should be taken up simultaneously with construction of the right embankment.

The Mrigi River Drainage Improvement Project would be implemented by the Bangladesh Water Development Board as the lead agency and is expected to cost US $1.3 million.

ACRONYMS AND ABBREVIATIONS

BBS	Bangladesh Bureau of Statistics
BFRSS	Bangladesh Fisheries Resource System Survey
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DPHE	Department of Public Health Engineering
EIA	environmental impact assessment
EIRR	economic internal rate of return
EMP	Environmental Management Plan
EPWAPDA	East Pakistan Water and Power Development Agency
FAP	Flood Action Plan
FFW	Food for Work
FPCO	Flood Plan Coordination Organization
FW	future with project scenario
FWO	future without project scenario
HTW	hand tube well
HYV	high yielding variety
IBRD	International Bank for Reconstruction and Development
IEE	Initial Environmental Evaluation
ISPAN	Irrigation Support Project Asia Near East
LLP	low-lift pump
LT	local transplanted
MPO	Master Planning Organization
NERP	Northeast Regional Water Management Planning Organization
NGO	non-governmental organization
NHC	Northwest Hydraulic Consultants
NPV	net present value
PD	person-day
PWD	Public Works Department
RCC	reinforced concrete
SLI	SNC-Lavalin International

US $1 = Tk 38

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1. INTRODUCTION

1.1 General Information

BWDB Division:	Tangail O & M
District:	Portion of Jamalpur and Sherpur
Thana:	Portions of Bakshiganj, Sribardi, Jhenaigati, Sherpur Nakhla and Jamalpur
MPO Planning Area:	19 (part)
Gross Basin Area:	57,600 ha
Net Basin Area:	45,520 ha
Net Project Area:	20,400 ha

1.2 Scope and Methodology

This is a prefeasibility study that was undertaken over a period of one month in early 1993. The field study team consisted of a water resources engineer, social anthropologist, agronomist, fisheries specialist, and wetland resources specialist. Additional analytical support was provided by an environmental specialist and economist.

1.3 Report Layout

A description of the physical 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 people's perceptions of the types of problems they face. Chapter 4 briefly reviews previous studies and Chapter 5 lists trends that are occurring in the project area. Chapter 6 reviews water resource development options and Chapter 7 describes the suggested options. Chapter 8 flags outstanding issues. The annexes consist of detailed information to support the text in the main body of the report.

2. BIOPHYSICAL DESCRIPTION

2.1 Project Boundaries

The project is located in Sherpur District between latitude 24°52' and 25°18'N, and longitude 89°52' and 90°12'E. It is bounded to the north by the Bangladesh border with India and to the south by the Old Brahmaputra River. The Jamalpur-Bakshiganj Road provides a western boundary and to the east, by the apex of the drainage boundary of the Karnajhora River and a river locally named the Someswari (Annex E, Figure 1).

2.2 Climate

There are no climatological stations within the project area. The nearest station is at Jamalpur. Climatological data for this station is presented in Annex A, Table A.1. April through September is the hot period and during this period, mean monthly temperature range between 26.5°C and 28.6°C. July is the warmest month. Minimum recorded temperatures occur between December and February when mean monthly temperatures range from 19.5°C and 21.0°C. January is the coldest month. The temperature data indicates that freezing temperatures do not occur and, in general, temperatures in the area are high enough to grow crops throughout the year.

A review of the rainfall distribution shows a general pattern which is increasing from the southwest to the northeast. The mean annual rainfall varies from 2650 mm in the northern part of the area to 2200 mm in the south. About 70% of the annual rainfall occurs during the four months between June and September of each year.

Wind velocity is low, varying from 3 knots (5.55 km/hr) to 6.0 knots (11.10 km/hr).

2.3 Land (Physiography)

2.3.1 General Description

The Project lies in the Old Brahmaputra floodplain. Old Brahmaputra floodplain lands consist of deposits that were laid down prior to the river's abandonment of this course in the 18th century. However, about 32.0 km^2 of the area north of Matiphata village is in the alluvial fan of the Meghalaya foothills. The Karnajhora River carries a high load of sand. Large quantities of this sand are deposited in this area (above Matiphata).

The land slopes from north to south with land elevations varying from 24.5 m PWD on the northern perimeter to 12.0 m PWD on the southern perimeter. There are a few small beels, most of which have been filled with sediment. Boysha Beel is the largest in the area.

The project basin elevation versus cumulative area relation is given in Annex A, Table A.2 and is shown graphically in Annex E, Figure 2.

2.3.2 Soils

The project area consists mostly of broad ridges and irregular relief near river channels. The ridge soils are generally wet or shallowly flooded at the peak of the annual floods and are mainly silt loams and silty clay loams. While the general soil type is predominately Dark Grey Floodplain, the ridges contain Brown Floodplain soils. Soil patterns in the areas close to hills are complex due to the irregular deposition of different textured sediments during successive flash floods. In these areas, Grey Piedmont soils and Noncalcareous Grey Floodplain soils are the major general soil types and the soils are loam to clay in texture, having slightly acidic to strongly acidic reaction. The highest ridge soils are rapidly permeable.

Lower ridge soils used for transplanted aman cultivation are slowly permeable, as are basin clays. Moisture holding capacity is high in deep silt loams on ridges, but is moderate or low in more sandy or shallowly ridged soils, soils puddled for transplanted aman cultivation and, especially, in basin clays. Clays predominate in the beels.

2.4 Water (Hydrology)

2.4.1 River System

The project area includes two river systems: the Old Brahmaputra River, which flows along the southern border of the project, and the Karnajhora-Mrigi River, which flows through the centre of the area.

The Karnajhora-Mrigi River originates in the Meghalaya Hills and flows 80 km inside Bangladesh to meet the Old Brahmaputra River near Char Astadhar. At Boysha Beel the river changes from Kharnajhora to the Mrigi River; the upper reach is the Karnajhora River (32.0 km) and the lower reach is the Mrigi River (48.0 km).

There are no hydrological measurement stations within the area except on the Old Brahmaputra River at Jamalpur and Sirkhali Offtakes (water level only). Measurement at Sirkhali Offtake was abandoned in 1985. The annual peak water levels at these two stations for different recurrence intervals are presented in Annex A, Table A.3.

The average annual peak level of the Old Brahmaputra River at Jamalpur and Sirkhali Offtakes is 17.01 m,PWD and 14.39 m,PWD respectively.

2.4.2 Flooding

The area is affected mainly by monsoon floods from the Old Brahmaputra River. While flooding is prevented by the Jamalpur-Bakshiganj Road and the embankment along the river from Nij Kamarer Char to Digir Char the area remains open to flooding from the downstream end near Chandrakona-Digir Char. In addition, embankment breaches at Jangalia which occurred during the 1988 floods have not been repaired and cause flooding in the project's southern area. Flood water also enters from the Old Brahmaputra River through Katakhali Khal.

The northern areas are inundated by monsoon spills from the Karnajhora River. These are flash floods of short duration. While water from these floods does not in and of itself damage crops, it carries sand which is deposited on the land, burying crops and reducing soil fertility.

2.4.3 Drainage

Drainage is mainly effected through the Karnajhora-Mrigi River to the Old Brahmaputra River. There are two minor outlets, Katakhali Khal and Bhaterpur Khal. The Karnajhora-Mrigi River has filled with sediment and this causes drainage congestion in the area.

2.4.4 Water Bodies

Open water bodies
About 21,290 ha (37%) of the project area is seasonally inundated to depths greater than 0.3 m, of which 680 ha (4%) is perennial beels (Annex A, Table A.4). The larger permanent water bodies are Kursa Beel, Mehididanga Beel, Pekua Beel, Dublakuri Beel, Bardubi Beel, Jhaiduba Beel, Betmari Beel, Kahunia Beel, Boysha Beel, Mrigi Beel, Dhiar Beel and Satpakia Beel (Para Beel). The Karnajhora and Mrigi Rivers are the main drainage channels in the project area. Excluding these rivers, a number of khals exist within the project area. Khals are narrow and seasonal; volume decreases daily due to siltation and human encroachment.

Closed water bodies
In addition to the open beels and khals, there are over 2100 ponds (having an area of about 300 ha) used for fish culture and day to day activities (Annex A, Table A.5). There are also about 1500 ditches (about 12-15 ha) which are suitable for seasonal fish production.

2.4.5 Surface Water Availability

Surface water is very scarce in the area. Fifty percent (2-yr), eighty percent (5-yr) and ninety percent (10-yr) dependable flow in the Old Brahmaputra River at Nilukhir Char (near Mymensingh) is presented in Table 2.1.

During a field visit, very little dry season flow was observed in the Karnajhora-Mrigi River System. The Mrigi River becomes almost dry during the lean period. There is however a small amount of inflow, seepage from the hills, at the head of the Karnajhora River (less than one m^3/s). This is used by the farmers who have put an earthen dyke across the stream at Karnajhora.

2.4.6 Groundwater

Usable and available groundwater, within the project area by thana, under different lifting techniques is given in Annex A, Table A.6 and summarized in Table 2.2

Table 2.1: Dependable Flow

Station No: 228.5
Station Name: Nilukhir Char
River Name: Old Brahmaputra

Month	Decade	Dependable discharge (m^3/sec)		
		2-yr	5-yr	10-yr
Jan	I	34	24	22
	II	30	22	20
	III	26	20	18
Feb	I	23	17	16
	II	20	16	14
	III	18	14	13
Mar	I	16	12	11
	II	15	12	11
	III	14	11	11

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Table 2.2 : Usable and Available Recharge

Usable Recharge (Mm³)			Available Recharge (Mm³)		
STW	DSSTW	DTW	STW	DSSTW	DTW
85	150	260	77	133	225

2.5 Land/Water Interactions

2.5.1 Siltation

Serious siltation occurs in the upper and lower reaches of the Mrigi River. The upper reaches of the river flow over an alluvial fan where the gradient is relatively flat. Incoming sediments are deposited on the rivers' bed and bank areas. At its outfall, the river is almost closed as a result of siltation. This has occurred as a result of backwater from the Old Brahmaputra River. The middle reaches of the river system some siltation is occurring. The sediments are brought in from the Old Brahmaputra River by flood water flowing through breaches in the embankment.

2.5.2 River Erosion

Except where it flows through the alluvial fan area, the river appears to be stable. Within the fan, there is lateral erosion mainly due to bed deposition.

2.5.3 Crop Damage

Mrigi River is the only drainage channel of the area. Because the river has infilled with sediment it cannot drain the rainfall or cross border inflows adequately. Consequently, areas cultivated with transplanted and deepwater aman are damaged when the crops are at the vegetative stage and/or the panicle initiation stage. Crop losses increase if the water stays for longer periods.

2.6 Wetlands and Swamp Forest

2.6.1 Natural Wetlands

Wetlands are not very prominent in this project area, with the exception of some perennial beels mostly in Nakhla thana. These perennial beels are listed in Annex A, Table A.4. Other beels are very shallow and usually dry in the winter. The situation is worsened by the utilization of their water for irrigation. These wetlands are neither very productive nor biodiverse.

Wetlands in the lower part of the project area, especially in Nakhla thana, are deeper and basically retain their original boundaries. But due to their marked boundaries, they look and behave like big ponds rather than beels. These beels are not very productive.

2.6.2 Swamp Forest Trees

There is no swamp forest within this project.

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)	45,520
Homesteads	2,600
Beels	680
Ponds	300
Channels	1,900
Hills	3,200
Fallow[1]	600
Infrastructure[2]	2,800
Total	57,600

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

General Description of Settlements.
Settlements within the project area are mainly villages along the levees of rivers and along various road sides. In places where land elevation is higher, homesteads are also constructed in the fields. The river banks and road sides are densely settled, as is the land around the thana headquarters and market centres. Settlements tend to be sparsely scattered in the fields and in low-lying beel areas. In the northern hilly areas, settlements are extremely sparse, found mainly along the foothills. Settlements are also sparse in the char lands in the southern part of the project.

