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)

SURMA-KUSHIYARA-BAULAI BASIN PROJECT

Draft Final
December 1993

Shawinigan Lavalin (1991) Inc.
Northwest Hydraulic Consultants

in association with

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

MPO Land Classification Terminology

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

EXECUTIVE SUMMARY

The purpose of this project is to protect *boro* crops grown in the low *haor* areas from winter and pre-monsoon floods; to mitigate the effect of monsoon floods on *aus* and *aman* crops; and to protect infrastructure in the higher area to the east while retaining the integrity of the wetlands and fish sanctuary in the Khaliajuri area to the west.

The natural resource and agricultural systems of *haors* within the project area are coming under increasing pressure as the number of people dependent on this system grows. The results of past attempts to increase productivity in the area through flood control and drainage are not satisfactory. These attempts involved construction of localized ring embankments (submersible) such as the Baram *haor*, Udgal *beel* and Shanghair *haor* projects. The embankments are breached or overtopped regularly by pre-monsoon floods, they hamper drainage and obstruct navigation. In addition, they have strong negative impacts on the natural resource base (fisheries and wetlands).

The solution proposed for this area is the completion of flood embankments on three sides of the area (along the left bank of the Surma-Nawa-Baulai Rivers and along the right bank of the Kushiyara-Kalni Rivers) to prevent pre-monsoon flood flows from the north and east. The south and southwest side would be left open for monsoon and post-monsoon drainage, for natural monsoon flooding, for the entry of spawning and other fish, and for navigation purposes. The drainage system to the south would be improved through the excavation and re-excavation of strategic channels. Ancillary structures (including regulators, fish passes, and navigation passes) would be provided at the off-takes of major spill channels in the north and southeast.

The project would be implemented by BWDB at an estimated cost of US$ 35.8 million.

NERP DOCUMENTS

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

Northeast Regional Water Management Plan

Main Report
Appendix: Initial Environmental Evaluation

Specialist Studies

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

Public Participation Documentation

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

Pre-feasibility Studies

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

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1. INTRODUCTION

1.1 General Information

BWDB Division:		Sylhet, Sunamganj, Netrokona, Kishorganj
District:		Sylhet, Sunamganj, Netrokona, Kishorganj
Thana(s):	*Under Sylhet District*:	Balaganj, Biswanath, Golabganj, Fenchuganj, Sylhet Sadar
	Under Sunamganj District:	Chhatak, Derai, Dowarabazar, Jagannathpur, Jamalganj, Sunamganj, Sullah
	Under Netrokona District:	Khaliajuri
	Under Kishorganj District:	Itna

MPO Planning Area:	23, 24, 26, 27, 29
Gross Area:	319,289 ha
Net Area:	254,589 ha
Population:	1,892,147
Households	311,107

1.2 Scope and Methodology

This pre-feasibility study was undertaken over a period of one month in mid 1993. The study team consisted of a water resources engineer, a socio-economist, an agronomist, a fisheries specialist, and a wetland resources specialist. Additional analytical support was provided by an environmental specialist and economist. The Rapid Rural Appraisal (RRA) technique was followed for collecting primary data where applicable.

1.3 Data Base

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

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

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

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

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

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

1.4 Report Layout

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

2. BIOPHYSICAL DESCRIPTION

2.1 Location

The Surma-Kushiyara-Baulai Basin Project covers a gross area of 319,289 ha in Sylhet, Sunamganj, Netrokona and Kishorganj districts, between latitude 24° 34' and 25° 00' N, and longitude 91° 05' and 92° 01' E. The project area boundaries are defined by the Golapganj Hills to the east, by the Surma-Nawa River to the north, by the Baulai River to the west and to the south by the Kushiyara-Kalni River from Fenchuganj to Ajmiriganj and by the Mora Surma River and Surma Khal channels between Ajmiriganj and Dhanpur (See Figure 1).

2.2 Climate

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

2.2.1 Variations in Annual Rainfall

The variation of annual rainfall over the project area is best represented by data for 1961-90 for the eight BWDB rain gauges in, or around the periphery of, the project area. The locations of these rain gauges are given in Table A1, and the data for 1961-90 in Table A2 (Annex A).

The data show that annual rainfall increases from an average of 2898 mm/year in the south to 5539 mm/year in the north, or by 91% across the project area. This latitudinal increase is mainly attributable to the presence of the Shillong Plateau to the north (Figure 2).

A regional analysis of annual rainfalls (NERP, 1993a) has shown that mean annual rainfall for 1961-90 was 10% greater than that for 1901-30, and that the variability of annual rainfalls for 1961-90 was 1.95 times that for 1901-30. These disturbing trends have been reflected in increased floods and flooding in recent years, but it is not known whether they will continue into the future, level off, or be reversed. Climate modelling research being undertaken in the West suggests these trends, particularly that in variability of the annual rainfalls, will continue in the decades ahead.

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

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

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

Table 2.1: Definition of Seasons in the Project Area

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

Table 2.2: Seasonal Distribution of Rainfall in the Project Area

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

These figures show that the rainfall is heavily concentrated in the monsoon season, but more so in the north than in the south, and that the dry season is slightly more intense in the north than in the south.

2.2.2 Climatological Averages and Extremes

The climate of the project area as a whole is best represented by data for Sylhet, the nearest BMD climatological station, located on the northeastern edge of the project area. Data are available for 1957-91 (35 years). The averages are given in Table A3, and the extremes of record in Table A4.

Annual sunshine hours average 6.4 hours/day, and average monthly sunshine hours range from a minimum of 3.6 hours/day in July to a maximum of 8.5 hours/day in November. No radiation data are available.

The mean annual temperature is 24.9°C, and average monthly temperatures range from a minimum of 18.9°C in January to a maximum of 28.3°C in August.

Monthly mean minimum temperatures range from 12.4°C in January to 25.1°C in July/August, and extreme minimum temperatures of record range from 5.7°C in January to 21.7°C in July.

Monthly mean maximum temperatures range from 25.1°C in January to 31.3°C in August, and extreme maximum temperatures have ranged from 28.5°C in January to 40.5°C in April.

The annual mean humidity is 79%, and monthly averages range from 65% in February to 88% in June through September.

The annual mean wind speed is 7.3 km/hour from the east-southeast. Monthly average wind speeds range from 2.1 km/hour to 8.8 km/hour, but the extreme gust of record is 168 km/hour. Winds are generally from the southeast during the monsoon season, and vary between southeast and east-northeast in the other seasons.

The mean annual rainfall is 4253 mm. Average monthly rainfalls range from 8 mm in January to 805 mm in June, and monthly rainfalls have ranged from 0 mm in November through February to as much as 1322 mm in July. The extreme daily rainfall of record is 508 mm.

Potential evapotranspiration averages 1550 mm/year, and ranges from 103 mm (3.3 mm/day) in December to 162 mm (5.2 mm/day) in March.

The surface water balance shows an annual excess of 2703 mm which runs off into the river system or recharges the aquifers. The monthly water balance is positive in April through October and ranges up to 680 mm/month in June, but during November through March the balance is negative reaching as low as -98 mm in January. The winter surface moisture deficit is generally met from residual soil moisture until February after which a demand for irrigation normally arises.

2.3 Land (Physiography)

2.3.1 General Description

The Project area is bounded by the Surma and the Kushiyara Rivers to the north and south respectively, and by the Baulai River to the west. The rivers in general have along their banks narrow natural levees composed of alluvial deposits, which are a few meters higher than the internal part of the basin. In the east, the Golapganj Hills separate the project from the remaining eastern part of the Surma Kushiyara basin, also called the Upper Kushiyara Basin.

The area in general slopes from northeast to southwest. The eastern part of the project comprises relatively higher gently sloping plains along the Surma from Sylhet to Chhatak extending south towards Sherpur, and lower depressions along the Kushiyara River which define its right bank floodway. This part of the basin belongs to the physiographic unit of the Surma/Kushiyara Floodplain, or Sylhet Plain.

The western part of the project, approximately west of the Chhatak-Jagannathpur line, comprises a bowl-shaped depression with the Baulai River defining its western boundary. This depression is open to the south towards the Upper Meghna between the channels of the Baulai and Kalni Rivers. This part of the basin belongs to the physiographic unit of Sylhet Central Basin.

Interfluvial depressions called *haors and beels* are present across the project with higher occurrence in the Sylhet Basin and along the Kushiyara floodway.

The area is laced with internal rivers and khals which are spill channels of the Surma and Kushiyara. Most of the Kushiyara channels are closed or have silted. Some of the Surma channels have also been closed, but five larger channels remain open.

The average ground elevation of the area varies from about 3 m PWD (with about 1.0 m PWD in the low pockets) in the southwest to about 11 m PWD in the northeast of the project. The elevation of the Golapganj Hills located along the eastern boundary of the project reaches 16 m PWD.

Project topography is shown in Figure 3. The project basin elevation versus cumulative area and storage volume relations are presented in Annex A and are graphically presented in Figure 5 through 9. Throughout this report, the project has been divided into five approximately homogenous sub-regions. These are demarcated along the dry season drainage boundaries and are shown in Figure 4.

2.3.2 Soils

The Surma-Kushiyara-Baulai project is covered by Old and Young Surma-Kushiyara floodplains.

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

The very poorly drained basin clays which remain saturated throughout the year, have a strongly reduced colour and near neutral reaction. Sometimes this landscape overlies a mucky or peaty layer within four feet of the surface. Depth to the organic layer gradually decreases from the periphery to the centre of the basins. Exposed organic layer was not reported in the project area.

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

2.4 Water (Hydrology)

2.4.1 Runoff Patterns

The hydrological regime of the Surma-Kushiyara-Baulai basin is governed mainly by the Surma, Kushiyara, and Baulai Rivers which surround the project area. The Lower Kushiyara (Kalni) and the Baulai are tidal and their water levels are affected by backwater from the Lower Meghna River. The Barak River, of India, bifurcates, on entry into Bangladesh at Amalshid, into the Kushiyara and Surma rivers. The Barak River, which has a drainage basin of 25,263 km^2, contributes much of the flow in the Kushiyara and Surma. The Kushiyara River has two left bank tributaries which augment its flow within the project area; the Juri River (2,963 km^2) and the Manu River (2,235 km^2). The Surma-Baulai River system has eight major and several smaller right bank tributaries with a total catchment of about 10,000 km^2.

The internal basin runoff pattern is from north to south in the east of the basin and from east to west. As the interior part of the basin is below the high levees along the peripheral river banks, these rivers dominate flooding of the basin and also control its drainage. The prevailing run-off patterns within and around the project area are shown in Figure 10.

All channels within the basin originating from the Surma River are spill channels. There is no drainage from the basin into the Surma River, with the exception of Madhabpur Khal which drains back into the Surma during the post-monsoon season.

All the Kushiyara right bank channels located between Ajmiriganj and Balaganj have been closed or are silted. The remaining four open channels located upstream from Balaganj act as spill and drainage channels, depending on the river stage.

At the stage when river levels are rising, there is no drainage from the basin into the boundary rivers. Flood water entering the basin from rivers and local runoff flows through the internal khals and across the lower land towards the Mora Surma and the Darain Khal channels. These channels then drain into the Baulai at Dhanpur and also spill southward over the floodplain.

2.4.2 Flooding

Three types of floods occur in the project area:

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

The winter floods, which occur between December and February, are caused by winter storms in the outlying hills as well as by local rainfall. They occur suddenly and are of a relatively short duration and hence are characterized as flash floods. They rarely overtop the river banks but water readily enters the haors because at this time of the year, there are numerous openings in the river banks including hydraulic structures of which the gates remain open. Because the drainage system generally is inadequate, water remains in the lowlands and submerges crops to depths and for durations beyond their tolerance. As a result the crops (usually boro rice at various early stages) is damaged. These floods do not occur every year and are rather unpredictable.

The pre-monsoon floods which occur between March and June are a normal feature of the region. While average pre-monsoon floods usually stay within the banks of the surrounding rivers and enter the project area through the open spill channels the higher frequency floods (1:10-year) overtop river banks reaches where the banks are low. These floods have high peaks and they may last from a few days to about two weeks, depending on the time of occurrence. The pre-monsoon flood volume is sufficient to fill the haor depressions, and they are the cause of major crop damages in the region.

The monsoon season floods are a combination of flood inflow from external rivers, seasonal rainfall, and in the lower part of the basin the lack of drainage due to backflow effect of the Lower Meghna. Agriculture damage from these floods tends to be less since farmers either leave their land fallow during this time or they plant flood tolerant low yielding deepwater aman.

The crop damage caused in the project area by the winter and the pre-monsoon floods can be reduced substantially by improving internal drainage to allow faster evacuation of the rainfall runoff and by reducing or regulating the external flood inflows into the area.

The monsoon season floods are large and normally last from July to October. With the exception of the higher Sylhet Plain and some highlands in the northeastern part of the project, there is very little scope of protecting the agricultural land from the monsoon flooding. The extent of monsoon season flooding in 1988 over the project area is shown in Figure 11.

The major sources of external floods in the project area have been identified as:

- The Kushiyara River and the Kura Gang in the upper part of the basin east from the Sherpur-Sylhet Road. There are four open spill channels in the Kushiyara right bank upstream from Balaganj: Kurkuchi Khal, two Betari Nadi channels, and the combined outlet of Patacharal Beel and Barbhanga Nadi at Balaganj.

- The Surma River. There are five open spill channels in the left bank of Surma and one in the Baulai. The channels with their estimated 10-year pre-monsoon flood inflows are: Bahia/Itakhola Khal (100 m^3/s), Kazanchi Nadi (136 m^3/s), Bhatta Khal (300 m^3/s), Madhabpur Khal (80 m^3/s), Old Surma at Nilpur (120 m^3/s), and Piyain River at its outfall into Baulai (150 m^3/s). The offtake of the Piyain from the Nawa River is closed.

2.4.3 Drainage

The project's drainage pattern mirrors the land gradient, sloping from north to south and southwest. Since the Surma River flows along the higher boundary of the project, all Surma left bank channels are spill channels. With the exception of the Madhabpur Khal near Chhatak which drains back in the post-monsoon season, there is no drainage from the project basin into the Surma River.

Historically the project area drained into the Kushiyara channel. However, due to siltation of the Kalni River (Lower Kushiyara) and resulting higher river levels, the river has lost its drainage capacity along the right bank.

At present, most of the project basin drains into the Baulai River through the Mora Surma and Darain River channels. A small part of the northwestern basin drains via the Piyain River. When water levels are falling in the rivers, a small part of the project east of Balaganj drains into the Kushiyara through the Kurkuchi Khal, Betari Nadi, Patacharal Beel Khal, and Barbhanga Nadi. The Barbhanga Nadi flow is divided, with part of the water discharging into the Kushiyara at the eastern end of Balaganj town and part flowing west into the Kushiyara right bank floodway through Khasipur Khal. There are no active drainage outlets from the project into the Kushiyara between Balaganj and Ajmiriganj.

Local drainage is effected through a dense network of khals which are intercepted by the Darain Nadi and the Mora Surma River channels. These two rivers drain into the Baulai River at Dhanpur. Most of the internal channels are interconnected, which makes the flow pattern quite complicated as it may change seasonally. Characteristically, the channels are larger in their upper sections and smaller or just dissipate into beels and haors near the low south central part of the project basin. Insufficient capacity of the channels in their lower reaches results in drainage congestion and prevents timely drainage from the basin.

Both, the existing system of internal channels, and their discharge capacities are inadequate to provide drainage to the project basin. At present, the runoff (including the spills from Kushiyara) from the upper part of the basin east of Sherpur-Sylhet road drains west through Sadipur Khal at Sherpur. The Sadipur Khal, which empties into the beels west of the Sherpur-Sylhet road, does not have a direct outlet into the Kushiyara River. As a result the flood water accumulates there until it overtops the Kushiyara right bank or finds its way through the Naljor River - Kamarkhali Khal and Darain Nadi into the Baulai River at the southwestern boundary of the project.

Runoff from the entire project basin is intercepted by the channels of Darain Nadi and Mora Surma River which discharge into the Baulai River at Dhanpur (see Figure 10). The Darain Nadi and the Mora Surma channels are too small to convey the rainfall runoff and the spills from the Surma, and as a result drainage from the entire project basin is delayed.

2.4.4 Water Bodies

Open water bodies
About 22,500 ha (7.0%) of the project is under permanent water bodies, of which 14,300 ha are haors and beels, and about 8,200 ha are channels. These open water bodies include 29 haors, 43 beels and 14 river and khal channels as listed in Table 3.7.

Most of the haors and beels are interconnected with channels through which water spills into the project from the Surma, Dhanu/Baulai and Kushiyara Rivers during the flood season and drains out at the end of the monsoon season.

Closed water bodies
In addition to the open beels and khals there are about 28,502 ponds and ditches used for fish stocking and other household purposes. The ponds have a total area of about 2300 ha. Most of the ponds are inundated during the high monsoon floods, particularly in low areas.

2.4.5 Surface Water Availability

The Surma-Nawa-Baulai and the Kushiyara-Kalni river systems are the source of external inflows into the project area. These rivers are perennial and spill into the project keeping internal khals active from April to October. During winter when the peripheral rivers are low the internal khals and rivers dry up along most of their reaches. Only the lower sections of Kalni, Darain, Mora Surma and Piyain rivers, which are influenced by backwater from the Lower Meghna, retain water and are navigable during the winter season.

Surma-Nawa-Baulai River
The Surma River has a smaller cross-section upstream of Chhatak and during the winter season, the channel bed is some times visible at Sylhet. Downstream of Chhatak, however, the channel is larger and is navigable throughout the year. Downstream of Sunamganj, the channel turns southward into the project area at Nilpur, but the main discharge of the river flows westward into the Nawa River channel. The historic Surma River channel is partly silted and is dry during the winter season in the upper reach of the channel now referred to as the Mora Surma. The Surma River is gauged at Kanairghat (St. No. 266), Sylhet (St. No. 267), Chhatak (St. No. 268) and Sunamganj (St. No.269).

The Nawa River flows into the Baulai River, which demarcates the western boundary of the Project. The Baulai (also called the Dhanu River) is gauged at Sukdevpur (St.No. 72B), Khaliajuri (St. No. 72) and Itna (St. No. 73).

The Surma-Baulai River has several right bank tributaries which carry high flash flood discharges. Maximum daily discharges measured at Kanairghat and Sunamganj are 2730 m^3/s and 4350 m^3/s respectively, the minimum daily discharge at Kanairghat is 2.2 m^3/s. There are no reliable low discharge records in the Surma downstream of Chhatak, where the river is deep but has very low velocity during winter.

Kushiyara-Kalni River
There are four gauging stations within the project boundary: Fenchuganj (St. No. 174), Sherpur (St. No. 175.5), Markuli (St. No. 270) and Ajmiriganj (St. No. 271). The River is tidal downstream of Sherpur and only water levels are measured at the stations below Sherpur. Daily discharges recorded at Sherpur vary from a minimum of 45.6 to a maximum of 3950 m^3/s.

The Kushiyara River has two major left bank tributaries within the project boundary, the Juri-Sonai-Bardal River and the Manu River. These rivers, with hilly catchments in India, convey flash floods.

During the winter season, water levels in the rivers bounding the project are below the average ground levels in the basin. As described earlier, average pre-monsoon floods are generally within the river's banks but water spills into the project through open khals and in some places over lower banks. Monsoon flood peaks overtop the river banks over their entire reach. Only homesteads located on high levees remain above the water line. In the lower part of the project (downstream of Sherpur) river banks remain inundated for extended periods of time.

Details on water levels and discharges are provided in Annex A.

2.4.6 Ground Water

The estimated total usable ground water recharge within the project area is 334 Mm^3. Of this, about 245 Mm^3 could be developed using DTW force mode technology. About 15 Mm^3 could be developed using STW technology and about 74 Mm^3 could be withdrawn using deep set STW's (Table 2.3).

Table 2.3: Estimated Ground Water Recharge

Mode	Useable Recharge (Mm^3)	Available Recharge (Mm^3)
STW	26.02	14.9
DSSTW	123.92	74.54
DTW	406.54	244.6

2.5 Land/Water Interactions

2.5.1 Siltation

Most of the project area is flood affected; about 60% by pre-monsoon and about 90% by monsoon floods. During the monsoon, there is some sediment deposition over the entire flooded area but, in general, this type of siltation has little negative effect on crops and local farmers consider that it improves soil fertility.

Siltation which damages crops occurs locally around embankment breaches and mainly in the existing submersible embankment haor projects in the Jagannathpur, Markuli and Dirai area.

There is no siltation problem along the Surma-Baulai River nor in the upper reaches of its spill channels upstream of Sunamganj. Downstream of Sunamganj, the upper channel of the Old Surma is partly silted; the offtake of the Piyain River from Nawa River has been silting rapidly and it was closed (by WFP) in April 1993. Reportedly the Piyain channel is also silting at its outfall into the Baulai River.

The Baulai River bed is rising in the reach from Sukdevpur to the outfall of the Piyain River. This affects navigation and the drainage capacity of the river, and increases floods in the upper areas.

Increased siltation takes place in the Kalni River downstream of Markuli and as a result, pre-monsoon flood levels are rising. In addition, drainage from the basin is impeded and flood conditions are deteriorating.

Within the basin, the siltation is most prominent in the internal channels located in the south central and south eastern part of the project. The outfalls of Sadipur Khal, Itakhola Nadi and Ratna River into the Kushiyara are completely silted (the Kalni outfall at Markuli has been closed). The channels that are partly silted and need to be improved are: Ratna and Naljor Rivers, Dahuka Nadi, Kamarkhali Khal, lower sections of Itakhola, Bhatta Khal, Moha Singh River. Channels of the Darain River and the Mora Surma are also silting and their cross-sections are too small to convey flood flows.

Insufficient drainage capacity in the lower reaches of the internal channels increases the flood hazard throughout the basin.

2.5.2 River Erosion

River bank erosion and breaching of the embankments occurs along the boundary rivers. Erosion rates are generally low and occur due to progressive migration of the river's meander pattern. This process is driven by secondary currents in the channel which deposit sediment on the convex side of the meander bend and scour material from the outer (concave) side of the bend. As a result, local sloughing and slow bank retreat are occurring at virtually each of the sharp bends in the rivers. Erosion rates on the rivers are limited by the cohesive nature of the banks and low velocities.

Increased erosion has been observed in the Surma River spill channels near their offtakes: Bahia, Kazanchi, Bhatta and Madhabpur Khal. The construction of flood embankments has resulted in the need for these channels need to convey proportionately higher volumes of water during flash floods resulting in the increased erosion. The material eroded in the upper reaches of the channels is deposited in the lower reaches causing drainage congestion. Due to erosion of the Surma spill channels at their offtakes the flood inflows into the basin are increasing.

Erosion of Balaganj Town

The old Balaganj town is located on a narrow strip of land from about 50 to 200 m wide and is confined between the Kushiyara River and Barbhanga Nadi. River erosion takes place at the outfall of the Barbhanga Nadi into the Kushiyara.

In recent years, the channels of the Barbhanga Nadi and the drainage channel of the Patachatal Beel have merged at their outfall into the Kushiyara just upstream of the Balaganj Hospital. The erosion is further intensified by two directional flow, from and into the Kushiyara, during the rising and falling stages of the river.

2.5.3 Crop Damage

Crops are subjected to various forms of damage including floods, drainage congestion, hailstorm, cyclones, and pests. Information on damage due to floods and drainage congestion were collected from the field. These were cross checked with the results of hydrologic analysis.

Most crop damage in the Surma-Kushiyara-Baulai Project area takes place in the pre-monsoon season when local and high yielding varieties of boro rice are in the reproductive phase and local varieties of broadcast aman is in the early vegetative growth phase. The crops are submerged as a result of sudden increases in water levels following rains in the catchment. The extent of damage is a function of the growth stage the crop is in and how long it remains submerged. Farmers are sometimes able to collect partially matured boro rice panicles from beneath the water in flooded fields. This substantially reduces yield levels of these crops. Local varieties of broadcast aman seedlings are damaged under conditions in which they are submerged before they are able to acquire the ability to elongate with the gradually increasing flood levels. Some, but not all, of the loss is offset by regrowth after the flood waters recede.

Local and high yielding varieties of transplanted aman rice are occasionally damaged by floods and drainage congestion in the monsoon season. The damage takes place mostly at the vegetative growth stage and results in reduced tillering which affects the yield.

Crops can also be damaged early in the winter when seedbeds and young plants are inundated. This can happen as a result of unseasonal rains in the catchment (see section 2.4.2). There were several recent examples of this. Large areas of the lowlands along the Kushiyara-Kalni River were flooded in late December 1991 by spills from the Kushiyara. In February 1993 crops were damaged in the Deker Haor area by rainfall and spills from the Surma River, and in Damrir and Dubrir Haor areas by flood spills from the Kushiyara River.

2.6 Wetlands Swamp and Reed Forest

2.6.1 Natural Wetlands

The Surma-Kushiyara-Baulai Basin Project covers a large area (319,589 ha) which includes many important perennial wetlands; included are about 30 major haor complexes. Most of the haors, each comprising several large beels are located in Catchments 3, 4 and 5 (See Figure 4). The present total area of the perennial wetlands is estimated at about 14,300 ha, which is 4.5% of the total project area.

The various attributes of these wetlands is a function of their location. The wetlands located in Catchments 1 and 2, such as Mailjail, Dubrir and Muktarpur haors are flat and shallow and have very few perennial water bodies. This type of environment in its natural state creates an excellent habitat for a number of submerged and rooted floating plants. However, extensive human interference such as encroachment of paddy fields inside the wetland and water utilization for irrigation makes the area unsuitable for both wild flora and fauna.

In Catchment 3, the major wetland is Deker Haor. The Deker Haor complex covers a large area which includes many deep perennial water bodies and also vast shallow floodplains. This type of relief offers a very diverse habitat for the wetland flora and fauna. In deeper regions, because of deep flooding and high wave action floating plant communities don't survive in the monsoon. But submerged plants grow very well particularly at the time of water recession. In the shallow floodplain, floating plant communities grow in abundance but sedge/meadow is the most important plant community here. However, this wetland is also been modified by human interference, and as a result, almost all of what was once a natural wetland is under rice cultivation for at least part of the year. At present, very little land remains here in its natural state, while the farming encroachment is a continuous process.

Catchments 4 and 5 cover the most deeply flooded parts of the project, and includes most of the large and deep wetlands. The major wetlands located in these catchments are: Tanguar Haor, Baram Haor, Pagner Haor, Pangasiar Haor, Sanghair Haor and Kaliagota Haor. These haors remain deeply flooded throughout the monsoon and cannot support much natural vegetation. However, as the water recedes, water plant communities start growing and they spread very rapidly throughout the entire area. The most important wetland plant community of this area is sedges/meadow, which produces number of very valuable grasses. These grasses are grown on very low land, and along the border of the perennial water bodies where residual moisture remains high throughout the dry season. Although there is less human interference in this area, encroachment is still a problem and most of the land where irrigation water is available has gone under rice cultivation.

Habitat degradation makes wildlife scarce in almost every part of the Surma-Kushiyara-Baulai Basin. The larger mammals have disappeared. Smaller mammals like the otter, rats and cats are the main wildlife species still existing within in the project area.

Waterfowl concentrations are restricted primarily to the larger haor complexes found mostly in Catchments 4 and 5.

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2.6.2 Swamp Forest Trees

Many small swamp forest plots ranging from about 5 – 10 ha still existing in the Surma-Kushiyara-Baulai Basin. The major swamp forests are listed in Table 2.4. All the forest patches are more or less similar in characteristics and they comprise mostly Barringtonia acutangula (*hizal*) and Pnogamia pinnata (*karoch*) trees. These forests are not dense and they have very little undergrowth. What undergrowth exists is mainly grasses.

2.6.3 Reed Swamp

At one time, much of the land in Catchments 4 and 5 was under reed swamps. In recent years these lands have either been converted into paddy fields or have degraded into smaller grass lands. At present, no large, clearly defined reed swamps exist within the project area. Only remnants of reed swamps can be found in some places. These remnant swamps consist of Phragmites karka (*khagra*), Vetiveria zizanioides (*binna*) and Sclerostachy fusca (*ikor*), with the most important and dominant species being the Hemarthria protensa (*chilla*). The Hemarthria protensa (*chilla*) has very important social and economic value. It is used to protect homesteads against wave erosion. Consequently, there has been some effort by people in the area to conserve the reed swamps.

Table 2.4: Major Swamp Forests in the Project

Name	Location
Sunamganj District:	
Islampur	Tangua Haor, Jagannathpur
Bhatidhal	Tangua Haor, Jagannathpur
Udaypur	Hatimara Fishery, Sullah
Kartikpur	Hatimara Fishery, Sullah
Netrakona District:	
Adampur Goalbari	Chela Piya Fishery, Kaliajuri
Adampur	Chela Piya Fishery
Bellavpur	Chela Piya Fishery
Jaganathpur	Along Dhanu River
Bolli	Rangchapur Fishery
Faridpur	Kaliajuri

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)	254,589
Homesteads	6,000
Beels	14,300
Ponds	2,300
Channels	8,200
Hills	3,200
Fallow[1]	21,000
Infrastructure[2]	9,700
Total	319,289

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

Settlements
Settlements within the project area are mainly found in the form of villages along the levees of the rivers and along various road sides. In those few places where land elevations are higher, especially in the northeastern part of the project, homesteads are also constructed in the fields. The river banks and road sides are densely settled, similarly the areas around the thana headquarters and marketing centres. In general, settlements tend to be sparsely scattered in the fields and are extremely sparse in the south-western low-lying haor areas where land elevations are very low.

Flood Damage to Housing
Generally, homesteads located on higher lands are not damaged by floods. In the north-eastern part of the project area, damage to homesteads occurs mainly as a result of pre- and monsoon flash floods. Damage to homesteads as a result of monsoon wave action is not very common in this area

In much of the rest of the project area (towards the southwest) damage to homesteads occurs as a result of erosion caused by wave action. Many villages in this part of the project are badly damaged and some are reported to have been completely eroded by monsoon wave action.

Coping Strategies
Homestead platforms are raised to one meter or more to avoid monsoon flooding. However, within the low-lying haor areas, homesteads are raised from three to five meters to avoid flooding. Necessary measures are taken to protect erosion of the homesteads against monsoon wave action. This is usually done by constructing a wall around the homestead made with a combination of soil, bamboo and locally available grasses (see section 2.6.3).

Flood water from monsoon flash floods usually recedes from the homesteads in the eastern part of the project area (Catchment 1 and 2) within a week or so. However, the monsoon flood water remains in the low-lying haor areas (Catchment 3,4 and 5) for a period of between five and six months starting from late May or early June. If flood depths are unusually high (as does occur in some years) villagers generally make platforms inside their houses and shift their belongings on to these to keep them safe. When such a situation arises, the poor are most affected.

3.1.2 Demographic Characteristics

The total population of the project area is estimated to be 1,892,147 of whom 926,784 are female. The gender ratio is calculated to be 104 (males to 100 females). The total households, are estimated to be 311,107 within 2,955 villages. The population increased by 23.94% between 1981 and 1991.

The cohort distribution for males is: 32.2% below 10 years of age, 45.6% between 15 and 54 years of age, and 6.6% above 60 years of age. The corresponding distribution for females is 34.0%, 47.0%, and 5.1% (see Table 3.2).

The average population density is 585 persons per km^2, with density ranging from a maximum of 1136 persons per km^2 in Sylhet Sadar to 260 persons per km^2 in Kaliajuri thana. The average household size in the area is estimated to be 6.1 persons.

3.1.3 Quality of Life Indicators

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

Literacy
Within the project area, literacy rates are found to vary. According to the 1981 census, the literacy of the population at 5 years of age and above ranged from 11.7% in Dowarabazar thana to 30.0% in Sylhet Sadar thana. The corresponding figures for females were 6.1% and 22.6% respectively for the same thanas. The rate appears to have increased slightly during the last 10 years. According to the 1991 census, the literacy rate for all people of Sylhet district is recorded as 25.42% for both male and female, while the corresponding figure for Sunamganj district is 17.20%.