Flood Damage to Housing
Generally, households located on higher lands are not damaged by floods. However, monsoon flash floods are common occurrences in the area and cause erosion to homesteads, especially those along the Karnajhora-Mrigi River and in areas where land elevation is low.

Coping Strategies
Homesteads platforms are usually raised to one meter or more to avoid monsoon flooding. Flood waters from the monsoon flash floods usually recede from the homesteads within a day or two. If there is severe flooding, villagers generally make platforms inside their houses and shift their belonging to safer places, if available. In such situations, the poor suffer the most.

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 255,490 of whom 125,240 are female. The gender ratio is calculated at 104 males to 100 females. The total households in 430 villages are estimated to be 105,630. The population increased by 20% in Sherpur and 29.6% in Jamalpur districts between 1981 and 1991.

homestead

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	17.4	16.4	14.2	44.2	1.9	5.9	100.0
Female	17.8	16.7	11.9	47.2	1.6	4.8	100.0
Total	17.6	16.5	13.1	45.7	1.7	5.4	100.0

Source: BBS, 1981 Population Census

The distribution for males is 33.8% below 10 years of age, 44.2% between 15 and 54 years of age, and 5.9% above 60 years of age. The corresponding distribution for females is 34.5%, 47.2%, and 4.8% (see Table 3.2).

The average population density is 986 persons per km², with density ranging from 679 persons per km² in Jhenaigati thana to a maximum of 1098 persons per km² in Jamalpur Sadar. The average household size in the area is estimated to be 5.4 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 services, pure drinking water facilities, and sanitation.

Literacy

In the project area the literacy rate is low. According to the 1981 census, the literacy rate of the population at five years of age and above varied from 12.3% in Jhenaigati thana to 19.5% in Jamalpur Sadar thana. The corresponding figures for females were 6.6% and 13.9% respectively for the same thanas. The rate appears to have increased in the last ten years. According to the 1991 census, the literacy rate for all people of Sherpur and Jamalpur districts is recorded as 14.7 and 16.3 for both male and female.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 12.4% in Sherpur Sadar thana to 18.5% in Jamalpur Sadar thana. Attendance for females in this age group in these two thanas varies from 10.5% to 16.1% respectively. Attendance for all youths between the ages of 5 and 24 is 12.5% and 19.0% for these thanas while the corresponding attendance for females is 9.2% and 14.6%.

The situation is worse for the rural poor. They cannot afford to send their children to school. Moreover, many villages, especially in Jhenaigati, Sribordi and Bakshigonj thanas, have no primary schools. The average number of primary schools per 10,000 population is estimated to be 3.7 for both Sherpur and Jamalpur districts (BANBEIS, 1990).

Access to Health Services
The district headquarters of Sherpur and Jamalpur have hospitals, and all thanas have hospital facilities located at their headquarters. Access to health services is generally limited for rural people and out of reach for the poor. According to the Directorate General of Health Services (1992), there is one hospital for every 276,771 persons and one doctor for every 34,596 persons in the district of Jamalpur. There is one hospital bed for every 7,598 persons in Jamalpur district and for every 6,594 persons in Sherpur district. The rate of immunization of children below two years of age is low for the project area, varying from 13% in Jamalpur Sadar thana to 24% in Sreebordi 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 Jamalpur, DPHE[1] reports the availability of one working tube well for 129 persons. For Sherpur district, 118 persons have one working tube well. In 1990, 93% of the households had access to potable water in the districts. It is noted that most tube wells are located in the houses of the rich. This results in the poor having very limited access to potable water.

Sanitation
Specific information on sanitation facilities is not available at the project level. During field reconnaissance, it was noted that open space defecation is a common practice in the villages, particularly for males. Women generally use kutcha latrines or defecate at a fixed spot which is protected by banana/betel nut leaves or by bamboo mats. Sanitary latrines are uncommon in the village environment, except for the very affluent and educated families.

Even DPHE could not give any data?

3.1.4 Employment and Wage Rates

Village employment opportunities are mainly limited to agricultural activities. The major crops in the area are boro and t.aman. Employment for men mainly consists of transplanting which occurs in July and August and harvesting which occurs in late October and November. Employment is also available during cultivation of hyv boro.

The wage rates for male agricultural labourers vary from Tk 30 to 40 with three meals per day during peak agricultural months. During months when there is no agricultural work, the wage rate varies from Tk 15 to 25.

During months when employment opportunities in agriculture are limited, some poor people migrate to the district headquarters or to Mymensingh or Dhaka to work as rickshaw pullers, construction workers, or household workers. A considerable number of labourers also migrate to Sunamganj and Sylhet districts to harvest boro crops. Employment opportunities for women are very limited in the area, except with the Rural Maintenance Program of CARE where a few poor women are employed. Some women also work in rice husking mills, especially in Sherpur Sadar thana. Their daily wage rate varies from Tk 15 to 25.

[1] DPHE, 1991-92

3.1.5 Land Ownership Pattern

Land ownership is extremely skewed in the project area. About 52% of the households are landless (with cultivable land less than 0.21 ha). Among the landless, about 2.0% have no homesteads of their own. If the definition of landless includes those with landholdings up to 0.4 ha, the proportion of households included increases by about 8.0%. Among the others, the small (0.21 - 1.00 ha), medium (1.01 - 3.00 ha) and large farmers (more than 3.00 ha) are 27.9%, 17.0%, and 3.1% of the households respectively.

The project area has little uncultivable land, except for a few wetlands and hills. As such, there is little community pasture in the area. The price of agricultural land varies from Tk 20,000 to Tk 30,000 per ker (0.12 ha) depending on the quality of the land, the intensity with which it can be cropped, and the demand on the land.

3.1.6 Land Tenure

Owner operation is common in the area. A few large land owners, particularly in Jamalpur and Sherpur thanas, lease their lands on a share cropping basis where one-half of the produce is retained by the land owners but no inputs are provided. For hyv rice cultivation, 50% of the input cost is generally borne by the land owners. The leasing of land for cash and kind is almost nonexistent in the area. Landless people have little access to land under this tenurial arrangement due to their inability to provide cash or agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area, with competition for the fish resources increasing every year. There are mainly two types of fishermen who fish to generate income — traditional and non-traditional fishermen.

Traditional fishermen live on fish; generations of their families have been fishermen. The jalmahals are generally leased out to them through the fishing cooperatives. The wealthy act as financiers and appropriate most of the profit from the catch, while the poor catch fish on a regular basis and sell the fish for their livelihoods. They also work as fishing labourers. There are an estimated 100 to 200 traditional fishermen households in the project area. Additional information on fishing practices is given in Section 3.5.6.

The non-traditional fishermen are mainly landless and poor agriculturists. They fish in open water, especially during monsoon months, and sell their catch. However, there are few non-traditional fishermen in the area; about 3-5% of the households are reportedly engaged in catching fish.

Members of the public also fish, but should not be referred to as fishermen. They fish only for their own consumption.

3.1.8 Situation of Women

Women's role in agricultural production is important. Women's contribution, however, tends to be devalued and under reported. Though women generally do not work in the fields, some poor women work outside their homes, mainly for the Road Maintenance Program of CARE, or engage in activities such as gathering wild vegetables and collecting fuel. The tribal women work in rice fields. The village women generally work at post-harvesting activities, especially drying, winnowing, storing and pre-boiling of rice. Most women prefer homestead gardening and raising poultry and ducks in addition to their regular household work.

3.1.9 People's Perception

General
Local people's perceptions of their problems were solicited. These were related mainly to water and its impact on their livelihoods, and their suggestions of interventions to solve these problems. These were collected through personal interviews, group discussions, and meetings with various cross sections of the people during field work in the project area. Opinions and suggestions were also sought at a one-day seminar held at Sherpur with the Honourable Members of Parliament, district and thana level officials, Union Parishad Chairmen, representatives of village level organizations, and NGOs. These are described below.

Problems
Flooding, both pre-monsoon and monsoon, was described as a major problem. Rice crops are damaged by floods. Boro is damaged by pre-monsoon flash floods in the low-lying beel areas between April and May.

The old Brahmaputra and the Karnajhora Rivers are the main sources of flooding in the area. Flash floods of the Karnajhora River overspill the banks, especially the right bank. Moreover, flood waters enter through various canals and through the Katakhali Khal to the interior areas, inundating the rice fields.

T.aman is damaged by monsoon flash floods from June to September, particularly in Nakhla, Jhenaigati and Sherpur Sadar thanas. The flood waters flow overland and cause damage to the standing t.aman. Sands and silts are left on the rice fields. The flood waters generally last one to two days in the upper areas, but there are three to four occurrences in every monsoon period.

Drainage congestion in the area for boro cultivation is not an acute problem, except in certain smaller pockets. The major drainage outlet for the area is the Karnajhora-Mrigi River to the Old Brahmaputra River. However, siltation of all the hilly canals, including the Karnajhora-Mrigi River, is a serious cause of flooding in the area. Sand deposition in the upper areas of Sribordi and Jhenaigati thanas is also a serious problem affecting soil fertility. In some areas, the human settlements are also affected by sand deposition.

Farmers also expressed their concerns about the scarcity of water for irrigation in boro fields, especially in the upper areas.

The fishermen reported the jalmohals, especially the beels and the rivers, are affected by continuous silt deposition. Most of the beels are being reduced in size, thereby reducing fish habitat. Open water fisheries in the area is almost non-existent. Fishermen tend to fish by dewatering the existing jalmahals and overfishing them during the monsoons. This is the major cause of declining fish production. They also stated that roads and embankments in the lower flood plains reduce fish production. Re-excavation of the Karnajhora-Mrigi River would be a positive step towards increasing fish production in the area.

Suggestions
Various suggestions were put forward by the local people. While all suggestions were taken into account in preparing this study, some of the suggestions related to very small and localised problems which require a different forum. The most common of the suggestions presented were:

- Stop overspilling by re-excavating the Karnajhora-Mrigi River and constructing embankments on both sides of the river.

- Develop the entire left bank of the Old Brahmaputra River to stop intrusion of flood waters in the area. Also, study the affect on the left bank of the proposed construction of a right bank embankment.

- Find ways to protect upper areas from sand deposition which comes from streams and rivers from the hills.

- Construct cross dams with gates at 8 - 10 km intervals on the Karnajhora River to hold water for winter irrigation in boro fields. A similar approach should be developed for other hill streams to bring more area under irrigation.

- Develop the important beels (such as Boysha, Mehedidanga, Kursa, Pekua, Dublakuri Beels) to ensure improved fish cultivation and better navigation in the lower areas. Increased water holding capacity will also enhance winter irrigation in boro fields.

- Lease jalmahals to local fishermen.

- Retain provision for the movement of fish from the Old Brahmaputra River to the interior rivers and beels.

- Initiate afforestation programs along the river banks as well as in the upper hilly and sandy lands to stop soil erosion and sand movement.

3.1.10 Local Initiatives

Information on specific local initiatives to avert flood-related problems in the project area was not collected during the field visit. However, people stated their traditional practice is to organize local people to counteract crises which arise as a result of flash floods and drainage congestion. The main activity is constructing dams on various localised canals to stop the intrusion of flash floods and save the rice crops. They also re-excavate canals for quick drainage. This is generally done on a voluntarily basis by the villagers when a particular canal threatens their property. More recently the Union Parishad allotted wheat for this purpose. The villagers also construct cross dams on hill rivers and channels to hold water for irrigating their boro fields.