The 1981 census indicates that school attendance in the project area for all children aged five to nine years varies from 15.1% in Dowarabazar thana to 33.4% in Fenchuganj thana. Attendance

Table 3.2: Population Distribution by Age Group (%)

Sex	Population Age Group (Years)						Total
	0-4	5-9	10-14	15-54	55-59	>60	
Male	16.4	15.8	13.6	45.6	2.0	6.6	100.0
Female	17.4	16.6	12.4	47.0	1.5	5.1	100.0
Total	16.9	16.2	13.0	46.3	1.8	5.8	100.0

Source: BBS, 1981 Population Census

for females in this age cohort in these two thanas varies from 12.5% to 31.2% respectively. Attendance for all youths between the ages of five and 24 is 12.0% and 28.7% for these thanas while the corresponding attendance for females is 8.0% and 24.8%.

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

Access to Health Services
The district headquarters of Sylhet has a Medical College with a hospital and the districts of Sunamganj, Netrokona and Kishorganj have hospital facilities at their headquarters. Similarly, there are hospital facilities in all the thana headquarters. Access to health services is generally limited for rural villagers and is out of reach of the poor. The situation is worst for the people of the haor areas of Sunamganj, Netrokona and Kishorganj districts. According to the Directorate General of Health Services (1992), there is one hospital for every 162,190 persons and one doctor for every 9916 persons in the district of Sylhet. The situation is similar for other districts of the project area. One hospital bed is available for: 2351 people in Sylhet district, 6625 people in Sunamganj district, and nearly 6000 for both Netrokona and Kishorganj districts. Immunization coverage of children below two years of age is high for the project area, except in Kaliajuri and Itna thanas. The rate varies from 22% in Kaliajuri thana to 65% in Golapganj 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 Sylhet, DPHE[1] reports the availability of one working tube well for 134 persons. For Sunamganj, Netrokona and Kishorganj districts, such figures are 181,108 and 122 respectively. In 1990, 59% of the households had access to potable water in the district of Sylhet. For the other three districts in the project area, more than 80% of the households had access to potable water. As throughout the region, most tube wells are located in the houses of the wealthier people in the community. This results in the poor having very limited access to potable water.

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

3.1.4 Employment and Wage Rates

Village employment opportunities are mainly limited to agricultural activities. The major crop in the area is boro in the low-lying haor areas and transplanted aman in the higher lands of Sylhet district. Employment for men related to the transplanted aman crop mainly consists of

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[1] DPHE, 1991-92

transplanting (carried out between July and August) and harvesting (carried out in late November and December). Employment related to boro cultivation relates to transplanting (this occurs at two peak times in January and February) and harvesting in (which takes place in mid-April to mid-May). Seasonal employment is readily available with well-off farmers, especially in the low-lying areas during winter months for boro cultivation.

The wage rates for male agricultural labourers vary from Tk 30 to 45 with or without meal per day during peak agricultural months. During months when there is no agriculture work, the wage rate varies from Tk 20 to 30. Opportunities for employment are reduced significantly during the monsoon months for the poor within the deeply flooded areas of Sunamganj and Netrokona districts. However, it was reported that during these months, many labourers (20-50 from a village) migrate to Companiganj, Tahirpur (Fazilpur) and Chhatak thanas to work on sand and stone carrying activities. They are usually involved in transporting these materials from the quarries to various storage or construction centres throughout Sunamganj and Sylhet districts. Some poor also obtain employment in operating boats during the monsoon months. An important activity of the poor during the monsoon months is catching fish. The average daily income from fishing can vary from Tk 50 to Tk 100 and these men are self-employed. When employment opportunities in agriculture are limited, some poor people will also migrate to the various districts headquarters within the project area to work as rickshaw pullers, as construction workers, or sometimes in household activities.

Employment opportunities for women are limited in the area. However, a few women are reported to be employed as seasonal labourers, especially with large farmers of the Haor areas. A few poor women are employed for the Rural Maintenance Program of CARE, and some women also migrate to Sylhet and Sunamganj towns to perform household work. But their numbers are very limited. Many villages have no such migrant woman labourers.

Migration to outside countries, particularly to the UK, is common in Golapganj, Biswanath, Balaganj and Jagannathpur thanas. However, this kind of migration is much less in the other thanas of the project area.

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

3.1.5 Land Ownership Pattern

Land ownership is extremely skewed in the project area. About 50% of the households are functionally landless (with cultivable land less than 0.2 ha). Among the landless, about 2.5% have no homesteads of their own. If the definition of landless includes landholdings up to 0.4 ha, the proportion of households included increases by 10%. Small landholders (0.21 - 1.00 ha) represent 23.3%, medium landholders (1.01 - 3.00 ha) represent 19.5%, and large farmers (more than 3.00 ha) represent 7.6% of all households.

Almost 40% of the land within the project area is not available for cultivation. This includes the deeper wetlands, reed lands, community pastures. The price of agricultural land varies from

Tk 2,000 to Tk 100,000 ker (0.12 ha) depending on the demand and quality of the land and the intensity with which it can be cropped.

3.1.6 Land Tenure

Owner operators are common throughout the area. The large land owners generally share out their land to tenants for operation. The share cropping system they use is that one-half of the produce is retained by the land owners but they provide no inputs. For high yielding varieties of rice, the input costs are shared by land owners on an equal basis with the tenant. Leasing out of land in kind (chukti) is declining in the area. However, leasing out of land with advance cash (pattani/Rangjama) is widely practised. The usual rate for this arrangement varies from Tk 400 to Tk 800 per ker (0.12 ha) and this is paid in advance to the land owner for one season. Landless people have very little access to land under this tenurial arrangement due to their inability to provide cash after which they must still purchase agricultural inputs.

3.1.7 Fishermen

Fishing is an important activity in the project area. Most of the important jalmohals are located here and competition over the fish resource is increasing every year. There are mainly two types of fishermen who catch fish to generate an income: the traditional fishermen and the non-traditional fishermen. Traditional fishermen live on fishing and have been engaged in the profession for generations. The jalmohals are generally leased out to them through their cooperatives. The richer fishermen among them act as the financiers and appropriate much of the profit from the catch while the poor catch fish on a regular basis and sell out their share in the lease for their survival. They also work as fishing labourers. There are an estimated 8,000 to 12,000 traditional fisherman households in the project area. Additional information on fishing practices is provided in Section 3.5.1.

The non-traditional fishermen are mainly an emerging group from the landless and poor agriculturists. They fish in open water especially during the monsoon months and sell their catch. These non-traditional fishermen are increasing in numbers and now an estimated 35-40% of the households, particularly in the deeply flooded areas, are engaged in catching fish.

Local residents also catch fish but should not be referred to as "fishermen". They catch fish for their own families consumption and do not sell the fish. Sometimes, the rich among them lease the jalmohals to earn a profit from the catch and may also act as financiers for fishermen cooperatives.

3.1.8 Situation of Women

Women's role in agricultural production is important. The role includes: drying and storing grain, preserving seeds, keeping draught animals, poultry raising, and vegetable gardening. Women's contribution, however, tends to be devalued and under reported. Though women generally do not work in the field, some poor women are reported to be working outside their homes, mainly for the Road Maintenance Program of CARE and activities, like gathering wild fruits, and vegetables and collecting fuel. The village women generally work in the post-harvesting activities of rice crops, especially drying, winnowing, per-boiling and storing of rice.

The small surface areas of the homesteads are highly productive (much more so than the less intensively cultivated rice fields) and these activities are the responsibility of women. Within the deeply flooded areas, however, women's work is made particularly difficult since the homesteads are generally smaller than throughout other parts of the region since they are constructed on raised earthen platforms and are constantly being eroded. In addition the large expanse of water throughout the monsoon season tends to isolate homesteads making health care and education facilities inaccessible to women.

3.1.9 People's Perception

General
Local people's perception of their problems were solicited. These were related mainly to water and its impact on their livelihood and their suggestions as to the nature of interventions which would solve these problems. These were collected through personal interviews, group discussions and meetings with various cross-sections of people during the relatively short field work in the project area. Also, opinions and suggestions were sought during the one-day seminars held at District headquarters within the project area. Participants included the Honourable Members of the Parliament, District and Thana level officials, Union Parishad Chairman, representatives from village level organizations and NGOs. These problems and suggestions which came out of the field work and from the seminars are described below.

Problems
Flooding and drainage congestion are described as the major problems of the project area. Pre-monsoon flash flooding is considered to be the most serious problem and its impact has been widespread throughout the area. This type of flooding mainly damages boro rice crops which are affected almost every year. The crop can be damaged fully or partly in the haors and beels between April and May. These flash floods generally enter into the area through various channels and tributaries from the major river system of the Surma, Kushiyara and Baulai. In addition, the water also spills over the banks of the rivers in where the banks are low. The situation is further aggravated if there is intensive local rainfall which creates additional water logging. In recent years this type of damage has become a regular feature of the agriculture system, particularly in the southwestern part of the project (Catchment 3, 4 and 5). The major entry points of these floods are the Bahia Nadi, Kazanchi Khal, Bhatta Khal, Madhabpur Khal, Mora Surma River, and Piyan River from the Surma-Baulai River system and Kura gang, Kurkuchi khal, Betari Nadi, Barabhanga Nadi, and Bheramohona Nadi (recently closed) from the Kushiyara River. Additionally, flood waters over spill the banks of the Kushiyara River down to Sherpur and near Ajmiriganj; the Baulai River downstream from Lepsa bazar. The major internal rivers whose banks overspill and inundate the boro fields are the Bahia Nadi, Bhatta Khal, Naljuru River, Mora Surma River, Piyan River, Kamarkhali Khal, Dahuka River, Sadipur Khal and Itakhola Nadi.

Aus and transplanted aman seed beds are also damaged by pre- and early monsoon flash floods in the north-eastern part of the basin. Transplanted aman is affected in these areas between June and September by monsoon floods which overspill the banks of the Surma and Kushiyara Rivers and their tributaries. The flood water generally lasts for seven to ten days in the upper areas and there are three to four such occurrences reported in every monsoon period.

Drainage congestion is reported to be the second most important problem of the basin, particularly in the low-lying haor areas (Catchment 3, 4 and 5) and in beel areas in the northeastern part of the project area. Because the Surma, Kushiyara, and Baulai River system as well as the internal smaller rivers and channels have been infilling with sediment, water does not drain in time to start cultivating boro. This delays transplanting (local and high yielding varieties) and, if delayed to long, transplanting is not possible.

Homestead damage by monsoon wave action is also referred to as a serious problem, especially in the villages of Kaliajuri, Itna, Sulla, Derai and Jamalganj thanas. Many villages of these thanas are eroding rapidly and their existence is reportedly threatened. Some of the villages in Kaliajuri, Jamalgonj, Derai and Itna thanas are reported to be completely eroded by wave action.

The poorer fishermen expressed two concerns: the powerful jalmohal lessees were prohibiting them from fishing in the open water, and since the jalmohal lessees were usually not from the area, their primary concern was short term profits at the expense of long term sustainability of the resource. It has generally been observed that local fishermen provide better management of a leased jalmohal to ensure the long term sustainability since it constitutes the sum total of their resource base. Fishermen considered that fishing by de-watering the jalmohals was a major cause of declining fish production. Fishermen also stated that roads, embankments, and river closures obstructed fish migration and reduced fish production. Specifically, fish migration from the Kushiyara and the Surma-Baulai Rivers was being affected because various channels and smaller rivers were being closed.

Fishermen of Chhatak and Dowarabazar thanas expressed concern about the industrial pollution in the Surma River from the Chhatak Cement and Pulp Factories. They stated that the pollution was having a negative impact on fish production in the area and was affecting the quality of the fish that were being caught.

People also expressed the need for boat transportation between the haors and the rivers. If provision for such transport is not made at critical points such as Bhatta khal, Paindamukh, Piyain outfall at Lepsa, and on various internal rivers, there would be tendency to cut embankments during the early monsoon months.

Suggestions

Various suggestions for improvements were proposed in the discussions with local people. While some of these suggestions were focused on very localized issues all were relevant to the problem at hand. The most common suggestions that were received included:

- Dredge the Kushiyara, Surma and Baulai Rivers to improve drainage of flash flood waters.
- Re-excavate the Mora Surma River, Bhatta Khal, Panda Khal up to the Mohasing River, Ham Hamia River, Piyan River, Darain River, Sadipur khal, Naljur River, Itakhola River, and Kamarkhali Khal to improve drainage of pre-monsoon flood waters.
- Improve the banks of the Kushiyara, Surma and Baulai Rivers to stop overspilling of pre-monsoon flash flood waters into the Haor areas.
- Reopen Panda Khal and provide a sluice gate to control the flow of water through Deker Haor up to the Mahasing River.

- Stop pollution of the Surma River water caused by Chhatak industrial waste.

- Stop intrusion of flash flood waters into Kaliagota Haor through Kalkolia khal at Alipur from the Piyain River and Chhayar Haor through Ujangaon Khal and Muktarpara Khal from the Mora Surma River.

- Construct a sluice gate on the Piyain River at Lepsa and make provision for navigation and fish movement.

- Reopen the Bheramohona River near Ajmiriganj and provide a sluice gate for drainage and navigation.

- Construct concrete flood walls to protect the most vulnerable villages of Khaliajuri, Itna, Derai, Jamalganj and Sulla thanas from erosion caused by monsoon wave action.

- Lease jalmohal only to local fishermen.

- Allow poor and subsistence fishermen to catch fish in the flood plain.

- Conserve enough fish habitat for normal production of fish and for that purpose, plant water resistant trees, like hizal, and karoch in the higher flood plains and river banks.

- Identify the duars in the area and protect them as fish shelters.

- Identify a few suitable jalmohals as fish sanctuaries and preserve them to increase fish production.

- Stop overfishing of jalmohals as well as fishing by complete de-watering.

- Provide for navigation requirements while developing embankments along the river so that there is no need to cut embankments. Navigation provision is also required in any submersible embankment in the flood plain to facilitate navigation in the early monsoon.

3.1.10 Local Initiatives

People stated that it is their traditional practice to organize themselves locally to counteract any crisis which arises as a result of flash floods and drainage problems. The primary activity is to construct dams on various localised canals to stop the intrusion of pre-monsoon flash floods. The boro crop can thus be saved. They also assemble to re-excavate canals to improve drainage. This is generally done on a voluntarily basis by the villagers around a particular canal which is threatening their property. More recently the Union Parishad have also allotted cash and sometimes wheat for this purpose.

3.2 Water Resources Development

3.2.1 Flood Control & Drainage

The existing water development infrastructure in the project area includes discontinuous peripheral flood embankments along the Kushiyara, Surma, and Baulai Rivers as well as haor development schemes with ring type submersible embankments and ancillary hydraulic structures. Re-excavation of some khals has been carried out as a part of drainage improvement schemes (for example the Damrir Haor Project).

There are nine existing submersible embankment haor schemes within the proposed Surma-Kushiyara-Baulai Basin Development Project (see Figure 11). Three of the schemes are completed, two have only embankments and four have completed embankments but the structures are still under construction. The salient data of the existing schemes are summarized in Table 3.3. In general, the existing schemes are only partly successful with actual benefits below projected benefits.

The Damrir Haor Drainage Scheme located in the eastern end of the project basin was designed to reduce damage to boro and t aman crops by improving pre-and post-monsoon drainage over a net area of 7285 ha. Re-excavation of Kurkuchi Khal, the main drainage channel, was expected to relieve pre-monsoon rainfall flooding and improve post-monsoon drainage thereby facilitating earlier crop planting. No other protection was provided against flood inflows. The open khals from the Kushiyara allow water into the area with the result that boro crops are inundated, on average, every second year prior to harvest. Crop damage ranging from 60 to 90%.

The haor development schemes are designed to delay the pre-monsoon flooding of the lowlands up to 15th May. Two of the oldest schemes, located in the northwestern part of the project are, Pagner Haor (1980) and Shanghair Haor (1985). The Pagner Haor embankments were completed in 1980 but the construction of structures started in 1992. The khals remained open so there was little impediment to flushing and drainage in this project. In Shanghair Haor, the embankments and structures were completed in 1985.

Embankments are overtopped before harvest and fail regularly in both projects. The Pagner Haor embankments fail by natural breaching mainly caused by the Baulai River erosion but also the result of increasing water levels resulting from the confinement of rivers within their banks. The Shanghair Haor embankments fail as a result of natural breaches but also due to public cuts. The public cuts are intended to improve variously drainage, flushing, navigation, or fisheries.