Table 3.3 : Existing FCD Projects - Salient Features

Project Name	Type	Gross Area (ha)	Agency	When	Project Component
Old Brahmaputra Left Bank Embankment	FC	9,300	LGEB	1980-82	Construction of 35 km of flood embankment along Old Brahmaputra River from Nij Kamarer Char to Digrir Char.
Re-excavation of Mrigi River	Drainage	57,600	BWDB	1961-62	Re-excavation of 26 km of Mrigi River from Boysha Beel to its outfall on Dashni River.
Janakipur Khal	FC	1920	BWDB	1981-82	Construction of a 3-vent Regulator across Janakipur Khal
Re-excavation of Karnajora River	Drainage	15,200	LGED	1992-93	Re-excavation of 28.0 km Karnajora River from Matiphata to Boysha Beel

3.2 Water Resources Development

3.2.1 Flood Control and Drainage

In this area, the following projects were implemented by different agencies. The projects are intended to provide full flood control improvement to a gross area of 11,220 ha and drainage improvement to 57,600 ha. Drainage improvement was made in 1961-62 through re-excavation of the Mrigi River which is again filled with sediment.

3.2.2 Irrigation

Surface Water
According to the AST 1991 Irrigation Census, LLPs and traditional technologies irrigated 3180 ha of boro rice. The LLP coverage is 350 ha or 11% of the total.

Groundwater
Ground Water is available in all thanas of the project area, both under STW and DTW technologies (Annex A, Table A.6). It is extensively used in the area for boro irrigation. According to the AST 1991 census, about 10,449 ha were irrigated by STW in the area and there is potential for irrigation of 2700 ha (Table 3.4). The tabular data show that in Sribardi thana, the resource is over exploited by 45%. This situation calls for monitoring the groundwater table to guard against possible resource mining.

3.3 Other Infrastructure

There is a 40 km metalled road from Jamalpur to Jhenaigati over Sherpur and Sribardi thana centres that belongs to the Roads and Highways Department. This road is in good condition. In addition, there are about 210 km of seasonally motorable roads (feeder roads) connecting the

Table 3.4 : Potential Groundwater Irrigation Under STW Technology

Thana	Available GW in the area in STW technology (Mm^3)1/	Duty (ha/Mm^3)1/	Area possible to be irrigated (ha)	1991 Irrigated Area (ha)2/	Future Potential (ha)
Bakshiganj	7.95	152	1208	470	738
Sribardi	13.93	163	2270	3289	-
Jhenaigati	0.50	170	85	111	-
Sherpur	35.70	154	5498	4368	1130
Nakhla	18.74	160	2998	2158	840
Jamalpur	0.26	139	36	53	
Total			12095	10449	2708

1/ Source : WARPO (MPO)
2/ Source : AST 1991 Census

different growth centres with thana and district headquarters.

3.4 Agriculture

Within the Mrigi River Basin the net cultivated area constitutes about 84% of the total area. The present cropping intensity is about 205%. Local transplanted aman occupies the major area followed by hyv boro, local aus, hyv aman and hyv aus. The major cropping pattern is local transplanted aman-hyv boro. The present crop patterns are presented in Table 3.5. The area which is potentially benefitted from the interventions proposed in this prefeasibility study is located below Boysha Beel, and comprises a net area of 20,400 ha.

Permeable soils on high ridges are used for aus followed by early rabi crop cultivation. On impermeable highland and medium highland soils, aus is cultivated followed by transplanted aman and dryland rabi crops or fallow. In some rainfed areas, hyv or local aus is transplanted followed by hyv aman. With irrigation, mainly hyv boro followed by rainfed local or hyv transplanted aman is grown. Mustard or pulses are grown in many areas as relay crops, drawing on residual moisture after the transplanted aman has been harvested and before hyv boro is transplanted.

Use of fertilizers and irrigation by LLPs, STWs or DTWs has helped to increase hyv rice production in boro season in many areas. The change from broadcast aus to transplanted aus in some areas reduced the farmers' need to produce jute. Mustard production has increased in some areas with the application of recommended doses of fertilizer. The present crop production in the basin is presented in Table 3.6.

Table 3.5: Present Crop Patterns

Crop Patterns	F0	F1	F2	F3	Total
l boro				14(70)	14
hyv boro			920(25)	4(20)	924
l aus-rabi	299 (3)				299
l aus-lt aman	598 (6)	201 (3)			799
l aus-lt aman-rabi	997(10)	403 (6)			1400
l aus-hyv aman-rabi		337 (5)			337
l aus-hyv aman-potato		135(2)			135
jute-lt aman			110(3)		110
hyv aus-lt aman	299 (3)	337 (5)			636
hyv aus-hyv aman	299 (3)				299
lt aman-wheat		135 (2)			135
lt aman-rabi		202 (3)	184(5)		386
lt aman-hyv boro	6481(65)	4509(67)	2208(60)		13198
hyv aman-hyv boro	997(10)	471 (7)			1468
b aman-rabi			148 (4)		148
b aman-hyv boro			110 (3)		110
b aman				2(10)	2
TOTAL	9970	6730	3680	20	20400

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

Boro HYV (1Yri) = 924
1 3198
1468
110
15700

Table 3.6: Present Crop Production

Crop	Damage Free area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
l aus	2971	1.5	4457	0	1.5		4457
hyv aus	935	3.5	3273	0	3.5		3273
b aman	52	1.8	94	208	1.44	300	394
lt aman	11508	2.5	28770	5292	1.9	10055	38825
hyv aman	1334	3.5	4669	770	2.6	2002	6671
l boro	14	2.5	35				35
hyv boro	15700	4.5	70650				70650
wheat	135	2	270				270
jute	110	1.65	182				182
potato	135	11	1485				1485
pulses	425	0.9	383				383
oilseeds	1414	0.8	1131				1131
spices	129	2.5	323				323
vegetables	771	4	3084				3084

Source: NERP estimates.

3.5 Fisheries

3.5.1 Floodplain Fishery

About 18 beels exist within the project area. Kursa, Mehididanga, Pekua, Dublakuri, Bardubi, Jhaiduba, Betmari, Kahunia, Boysha, Mrigi, Dhiar, and Satpakia Beels are the best known for fish production. These beels serve as good overwintering habitats for a variety of fishes. Most of the beels are oxbow shaped, isolated basins.

Except for a few beels (Kursa and Mehididanga Beels, which are under Nitimala), most of the beels are leased by a few rich, influential persons for a period usually of one to three years. They generally reside in the thana headquarters and appropriate the profits from the catch. Local fishermen, especially the poor, cannot compete in the bid for the lease. In some cases, they work as fishing labourers but, generally, fishermen from outside areas are hired as their rates are lower and they create fewer problems for the lessees.

Conflicts and tension are common over the issue of fishing the jalmohals in the area. The jalmohal lessees construct and maintain earthen water retention dams on the beels' drainage canals and this prevents timely boro cultivation in the peripheral zones of the beels. It is also reported that water is completely drained by lessees each year in early February, the critical period for boro crop irrigation, to maximize the catch. This process of annual beel fishing by dewatering is reportedly common in the area. This affects boro cultivation, and fish resources decline seriously.

3.5.2 Species Present in the Area

Of the 150 species in the region, about 30% of the species inhabit the project area, of which 80% are smaller variety fish. The most common of these species are listed in Table 3.7.

Table 3.7: Common Species in the Area

BARAMACH	CHOTAMACH
Catla, Rui, Mrigel, Kalibaus, Boal, Shol, Gazar, Air, Ghagot, Chital.	Singi, Magur, Koi, Bheda, Khoilsa, Napit, Cheng, Taki, Fali, Pabda, Gulsha, Tengra, Bajori, Mola, Dhela, Batashi, Kanpona, Chela, Chanda, Puti, Titputi, Darkina, Chapila (Korti), Tara baim, Kaikka, Boicha, Icha.

3.5.3 Spawn Fishery

Reportedly there is no duar fishing in the area. But major carp and other fish breed in the Old Brahmaputra and other rivers. Large numbers of spawn, fry and fingerlings are collected during the rainy season, usually from May to July, from those rivers for pond culture. It is also reported that there are more than 140 people engaged in spawn collection in the Old Brahmaputra River and more than 130 kg of spawn were collected around the project area during 1988. In Chandrakona-Dighirchar area, about 500 people are also engaged in the fry and fingerling collection business.

3.5.4 Sources of Fish and Breeding

It is generally understood that early rain, thunder, flooding, temperature, and grassy or rocky land influence spawning of fresh water fish. If conditions are favourable, during the pre-monsoon and early monsoon period fish migrate into shallow areas, usually from beels to adjacent grassy areas, to the rivers, and vice-versa. Migrations are usually counter current during that period. These types of migration are seen in the Belkuchi and Gaibandha area of the Dashani River, Balair Char near Satpakia Beel, Halgara village near Boysa Beel, Dhiar Char, Char Astadhar and Poragar area near Mrigi Beel. Where rain is localized, the adjacent upland area will drain into the beel, and water will flow from the beel down the khal into the river. In this case, fish will tend to move from the river up to the khal to the beel. Localized breeding migration is seen in Medidanga, Dublakuri, Jhaiduba, Pekua, Bardubi, Barbila, Rewa, and Durunga Beels. The following species migrate to these beels for breeding from late April until

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June: Koi, Puti, Tengra, Magur, Icha, Taki, Shoal, Gazar, and Singi. In general, the breeding period depends on rain and flooding. Certain species such as Boal, Pabda, and Fali migrate against the current from the beels up to the grass-covered highland khals (Para Beel, Boysa Beel, Mrigi Beel) to breed.

It is generally considered that the Old Brahmaputra and Jamuna are the major sources of natural carp spawn in Bangladesh. The Mrigi River is the main source of carp and catfish for the project area. There are several carp spawn and fry collection centres adjacent to the project area (see Table A.7). Some fry collection centres (near Chandrakona) were destroyed after the construction of the Janakipur Khal regulator. Carp fry and fingerlings enter through the current and use that area as grazing ground.

3.5.5 Production Trends

According to the NERP study, fish abundance is directly related to flood duration and water depth, and access to the flood lands. Fish production in the Mrigi River area has apparently declined by 30-40% over the last five years. The identified causes of the decline are outlined below:

- Siltation of beels. The beel area has been reduced by about 30-35%; both depth of water and water hectare-month are gradually declining.
- Siltation of canals. The canals connecting the beels to the rivers have been filled with sediment and restrict fish migration within the area.
- Construction of embankments along the river banks for flood control purposes hampers the movement and migration of fish into the beels, floodplains, and canals.
- Fishermen randomly collect the broodfish as they migrate to their breeding grounds.
- Reduction of fish population due to overfishing and loss of fish habitat.
- Reduction of reproductive stock due to indiscriminate use of some fishing gear in the beels and floodplains (current jal, Chat jal).
- Increased fish mortality due to fish diseases caused by water pollution in the beels, particularly during the winter and summer season.
- Annual beel fishing as a result of short term leasing.
- Rapid deforestation, expansion of paddy land, and use of water for irrigation.
- Ponds not specifically designed for fish culture and having multiple uses (washing, bathing, fishing, irrigation). Moreover, most of the ponds are jointly owned which makes decision making for investment very difficult. About 60% of the ponds are seasonal or do not retain sufficient water during the dry season.

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

While no actual count has been made of overall fish production for the project area, the estimated production is about 870 metric ton per year (see Table 3.8).

Table 3.8: Present Fish Production

Types of water body	Area (ha)	Rate of production (kg/ha)	Total production (mt)
Beel	680	162*	110
Floodplain	21290	22	468
Pond	300	800	240
River/Channel	1900	31*	59
Total			877

Source: BFRSS and NERP* study

3.5.6 Fishing Practice

Floodplain

Floodplains and beels are the major sources of fish in the area (floodplains and beels 66%, ponds 27%, rivers/channels 7%). Subsistence fishing occurs during the flooding period (mainly June to September) and beel fishing occurs from November to February. In most cases beel fishing is done on an annual basis. Katha installation is very rare in the area but, when used, mainly mango and shawra tree branches are used with bamboo stakes. Generally kathas are installed in the months of August and September, when water starts to recede from the adjoining floodplains. For floodplain fishing, mainly current jal, chat jal, thela jal, jhaki jal, borshi and unniya are used. Ber jal, chat jal, jhaki jal and polo are the major gear for beel fishing.