Maintenance of the embankments is carried out on annual basis. Recently (1992), through the systems rehabilitation project embankment height in some projects were increased by 1.4 m; from 6.1 to 7.5 m PWD.

The other seven haors are located in the deeply flooded Sylhet Basin area on the right bank of the Kushiyara-Kalni River. Both, earthworks and structures have been completed at the same time in some schemes while in others only earthworks have been completed and the structures remain under construction. As described for the two projects above, embankments failure is common. Also as described above, these breaches can be either natural or man made. Despite the investment in infrastructure, the crops are only partly secure from the pre-monsoon flooding (the areas least affected by embankment breaching are crops on higher lands). To improve the performance of these projects crest levels are being upgraded.

The existing submersible embankment schemes in the proposed Surma-Kushiyara-Baulai Project cover a gross area of 61,068 ha enclosed by a total of 315 km of embankments. About 65 km of the schemes' embankments are along the peripheral rivers of the project.

While the projects provide some flood protection, boro crops are still subjected to pre-monsoon inundation at various locations throughout the projects. Under these circumstances it is difficult to determine the net area actually benefitted by these schemes. Also, as some of the schemes have never been fully completed, it is not possible to assess their actual effect on parameters such as flood levels, siltation, or drainage in the basin.

The embankments are substantially damaged by overtopped and by wave action. According to BWDB records (based on FFW wheat allocation), the annual repair requirements of submersible embankments amounts to about 30% of the original earthwork volume. This is equivalent to construction of about 100 km of new embankments every year (this figure includes the embankments along the boundary rivers. The annual cost of repair of the internal haor embankments, excluding roads cum embankments, is estimated at about Tk 12.0 Million.

Table 3.3: Existing Projects

Name of Project	Area (ha)		Embankment Length (km)	Structures	Remarks
	Gross	Net			
Pagner Haor	19,075	17,165	65	2 Regulators	Regulators not completed
Shanghair Haor	5,000	4,200	25	3 Regulators; 30 Pipe inlets	Completed
Naluar Haor 1	9,840	8,800	52	6 Regulators	Regulators not completed
Naluar Haor 2	2,300	1,924	26		Regulators not constructed
Chaptir Haor	4,453	3,624	35		Regulators not constructed
Udgal Beel	5,900	4,700	34	1 Regulator 3 Pipe sluices	Under Construction
Baram Haor	5,500	4,800	26	3 Regulators 3 Pipe sluices 34 Pipe inlets	
Tangua Haor	5,000	4,500	20	2 Regulators 6 Pipe sluices	Under Construction
Bhanda Haor	4,000	3,600	32	1 Regulators 5 Pipe sluices 20 Pipe inlets	
Total	61,068	53,313	315		

Embankments
The flood embankments presently existing within the Surma-Kushiyara-Baulai Project are shown in Figure 12 and include:

- Surma River left bank embankment 147 km
- Kushiyara River right bank embankment 72 km
- Submersible Embankment Schemes 315 km

Embankments along the boundary rivers which were constructed as part of the haor schemes were designed for pre-monsoon floods and are therefore lower in height. The other existing embankments along the Surma and Kushiyara Rivers were originally constructed as submersible embankments, but were upgraded annually as local funds become available and at present most of these embankments are above the average annual flood level.

Structures
The hydraulic structures within the Surma-Kushiyara-Baulai Basin Project include 19 regulators, 12 pipe sluices and 84 LLP irrigation pipe inlets. These structures are all part of seven existing submersible embankment projects. Two projects, Chaptir Haor and Naluar Haor Polder 2 do not have any structures as yet. Of the 19 regulators, 8 are completed and 11 are under construction.

The completed regulators were constructed on the basis of an old design type which features 1.5 m wide vents with wooden stop-log closure. Removal of the wooden logs is extremely difficult with the result that farmers find it easier to cut the embankments to drain the water at the end of monsoon than to struggle with the logs under water. Consequently, the structures have not been fully effective.

The regulators presently under construction are, 1.5 x 1.8 m box type structures with vertical lift gates or 2.0 m open vent type with a double set of mechanically lifted steel stop-logs (Naluar Haor Polder 1). The 2.0 m wide vent opening permits passage of small country boats. The double set stop-log design allows top and bottom opening, which can be used to facilitate passage of fish.

3.2.2 Irrigation

About 113,254 ha or 44% of the project cultivated area is under irrigation. Surface water is used in about 99.5% of the irrigation out of which 21% is pump irrigation (LLPs) and 79% is traditional irrigation.

Ground water is used to irrigate about 635 ha or about 0.5% of the irrigation in the project area. All the irrigation ground water is extracted with deep tubewells. According to the AST Census data, there were 9 shallow tubewells in Kotwali Thana in 1991, however, no STWs were reported operating during NERP field inspections in early 1993.

It should be noted that more than half of the DTWs constructed in the project area are out of operation. This reflects the poor quality of aquifer. The status of irrigation in the Surma-Kushiyara-Baulai Basin is summarized in Table 3.4.

Table 3.4 Present Irrigation

Thana	Mode of Irrigation						
	Deep Tube Wells (DTWs)			Low Lift Pumps (LLPs)			Traditional (ha)
	Area (ha)	Wells		Area (ha)	Wells		
		Operating	Disabled		Operating	Disabled	
Chhatak	255	7	10	1640	145	23	9257
Derai	0	0	0	4147	253	74	16263
Dowarabazar	35	1	0	662	56	1	2734
Jagannathpur	70	2	0	2233	202	10	11427
Jamalganj	0	0	0	679	0	0	4847
Sullah	0	0	0	4909	275	4	10324
Sunamganj	0	0	0	2593	158	20	13709
Balaganj	108	12	18	1872	181	51	4746
Biswanath	34	2	3	708	83	21	3785
Fenchuganj	0	0	0	105	12	0	1441
Golapganj	18	1	1	584	72	5	2214
Kotwali	115	6	3	698	71	13	3400
Itna	0	0	0	1236	62	0	220
Khaliajuri	0	0	0	1740	147	7	4451
Totals	635	31	34	23806	1717	229	88820
Irrigated by Ground Water		635 ha					
Irrigated by Surface Water							112612 ha

Source: AST 1991

3.3 Other Infrastructure

There are 245 km of metalled road, about 78 km of unmetalled road and an estimated 220 km of village roads in the project area. The road network is better developed in the eastern and central part of the project where the ground elevation is above the seasonal flood level. The Sylhet-Sunamganj regional highway is the only all-weather road in the western deeply flooded area of the project. There are roads linking Sunamganj with Dirai and Sunamganj with Jagannathpur. These roads are passable only during the winter. During the monsoon, with the exception of Sunamganj town, the entire western part of the project relies on water transport.

3.4 Agriculture

Agricultural data collection and analysis for the project was undertaken by sub-dividing the project into 5 catchments to generate data on flooding conditions. Water level data at designated locations in each of the catchments was established along with the development of area-elevation curves. These data were analyzed to compute approximate areas under different land types. The area flooded by different depths upto May 15th was also computed since prior to this time is when the boro crop is damaged by pre-monsoon floods.

Present cropping patterns reflect farmer's efforts to adjust crop production practices to the hydrologic regime within which they farm. Areas flooded in excess of 1.8 m (F3 land type) constitute 54% of the cultivated area, another 26% of the area is classified as F2 land. These areas are generally flooded early in the pre-monsoon season and continue to remain wet well into the rabi (winter) season. The dominance of such a semi-aquatic environment during most of the year has led to the emergence of rice as the single major crop on these land types. Local boro is the only crop grown in most of the F3 land type. It is planted into standing water at the end of the monsoon and, as the water drains, is provided with irrigation if it is available. If irrigation is not available, farmers depend on pre-monsoon rains. Local varieties of broadcast aman are the dominant crop on the F2 land type. Because it is such a long duration variety, most of the broadcast aman is grown as a single crop except in a few areas where flood waters recede early and permit short duration rabi crops in the winter. Depending on the availability of irrigation facilities and when the flood comes, high yielding varieties of boro rice can be grown. High yielding varieties of boro are mostly grown as a single crop though these varieties may be found in sequence with transplanted deep water aman rice.

Rice based multiple cropping is practiced in F0 and F1 land types. The high yielding varieties are concentrated on these higher elevations. Crops grown on these land types include local and high yielding varieties of aus in the 1st kharif season and local and high yielding varieties of transplanted aman rice in the 2nd kharif season. These crops are usually followed by rabi crops grown in the winter with residual soil moisture. The rabi crops include different varieties of pulses, oilseeds, spices and vegetables.

Cropping patterns, presently practiced on the various land types are presented in Table 3.5. Crop production data have been generated separately for damage-free and damaged area using information on yield obtained under damaged and damage-free condition. These are presented in Table 3.6.

Storage and marketing facilities are limited. Most farmers require cash to pay production and other costs so they sell part of their agricultural produce in the village market immediately after harvest when prices are normally low. Later, when prices are higher, they are often compelled to buy rice for family consumption. It is estimated that between 20 and 25 percent of the production actually enters commercial markets. Private traders handle most of this amount.

Homesteads are an integral part of the farming system. Homestead agriculture production varies with the size of the homestead. On the higher homesteads in the eastern part of the project area, trees (mango, betel nut, bamboo, banana etc.) are common providing fruit, fuel, and building material. The lower homestead in the western part of the project (which are also smaller and more vulnerable to flooding, have fewer trees. Most of the vegetables consumed by the family are produced in the kitchen garden, which are part of their homesteads.

Table 3.5: Present Cropping Patterns
(Areas in ha)

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					47192	70	0	0	47192
fallow-l boro					0	0	134089	98	134089
fallow-hyv boro	0	0	0	0	3371	5	2736	2	6107
b aus-fallow-rabi	0	0	2682	10	3371	5	0	0	6053
b aus-lt aman	4705	20	9388	35	0	0	0	0	14093
b aus-lt aman-potato	1176	5	0	0	0	0	0	0	1176
b aus-lt aman-rabi	2353	10	4023	15	0	0	0	0	6376
b aus-hyv aman-fallow	3058	13	0	0	0	0	0	0	3058
b aus-hyv aman-rabi	706	3	0	0	0	0	0	0	706
hyv aus-rabi	2353	10	1341	5	0	0	0	0	3694
hyv aus-lt aman	941	4	1878	7	0	0	0	0	2819
hyv aus-hyv aman	2117	9	536	2	0	0	0	0	2653
lt aman-fallow	1882	8	1073	4	0	0	0	0	2955
lt aman-rabi	2117	9	4023	15	0	0	0	0	6140
hyv aman-wheat	941	4	0	0	0	0	0	0	941
hyv aman-potato	0	0	805	3	0	0	0	0	805
hyv aman-rabi	1176	5	1073	4	0	0	0	0	2249
b aman-rabi	0	0	0	0	10113	15	0	0	10113
b aman-hyv boro	0	0	0	0	3371	5	0	0	3371
Total	23525		26822		67417		136825		254589

Table 3.6: Present Crop Production

Crop	Damage Free Area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)	
b aus	28962	1.25	36202	2500	1.05	2625	38827
hyv aus	9166	3.75	34372	0	0	0	34372
b aman	43175	1.75	75557	17500	1.45	25375	100932
lt aman	25059	2.15	53876	8500	1.75	14875	68751
hyv aman	8912.5	3.95	35204	1500	3.55	5325	40529
l boro	103589	2.25	233074	30500	1.45	44225	277299
hyv boro	4978	4.55	22651	4500	2.75	12375	35026
Total Rice			490936			104800	595736
wheat	941	2.05	1929				
potato	1981	12	23771				
pulses	5300	0.85	4505				
oilseeds	17665	0.75	13249				
spices	1766	2.25	3975				
vegetables	10599	3.75	39747				

3.5 Fisheries

3.5.1 Floodplain fishery

There are more than 400 important seasonal and permanent fisheries existing within the project area. Most of the beels are interlinked by narrow channels which dry up during the winter season. The most important open water fisheries are listed in Table 3.7.

Most large fisheries are leased by a few rich influential persons for a period, usually of three years. The lease holders generally reside in cities and appropriate the profits from the catch. Usually they appoint guards and hire outside labour for the final catch. This system deprives local fishermen of access to the fisheries resources and also takes away job opportunities from local people.

The operation of the jalmohals creates conflicts, particularly between farmers and fishermen. The jalmohal lessees construct and maintain water retention dams across the khals which control drainage from beels at the end of the monsoon; this prevents timely boro cultivation in the peripheral zone of the beels. To harvest the fish in a beel, the fishermen completely drain the beels mid-winter, after which the farmers are left with no water for irrigation.

It was reported that lessees do not permit fishing by either traditional or non-traditional fishermen in the vicinity of the jalmohals even during the monsoon months. This assertion is in agreement with another study in the area (Minkin, 1992). A few years ago a mass movement, locally called "Vashan Pani Andolan", was organized by the local people to protest against the control of the floodplain by the lessees. In response, the hired guards resorted to shooting at local fishermen and the conflict remains unresolved.

The extent of the jalmohal lessees' control over the area needs to be examined during feasibility studies, since it will have a significant bearing on implementation of any proposed intervention.

Table 3.7: Open Water Fisheries

Haors	Beels	Channels
Baram	Aila	Chamti
Certain	Asa	Chelapiya
Chaimer	Bajibari Bana	Darain
Chankhai	Baradal Barak	Haashmela
Chaptir	Bardoi-Kastaganga	Hatkapani
Chaudhuni	Bhagdoba Bhanda	Kalni
Chaular	Chapra Chatal	Karkol
Chunai	Chowtar	Kathalgang
Deker	Dabar	Magura
Dhailong	Dhailang	Maramoha-
Dhamalia	Dhalai	singh
Dubrir	Dirai	Mora Surma
Fatar	Dubri	Piyain
Gutumanik	Dubria Felua	Rangamati
Jaliar	Ghoraduba	Satua
Kacharia	Hapardara	
Kaliagota	Haraban Harmara	
Kayma	Hatimara	
Khai	Kachari Kalenga	
Majail	Kamakosmakatua	
Naluar	Khuncha	
Pagnar	Kuri	
Pangasiar	Lairadigha	
Rukshir	Lamba Majail	
Sanghair	Makhnai	
Shapardhar	Maraang Muldair	
a Talka	Patachatal	
Tanguar	Phenkhai	
Teli	Atni	
	Raua	
	Rua	
	Tatua	
	Terajan	
	Urla	

3.5.2 Species present in the area

Of the 155 species in the region, about 60-70 species inhabit the beels and floodplain within the project area. For various reasons, important species such as *Mohashoal*, *Nanid*, *Pangas*, *Angrot*, and *Berkul* are almost extinct. In addition, *Catla* and *Mrigel* are becoming rare species in the region. The species found in the project area are listed in Table 3.8.

3.5.3 Duar fishery

Duars, which are an indispensable part of a typical floodplain fishery, act as a refuge for the large mother fish during the winter season. These fish migrate to a suitable spawning ground for breeding when water levels begin to rise. 152 duars have been identified in and around the project area: 34 in the Surma River, 11 in the Old Surma River, 6 in the Brahmoni River, 30 in the Dhanu/Baulai River, 46 in the Kushiyara River, 24 in the Piyain River and 1 duar in the Mora Dhanu.

3.5.4 Sources of fish and breeding

It is generally understood that early rain, thunder, flooding, temperature, grassy or rocky land influence spawning of freshwater fish. If favourable conditions exist during the flooding in the pre- and early monsoon season, fish migrate from beels to adjacent grassy areas, to rivers, and vice-versa. At this time, migration is usually contranatant.

Where rainfall is localized and the beels drain into rivers (providing that river water level is lower) fish tend to move from rivers up to the beels and onto the floodplain. Localized breeding migration has been observed for Boal, Ghonia, Pabda, Fali, Koi, Singi, Magur, Puti, Lati, Shoal, Gazar and some other smaller varieties fish. Generally, perennial water bodies with shallow floodplain and reeds are the best potential breeding grounds for most species.

Within the project area, the species composition is dominated by miscellaneous species (60-70%) followed by carps (20-30%) and catfish (5-10%).