Closed water

The government fish seed multiplication farm (FSMF) and some private farms in Jamalpur are the main sources of induced breed carp fry in this area. Large quantities of carp fry are collected from the Old Brahmaputra River and distributed for pond culture. The culture pattern is more or less extensive. Most pond owners release an uncounted number of fingerlings into their ponds without undertaking other basic management activities such as eradicating predatory and weed fish; eradicating aquatic weeds; ensuring sufficient sunlight penetration; and applying lime, fertilizer, and feed.

Due to a lack of proper extension services, farmers mainly follow the suggestions of the fry vendors for pond preparation and management. Monitoring of growth and health of the fish is not done on a regular basis which results in a poor harvest of fish. The fish are usually harvested during the dry season. Ber jal and jhaki jals are used for fishing. It should be noted that many

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ponds adjoining homesteads provide the domestic water supply for a wide variety of activities (bathing, washing clothes and dishes, occasionally watering of homestead vegetable plots, and so on).

3.6 Navigation

The western part of the project area is bounded by the Old Brahmaputra River which remains navigable mainly during the monsoon season. During winter months, the river has too little water for navigation. However, limited navigation from Jamalpur downstream takes place in the early winter months.

The Karnajhora-Mrigi River flows through the project area, but is not navigable the entire winter. It is only navigable by smaller boats during the monsoon season. However, the use of small country boats increases when the village roads in the extreme low lying areas are submerged during the peak monsoon months. At present, small and medium sized engine boats ply through some canals and rivers, especially through the Dashani River in the south, for about three to four of the monsoon months.

3.7 Wetland Resource Utilization and Management

Utilization of wetland resources is not prominent in this area because of low productivity. The only important use of natural wetland products is fodder gathered in the monsoon from various aquatic macrophytes such as *Eichhornia crassipes*, *Nymphaea* and *Nymphoides*. The estimated total economic value and the estimated generated employment of this would not be significant.

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. Information on resource management practices is not available.

4. PREVIOUS STUDIES

No prior studies have been undertaken of this area. The re-excavation was proposed by BWDB for approval based on local demand and based on field observations.

5. WITHOUT PROJECT TRENDS (NULL OPTION)

Independently of any water resource development, certain trends are occurring in the area:

- Net population growth: The future population will be 688,600 by the year 2000 and 899,900 by the year 2015, down from the yearly growth of 2.3% experienced over the past 10 years.

- Foodgrain production growth: Foodgrains in the project area consist of rice, wheat, and some minor cereals such as millet. At present, total foodgrains production is estimated to be about 124,000 tons. On average, rice accounts for 99% of the total production. Crop losses will increase in future with the increase in area inundated due to drainage congestion. The future crop patterns and production without project are given in Tables 5.1 and 5.2.

- Floodplain fisheries: Floodplain fisheries are expected to be reduced from the current level due to exploitation and infilling of beels by sediment coming from upland hilly areas. However, culture fisheries are likely to increase in ponds and tanks.

- River courses: The rivers in the project area seem to be stable and no changes in their courses are anticipated. But the upstream reach of the Karnajhora River flows over the Meghalaya alluvial fan for a short distance. It is not unlikely that the river will change its course there. However, such a change will have very little impact on the entire basin area.

- Arable land: Due to an increase in population over time, there will be loss of arable land to settlement. The fertility of land in the northern area continues to be reduced due to sand deposition coming from upland hilly areas.

Table 5.1: Projected Crop Patterns - Future Without

Crop Patterns	F0	F1	F2	F3	Total
l boro				14 (70)	14
hyv boro			920 (25)	4 (20)	924
l aus-rabi	299 (3)				299
l aus-lt aman	598 (6)	202 (3)			800
l aus-lt aman-potato		135 (2)			135
l aus-lt aman-rabi	698 (7)	336 (5)			1034
l aus-hyv aman-rabi		336 (5)			336
jute-lt aman			110 (3)		110
hyv aus-lt aman	399 (4)	336 (5)			735
hyv aus-hyv aman	299 (3)				299
lt aman-wheat		135 (2)			135
lt aman-rabi		202 (3)	110 (3)		312
lt aman-hyv boro	6281 (63)	4375 (65)	2208 (60)		12864
hyv aman-hyv boro	1396 (14)	673 (10)			2069
b aman-rabi			221 (6)		221
b aman-hyv boro			110 (3)		110
b aman				2 (10)	2
TOTAL	9970	6730	3680	20	20400

Note: Numbers in parenthesis indicate percent of cultivated area under the relevant land type.

Table 5.2: Crop Production - Future Without

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Total (t)	Area (ha)	Yield (t/ha)	Total (t)	
l aus	2605	1.5	3908				3908
hyv aus	1034	3.5	3619				3619
b aman	67	1.8	121	266	1.37	364	485
lt aman	10569	2.5	26423	5557	1.8	10003	36426
hyv aman	1896	3.5	6636	809	2.5	2023	8659
l boro	14	2.5	35				35
hyv boro	15967	4.5	71852				71852
wheat	135	2.0	270				270
jute	110	1.65	182				182
potato	135	11.0	1485				1485
pulses	369	0.9	332				332
oilseeds	1231	0.8	985				985
spices	110	2.5	275				275
vegetables	661	4.0	2644				2644

Source: NERP estimates.

6. DEVELOPMENT OPTIONS

6.1 Problems

The following problems have been identified in the area:

- Flash floods and sand deposition in the upland area.
- Flooding from the Old Brahmaputra River through the unembanked portion between Chandrakona and Digrir Char.
- Drainage congestion due to siltation of the Mrigi River.
- Flooding through breaches of the existing Old Brahmaputra left embankment and Katakhali Khal.
- Rise of water level due to proposed embankment along the right bank under Jamalpur Priority Project and consequent increased flooding of the left bank.

6.2 Development Options

Following is a summary of recommendations of the Sherpur Seminar[1] related to the development of this project area. The recommendations pertaining to the development of Jhenaighati, Nalitabari and Nakhla thanas have been addressed in the Kangsha River Basin Development.

- Effects of the construction of a right bank embankment on the Old Brahmaputra River on flooding conditions of its left bank area should be studied.
- The existing embankment from Kamarer Char to Gograkandi should be rehabilitated.
- The canal extending from Karnajhora Nadi to the Old Brahmaputra River via the Mrigi River should be provided with embankments after thorough study.
- The Karnajhora River is being re-excavated through a voluntary canal digging program from Karnajhora to Rohabetmari. The river should be provided with water control structures and other facilities so that its water can be used for irrigation in the lean period.
- The Mrigi River from Boysha Beel to its outfall should be re-excavated.
- Steps should be taken to store sand carried by hilly streams. This sand should be used as a construction material for roads and other structures.

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[1] Details of the seminar discussions and output are given in the "Proceedings of the Sherpur Seminar" February 18, 1993 published by the Northeast Regional Project.

- The beels should be developed in such a way that fish cultivation is possible.
- Afforestation programs must be undertaken to save existing hills from soil erosion due to deforestation.
- For irrigation and fish cultivation, Dhalia Beel, Matiphata Boysa Beel, and Boalia Beel should be encircled by embankments.
- Shatpakia Beel should be developed to ensure navigation, fish cultivation, and irrigation.
- Ichali Beel and Aura-Baura Beel should also be developed to ensure navigation, irrigation, and fish cultivation.
- A sluice gate should be provided at the outfall of Khailsakuri after re-excavating Katakhali Khal.
- Re-excavation of miscellaneous drainage channels.

In view of the problems and suggestions, the following developments options were examined:

- Sabo-Dam on the Karnajora River at Border Road cross point.
- Empolderment of the Mrigi River basin.
- Effect of construction of embankment on the Old Brahmaputra River right bank on flooding conditions of its left bank area.
- Mrigi River Drainage Improvement.
- Fisheries development.
- Afforestation program.

It is expected that the LGED, the agency which constructed the Old Brahmaputra left embankment, will close the two breaches and the Katakhali Khal on a priority basis to bring the 35.0 km Old Brahmaputra left embankment into use. The other development options mentioned above are described in 6.2.1 through 6.2.6.

The following points are relevant with regard several other of the issues raised in the Sherpur Seminar:

- **Embankments on the banks of the Karnajhora-Mrigi River.** The Karnajhora-Mrigi River is the main drainage channel of the area. Lands on both banks of the river slope towards it. It receives drainage from the area through overland flows. Construction of embankments will impede the drainage create difficulties in the area.

  The suggestion of embankment construction has been put forward, perhaps for relief of inundation. The inundation is caused because the river is incapable of conveying the drainage discharge from its catchment area due to siltation. The best way to solve this problem is to increase the carrying capacity of the channel through re-excavation. The next chapter examines this option in detail.

- **Mrigi River to serve as an irrigation canal.** As stated earlier, land on both sides of the river slopes towards the river making it very difficult to use the river as an irrigation canal. In addition, its discharge is too small to design an irrigation scheme around it. However, a control structure could be constructed at the border cross point to turn the upland hilly areas into a desilting basin which would also act as a water reservoir for lean period irrigation. This option is also examined in this study.

- **Desilting hill streams.** It was proposed that the silt coming down the hill streams be trapped for use as construction material.

  The problem is that there is no large wasteland that can serve as a desilting basin. The river bed may be used for this purpose by constructing embankments and a cross dam but this will require that the storage area be cleaned regularly. It is anticipated that the demand for sand as a construction material is limited in the immediate vicinity and that transportation to Dhaka, where this construction material may have a good market, is not cost effective. It is considered that at present there is no economically viable solution to this problem and that when it does become cost effective to market this material into growing urban centres, the private sector will be involved.

- **Regulator on Katakhali Khal.** A regulator at Katakhali Khal will not be required if the drainage capacity of the Mrigi River is enhanced since all drainage will be managed through the Mrigi River. Consequently, the Katakhali Khal will be closed off.

- **Re-excavation of other khals.** Re-excavation of other khals is supposed to be undertaken through local union parishads once the major channel, the Mrigi River, is re-excavated.

6.2.1 Sabo-Dam on Karnajora River at Border Road Cross-Point

There is a 32.0 km^2 catchment area above the Border Road (Annex D, Figure 1). This area is full of low hills and valleys. It was proposed that the area be used as a sediment basin by putting a structure on the road with a high invert to trap sediment within the valleys of the hills. This would be expected to directly help the area around Karnajhora and indirectly help the Karnajhora-Mrigi River System by preventing rapid siltation. In addition, impounded water could be used for irrigation in the adjoining areas where both surface and ground water are very scarce. The people of the area are very poor because their lands are not highly productive due to sand deposition, and they cannot cultivate hyv boro without irrigation water.

This initiative appears very promising but it could not be assessed because of the absence of the following data:

- Land elevation north of the Border Road.
- The Karnajhora River discharges and water levels.
- Sediment measurements of the Karnajhora River.

However, this option is listed in Chapter 8 as an outstanding issue.

6.2.2 Empoldering Mrigi River Basin

The project area is now open to Old Brahmaputra River flooding from the southeast corner. Flood routing was carried out for the period from April to November by closing the gap with a 20 vent structure (each vent 1.52 m x 1.83 m) and by adding 5.0 km of embankment. Several routings were carried out with different rainfall and outfall water level conditions. The flood routing result for a two year rainfall (Sherpur Station) and a five year outfall river flood level are presented in Annex A, Table A.8. The maximum polder level is 15.28 m PWD corresponding to a river level of 15.27 m PWD. The analyses show that even under average rainfall conditions, poldering does not reduce the flood level in the area.

In addition, empoldering will inhibit land development, reduce land fertility since sediments are no longer deposited on the land, and obstruct fish movement. Consequently, it is considered appropriate that the gap be kept open.

6.2.3 Old Brahmaputra River Right Bank embankment effects on the River's Water Levels.

It is proposed that the right bank of the Old Brahmaputra River will be embanked as part of the Jamalpur Priority Project. The impact of this scheme was assessed and it was determined that flood levels would be raised by up to 0.54 m at Jamalpur. To mitigate damage on the left bank, further raising and strengthening of the left bank embankment should be taken up simultaneously with construction of the right embankment.