Table 3.8: Major Fish Species

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

Currently four *Mother Fisheries* have been identified in the Northeast Region. One of these, the *Kaliajuri Mother Fishery* is located within the project area. The Khaliajuri Mother Fishery encompasses a large floodland area which has favourable topographic and hydrological conditions for fish habitat. These include: deep river duars, clear tributary streams, deep beels and sediment free khals. This area, which is also rich in wetland forest stands, reedbeds and wetland grasses is inhabited by abundant diverse high quality fish species.

About 20 fish spawning grounds have been identified within the project area (Table 3.9). With the exception of the Majail and Patachatal Beels which are located in the western part of the project, all the spawning grounds are located in the deeply flooded Sylhet Basin in the eastern part of the project area. During the flood season, the spawning grounds are hydraulically connected to the Khaliajuri Mother Fishery.

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The proximity of the mother fishery to the spawning grounds and the existence of a large number of deep duars in the adjacent river system makes the lowlands in the western part of the project an excellent habitat for fish production.

The giant freshwater prawn (M. rogenbergii) which is highly valued for its export quality is widespread in the rivers and floodplain of the Kaliajuri, Itna, Sullah, Derai, Jamalganj and Jagannathpur thanas. In 1992, it is estimated that 5200 kg of these prawn were harvested in Pangasiar haor area (Piyain river floodplain near Laipsa bazar).

The freshwater prawn adults migrate downstream to spawn in estuaries and in the sea. The juveniles then migrate back into freshwater rivers to grow and mature.

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

Table 3.9: Fish Spawning Grounds

Thana	Name
Balaganj	Majai Haor Patachatal Beel
Derai	Kolakhai Beel Nagdora Beel Suriya Nadi
Dowarabazar	Panda Khal*
Itna	Muldair Beel Shawlile Beel Dhailang Beel
Jagannathpur	Ranigonj Area Roail Area Chilaura Beel
Jamalganj	Pagner Beel
Kaliajuri	Makhnai Beel Chowtara Beel Elonguri Beel Bolli Beel Rautala Beel
Sullah	Bheramona Beel Bhanda Beel

Note: The Panda Khal spawning grounds in Deker Haor have been destroyed by the closure constructed at the offtake from the Surma River.

3.5.5 Production trends

Presently, fin fish production in the project area is estimated at 21,500 tonnes per year (see Table 3.10). In addition, a further 32 tonnes of giant prawn are produced every year. According to the NERP study, fish abundance is directly related to the depth and duration of inundation and access to the floodplains.

Fish production in the area has apparently declined by 20-30% over the last five years. The identified causes of decline in fish production are:

- Beels infilling with sediment. This results in a decline in beel area and water depth and hence a reduction in the water hectare-months.
- Overfishing and loss of fish habitat.
- Fewer reproductive fish stock due to indiscriminate use of some gear (current jal, kona ber jal etc).

Table 3.10: Present Fin Fish Production

Regime	Area (ha)	Production Rate (kg/ha)	Total Production (mt)
Beel	14,300	550	7,865
Floodplain	231,064	44	10,167
Pond	2300	800	1,840
Channel	8200	200	1640
Total	-	-	21,512

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

- Construction of regulators and embankments in Pagner Haor, Gachar Dohor, Bhanda Beel, Tangua Haor, Suriya River, Naluar Haor, Baram Haor, Panda Khal and Deker Haor have restricted fish migration to and from the haor during early flooding (relates to the spawning migration), which reduces fish resource in the area.

- Rapid deforestation (cutting of trees and reeds) in the floodplain causes fish loss by reducing fish refuge areas, fish food organisms, and fish breeding places.

- Reduced fish habitat because of agriculture encroaching onto fish producing beels.

- Remote effect of industrial effluent caused by Fenchuganj fertilizer factory and Chhatak pulp mill reduced fish production as well as market price.

- Leasing of smaller beels to outsiders which encourages overfishing by complete de-watering. Previously, when most of the small beels were kept under common village use the overwintered stock were maintained in those beels.

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

- The absence of strong leadership, poor communication facilities, and inadequate infrastructure prevents the fishing community from adequately defending its interests.

- The short term leasing system combined with insufficient security of lease renewal encourages over exploitation of the jalmohals.

3.5.6 Fishing practice

Floodplain

Open water fisheries are the major source of fish in the area (floodplain 52%, beels 33%, riverine 7% and pond 8%). Subsistence fishing occurs mainly during the flooding period and large-scale beel and duar fishing occurs from December to March. Except for the pile fishery, most beel fishing is done on an annual basis.

There are a number of pile fisheries within the project area (both in rivers and in deeper beels), of which Dhailang Beel, Bhanda Beel and Kaliajuri Fishery are the most developed. The most widespread and common fish production method in the area is the *katha*, where tree branches and bushes are set on the river and beel bottom. These branches increase fish food supply and provide shelter. During the dry season, fish gather in the katha and are thus relatively easy to catch. Hizal, koroch, Am, Jam, Bot, Tetul, Shawra tree branches are used in the area for the katha. In Kaliajuri area Barun, Mera, Jarul and Jam tree branches are used along with Hizal and Koroch. In all cases, bamboo stakes are used for fencing and anchoring the katha to prevent it from being swept away. Kathas are installed when the water is receding (between August and September). Fish are harvested from January to March. They are usually transported to their destination by two engine boats strapped together. Such a double boat load of katha is called a Jurinda.

One variation on the katha is called *Khaw*. The khaw consists of one or a group of kathas made of a large number of bamboo stakes, usually placed near hizal or koroch plantations. Fifteen khaws are maintained in Ranichapur and Dhalimati Fishery in Kaliajuri area.

Closed water

There are no fish culture ponds in the deeply flooded area of the Sylhet Basin. The pond fisheries are found mainly on the relatively high ground in the eastern part of the project where the risk of flooding is lower.

The present pond fish culture practices are mainly based on extensive type of production. Most owners stock their ponds with an uncounted number of fingerlings. No other basic management activities are undertaken such as eradication of predators and weed fish, eradication of aquatic weeds, and regular application of feed and fertilizers. There is no monitoring of growth and health of the fish. The fish are usually harvested during the late winter season. Recently semi-intensive fish culture systems have been introduced in the Sylhet area, but the development process is very slow.

3.5.7 Present Fisheries Resource Development

Fish sanctuaries

Through the Integrated Fisheries Development Project (DOF), one fish sanctuary is being established in the Surma River (80/3) near Brahmangaon village in Sunamganj District. This sanctuary covers an area of about 1000 ha of water bodies.

Fish processing & marketing

Only a small portion of the catch, which is destined for export, undergoes processing. There are three processing plants situated in and around the Surma-Kushiyara-Baulai Basin:

The Ajmiriganj Fish Industries Ltd, Ajmiriganj: The plant is in operation since 1972. The plant fish processing and freezing capacity is 4 tonnes per day and ice production capacity is 10 tonnes per day. In 1992 the plant exported 262 tonnes of fish, out of which about 70% came from the project area.

BFDC Fish Marketing Centre, Dabor: The centre was opened in May 1991. It has a 50 tonne cold storage capacity and 20 tonne per day ice production capacity. The centre operates far below capacity.

Saidowla (PVT) Enterprise Ltd, Sunamganj: This plant went bankrupt in 1989; there are plans to re-start it.

In addition to the above, there are eight ice plants which support fish preservation and marketing, and also four fish processing centres, at Kaliajuri, Jamalganj, Derai and Sunamganj. Sun-dried (Sutki) and fermented fish (Sidal) are produced at these centres, and marketed to other parts of the country from November to May.

3.5.8 Required Mitigation Measures

The topographical and hydrological conditions prevailing in the south western part of the project make the area an ideal fish habitat. Preservation of the Kaliajuri mother fishery and other deep duars, and the many fish spawning grounds existing in the area is essential for maintaining sustainable fish production in the project area as well as in the rest of the Northeast Region.

To prevent further decline of fish production, and possibly to improve the open water fish production, both physical and institutional measures need to be implemented. Some of the measures are discussed below.

Silt deposition in channel beds and beels causes degradation of natural fish habitat resulting in reduction of overwintering grounds and overfishing.

A short term solution would be re-excavating silted channels and constructing embankments around beels. However, the long term impacts of this structural solution need to be investigated.

Fish broodstock is declining due to degradation of mother fisheries and the lack of secure fish sanctuaries.

Local fishermen propose exempting important duars from the present revenue system and creating duar fish sanctuaries under biological management.

Fish sanctuaries need to be established. Overwintering grounds, spawning grounds and migratory routes should come under a comprehensive community based management system. The proposed fish sanctuaries are listed in Table 3.11.

Government regulations regarding protection and conservation of fish by prohibiting fishing of certain species from 1 April to 30 June (1985) are not enforced.

For the Laws to be effectively implemented, peoples' motivation and participation is required.

Fish shelter and breeding places are deteriorating due to deforestation and encroachment of agriculture.

At least 15 to 20 ha of reedland are required in each haor complex. This land need to be established and protected as a reserve forest .

Table 3.11: Proposed Fish Sanctuaries

Location	Sanctuary Name
Boromach Sanctuaries	
Surma River	Digholir Duar, Dowarabazar Duar, Jamlabazar Duar, Sharifpurar Duar
Kushiyara River	Bara Pecchir Duar, Digholbar Duar, Kittar Duar, Ranigangar Duar, Roailar Duar
Piyain River	Faridpur Duar, Shisur Duar
Chotomach Sanctuaries	
Jagannathpur	Chilaura Beel
Balaganj	Mailjail Beel
Kaliajuri	Makhnai Beel (part of), Ratna Beel
5-7 years reserved fisheries to be harvested on rotational basis	
Kalni River	Section from Tonakhali to Markuli
Kaliagota Haor	Kamal Beel
Pagner Haor	Pagner Beel
Pangasiar Haor	Chunai, Dhanimati and Ranichapur Fisheries
Derai	Bhanda Beel, Sunai Nadi,
Deker Haor	Bardoi-Kastaganga Fishery, Rangamati Beel
Naluar Haor	Chondir Dor, Karkol Nadi
Baram Haor	Chatal Beel or Bhulai Beel
Chaptir Haor	Felua Beel

3.6 Navigation

All three major rivers - Kushiyara, Surma and Baulai, around the project area are navigable year-round. These are classified as class A route by the BIWTC. The important landing centres are Fenchuganj, Balaganj, Sherpur, Inatganj, Markuli and Ajmiriganj on the Kushiyara River, and Sylhet, Gabindaganj, Chhatak, Dowarabazar, Sunamganj, Sachnabazar, Gaglajur, Lepsa and Dhanpur along the Surma-Baulai Rivers. Some internal rivers such as the Mora Surma the Piyain, the Mohasingh and the Darain also remain navigable throughout the year in major sections of their channels. The Mora Surma and Piyain rivers provide the only means of transportation in the eastern part of the project when roads are flooded during the monsoon season. Passenger launches and cargo boats (500 mounds capacity) play between Sunamganj and Dirai along the Surma River. Small boats can play through many other localised canals in the project area in winter months.

The other major rivers/khals of the project area such as the Bhatta Khal, Naljur River, Itakhola River, Kazanchi Khal, Betari Nadi, Kura Gang and Barbhanga Nadi are silted up in many places or carry too little water for navigation during the winter months. However, these channels become important navigation routes during the monsoon months.

Since the entire village road communication of the Catchments 2 to 5 as well as the low-lying areas of Catchment 1 are submerged during the monsoon months, boats are the only means of transportation. At present small and medium-sized engine boats operate for more than six months a year all over the west part (Catchment 2-5). Usage to this extent is also common in the eastern part (Catchment 1) of the project area. The residents of the haor areas need small-sized country boats during monsoon months for their daily work and movements, and those who can afford to buy boats own them.

Reportedly, though water borne transport has historically been the primary means of communication in the haor area, the network has been disrupted by silt deposits in the channels, and by flood embankments which separate the channels from the flood plains and haor areas.

Most of the existing submersible embankments in the Surma-Kushiyara-Baulai Basin area are not-passable by boats for most of the monsoon season. Only during the peak floods are the embankments sufficiently submerged for boats to pass. Embankments constructed along the rivers and around the haors has resulted in disrupting the traditional navigation routes across the flood plains. These navigation routes are very important for the haor residents.

3.7 Wetland Resources Utilization and Management

The most important use of the natural wetland products in the project area is as thatching material. Various types of grasses are used for making structures to protect homesteads from wave action or for making homestead roofs or panels for mats. The species used for protecting the homesteads is Hemarthria protensa (*chilla*) and the species mostly used for other purposes are Vetiveria zizanioides (*binna*), Sclerostachya fusca and some Phragmites karka (*khagra*). These species generally grow on the border of the perennial beels, and it is difficult to estimate accurately the area they cover. The best current estimate is that about 7000 ha of these grasslands exist. The estimated value of the crop is about Tk 150 ha^{-1} $year^{-1}$. The total value of the wetland grasses is therefore estimated at about Tk 1.05 million $year^{-1}$ and the employment (at 2 pd ha^{-1}), is about 0.014 million pd $year^{-1}$.

A second important use of the grasslands is fodder. The people in the Catchment 4 and 5 are fully dependent on these materials, particularly during the monsoon season when water covers almost the entire grazing land. Plants such as Nymphaea sp. (*shapla*), Nymphoides sp. (*chandmela*) and other grasses are commonly used. Quantification of the real economic value of this product is difficult, as most people collect their requirements themselves as they need it. An approximation follows which uses a replacement value for the fodder. The fodder grass grows mostly on F3 land which occupies about 100,000 ha and remains fallow in the summer. At an estimated value for the wetland fodder at Tk 40 ha^{-1}, the total value is about Tk 4 million $year^{-1}$. The estimated employment in gathering the fodder (at 1 pd ha^{-1}), is about 0.1 million pd per $year^{-1}$.

Another important wetland product is the hizal and koroch trees for fishing (see Section 3.5.6). The fish lease holders usually buy the branches to make a Kata. The cost of each branch ranges

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from Tk 30 to Tk 150, depending on its size. A single tree can produce at least two branches every year and a garden (*Mahal*) with 300 trees can provide returns of between Tk 30,000 and Tk 50,000 per year. The estimated annual production value of the major gardens in the project area, listed in Table 2.4, could reach about Tk 500,000.

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

Other uses of the wetlands are:

- Food material. Mostly from Nymphaea sp. (*shapla*) and Aponogeton sp. (*ghachu*).
- Bio-fertilizer. From various weeds of the wetland.
- Medicinal plants. Mostly form Polygonum sp (*kukra*) and many others.

These common property resources are of importance to the poor, who are the most likely to engage in gathering for income and for consumption the wetland products. Customarily, fodder and building materials are collected by men, and food and medicinal herbs are collected by women.

4. PREVIOUS STUDIES

This study is the first investigation aiming at optimum development of water resources based on the single hydrological unit of the Surma-Kushiyara-Baulai inter-basin area.

Some major river regulating work has been carried out on the boundary rivers such as loop cuts as well as major river and khal closures (for example: the Kalni River at Markuli, the Old Surma River at Bheramohona, and the Piyain River at Amria were all closed). This work was carried out on the basis of local public demand or by BIWTA to improve navigation routes. It was generally executed without prior feasibility analysis.

Nine EIP type[1] haor development schemes and one drainage improvement scheme have been constructed in the project basin by BWDB in the past 10 years. The schemes are listed with salient data in Chapter 3.2 of this report under Water Resources Development (present). Implementation of these schemes (some still under construction or under rehabilitation) was preceded by feasibility studies carried out under EIP and IDA Programs. For a detailed description of each scheme please refer to the July 1992 FAP 6 report on Regional Water Resources Development Status.

[1] The nomenclature developed from the Netherlands financed Early Implementation Projects which were characteristically short gestation, relatively small projects.

5. WITHOUT-PROJECT TRENDS (NULL OPTION)

Certain trends are occurring in the project area. These trends provide some indication of what the future in the project area will be if no intervention is undertaken:

- Net population growth: Population growth in the project area during the period 1981-91 averaged 2.16% per annum, and it is declining. For the purpose of this study it has been assumed that the population growth will gradually decline to 1.8% by the year 2000 and to 1.2% in 2015. Based on these assumptions, the project population will increase from 1,892,147 in 1991, to 2,302,136 in 2000, and 2,869,964 in year 2015.