6.2.4 Mrigi River Drainage Improvement

From field observation, discussion with local people, and recommendations of local MPs and public representatives at Sherpur Seminar, it appears that drainage improvement through the Mrigi River is the greatest need of the area. As such this initiative is selected for further consideration and is described more fully in Chapter 7.

6.2.5 Fisheries Development

Based upon NERP field observation and the Sherpur Seminar, the following recommendations, related to the development of fisheries of the area, are made:

- For irrigation and fish cultivation purposes, important beels (Boalia Beel, Satpakia Beel, Boisha Beel) should be re-excavated if technically feasible, to increase water holding capacity.
- Jalmahals should be leased to the genuine fishing community.
- More beels should be brought under the New Fisheries Management Policy (NFMP).
- Pond owners should be encouraged and trained through better extension services to develop culture fisheries. Credit facilities should be extended for re-excavation of derelict ponds and lakes.

To enhance fish population in the project area, the following is suggested:

- Siltation causes the infilling of river beds and beels. Major siltation is occurring in the upper part of the project area (around Sribordi area). As a result the natural fish habitats are being degraded and the mean depth and volume of overwintering grounds reduced (as has occurred in Mehididanga Beel, Boisha Beel, Pekua Beel, Betamari Beel, and Dublakuri Beel). This facilitates overfishing and agricultural land expansion. The immediate solution to the problem is re-excavation of the silted beels, and separation of beels (government/khas) from paddy land (private) by building either submersible embankments or pillars around the beels.

- There are good prospects for reversing the decline in fish production by adopting a culture-based fisheries model in the beels of the project area. Most of the beels are permanent and similar to Jessore oxbow lakes. Expanding fish yield has already been demonstrated in Jessore oxbow lakes. Systematic stocking with fast-growing carp, improved resource management, and enforcement of harvesting regulations are the key points of culture-based, open water jalmohal management. During field visits, it was indicated Kursha, Mehedidanga, Bardubi, Dublakuri, Jhaidula, Betmari Beels, and Godadanga Beel in Nakhala thana have high potential for culture-based fisheries development. However, for development of these beels, feasibility detail is required.

- Fishing regulations need to be strictly implemented in order to conserve fish stock. Under the regulation (The Protection and Conservation of Fish Rules, 1985), government has prohibited some areas from catching certain fish during certain periods (from 1 April to 30 June). In that regulation, government has also restricted some fishing methods and gear. To effectively implement the laws, people's motivation and participation are highly required.

- Appropriate extension service is required for the pond owners to raise the average yield of the ponds. The "trickle down" approach (training, follow up, and training) needs to be adopted in the area.

6.2.6 Afforestation Program in the Hills

Drainage congestion due to siltation of the Mrigi River and sand deposition in the upland area are the two major problems in the project area. These problems are mostly created by soil erosion in the catchment area due to deforestation. Water flows more rapidly due to lack of tree coverage in the upland hills and thus creates frequent flash floods. To reduce this problem, afforestation programs must be undertaken in the catchment areas, with the assurance of no more deforestation.

7. PROPOSED PROJECT - MRIGI RIVER DRAINAGE IMPROVEMENT

7.1 Project Rationale

Under the prevailing situation, agricultural development in the project area is constrained by drainage congestion. With the Karnajhora River re-excavation this year (1993), the Mrigi River will receive run-off more quickly, resulting in more crop damage. The area's people depend almost solely on agriculture. Damage to agriculture in any form, including drainage congestion, has a significant affect on the economy of the area. According to a previous survey, the distress level of this area is shown to be very high. Crop damage due to this drainage congestion may be attributed as one of the causes for this high distress level.

Table 7.1: Current Land Use

Use	Area (ha)
Cultivated (F0+F1+F2+F3)	20,400
Homesteads	1,100
Beels	575
Ponds	135
Channels	1,200
Hills	-
Fallow[1]	350
Infrastructure[2]	700
Total	24,400

7.2 Objectives

The objective of the project is to reduce crop damage from drainage congestion, without negatively affecting fisheries, navigation, or the natural resources of the wetlands.

7.3 Description

Prior to any intervention in the drainage system, the existing breach in the Old Brahmaputra River left bank embankment requires repair. The proposed project includes re-excavation of 28.2 km of the Mrigi River from Boysha Beel to Char Betmari (Annex E, Figure 1). The catchment area of the river in this reach is about 24,400 ha. Current land use is provided in Table 7.1.

The requirement for drainage improvement for the remaining 19.8 km in the downstream river reach could not be assessed since river cross-sectional data was unavailable. The re-excavation design cross section and levels required for the river reaches are furnished in Annex E Figure 3.

The 28.0 km of the Karnajhora River (Upper Mrigi) from Matiphata to Boysha Beel is being re-excavated this year (1993) under the Canal Digging Programme.

7.3.1 Analysis of Results and Expected Benefits

The method of analysis has been described in Annex B. The resultant change in land type under pre-and post project conditions is given in Table 7.2. This land type change has been estimated on the basis of pre and post project water levels furnished in Annex B, Table B.2.

These changes in land type are expected to be associated with changes in area under different cropping patterns (Table 7.3). Projected crop production (Table 7.4) was determined, based on these changes to the cropping patterns and the assumption that present yield levels in the damage free areas can be obtained throughout the project area.

Table 7.2 : Area by Land Type - With and Without Re-excavation

Land Type	Without Re-excavation		With Re-excavation	
	Gross Area (ha)	Net Area (ha)	Gross Area (ha)	Net Area (ha)
F0	4,600	3,700	15,400	14,500
F1	10,000	8,600	5,800	4,400
F2	8,500	7,300	2,700	1,500
F3	1,300	800	500	0
Total	24,400	20,400	24,400	20,400

7.3.2 Mitigation Measures Incorporated

No mitigation measures were incorporated into the project design. From past experience, it has been observed that with the high rainfall encountered through the region, improved drainage on some hydraulic regimes can secure agriculture production systems without a significant corresponding loss in fisheries or wetlands (and their associated bio-diversity).

Table 7.3: Projected Cropping Pattern

	F0	F1	F2	Total
hyv boro			300 (20)	300
l aus-rabi	290 (2)			290
l aus-lt aman	580 (4)	176 (4)		756
l aus-lt aman-potato		176 (4)		176
l aus-lt aman-rabi	725 (5)	352 (8)		1077
l aus-hyv aman-rabi		352 (8)		352
jute-lt aman			60 (4)	60
jute-hyv aman			45 (3)	45
hyv aus-lt aman	290 (2)	308 (7)		598
hyv aus-hyv aman	435 (3)			435
lt aman-wheat		88 (2)		88
hyv aman -wheat		132 (3)		132
lt aman-rabi		88 (2)	30 (2)	118
hyv aman-rabi		88 (2)		88
lt aman - hyv boro	7830 (54)	1760 (40)	960 (64)	10550
hyv aman - hyv boro	4350 (30)	880 (20)		5230
b aman-rabi/potato			30 (2)	30
b aman-hyv boro			75 (5)	75
TOTAL	14500	4400	1500	20,400

Notes: *Numbers in parenthesis indicate percent of cultivated area under the relevant land type.*
An increase of fifteen hectares of cultivated land is a consequence of a decrease in beel area (Art. 7.8.1).

Boro HYV (1+2)

300
10,550
5,230
75
16,155

Table 7.4 : Projected Crop Production

Crop	Area (ha)	Yield (t/ha)	Production (t)
l aus	2651	1.5	3,976.50
hyv aus	1033	3.5	3,615.50
b aman	105	1.8	189.00
lt aman	13423	2.5	33,557.50
hyv aman	6282	3.5	21,987.00
hyv boro	16155	4.5	72,697.50
wheat	220	2.0	440.00
jute	30	1.65	49.50
potato	176	11.0	1,936.00
pulses	293	0.9	263.70
oilseeds	978	0.8	782.40
spices	98	2.5	245.00
vegetables	587	4.0	2,348.00

Source: NERP estimates.

Cereal production is expected to increase annually by an estimated 7364 tonnes, from 125,252 (future without) to 132,616 tonnes as a result of the project. This represents an increase of 6%. Non-cereal production would increase by about 109 tonnes which is a 2% increase. This increase is mainly due to better drainage.

The cereal production increase implies an increase in cereal availability from 381 (FWO) to 403 (FW) gm per person per day, an increase of 6% (Table 7.5). Current average consumption in Bangladesh is 440 gm per person per day.

7.4 Project Operation

As the project work includes only re-excavation of an existing river, there are no operational considerations.

Table 7.5 Indicators of Food Availability (grams/person/day)

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	1363	1282	981	900
Non-Cereals	72	54	41	42
Fish	9.9	8.3	6.3	6.5

1993 Population - 250,490; 2000 Population - 291,700; and 2015 Population - 382,200

7.5 Organization and Management

During the early part of the feasibility study process, a client group would be organized to oversee project development. This client group would be composed of representatives from the local farming community and a local MP nominee. The group would ensure the problems of the area be clearly understood and adequately reflected in the feasibility work. The local MP should be appraised of the project, its problems and means of solution, and the MP's concurrence should be obtained. The group would ensure proper utilization of funds.

7.6 Cost Estimate

The project's physical features mainly includes re-excavation of 28.2 km of the Mrigi River. The estimated capital cost is Taka 51.61 million while annual O & M cost is Taka 1.55 million. Details on physical components and capital and O & M costs are given in Annex B, Table 4. Earthwork costs are based on the BWDB schedule of Rates for Mymensingh O&M Circle, indexed to June 1991 prices.

Table 7.6: Changes in Land Use

Use	Change in area (ha)
Cultivated	(+) 15
Homesteads	-
Beels	(-) 15
Ponds	-
Channels	(+)300
Hills	-
Fallow[1]	(-)300
Infrastructure[2]	-

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

7.7 Project Phasing and Disbursement

Considering the small size of the project, it is possible to complete the project work in one year. The small investment may not warrant a full feasibility study on the project. However, proposed sections as shown in Annex D, Figure 3 should not be taken as the final design.

Table 7.7: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production (t)	Area (ha)	Change in Area Equivalent	Production Impact ('000 kg)	Net Value ('000 Tk)
Flood Plain	10430	458.9	5915	-3923	-173	-5681
Beels	575	235.8	560	102	42	2513
Channels /River	1200	210.0	1500	615	108	6919
Net Project	20400	904.7	20415	n/a	n/a	3750

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
No land acquisition will be required for the project work. Due to project implementation, however, the beel area will be reduced by 15 ha, but re-excavation will increase channel area by 300 ha (see Table 7.6).

Agriculture
Increased cereal production is documented in Section 7.3.1, Expected Benefits. The cereal production increase implies an increase in cereal availability from 900 (FWO) to 981 (FW) gm per person per day, an increase of 9% (Table 7.6), allowing 10% for seed, feed, and waste, and 65% for conversion of paddy to rice.

Non-cereal production is expected to decrease 3% from 5902 tonnes (FWO) to 5746 tonnes (FW). This results from a 375 ha decrease in area cultivated to non-cereals from 2506 ha to 2131 ha and implies a decrease in the availability of non-cereals from 42 to 41 grams per person per day (Table 7.5). This change is expected to occur as a result of an increase in the area cultivated to rice.

Fisheries[1]
There are three important impacts. The first relates to reduced flood plain fisheries resulting from reduced grazing areas; the second relates to reduced beel fisheries resulting from drainage; and the third relates to increased depth and duration (volume-months of water) of in-channel habitat.

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[1] The model used to analyze fisheries impacts is described in Annex D.

The drainage improvement will reduce floodplain area by an estimated 43%; and beel area by 2.6%. As a result of the project, however, the in-channel habitat will be increased by 25% and this increase will facilitate fish migration (see Table 7.7).