- Food grain production growth: about 0.5% per year over the next 5 to 8 years. Current trends in agricultural production would continue in the absence of any intervention in the Surma-Kushiyara-Baulai project area. High yielding varieties of aman would continue to replace local varieties of transplanted aman, particularly on the F0 land type. On F3 land types, sedimentation would continue to take some area of the area planted to local varieties of boro rice out of production. Farmers indicated that they were growing local varieties of broadcast aman in these area mainly because of a shortage of water in the dry season. This would mean continued damage to the broadcast aman and local boro rice.

  The expansion of irrigation facilities would be marginal because of the limited availability of water in the dry season. This would facilitate an expansion of the area cropped to high yielding varieties of boro but this crop would continue to be exposed to be damaged by pre-monsoon floods. Prior to making these investments, farmers are expected to use their judgement in selecting sites with the least possibility of flood damage.

  Damage to local and high yielding varieties of transplanted aman as a result of drainage congestion, particularly on the F1 land type would continue. Consequently, little change in the production of this crop would be expected. Future crop patterns and crop production with no intervention are presented in Tables 5.1 and 5.2.

- Floodplain fisheries production: Observations of past fish production trends indicate that production is declining by 1-3% per year overall. The decline is due to present management practices which include overfishing of brood stock. It is suggested that great increases in fish production are possible through introduction of non-structural interventions under improved biological management of the fishery. Lacking any specific information about future developments in fisheries, for the purpose of this study, it is assumed that the FWO project openwater production is equal to present production.

d0

- River course changes: The pattern of future river channel changes will be affected by three upstream factors:

  - climatic changes and trends in the magnitude and frequency of floods;
  - whether Tapaimukh dam is constructed;
  - future changes at the Amalshid bifurcation.

  For the purposes of this discussion it has been assumed that climatic conditions will remain similar to those experienced over the last decade.

  Construction of Tapaimukh dam will reduce monsoon season flows and increase discharges during the dry season. As a result the range in discharges and water levels will be reduced, particularly on the upper Kushiyara River (upstream of Manu River) and the upper Surma (upstream of Chhattak). This will tend to slow the average rate of bank erosion along the Kushiyara/Kalni River and the Surma River since river velocities and sediment transport rates will be reduced. The change in flow regime could induce local sediment deposition at tributary junctions (such as at Manumukh on the Kushiyara). This deposition can be expected since the reduced flows may not be sufficient to flush the high sediment loads that are brought in from the unregulated tributaries.

  The most likely scenario is that the distribution of flows between the Surma and Kushiyara River will remain approximately similar to present-day conditions. This conclusion is based on the fact that the flow split at Amalshid has been insensitive to past morphologic changes at the bifurcation. However, if a major channel shift occurred on the Barak River near Amalshid then it is likely that the flow split to the Kushiyara River would increase and the flow in the Surma River would decrease. Such a change could induce more rapid channel shifting and bank erosion along the Kushiyara River. The probability of such a change occurring over the next 20 years is probably small, but not negligible.

  Ongoing aggradation is expected to continue on the Kalni River downstream of Markuli. This will lead to development of a shallower, wider river and a greater tendency to channel shifting and bank erosion in this reach. Increased spills towards the Baulai River will also occur which could lead to the opening up of new distributary channels on the north side of the Kalni.

  Ongoing channel changes will also occur along the Baulai River between Sukdevpur and Itna in response to recently constructed loop cuts and channel straightening efforts. The channel shifting will include widening in the narrowly constructed pilot channels and increased bank erosion due to meander formation.

- Loss of arable land to settlement: By the year 2015 the number of households is expected to increase by about 180,000, which will require about 3,600 ha of land. It is assumed that the settlements will expand into the fallow land and infrastructure land owned by the government.

Table 5.1 Cropping Patterns under Future Without Project Condition

Cropping Pattern	F0		F1		F2		F3		Total Area
	Area	%	Area	%	Area	%	Area	%	
b aman-fallow					47192	70	6841	5	54033
fallow-l boro					0	0	123143	90	123143
fallow-hyv boro	0	0	0	0	6742	10	6841	5	13583
b aus-fallow-rabi	0	0	2682	10	3371	5	0	0	6053
b aus-lt aman	3058	13	9388	35	0	0	0	0	12446
b aus-lt aman-potato	1176	5	0	0	0	0	0	0	1176
b aus-lt aman-rabi	2353	10	4023	15	0	0	0	0	6376
b aus-hyv aman-fallow	4705	20	0	0	0	0	0	0	4705
b aus-hyv aman-rabi	706	3	0	0	0	0	0	0	706
hyv aus-rabi	2353	10	1341	5	0	0	0	0	3694
hyv aus-lt aman	941	4	1878	7	0	0	0	0	2818
hyv aus-hyv aman	2117	9	536	2	0	0	0	0	2653
lt aman-fallow	235	1	1073	4	0	0	0	0	1308
lt aman-rabi	2588	11	4023	15	0	0	0	0	6611
hyv aman-wheat	941	4	0	0	0	0	0	0	941
hyv aman-potato	0	0	805	3	0	0	0	0	805
hyv aman-rabi	2353	10	1073	4	0	0	0	0	3426
b aman-rabi	0	0	0	0	6742	10	0	0	6742
b aman-hyv boro	0	0	0	0	3371	5	0	0	3371
Total	23525		26822		67417		136825		254589

Table 5.2 Crop Production Under Future Without Project condition.

Crop	Damage free area			Damaged Area			Total Production
	Area	Yield	Prod.	Area	Yield	Prod.	
b aus	28962	1.25	36203	0	0	0	36203
hyv aus	9166	3.75	34373	0	0	0	34373
b aman	46646	1.75	107006	17500	1.45	25375	107006
lt aman	21736	2.15	62482	9000	1.75	15750	62482
hyv aman	11735	3.95	51678	1500	3.55	5325	51678
l boro	87643	2.25	248672	35500	1.45	51475	248672
hyv boro	10454	4.55	65441	6500	2.75	17875	65440
Total Rice						118425	605854
wheat	941	2.05	1929				
potato	1981	12	23772				
pulses	5041	0.85	4285				
oilseeds	16803	0.75	12602				
spices	1680	2.25	3780				
vegetable	10082	3.75	37808				

6. WATER RESOURCES INFRASTRUCTURE DEVELOPMENT OPTIONS

6.1 Summary of Problems

The problems within the area were described in earlier sections of this report. They are summarized here as follows: inadequate drainage, inundation of lowlands during winter by local rainfall augmented by spills from the boundary rivers, flooding of standing crops by short duration pre-monsoon flash floods carried by the surrounding rivers, and seasonal inundation by monsoon floods.

Agriculture has evolved to accommodate the monsoon floods so damage during the monsoon season is mainly to infrastructures and communication systems in the affected areas. However, the pre-monsoon floods combined with inadequate drainage cause severe damage to or completely destroy standing crops.

There have been significant investments in flood control infrastructure within the proposed project area. However, this infrastructure has not been as effective as anticipated. In addition, maintenance costs are high and general environmental effects have been negative.

6.2 Water Resources Development Options

About 90% of the project basin is flooded during the monsoon season because inadequate drainage which is partially due to high water levels in the Lower Meghna. Consequently, there is little scope to significantly alter the monsoon regime. The impacts of pre- and early monsoon floods, however, can be mitigated. Water resources planning needs to focus on protecting the boro crops (which is the primary agriculture output in the area) without disrupting the various other economic activities which are an important part of the areas development system.

There are three basic options for water resources development in the project area:

i) *Drainage Improvement by re-excavating internal khals.* Drainage improvement by re-excavating the khals which convey local rainfall runoff along with flood spills from the boundary rivers would reduce flood levels in the lower parts of the area. However, the hydraulic gradient in the spill channels would increase. This would accelerate erosion of the spill channels at their offtakes and increase flood inflows into the basin. The improved drainage system soon would not be able to convey the increasing flood inflows, and as a result the flood conditions in the lower parts of the basin would start to deteriorate.

ii) *Provide flood protection to lowland haor areas with ring type submersible embankments.* This option which has been adopted throughout the region has not proven to be fully satisfactory in the deeply flooded area of the project basin. The main drawbacks of this type of development include: the amount of land lost to embankments is substantial, annual maintenance costs are high, drainage is reduced, in-channel sediment deposition increases, fisheries and navigation are disrupted. Drainage improvements to evacuate flood water from the basin is also necessary under this option.

iii) *Control flood spills from the boundary rivers into the project area and improve the internal drainage system.* Under this option, the external flood inflows would be checked at source (4 spill channels in the Kushiyara and 5 channels in the Surma); controlling the external inflows will allow design of an internal drainage system that will not need to be increased in the future. To maintain the internal navigation system, navigation locks will be provided at the navigable channels. There will be a limited impact on fisheries as the structures will remain open during normal water levels, and controlled discharge will be maintained throughout the premonsoon season, including the peak flood periods. This is unlike the regulators constructed in haor development projects which remain closed from 1 April to 15 May. Also it is proposed that each structure be equipped with a fish passage facilities.

The project concept presented in Chapter 7 is based on option No.3, which has been adopted for the development of the Surma-Kushiyara-Baulai Basin Project area.

7. PROPOSED PARTIAL FLOOD PROTECTION PROJECT

7.1 Rationale

This plan provides for improved drainage and pre-monsoon flood protection of cultivable lands and infrastructure. A new channel will be provided to remove pre-monsoon water logging in the lowlands located along the Kushiyara River east of Jagannathpur. Improvement of the Dakuka-Kamarkhali-Darain Nadi system will allow rapid drainage of local runoff from the Bhatta Khal and the Moha Singh River basins which are also flooded during winter months.

Re-sectioning of 217.5 km of the existing embankments and construction of 99.5 km of new submersible embankments along the peripheral rivers, and provision of 10 hydraulic structures constructed on the spill channels from the Surma and Kushiyara Rivers will reduce the pre-monsoon flooding in the project basin. It will increase the pre-monsoon season flood free cultivable area from about 114,764 ha to about 221,964 ha and improve living conditions in the homesteads as well as providing improved communications.

It should be noted that the existing embankments along the Surma and Kushiyara Rivers should not be re-sectioned to a level which is above the pre-monsoon flood level unless they are presently being used as roads. Confinement of the monsoon season floods within these channels would result in a substantial increase in flood discharges in the rivers, for which the present embankment set-back distance is not sufficient.

7.2 Objectives

The objectives of the Surma-Kushiyara-Baulai Project are:

i) to prevent winter and pre-monsoon flood damage of boro rice;

ii) to reduce flood damage of aus and deep water aman rice;

iii) to promote expansion of HYV rice onto lower lands by reducing flood depths on these lands, improving internal drainage and reducing risk of early flooding; and

iv) to avoid disruption in navigation and fish migration routes by limiting the project infrastructure to peripheral submersible embankments and by providing hydraulic structures with navigation and fish passage facilities.

v) to protect and improve homesteads, infrastructure, and communication systems.

7.3 Description

The area encompassed by the proposed project corresponds to the natural drainage basin confined by the Surma, Kushiyara and Baulai rivers and their connecting channel the Surma Khal. Along the eastern boundary, the project borders the Upper Surma-Kushiyara Project along the divide line in the Golapganj Hills.

In general, the project involves the completion of flood embankments on three sides of the area (along the left bank of the Surma-Nawa-Baulai Rivers and along the right bank of the Kushiyara-Kalni Rivers) to prevent pre-monsoon flood flows from the north and east. The south and southwest side would be left open for monsoon and post-monsoon drainage, for natural monsoon flooding, for the entry of spawning and other fish, and for navigation purposes. The drainage system to the south would be improved through the excavation and re-excavation of strategic channels. Ancillary structures (including regulators, fish passes, and navigation passes) would be provided at the off-takes of major spill channels in the north and southeast.

7.3.1 Flood Protection

Flood embankments with hydraulic structures along with an improved drainage system form an integral component of the flood protection infrastructure in the Surma-Kushiyara-Baulai Basin Project. The infrastructure proposed is a continuous submersible flood embankments and control structures in the spill channels will provide an active flood protection in the Sylhet Plain and in the upper part of the Sylhet Basin where the ground elevations are relatively higher.

The lower part of the Sylhet Basin, the area south of the Piyain River where ground elevations are below 3.0 m PWD (Khaliajuri, and the southern part of Itna thana), will have a passive type of flood protection. This means an open embankment. During floods, water from the Baulai and Kalni rivers will enter the area from the south as a result of backflow.

As the average pre-monsoon water levels in the rivers and khals around the most southwestern part of the project are above elevation 3.0 m there is no natural drainage from this area when the rivers start rising. Were ring type embankment schemes to be constructed instead, the hazard of water logging in this area would be increased and post-monsoon drainage from the entire region would be affected.

Embankments
To prevent pre-monsoon floods spilling into the project area it is proposed to maintain a continuous submersible embankments along the right bank of the Kushiyara-Kalni River and the left bank of the Surma-Nawa-Baulai River system. This embankment would be designed for a pre-monsoon flood (prior to May 15) with a 1:10-year return period.

The length of the project boundary along the Surma-Nawa-Baulai Rivers is 202 km. Of this, 145 km is embanked (120 km with flood embankments and 25 km with local roads cum embankments). Of the remaining 55 km, high land borders about 45 km of the river system from Sylhet to Chhatak, and lowland about 12 km between the outfall of the Piyain River and Khaliajuri. See Figure 12. The embankments along the Surma and Nawa Rivers are sufficiently high to protect against pre-monsoon floods (the upper reach of the left bank Surma embankment from km 0 to 25 was designed for 1:20-year annual flood). However, some sections of the embankment and the roads along the Baulai River are low and are frequently overtopped by pre-monsoon floods.

Of the 115 km project boundary along the Kushiyara-Kalni River, 72 km is already embanked. The unembanked sections are: about 5 km upstream of Balaganj, 23 km from Sherpur to Ranigonj Bazar, and 15 km from the end of the existing Bhanda Beel embankment to the Bheramohona closure of the Mora Surma River. To reduce the hazard of scouring out the Bheramohona closure during the flood inflow into the Old Surma channel the flood embankment should be extended 1 km downstream from the closure.

At present the average pre-monsoon floods do not spill over the Surma and Kushiyara banks in the sections without embankments. However, due to confinement of the river flows a rise in the pre-monsoon flood levels is anticipated after project completion and new embankments need to be constructed.

Based on the secondary data used in this study, it is not possible to determine accurately the effect of the project on the water levels in the surrounding rivers. From preliminary estimates, using the existing rating curves and the flood levels based on historic data, a rise in the pre-monsoon flood levels from 0.2 to 0.8 m could be expected; the Surma River would rise up to 0.8 m if all the spill channels were closed during the 1:10-year pre-monsoon peak flood. However, the increase in the Surma River flood level can be limited to about 0.3 m by regulating the spill inflows at the head regulators.

Data on pre-monsoon spills from the Kushiyara River are insufficient to determine effects of river confinement with regulated inflows into the basin. However, it is assumed that the increase will be below 0.3 m. Since the Kushiyara discharges will be reduced by controlling the present spills from the Surma River into the Kushiyara River through Kakura Khal (Refer to NERP Upper Kushiyara Project Pre-Feasibility Report). The monsoon season flood levels are expected to remain at the present level.

For the purpose of estimating costs, the design crest elevation of the submersible embankments along the Surma, Nawa and Baulai rivers is fixed at about 1.0 m above the 1:10-year flood level expected before 15th of May. The flood level is based on the historic stage records. The additional 1.0 m would include anticipated future increase in water levels and safety freeboard. The design crest elevation of the embankments along the right bank of the Kushiyara-Kalni River has been fixed at 0.5 to 1.0 m above the 1:10-year pre-monsoon flood level.

To minimize land acquisition and earthwork volume, it is proposed that the alignment of the existing embankments be followed provided that there is no danger of river erosion. Otherwise, retired embankments should be constructed at a minimum setback distance of 30 m from the river bank. The new submersible embankments should also have a minimum set back distance of 30 m.