As indicated in Chapter 5, floodplain fisheries have been declining within the project area by an estimated 1.5% per year over the past ten years. The fisheries projects described in Chapter 6 will likely stabilize production within five years, but during this period, production will probably continue to decline at about 1.5% per year. Future without-project production is estimated at 904.7 tonnes per year. The future with project condition is estimated to be 881.7 tonnes per year or a 2.5% decline in floodplain fish production (Table 7.7).

The water linkage between project floodplains and the Old Brahmaputra River, which is considered to be a spawning ground for carp, will be maintained and improved. This area does not contain a "mother fishery" so there are no regional affects on fisheries as a result of the implementation of this project.

Table 7.8: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	1296	1740	+440	
sc/wf F1	538	176	-362	
sc/wf F2	110	30	-80	
Fallow Highland	300	50	-250	
Total	1912	2393	+481	+11

Land Type	Winter Wetland			
sc/wf F3	2	0	-2	
F4, Beel, Channel	1825	2060	235	
Total	1827	2060	235	+12.75

Land Type	Summer Wetland			
wc/sf F1	0	0	0	
wc/sf F2	920	300	-620	
wc/sf F3	18	0	-18	
F4, Beel, Channel	2125	2110	0	
Total	3063	2410	-653	-21

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.

Homestead flooding

Homestead flood damage would be reduced. Due to the lack of historical data on flood damage costs, a simple model was used to estimate future costs. There are about 52,815 homesteads in the area, and the average plinth level is at about the 1:5 year flood level. About two percent of homesteads are affected by flooding of 10-20 cm in the 1:10 to 1:25 year floods. The estimated annualized economic value of reduced flood damage is Tk 2.4 million.

Wetland Habitats and Grazing Area

Impacts are difficult to quantify, but a general impression is given by Table 7.8, 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

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moisture. While it is clear that animals do graze on such areas, productivity per unit area is not known.

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

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

The impact of the project would be to decrease winter grazing areas by 11%, increase winter wetland areas by 12.75%, and decrease summer wetland areas by 21%.

Economic and employment impacts of the project on wetland plant and animal production would not be large, because of the small size of the wetland area and its poor productivity.

Transportation/navigation

The total length of existing roads in the project is 250 km, of which 50 km are inundated every year. The project would make 50 km of these roads flood free. Assuming a capital cost of Tk 190,000/km and 15% flood damage, the annual benefit of flood protection is Tk 2.6 million.

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 0.52 million person days per year. This is composed of:

- an increase in owner-labour employment of 110,000 pd yr^{-1}, of which roughly 20% is engaged in post-harvest processing activities traditionally done by the women of the household. This increase is partly enhanced by the following:

- a net increase in employment opportunities for landless people of 410,000 pd yr^{-1}, composed of changes in the following areas:

- Agricultural hired labour: 434,000 pd yr^{-1}, of which about 10% is for post-harvest processing, traditionally done by women hired (mainly by larger farmers) for the purpose.

- Fishing labour: -23,000 pd yr^{-1}; 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.

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

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This is the main benefit (96% in economic terms) of the project and its distribution is quite *regressive*.

Who loses?

- Families dependent upon fishing labour. These families are mainly landless and tend to be poorer than average. *Regressive*.

Gender Equity
The net equity impact would appear to be somewhat *progressive*. Employment opportunities for women will increase in all categories. Reduced homestead flood damage will disproportionately favour women, given that most women still spend most of their lives within the homestead.

Qualitative Impact Scoring
Table 7.9 provides a qualitative assessment of various project parameters. The qualitative criteria 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 7.10. The scoring procedure is analogous to that used in the FAP 19 EIA case studies, but simplified to eliminate half-point scores (1.5, 2.5, 3.5). Here, each score sums across five equally weighted logical (true/false) criteria, with each "true" counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative.

Table 7.9 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 Mrigi River Basin	-1	0	0	0	0	1	-1
Regional Biodiversity	-1	0	0	0	0	1	-1
Road Transportation	1	0	0	0	0	1	-1
Flood Levels Outside Project Area	+1	0	0	1	0	1	+2
Conflicts	-1	0	0	1	0	1	-2
Socioeconomic Equity	-1	1	0	1	0	1	-3
Gender Equity	-1	0	0	1	0	1	3

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7.8.3 Economic

The project has a very high economic rate of return of 79%. It is a relatively low investment project at Tk 52 million or Tk 2549 per hectare, and it covers a net geographic area of 20,400 ha (24,400 ha gross). The most sensitive variable is the timing of the benefits, and a delay in benefits by two years would reduce the ERR to 35%. The rate of return, is quite sensitive to increases in capital costs (a 20% increase in capital costs would reduce the rate of return to 62%). Should fisheries production be 20% lower than anticipated, the ERR would drop by 25% to 54%.

The foreign costs associated with the project are low at 7% (excluding FFW contributions), making it a relatively small project from a donor perspective. Donor funding considerations would clearly need to include funding local costs.

Almost all of the benefits of the project relate to increased rice production, mostly resulting from reduction in crop damage. Average crop yields would increase as a result of reduced damage from drainage congestion. Non-cereal production would decrease by 3%. Floodplain fish production falls by about 17% of future, without project production. However, the value of the lost fisheries output amounts to less than 1% of the value of increased agricultural output. About 3% of project benefits would result from reduced homestead flooding. A small amount of disbenefits 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 7.11.

It is anticipated that the established crop marketing system will handle incremental crop production without any reduction in prevailing average price levels. Assuming the current annual growth in the demand for grain remains about 1.8%, the increased cereal production is unlikely to present any marketing difficulties.

A significant caution is that the benefits are based largely on assumed shifts in cropping patterns, and if this did not occur, the project would not be viable. Lessons of the past have shown that producers have not always responded as predicted, and this case warrants special efforts in predicting producer responses.

7.8.4 Summary Analysis

Past experience shows that drainage projects tend to better achieve stated objectives than other forms of intervention in hydraulic systems. This project is attractive from a multi-criteria perspective (Table 7.12) since:

- No homesteads are displaced by the project.
- Homesteads are protected from flooding.
- There is a net increase in food supply albeit entirely from increased rice production.
- The net employment impact is positive, though it is composed of a large gain in employment for owners at the expense of a significant number of jobs for hired labourers.

- A high rate of return.

- Increased economic returns to land owners.

- Somewhat progressive gender equity of impacts.

- Responsive to public concerns.

- Does not require complicated (any) operating procedures.

Several aspects of the project are unattractive from a multi-criteria perspective. These are:

- The benefits derive entirely from increased rice production and to a point, at the expense of diversification to non-cereals.

- The net employment impact is positive, but it is composed of a comparatively large gain in employment for agriculture with a loss of employment in fisheries.

Project area 204400 ha
Project cost 52 million
cost/ha - Tk25 49

Table 7.10: Summary of Salient Data

Economic Rate of Return (ERR)	79			
Capital Investment (Tk million)	52			
Maximum O+M (Tk million / yr)	1			
Capital Investment (Tk/ha)	2,530			
Foreign Cost Component	7%			
Net Project Area (ha)	20,400			
Land Acquisition Required (ha)	Nil			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	18.35			
Cropping Intensity		2.1	2.0	2.1
Average Yield (tonnes/ha)		3.1	3.2	3.4
Average Gross Margins (Tk/ha)		17,366	17,336	17,858
Owner Labour (md/ha)		129	130	130
Hired Labour (md/ha)		37	38	48
Irrigation (ha)		16,870	17,008	17,235
Incremental Cereal Prod'n (' 000 tonnes / yr)	11			
Incremental Non-Cereal (' 000 tonnes / yr)	0			
Incremental Owner Labour (' 000 pd / yr)	110			
Incremental Hired Labour (' 000 pd / yr)	434			

FISHERIES IMPACTS		Flood plain	Beels	Rivers/ Channels
Incremental Net Econ Output (Tk million / yr)	2.63	-3.97	1.75	4.84
Impacted Area (ha)		-4515	-15	+300
Average Gross Margins (Tk/ha)		1540	28700	12,250
Remaining Production %		62%	118%	151%
Incremental Fish Production (tonnes / year)		-173	42	108
Incremental Labour ('000 pd / yr)	-23	-173	42	108

FLOOD DAMAGE BENEFITS				
Households Affected		1056		
Reduced Econ Damage Households (Tk M / yr)	0.58			
Roads/Embankments Affected -km		250		
Reduced Econ Damage Roads (Tk M / yr)	1			

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

Table 7.11: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	79
EIRR, Increase Capital Costs by 20%	per cent	62
EIRR, Delay Benefits by Two Years	per cent	35
Net Present Value	'000 Tk	130,132

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	11,000	2
Incremental Non-Cereal Production	tonnes	0	0
Incremental Fish Production	tonnes	-23	-2.5
Change in Floodplain Wetland/Fisheries Habitat	ha	-4230	21
Homesteads Displaced Due to Project Land Acquisition	homesteads	Nil	0
Homesteads Protected From Floods	homesteads	1056	2
Roads Protected From Floods	km	50	20
Flood Levels	m PWD	0	-
Owner Employment	million pd/yr	0.11	+2
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	0.41	+16

Qualitative Impacts (ranked from -5 ...0... +5)	
Impact	**Rank**
Regional Biodiversity	-1
Road Transportation	+1
Navigation	+3
Flood Levels Outside Project Area	+3
Conflicts	-1
Socioeconomic Equity	-2
Gender Equity	-1
Responds to Public Concerns	+3
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; Kushiyara water level; and total employment for owners and hired labourers.

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

8. OUTSTANDING ISSUES

To complete the study of the area, it is required to investigate whether the area above Karnajhora could be economically used as a sediment settling basin. This will reclaim about 1000 ha of sand laden land, supply irrigation water, and also help prevent rapid siltation of the Karnajhora-Mrigi River. The study requires the following data:

- Contour survey of the area above Border Road
- Water level, discharge and sediment measurement of the Karnajhora River at Karnajhora

ANNEX A

TABLES

Table A.1: Climatological Data

Station: Jamalpur Location: 24°57'N;89°56'E

Month	Mean Temperature (oC)	Rain[1/] (mm)	Humidity (%)	Wind (Knots)
Jan	19.5	23	80	6
Feb	21.0	10	78	4
Mar	24.2	13	73	5
Apr	26.9	53	73	6
May	27.6	184	81	6
Jun	28.2	244	88	5
Jul	28.6	288	90	5
Aug	28.4	315	91	5
Sep	26.5	288	88	4
Oct	26.0	133	87	4
Nov	23.1	5	84	3
Dec	19.8	4	82	3
Year	25.2	1618	82	4

Source: BMD

[1/] Rainfall collected at this station significantly varies with the rainfall amount in the surrounding stations collected by BWDB.