The existing embankments along the Surma and Kushiyara Rivers need to be re-sectioned. New embankments along the Surma and Kushiyara Rivers will need to be constructed with a crest level up to 1.0 m above ground level. New embankments along the Baulai and Kalni Rivers will require that crest levels be up to 1.5 m. The proposed cross section of the embankments is 4.27 m crest width, with side slopes 1:2 and 1:3 on country and river side respectively. Longitudinal profiles of the proposed embankments are shown in Figures 13 and 14, and typical cross sections of the embankments are shown in Figure 15. Project embankment work include the following.

- Construction of new embankments (99.5 km):
  - along the left bank of Surma River between the offtake of Bahia Gang at Darsa and Chhatak (44.5 km),
  - along the left bank of Baulai from the outfall of Piyain River to Khaliajuri (12 km),
  - along the right bank of Kushiyara upstream from Balaganj from 20 to 25 km (5 km) and from Sherpur to Ranigonj Bazar (23 km), and
  - along the right bank of Kalni from Protappur to 1 km downstream from Bheramona closure near Ajmiriganj (15 km).
- Re-sectioning of existing embankments (217.5 km):
  - along the left bank of Surma River from Maulavir Bazar to the offtake of Bahia Gang at Darsa (high embankment, 25.5 km),
  - along the left bank of Surma, Nawa and Baulai from Chhatak to below the outfall of Piyain River (total 108 km) and from 190 to 202 km (12 km), and
  - along the right bank of Kushiyara from 0 to 20 km (20 km) and from 25 to 47 km (22 km).
  - along the right bank of Kushiyara from 70 to 100 km (30 km) (existing embankments of Naluar, Tangua and Bhanda Haors).

Protection Measures for Embankments During Overtopping

Submersible embankments are most vulnerable to erosion during overtopping. In the polder type schemes, this hazard is reduced by flushing water through regulators into the basin so that the difference in water levels (inside and outside the haor) when the embankment overtops is less than 0.3 m.

Though the structures provided on the Surma and Kushiyara spill channels will be used for flushing, their capacity is insufficient to infill the basin. Also, the large size and the topography of the project area makes the flushing for the purpose of equalizing water levels impractical.

To reduce embankment erosion resulting from overtopping at high hydraulic heads, flood water would be flushed into the basin over the river's natural banks. For this purpose it is proposed to provide overbank floodways. The overbank floodways would simply be unembanked sections of the rivers where natural ground levels are at about the expected design flood level, while also taking account of the effects of confinement. To prevent ground erosion the overbank flood relief ways should be protected with grass cover.

Embankment design crest elevations are shown in Table 7.1. Details are provided in Annex B.

Table 7.1: Embankment Design Crest Elevations

Locations	Section (km)	Crest Level (m PWD)
Surma-Baulai River		
Moulavir Bazar	0	14.00
Sylhet	18	13.65
Bahia Nadi	25.5	13.50
Bahia Nadi	26	10.8
Chhatak	68	8.90
Sunamganj	110	8.20
Sukdevpur	162	5.90
Khaliajuri	190	5.60
Dhampur	202	5.40
Kushiyara-Kalni River		
Manikkona	0	10.60
Fenchuganj	6	10.35
Balaganj	24	9.67
Sherpur	47	8.80
Markuli	90	7.10
Ajmiriganj	115	5.40

Structures for Flood Control

To check the flood inflow into the project area through the open khals, five structures are proposed on the Surma spill channels, four structures on the Kushiyara channels, and one structure on the Piyain River spill/drainage channel.

Three types of structures are proposed: flushing regulators, flushing and drainage regulators, and regulators combined with navigation locks. All the khals connected to the Surma River are spill channels, and flushing regulators should be provided on these channels. The only exception is the Bahia Nadi which also drains back into the Surma and requires flushing/drainage regulator.

Regulators with locks will be provided on khals which at present are used for navigation. At this preliminary stage of planning, three sizes of locks are considered: they would have 3.0 m, 5.0 m and 6.0 m widths.

To prevent excessive water level rise in the boundary rivers and to maintain sufficient depth for navigation in the internal khals, the structures (and the channels) should be designed for a continual flow from the river into the channel. One or more regulator gates may need to remain open all the time. This would also serve to reduce project impacts on fisheries. In addition, each structure will be equipped with fish pass facilities.

To preserve the Kaliajuri Fish Sanctuary, it is proposed to leave the Piyain River open at the offtake from the Baulai and to construct one flushing/drainage regulator across the Kolkolia Khal near Alipur. The Kolkolia Regulator will prevent direct spill of the pre-monsoon floods onto the boro paddy lands in the Kaliagota Haor area.

Proposed structures are listed in Table 7.2. A line drawing of the proposed lock cum regulator structure is provided in Figure 16.

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Table 7.2: Proposed Structures

Location	Structure Type	Structure Size	Design Q (m^3/s)
On Surma River Khals:			
Bahia Nadi	Lock/Regulator	5.0 m lock / 2-2.0 x 6.0 m	100
Kazanchi Nadi	Regulator	4-2.0 x 6.0	80
Bhatta Khal	Lock/Regulator	5.0 m lock / 6-2.0 x 6.0 m	180
Madhabpur Khal	Regulator	4-2.0 x 6.0	80
Old Surma River	Lock/Regulator	6.0 m lock / 3-2.0 x 6.0 m	130
On Kushiyara River Khals:			
Kurkuchi Khal	Lock/Regulator	3.0 m lock / 2-2.0 x 6.0 m	85
Betari Nadi at Narayanpur	Lock/Regulator	3.0 m lock / 2-2.0 x 6.0 m	85
Betari Nadi at Hariyargaon	Regulator	2-2.0 x 6.0 m	40
Barbhanga Nadi	Lock/Regulator	5.0 m lock / 4-2.0 x 6.0 m	140
Piyain River:			
Kolkolia Khal	Regulator	3-2.0 x 6.0 m	60

Protection of Balaganj Town

The intensive bank erosion which occurs at the eastern end of Balaganj town is the result of bi-directional flow in the common channel of the Barbhanga Nadi and the Patachatal Beel. Historically, as shown on the 1963 topographic maps, there were two separate channels discharging into the Kushiyara upstream of Balaganj, the Barbanga Nadi draining upper areas and the outfall channel of the Patachatal Beel draining the Majail and Dubrir Haor lowlands into the Kushiyara River. In recent years as the two channels have merged into one, river erosion has intensified and is progressing downstream onto the Balaganj town (See Figure 17).

When water levels in the Kushiyara River are rising, water flows into the beels from the river, it then flows back into the river at high velocities when river water levels are falling. The high intensity water currents at the constriction point erode the Kushiyara River bank; the Balaganj thana hospital boundary walls have already collapsed and the buildings are now in danger of being undermined.

To prevent further erosion, it is proposed to close the present opening in the Kushiyara bank and shift the outfall channel further upstream as shown in Figure 17. A navigation lock with flushing/drainage regulator constructed at this point would allow boat passage during the monsoon season, drainage during the post-monsoon and flushing or diverting part of the Kushiyara's flow into the right bank floodway to reduce flood levels in the Kushiyara main channel.

The Barbhanga Nadi channel will remain open upstream of the proposed closure at the Balaganj Hospital site, to let water in and possibly to induce siltation. Initially it may be used for navigation between the closure and the Khasipur Khal. Following the anticipated siltation of this channel, it can be reclaimed for other uses.

Other Infrastructure
There are two district towns in the project area, Sylhet and Sunamganj. While Sylhet has a direct road link with Dhaka, the road to Sunamganj passes through Sylhet town. A National Highway traverses the project area from Sherpur to Sylhet and a Regional Highway connects Sylhet with Sunamganj. However, traffic is very heavy in the streets of Sylhet and it requires, on average, about one hour to cross the Surma Bridge and travel through town to the Sunamganj road. All road transport bound for Sunamganj and Chhatak is delayed at Sylhet, which further adds to the existing congestion on the streets of Sylhet.

A road has been constructed to Sunamganj via Jagannathpur, but it is presently not passable. The section from Jagannathpur to Pagla, which is located in the deep part of the Sylhet Basin is damaged by wave action during every monsoon. To improve the main road transportation within the project, it is proposed that a new link road be constructed connecting the Sherpur-Sylhet road with the Sylhet-Sunamganj road via Biswanath. In addition to general public requirements, this road would facilitate transporting construction materials and components of the proposed structures to the left bank of the Surma River (for example: the large steel gates for locks and regulators).

At present a new paved road exist between Biswanath and Sripur, and to complete the proposed link an additional 6 km of new road with one bridge (about 30 m span) and two culverts need to be constructed from Sripur to Kazirgaon. Existing village roads cover about 3 km of the proposed alignment of the link road shown in Figure 12. It should be noted that the cost of this road has not been included in this pre-feasibility study.

Impact on Flooding
The flood protection measures will reduce the depth of flooding and the area of flood-free land will be increased. Table 7.3 shows the combined areas under different depths of flooding in the whole Surma-Kushiyara-Baulai Basin Project. Annex A, Table 26 shows the break down of the flood depth areas in the five catchments or sub-basins of the project identified according to the topographic and hydrologic characteristics.

The pre-project areas under various depth of flooding have been derived by superimposing the averaged flood elevation on land elevations. These were obtained by interpolating the historic flood levels between the points of flood inflows from the boundary rivers into the relevant catchment on the area-elevation curves of the catchment. It is recognized that there may by some degree of inaccuracy in estimating the pre-project flood depths because of:

- varying flood water levels on a slopping land,
- the mitigating effect of the existing embankments along the boundary rivers on the floods inside the protected area, and
- the existence of the haor type schemes in the project area.

Adjustments have been incorporated by taking account of the areas protected by existing haor schemes. However, information regarding their actual effect on the flood levels is not available.

The post-project areas under various depths of flooding have been identified by referring to:

- the design water levels in the drainage channels inside the project area, for the upper part of the project where there is free drainage through the re-excavated channels, and

- the average pre-monsoon water levels at the outfall into the Baulai River, for the lower part of the basin.

Similarly, as with the pre-project scenario, adjustments were incorporated into the catchments with existing haor schemes. The reference pre-monsoon flood levels in the project catchments under the pre- and post-project scenarios are presented in Annex A, Table xx.

7.3.2 Drainage

The Surma-Kushiyara-Baulai basin is laced with a dense network of internal channels and in general there is an adequate micro drainage system. However, the macro level drainage system is inadequate. The major khals, which are spill channels of the Surma River, have large sections in the upper reaches but are small and silted in the middle and lower reaches.

In the eastern part of the project, the Muktarpur Haor area in Catchment 1 (See Figure 10) has no outlet. Flood water flows from Catchment 1 into the lowlands in the southeastern part of Catchment 2 which also has no direct connection to the Kushiyara River. The water flows through Sadipur Khal and through several small bridges in the Sherpur-Sylhet road. As a result, water logging occurs in the lower parts of Catchment 1 and 2.

Large parts of the Deker Haor area in Catchment 3 are flooded following winter and pre-monsoon rains. This is caused by siltation in parts of the Moha Singh, Dahuka, Naljor and Kamarkhali Rivers, and the small section of the Darain Nadi which now drains more than half of the project area.

Table 7.3: Pre-Monsoon Basin Flood Depth
(1:10 yr flood before May 15)

Flood Depth (m)	Gross Area (ha)		Net Area (ha)	
	Pre-Project	Post-Project	Pre-Project	Post-Project
< 0.30	129964	237564	114764	221964
0.30-0.90	66825	43125	66825	32105
0.90-1.80	52025	34100	52025	0
> 1.80	70475	4500	20925	0
Total Basin	319289	319289	254589	254069

To improve drainage within and from the project area, major channel improvement works need to be carried out. These include re-excavation of about 117 km of the internal rivers and main khals, excavation of about 10.5 km of new channels and dredging of about 82 km of internal rivers (Mora Surma and Datain rivers).

The new channels will provide drainage outlets for the lowlands in Catchments 1 and 2 by linking the Majail Haor with Muktarpur Haor and draining the area through the Sadipur Khal linked with Itakhola Nadi and Kamarkhali Nadi. A short new channel (about 2 km) linking the Hamhammia River with Mohasingh River will eliminate drainage congestion in the lowlands near Sunamganj.

The proposed development of the Surma-Kushiyara-Baulai Basin drainage system includes upgrading three main water courses as shown in Figure 12: Channel A – the main drainage collector of the northeastern and northern part of the project, Channel B – drainage outlet for the lowlands in the Deker Haor area, and Channel C – the main drainage collector of the eastern and southern part of the project basin. Channels A and C will also act as a flood relief channels of the Surma and Kushiyara rivers.

Channels
The project main drainage channels with the proposed improvement works are listed below.

Channel A — Channel course: Bhatta Khal starting from the offtake from the Surma at Gobindaganj - Dahuka River - Kalni River - Mora Surma River - Surma Khal discharging into Baulai River at Dhanpur.

Improvement works: re-excavation of the middle and lower Bhatta Khal (15 km) and re-excavation of Dahuka River along the northern boundary of Naluar Haor and Chaptir Haor Project to the outfall into the Kalni River (about 32 km) and dredging of Mora Surma (42 km).

Channel B — Channel course: Mohasingh River.

Improvement works: link channel from Hamhammia River to Mohasingh River (2 km), re-excavation of the Mohasingh River in the middle section downstream from Deker Haor (5 km) and in the lower section (about 7 km).

Channel C — Channel course: starting from Patacharal Beel at Balaganj across Muktarpur Haor - Sadipur Khal - new link channel - Itakhola Nadi - Naljor and Ratna River (between Polder 1 and 2 of Naluar Haor Project) - Kamarkhali Khal - Old Kalni River - Darain River - Old Surma into Channel A (Surma Khal).

Improvement works: excavation of about 0.5 km long link channel from the Patachatal Beel to Khasipur Khal crossing Barbhanga Nadi, improvement of the existing channels across the Muktarpur Haor (10 km), excavation of a new link channel between Sadipur Khal and Itakhola Nadi (8 km), re-excavation of Naljor and Ratna Rivers (28 km), improvement of lover Kamarkhali Khal (20 km) and dredging of Darain River (40 km). The improvement of the Kamarkhali and the Darain channels should include several loop cuts, which would reduce substantially the length of the channels and the volume of earthworks.

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Channel discharge capacities should be sufficient to pass, within bank, pre-monsoon flood flows generated by a 5-day basin rainfall with a 1 in 5 year return period. Overbank spilling in lowlands would be allowed during the design flood of a 1:10-year return period, but the flood water should recede to less than 0.3 m depth within three days. During the monsoon and the post-monsoon drainage periods the channels will remain submerged; along with most of the lowlands in the basin.

Longitudinal profiles showing ground elevations along the main drainage channels and having design bed levels are presented in Figures 18 through 20. The available channel cross sections surveyed by the BWDB Morphology Directorate or by the SWMC are outdated or insufficient for earthwork estimates.

Channel design parameters vary according to local soil conditions and flow discharges. The side slopes in the rivers and khals of the project basin vary from about 1:0.7 to 1:2. An average side slopes of 1(v):1.5(h) has been adopted for excavation of new and for re-excavation of the existing channels. The design parameters of the project drainage channels to be improved are shown in Annex A, Tables A21 through A23.

Bridges

To improve surface communication two new bridges need to be constructed on the existing roads; one on the Dhaka-Sylhet road over Sadipur Khal at Sherpur, to replace the temporary pontoon bridge, and one on the Sylhet-Fenchuganj road over Baksi Nadi. Construction of the Baksi Nadi bridge has already started, but it was abandoned several years back. The bridges are located on the existing National Highways, and their construction should be undertaken by the Roads and Highways Department.

One 30 m span RCC Bridge across the Kazanchi Khal and two RCC Box culverts across local khals need to be constructed on the proposed Sunamganj link road between Sripur and Kazirgaon in Biswanath thana. While it is recommended that the road as well as the bridge and culverts be constructed under the Surma-Kushiyara-Baulai Basin Project and they have been costed (see Annex B Tables 38 and 39) their costs are not included in total project cost or economic analysis since the benefits provided by improving the road network are independent of the benefits provided by the water management infrastructure.

7.3.4 Expected Benefits

The primary benefits from the project relate to agriculture. Protection from floods in the pre-monsoon season through dwarf embankments would enable farmers to harvest local and high yielding varieties of boro rice. This would reduce damage to these crops and increase production to a level which is similar to that obtained under damage free conditions. This may also encourage farmers to replace some of the local boro with high yielding varieties of boro rice since the risk of pre-monsoon flood damage would be eliminated.