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Table A.2 : Area-Elevation

Elevavion (m,PWD)	Area Under Elevation (ha)	Elevavion (m,PWD)	Area Under Elevation (ha)
12.0	117	17.5	35,707
12.5	350	18.0	42,592
13.0	1,284	18.5	46,793
13.5	2,800	19.0	49,477
14.0	4,784	19.5	52,861
14.5	8,635	20.0	55,778
15.0	11,086	20.5	56,361
15.5	14,353	21.0	56,945
16.0	18,087	21.5	57,062
16.5	24,622	22.0	57,100
17.0	30,340	24.5	57,600

Table A.3 : Annual Maximum Water Level of Old Brahmaputra River at Different Locations for Different Recurrence Interval

Stn No.	Station Name	River Name	Annual Peak Level (m,PWD)			
			2-yr	5-yr	10-yr	20-yr
225	Jamalpur	Old Brahmaputra	17.01	17.37	17.53	17.64
226	Sirkhali Offtake	Do	14.39	14.66	14.77	14.84

Table A.4 : Water Bodies in the Mrigi River Drainage Project

Beel Name	Dry Season Area (ha)	Beel Name	Dry Season Area (ha)
Goalgaon beel	12	Boisha beel	129
Kaladangar beel group	12	Para beel (Satpakia)	42
Singijani beel	17	Betmari beel	53
Kursha beel	47	Jaiduba beel	58
Mrigi beel	29	Matidanga beel	54
Chatla beel	9	Dublakuri	21
Bochadaha beel	9	Kaid beel	12
Dhiar beel	24	Bardubi beel	84
Saguna beel	7	Kursa beel	61
TOTAL : 680 ha			

Source:NERP

Table A.5: Closed Water Bodies in the Project Area

Thana	Number of ponds	Pond area (ha)	Average pond size (ha)	Pond concentration (nos/km2)
Bakshiganj	175	25	0.14	3.72
Sribordi	745	109	0.14	3.64
Jhinaigati	46	6	0.13	3.69
Sherpur	768	108	0.14	3.70
Nakhla	288	40	0.13	3.69
Jamalpur	90	12	0.13	3.67
Total	2112	300	0.14	3.68

Source: BFRSS,1986

Table A.6 : Usable and Availabe Groundwater Recharge Within the Project by Different Techniques

Thana Name	Area Within Basin (km²) Project	Total Area of Thana (km²)	Percent Area Within Project	Usable GW in the Basin by Different Techniques (Mm³)			Available GW in the Thana by Different Techniques (Mm³)			Available GW in the Thana by Different Techniques (Mm³)			Available GW in the Basin by Different Techniques (Mm³)		
				STW	DSSTW	DTW	STW	DSSTW	DTW	STW	DSSTW	DTW	STW	DSSTW	DTW
Bakshiganj	47.80	204	23	35.30	80.70	79.50	8.12	18.56	18.29	34.58	59.45	77.87	7.95	13.67	17.91
Sribardi	205.80	256	80	25.70	41.10	108.90	20.56	32.88	87.12	17.41	27.85	73.78	13.93	22.28	59.02
Jhenaigati	12.20	208	6	8.80	16.80	89.40	0.53	1.01	5.36	8.16	11.89	49.71	0.50	0.71	2.98
Sherpur	208.10	358	58	62.1	106.7	187.4	36.02	61.89	108.69	61.56	105.77	185.77	35.70	61.35	107.75
Nakhla	78.50	174	45	42.80	78.70	84.33	19.26	35.42	37.95	41.64	76.57	82.05	18.74	34.46	36.92
Jamalpur	23.60	489	5	5.36	14.59	28.02	0.27	0.73	1.40	5.12	13.96	26.81	0.26	0.70	1.34
Total							84.76	150.49	258.81				77.08	133.17	225.92

Source: WARPO, National Water Plan Project, Phase II, 1991, Thana Recharge Volume Estimates.

Table A.7: Carp Spawn Collection Center Around Project (Old Brahmaputra River)

Collection Center	Number of		Quantity of Spawn Caught (kg)
	People Engaged	Net Used	
Pullakandi	101	215	111.00
Nandinabazar	23	30	14.75
Baiboonbari *	20	30	12.25
Total	144	275	138

Source:BFRSS, 1988 & * NERP,1992

Table A.8
Flood Routing Result Polder Analysis

Month	Decade	Inflow (m^3/s)	Outflow (m^3/s)	Pold. Wl (m,PWD)	River.Wl (m.PWD)	Area Flooded (Ha)		Head Diff (+ive,m)
						With	Without	
Apr	I	0.00	0.00	9.42	9.39	102.4	102.3	0.03
	II	0.00	0.00	9.58	9.59	103.3	103.4	0.00
	III	0.00	0.00	9.92	9.95	105.3	105.5	0.00
May	I	0.00	0.00	10.60	10.64	109.2	109.5	0.00
	II	0.00	0.00	11.47	11.50	114.2	114.4	0.00
	III	0.00	0.00	11.96	11.98	116.7	116.7	0.00
Jun	I	14.67	5.84	12.42	12.41	315.0	308.1	0.01
	II	30.55	0.00	13.72	13.78	3679.5	3911.5	0.00
	III	30.58	17.64	14.75	14.74	9860.3	9811.3	0.01
Jul	I	35.08	33.09	14.79	14.74	10049.3	9811.3	0.05
	II	32.22	2.26	14.97	14.97	10954.6	10938.6	0.00
	III	32.95	21.68	15.28	15.27	12935.5	12849.9	0.01
Aug	I	26.25	54.38	15.21	15.14	12442.4	12000.4	0.07
	II	21.11	53.08	15.00	14.94	11087.7	10791.5	0.06
	III	23.02	39.45	14.72	14.67	9705.1	9468.3	0.05
Sep	I	20.90	23.75	14.73	14.71	9743.5	9664.3	0.02
	II	27.55	40.86	14.60	14.56	9122.9	8929.1	0.04
	III	13.28	36.38	14.54	14.51	8852.0	8684.1	0.03
Oct	I	0.00	52.79	14.02	13.97	4958.5	4665.3	0.05
	II	0.00	19.92	13.37	13.33	2411.9	2284.8	0.04
	III	0.00	3.92	12.30	12.25	255.0	233.4	0.05
Nov	I	0.00	0.93	11.34	11.30	113.5	113.3	0.04
	II	0.00	0.01	11.00	10.72	111.6	109.9	0.28
	III	0.00	0.00	11.00	10.29	111.6	107.4	0.71

ANNEX B

ENGINEERING ANALYSIS

ENGINEERING ANALYSIS

1. Data Preparation

Cross section

Cross-sectional data for the Mrigi River from Boysha Beel to Char Betmari for a reach length of 28.207 km has been obtained from the BWDB Sherpur Section Office. The remaining 19.8 km of river reach from Char Betmari to Char Astadhar has not been surveyed so the requirements for channel improvement for this reach could not be assessed. Water surface slope for this reach is assumed to be 5 cm/km.

Discharge and Water Levels.

The river is not gauged. In absence of any flow measurement, design discharge has been estimated from drainage modules. For design purposes, the river length under consideration has been divided into three reaches. These sections are shown in Annex E, Figure 1. The estimated discharge is given in Table B.1. Due to topographical characteristics, a drainage module of 40 mm/day has been assumed for a catchment area of 7,890 ha above the Border Road. For the remaining area, a drainage module of 35 mm/day has been taken for discharge estimation.

Water level at the outfall (Char Betmari) is assumed to be 0.95 m (slope: 5 cm/km) higher than that in the Old Brahmaputra River at Sirkhali Offtake. Water level at the Sirkhali Offtake is given in table A.3.

Table B.1

Section	Catchment Area (ha) above the Section	Drainage Module for the reach (mm/day)	Discharge (m^3/sec)	Remarks
Border Road	7,890	40	37	Karnajora
0.00 km	23,000	35	99	Boysha Beel
10.825 km	31,150	35	132	
16.892 km	39,250	35	165	
28.207 km	47,400	35	198	Char Betmari

2. Methodology

HEC-2 Program which is the computer version of Standard Step Method has been used for computing water level profiles for design discharge. A sensibity analysis has been made for different outfall water levels. It was observed that the outfall water levels have no significant change on water level profiles in the upstream. However, a 5-yr water level which comes to be 15.61 m,PWD is selected for the final run. A Manning's roughness co-efficient of 0.03 is assumed for the analysis. In absence of measured data, these assumed values could not be verified. The water levels at different cross section points in pre and post project conditions are tabulated in Table B.2 and graphically shown in Annex E, Figure 3.

The design bed levels and bed widths are also shown in Annex E, Figure 3. However, these should not be considered as the final design for the river.

The longitudinal profile with the existing cross sections shows a sharp drawdown at the outfall indicating that the channel has been choked up due to heavy siltation.

Area by land type. Areas under different land types, with and without re-excavation, have been computed from flood depth maps prepared on the basis of the computed water levels as given in Table B.2. Area by land type is given in Table B.3.

Table B.2 : Water Level of Mrigi River
(Before excavation and after excavation)

Distance at Cross-section Point (km)	Water Level (m,PWD)	
	Before Excavation	After Excavation
28.207	15.61	15.61
27.811	15.69	15.63
26.811	16.07	15.7
25.811	16.21	15.77
25.422	16.22	15.77
25.079	16.25	15.79
24.872	16.24	15.78
24.079	16.35	15.84
23.500	16.42	15.91
22.500	16.53	15.98
21.500	16.6	16.04
20.500	16.71	16.13
20.073	16.75	16.17
19.073	16.89	16.26
18.122	16.99	16.34
17.909	17.02	16.36
17.756	17.03	16.36
17.603	17.03	16.39
16.982	17.07	16.43
16.799	17.08	16.43
16.601	17.09	16.42
16.525	17.09	16.43
15.793	17.15	16.51
14.793	17.25	16.61
14.000	17.35	16.7
13.628	17.47	16.79
13.476	17.47	16.78
13.335	17.51	16.8
13.323	17.5	16.83
13.235	17.51	16.82
12.784	17.56	16.89
11.784	17.65	16.96
11.631	17.66	16.97
11.540	17.68	17.02
10.825	17.74	17.07
9.825	17.84	17.14
9.672	17.87	17.17
9.381	17.89	17.18
9.198	17.9	17.2
9.076	17.91	17.21
8.762	17.95	17.25
8.609	17.98	17.26
8.304	18.01	17.3
8.060	18.04	17.33
7.907	18.03	17.34
7.000	18.14	17.44
6.000	18.24	17.56
5.625	18.28	17.6
5.183	18.32	17.64
5.000	18.34	17.65
4.000	18.41	17.73
3.854	18.43	17.75
3.701	18.46	17.77
3.548	18.47	17.77
3.000	18.51	17.82
2.793	18.53	17.85
2.640	18.53	17.85
2.000	18.58	17.87
1.229	18.68	17.96
1.000	18.73	17.99
0.656	18.77	18.03
0.000	18.79	18.01

Table B.3 : Area by Land Type - With and Without Re-excavation

Land Type	Without Re-excavation		With Re-excavation	
	Gross Area (ha)	Net Area (ha)	Gross Area (ha)	Net Area (ha)
F0	4,600	2,000	15,400	12,800
F1	9,300	9,300	5,100	5,100
F2	8,000	8,000	2,200	2,200
F3	2,500	1,300	1,700	500
Total	24,400	20,600	24,400	20,600

Table B.4: Estimated Capital and O & M Cost

Item of Work	Quantity m^3	Unit Price (Tk/m^3)	Capital Cost (mtk)	O&M Cost (%)	O&M Cost (mtk)
Drainage Channel Re-Excavation	2,331,000	15.40	35.90	3	1.08
Physical contingency 25%			8.98	3	0.27
Sub-total			44.88		1.35
Engg. & Admin 15%			6.73	3	0.20
Total			51.61		1.55

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

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 FCD 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: 57,600 ha (Basin Area).
Impacted (net) area: 20,400 ha.
Impacted area outside project: none

Temporal:

Preconstruction: years 0 through year 1
Construction: year 1 through year 2
Operation: channel maintenance will be required; there are no other operational requirements.
Abandonment: after year 20.

Cumulative impacts:

With other floodplain infrastructure: none
With pre-existing no-project trends. Described in Chapter 5.

C.2.5 Field Investigations (Step 5)

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

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 and Tables 7.5 through 7.11.

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. Negative impacts are expected to be minimal so no mitigation measures were incorporated.

Compensation. There is no requirement for land acquisition; no compensation is required.

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). The project will improve drainage and thus permit farmers to shift to more intensive and higher input agriculture. The risks associated with this relate to gradual infilling of the Mrigi River system over time as a result of no on-going maintenance and a gradual return to present (pre-) project conditions.

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.

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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 N/A										
	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 N/A										
		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

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 <u>outside the project area</u> 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 <u>duars</u>. <u>Duars</u> are somewhat a separate problem as they are located in rivers and larger channels, not on the floodplain.

The foregoing is represented quantitatively here as:

FWO production =

$$(R_0 * P_{R0}) + (B_0 * P_{B0}) + (W_0 * P_{W0})$$

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FW production =

$$[\ M *\ Q * (\ R_1 * P_{R0}\ )\ ] + [\ M * Q * (\ B_1 * P_{B0}\ )\ ] + [\ M * (\ W_1 * P_{W0}\ )\ ]$$

Thus,

Impact = FW - FWO production =

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

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

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

where

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

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

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

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

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

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

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

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

Estimated values for this project are shown in 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.

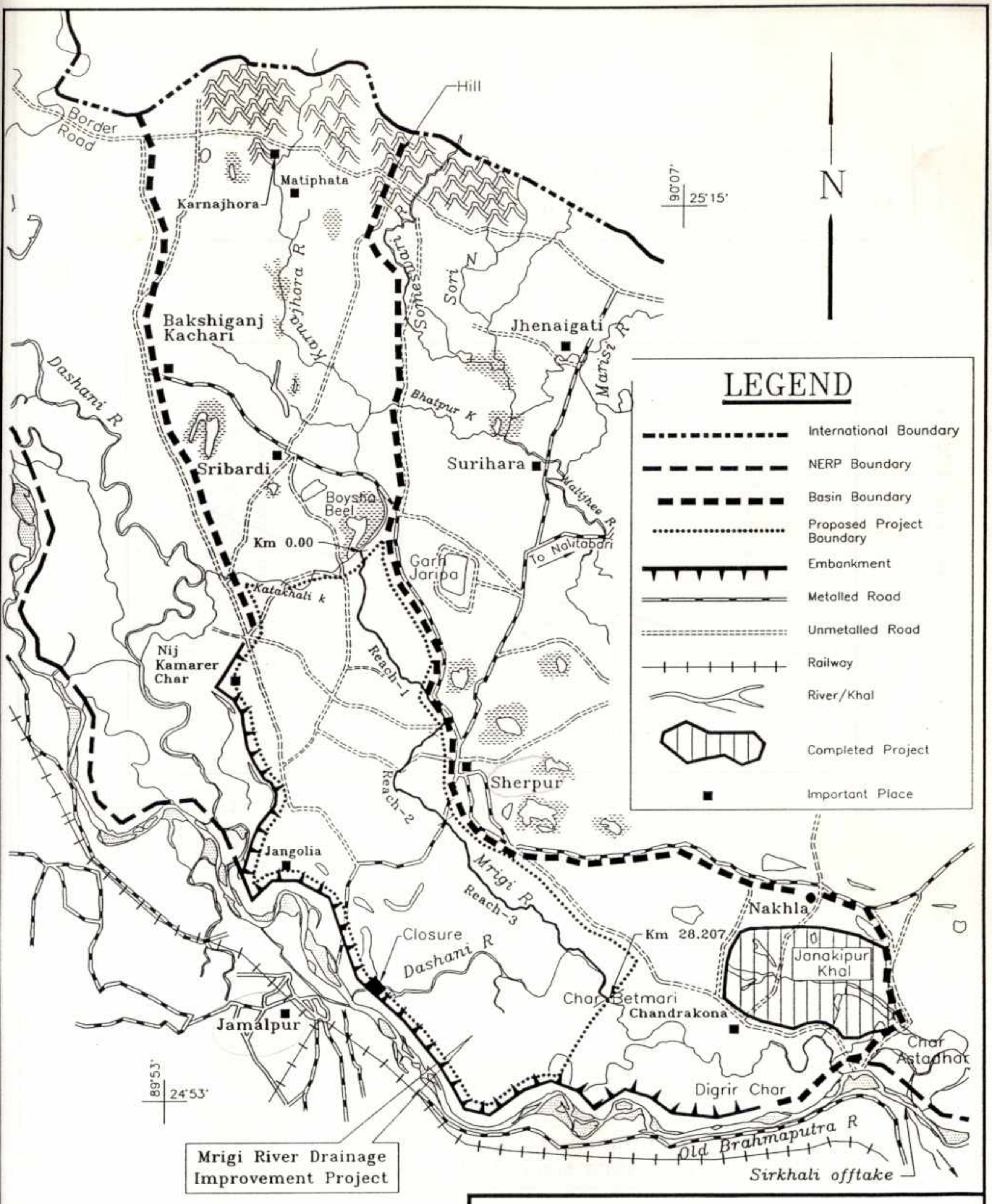
Table D.1: Fisheries Parameters

Var	Value	Stnd value?	Comments
M	1.1	0.8	Fish migration routes will be improved with channel re-excavation and access to the Old Brahmaputra will be retained.
Q	1.1	0.8	Water quality is expected to improve since water will not stagnate in the system.
R_0	1200		
R_1	1500		The project will improve the over-wintering habitat since the river channel will be deeper and the rivers surface area will increase.
B_0	575		
B_1	560		Beel area will be reduced because of improved drainage.
W_0	10430		
W_1	5915		
P_{R0}	175	175	
P_{B0}	410	410	
P_{W0}	44	44	
A_M	—	100000	There is no "mother fishery" in this area.

ANNEX E

FIGURES

Figure 1



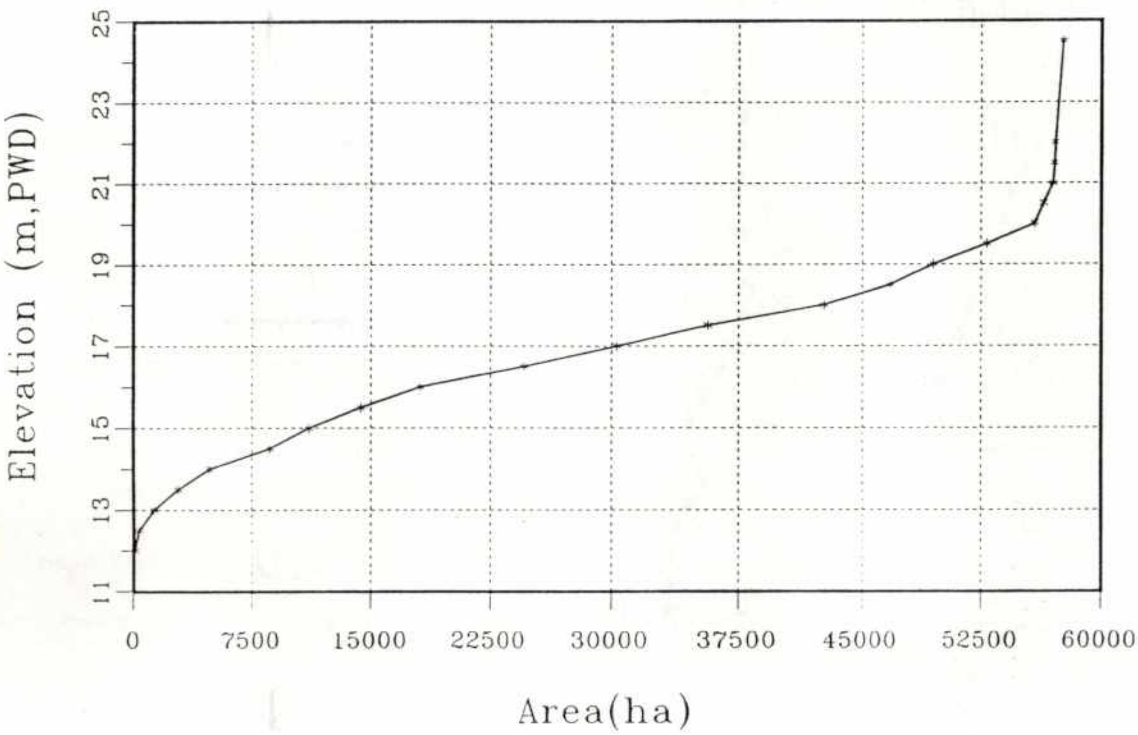
Northeast Regional Project

Mrigi River Basin

Prepared by: FR/Jalal	April 1993

FILE: NERP-119.DWG

Area Elevation Curve
Mrigi River Drainage Improvement Project

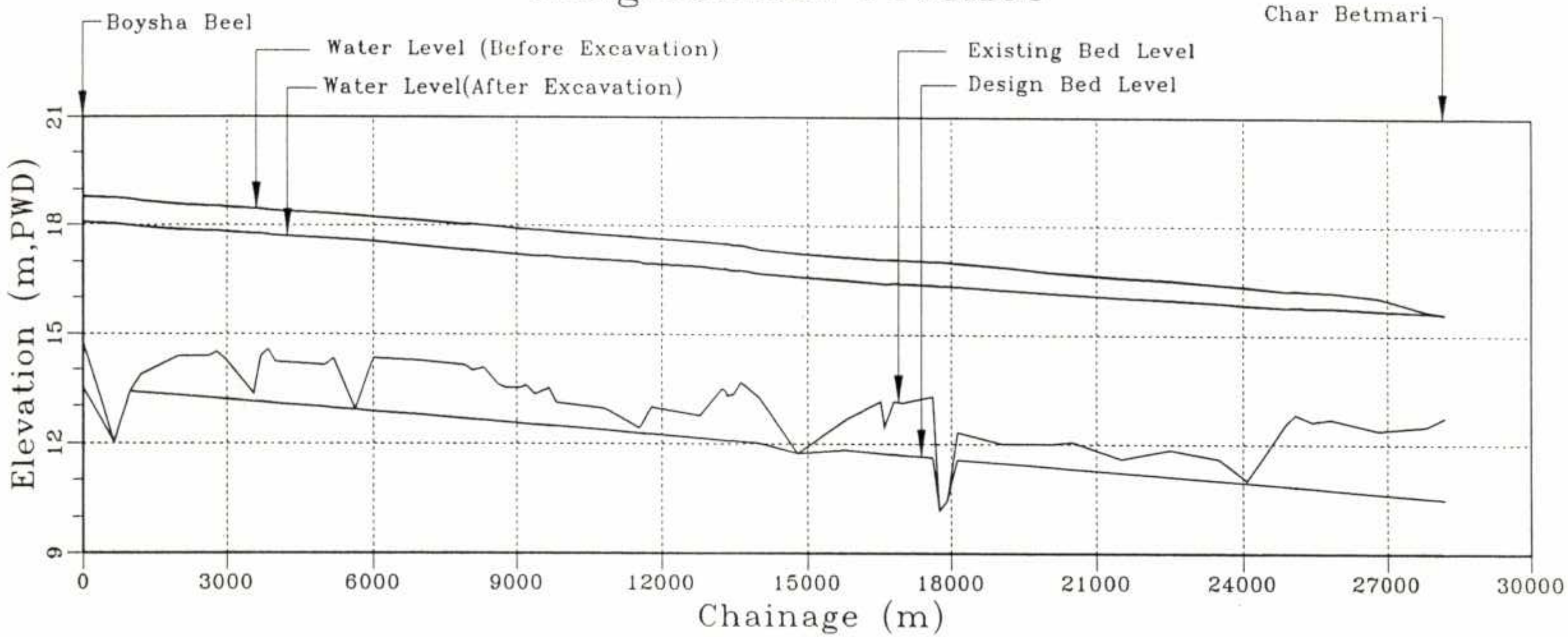


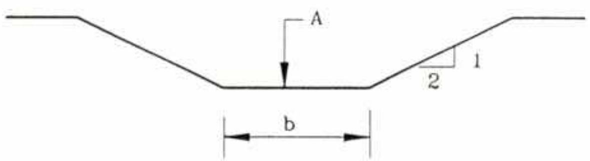
Data :

El(m,PWD)	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0
	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	24.5
Area(ha)	117	350	1284	2800	4784	8635	11086	14353	18087	24622	30340
	35707	42592	46793	49477	52861	55778	56361	56945	57062	57100	57600

Figure 3

Mrigi River Drainage Improvement
Longitudinal Profiles





Typical D. X-Section

Existing X-section at 11784 m

Distance km	Design B.Lev (A) m,PWD	Design B.Width (b) m
0.000	13.50	25.00
10.825	12.35	25.00
16.982	11.69	40.00
28.207	10.50	40.00