Delayed monsoon flooding would also provide the time required by local varieties of broadcast aman to acquire the ability to elongate with gradually increasing water levels during the early monsoon. The dwarf embankments would, therefore, reduce the damage presently incurred in this crop. However, since it is improbable that pre-monsoon flooding will be totally eliminated from the entire area, it has been assumed that localized flood damage to local and high yielding varieties of boro rice and local varieties of broadcast aman would continue.

The monsoon flood regime will not change. Consequently, for all practical purposes, cropping patterns are expected to remain much the same as those described under the future without project scenario (Table 5.1) and the current level of damage to local and high yielding varieties of transplanted aman is expected to continue. In summary, the major impact of the project would be increased crop yields from those crops affected by pre-monsoon flood damage. Crop production under future with project condition are presented in Table 7.4

Table 7.4: Crop Production - Future With Project

Crop	Damage free area			Damaged Area			Total Production (t)
	Area (ha)	Yield (t/ha)	Production (t)	Area (ha)	Yield (t/ha)	Production (t)	
b aus	28870	1.25	36088	2500	1.05	2625	38713
hyv aus	9140	3.75	34276	0	0	0	34276
b aman	62163	1.75	108785	2500	1.45	3625	112410
lt aman	21638	2.15	46521	9000	1.75	15750	62271
hyv aman	11703	3.95	46229	1500	3.55	5325	51554
l boro	102664	2.25	230995	2500	1.75	3625	234620
hyv boro	33295	4.55	151492	750	2.75	2063	153554
Total Rice			654385			33013	687398
wheat	939	2.05	1925				
potato	1975	12	23705				
pulses	6037	0.85	5131				
oilseeds	20123	0.75	15092				
spices	2012	2.25	4528				
vegetables	12074	3.75	45277				

Annual cereal crop production is expected to increase by about 78,913 tonnes from 607,783 tonnes (future without) to 686,696 tonnes as a result of the project, an increase of 13.0 %. Non-cereal production would increase by about 11,487 tonnes, which is a 14% increase.

The increase in cereal crop production implies a per person increase in cereal availability from 339 (FWO) to 384 (FW) gm per person per day, an increase of +13.3% (Table 7.7). Current Bangladesh average consumption is 440 gm per person per day.

7.3.5 Mitigation Measures Incorporated

Closing flood spill channels from the project boundary rivers with permanent earthen dams has been a common practice in the past years. While this kind of intervention may improve flood condition in one place at a particular time it can hamper drainage when it is most required. Closing of any open watercourse obstructs navigation routes used by local inhabitants during the wet season and it disrupts traditional fish migration.

To date, all of the minor and medium khals along the project boundary, whose inflows were threatening the protected lands, have been closed or silted. The few khals that still remain open do not pose any flood danger; these are used for local drainage. Therefore, it is not recommended that the small khals that still remain open be closed without detailed (and documented) analysis.

There have been requests for re-opening and constructing "sluice gates" on several Surma River khals which have been closed in the past (Dhopakhali, Panda Khal, Piyain River). Since these khals are purely spill channels which do not drain the protected basin areas, reopening them would be of no benefit to agriculture. If they are to be re-opened the impacts would need to be analyzed in the context of the specific benefits that would be sought (for example, navigation or fisheries). Specifically, it is not is not recommended that a hydraulic structure replace the closure on the Dhopakhali channel.

The Panda Khal formerly spilled into the Deker Haor complex which was an important fisheries area. Further studies are needed to determine the viability of restoring flows in the Panda Khal and the Piyain River at its offtake from the Nawa River to establish their impact on the fishery; these should be carried out during the feasibility investigations.

To minimize the negative effects of the proposed hydraulic structures constructed over the main spill channels (five on the Surma left bank and four on the Kushiyara Right bank), it is proposed that a nominal flow be maintained at each structure throughout the pre-monsoon season. This can be effected with partly open gate(s). Also, each structure would be equipped with a fish passage facility. Under normal conditions, when the inflow from the river does not pose any flood danger in the lower part of the basin, the structures should remain open.

The gates should be closed (after part of the flow has been released) only during peak flood stages in the river. Usually pre-monsoon flash flood peaks last for no more than several days at a time. In case of unseasonal floods, usually in December and February, the structure gates may need to be partly closed for the period of high river stage.

After the boro crops have been harvested, all structures should remain open throughout the monsoon.

7.4 Project Operation and Maintenance

The Surma-Kushiyara-Baulai Basin Project structural components consist of flood embankments along the major boundary rivers, re-excavated major internal drainage channels and newly constructed medium and large size hydraulic structures. The project covers a large area of 319,289 km^2 extending over four districts and four BWDB Divisions. Under these conditions, the most important factor of the project operation is a reliable communication system.

The project is designed to prevent the pre-monsoon flood damage to the crops grown inside the basin, without significant rise in the flood levels in the boundary rivers which could adversely affect neighbouring areas. The concept is based on preventing unseasonal flood spills from the boundary rivers into the basin with flood embankments, and regulating the inflow into the drainage/spill channels through the hydraulic structures.

Project operation will consist of regulating flows through the hydraulic structures in a timely manner. This will involve monitoring water levels inside the basin along internal drainage channels and at other control points, as well as in the boundary rivers.

It is proposed that a single Project Operation Unit (POU) be formed for the purpose of operating and maintaining the Surma-Kushiyara-Baulai Basin Project. The POU should have on its staff a hydrologist/hydraulic engineer, an agronomist, a fisheries specialist, and representatives of local bodies in various capacities, field monitors and structure operators.

The field monitors would be responsible for inspecting project components (embankments, channels and structures) and for monitoring water levels. They would relay the information to the central office through a separate communication system set up for the project. The central office would analyze the information and transmit orders to the structure operators.

The maintenance works like repair of embankments and structures, and re-sectioning of drainage channels should be the responsibility of the POU.

To function properly, the POU should have the authority to make decisions independently of the four Districts and BWDB Divisions of the project area.

7.5 Organization and Management

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

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

During the construction phase, BWDB would be responsible for establishing a Project Operation Unit (see above) to undertake project operation and maintenance activities. The POU would liaise with the various agencies responsible for providing services to the project community including agriculturalists and fishermen.

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

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

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

Table 7.5: Capital Cost Summary

Item	Cost ('000 Tk)
Structures	181,724
Embankments	66,522
Channels	510,133
Roads	(11,964)
Bridges	(12,036)
Buildings	9,250
Land	204,870
Base Cost	972,499
Physical Contingencies	243,124.7
Subtotal	1,215,623.7
Study Costs	182,343.6
TOTAL	1,397,976.3
Net Area (ha)	254,069
Unit Cost (Tk/ha)	5,502

Notes: 1. The total cost does not include the costs shown in brackets.
2. Physical Contingencies are 25% of Base Costs
3. Study Costs are 15% of the Subtotal and includes the cost of an EIA and preparation of an Environmental Management Plan.

7.6 Cost Estimates

Total project costs are estimated at Tk 1,397.97 million. A summary of total costs is presented in Table 5.5 with details provided in Annex B. Estimates of land required and of the physical work to be undertaken are based on preliminary designs and lay-out plans using four inch to one mile topographic maps and historic hydrologic data.

Land costs reflect the current prices obtained from field interviews: land

Table 7.6: Implementation Schedule

Activity	Year (% Completion)				
	0	1	2	3	4
Preconstruction Activities					
Feasibility Study	100				
Engineering Investigation	70	30			
Detail Designs		70	30		
Land Acquisition		30	40	30	
Construction Activities					
Construction of Embankments		30	30	40	
Re-excavation of Channels		20	30	30	20
Dredging of Channels		20	30	30	20
Construction of Structures		20	40	40	
Construction of Road		40	60		
Construction of Bridges		40	60		
Project Buildings				100	

on the higher ridges along the rivers was priced at Tk 300,000 per ha, land in the lowlands (for re-excavation of drainage channels) was priced at Tk 260,000 per ha. Earthwork costs are based on the BWDB Schedule of Rates for Sylhet Circle indexed to June 1991 prices. Structure costs are based on preliminary line drawings and parametric costs developed for the region. These were also indexed to June 1991 prices in accordance with FPCO Guidelines for Project Assessment.

7.7 Project Phasing and Disbursement Period

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

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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.

Agriculture
The annual grain crop production (paddy + wheat) is expected to increase by about 78,913 tonnes from 607,783 tonnes (future without) to 686,696 tonnes as a result of the project, an increase of 13.0 %. The cereal production increase implies a per person increase in cereal availability from 339 (FWO) to 384 (FW) gm per person per day, an increase of 13.3%. Current Bangladesh average consumption is 440 gm per person per day.

Non-cereal production is expected to increase by 11,487 tonnes, from 82,247 tonnes (FWO) to 93,734 (FW) tonnes, an increase of 14.0%. This results from a 6634 ha increase in area cultivated to non-cereals from 35,587 ha to 42,221 ha. It indicates an increase in the availability of non-cereals from 79 to 89 grams per person per day (Table 7.7).

Fisheries
The proposed project is a partial flood protection and drainage improvement project, and as such it will not significantly reduce the area of the floodplain fishery (there will be a 164 ha area that will be occupied by flood embankments).

The project would delay inundation of floodplain on about 46,532 ha (20% of the monsoon season floodplain), and increase the surface area of the channels by 248 ha (1.5%). (The pre-monsoon floodplain area is exclusive of the existing Haor Projects covering a gross area of 61,086 ha.)

The southern periphery of the project basin is to remain open. Also it is proposed to leave the outfall of the Piyain River open to preserve the link between the Kaliajuri fish sanctuaries and duars in the Baulai River. Fish passage facilities will be provided or a continuous flow will be maintained at each hydraulic structure to minimize the impacts of the embankments

The project is expected to have little impact on spawning since the water linkage between the Baulai and Piyain rivers and the haors in the Khaliajuri area will be maintained. This is considered to be a key spawning area for carp.

Table 7.7: Food Availability Indicators
grams/person/day

Food Group	Present (1993)	FW (2000)	FW (2015)	FWO (2015)
Cereals	485	478	384	339
Non-Cereals	119	112	89	79
Fish	30	21	17	21

Impacts on open water fisheries production were assessed using a simplified model that represents the major system processes. These factors include migration, overwintering habitat extent, wet

Table 7.8:: Fish Production Indicators

Regime	FWO (2015)		FW (2015)			
	Area (ha)	Production ('000 kg)	Area (ha)	Area Equivalent	Production Impact ('000 kg)	Net Value ('000 Tk)
Flood Plain	231064	10167	230900	184720	-2039	-70165
Beels	14300	7865	14300	11440	-1573	-98069
Channels /Rivers	8200	1640	8448	6758	-288	-18741
Totals	254589	19,672.0	253,648	202,918.0	-3,900.0	-186,975.0

season habitat, habitat quality and spawning habitat. The basis for this model is summarized in Section C.2.7 of Annex C. The sign and magnitude of these impacts is provided in Table C1. Summary outputs are provided in Table 7.8.

The analysis indicated that the total annual open water fisheries production impact from the project will be negative (-3,900 tonnes per year). This decreased production amounts to about 20% of the expected FWO annual production of 19,672 tonnes per year. This implies the open water source fish availability per person will decrease from 18 to 15 gm per person per day after project implementation.

Pond aquaculture is expected to increase from the present 1,840 tonnes per anum to an estimated 2,116 tonnes per anum by the year 2000. The project is not expected to have any impact, positive or negative, on pond fish production.

Total annual fish production (beel+floodplain+channel+pond) would thus decrease from 21,788 tonnes (FWO) to 17,888 tonnes (FW) (-17.9%). This implies an decrease in fish availability per person due to the project from 21 (FWO) to 17 (FW) gm per person per day (Table 7.7).

Homestead flooding

The project is designed for the protection of winter crops by means of submersible embankments and improved drainage. As such, there will be no change the monsoon flood levels in the seasonally flooded area. The proposed improved internal drainage system is expected to alleviate somewhat the monsoon flooding in the eastern and northeastern parts of the project which suffer from water logging or are inundated periodically by peak floods spilling from the Kushiyara and Surma Rivers. As no reliable information could be obtained during the limited investigation, regarding the extent of homestead damage by this type of floods, the homestead protection benefits have not been considered in the economic analysis.

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Wetland Habitats and Grazing Area

Impacts are difficult to quantify, but a general impression is given by Table 7.9 which shows the impact on:

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

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

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

Table 7.9: Floodplain Grazing and Wetland Changes

Land Type	Winter Grazing Area			
	FWO	FW	Change	%
sc/wf F0	122233	122233	0	
sc/wf F1	12339	12339	0	
sc/wf F2	40450	40450	0	
Fallow Highland	20000	20000	0	
Total	85022	85022	0	0

Land Type	Winter Wetland			
sc/wf F3	6841	6841	0	
F4, Beel, Channel	7000	6900	-100	1.4
Total	36341	36241	-100	0.3

Land Type	Summer Wetland			
wc/sf F1	0	0	0	
wc/sf F2	10113	10113	0	
wc/sf F3	129984	129984	0	
F4, Beel, Channel	21000	20900	-100	
Total	189597	189597		0

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.

The impact of the project would be to decrease winter floodplain wetland area by 1.4%.

There would be no impact on swamp forest trees, if they are maintained properly. Impacts on the reed swamp community would be insignificant; which is mainly because the reed swamps have almost disappeared from the project area.

Economic and employment impacts of the project on wetland production relates mainly to elimination of chilla from about 100 ha of land that will be converted into channels (this land will remain as a summer floodplain wetland). Assuming an annual economic production of Tk 150 per hectare for both summer and winter wetland areas gives a total annual loss of Tk 15,000 per year. Assuming 0.5 pd/ha-yr for harvesting, the employment impact would be insignificant.

Land Use

Land use changes are summarized in Table 7.10. A total of 699 ha of land (about 0.2% of the project gross area) will be required for the project infrastructure (including re-excavation of channels). Of this:

Table 7.10: Land Use Changes

Use	Change in Area (ha)
Cultivation	- 520
Homesteads	- 49
Beels	
Ponds	
Channels	+ 248
Hills	
Fallow[1]	- 130
Infrastructure[2]	+ 451

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

- 520 ha will be taken from cultivated area. Assuming average yields and that this is all under rice, this corresponds to incremental cereal production foregone of about 639 tonnes per year or about 1.4% of total incremental cereal production.

- 100 ha will be taken from winter floodplain wetland areas. These are mostly producing chilla worth roughly Tk 150 per ha, which means a total wetland production foregone of Tk 15,000 per year. Employment in wetland gathering is about 0.5 pd/ha-yr, which means employment foregone of 50 pd/yr, which is rather insignificant.

- 49 ha will be taken from homestead area. This is 0.8% of total homestead area, which implies that 2450 households or about 15,000 persons will be displaced. Also, homestead garden agricultural production from these sites will be lost. Roughly estimating homestead garden area at 20% of the homestead area, and the garden production at Tk 1000 per decimal or Tk 200,000 per ha, this comes to about Tk 2.0 million per year.

Transportation/navigation

The project is designed for the pre-monsoon flood control, and as such there will be no additional benefit of flood protection of the roads.

The proposed Sylhet bypass road linking the Sherpur-Sylhet road with the Sylhet-Sunamganj road via Biswanath (see Figure 12) will reduce the distance and the travel time to Chhatak and Sunamganj by about 25 km and 2 hours respectively. An additional benefit of this road will be a reduction in the vehicular traffic in the Sylhet town.

At this stage of study, the economic benefit of the proposed road has not been evaluated, and as such its cost has not been included in the project economic analysis.

Re-excavation of major drainage channels will enhance the internal navigation which will benefit from an improved channel sections as well as from an extended navigability period.

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Higher flood levels
At Chhatak the 1:10-year pre-monsoon flood level in the Surma River could increase from 0.20 m to 0.80 m. The 0.80 m increase would occur if all spill channels were completely closed. This could affect areas outside the project, most likely worsen the flood conditions along the right bank of Surma River. The project structures are designed to pass about 85% of the estimated present spills into the basin, at 1:10-year flood levels. With 85% of the present flow released into the basin, water levels in the Surma would rise by only about 0.20 m. A 0.30 m rise in the river flood level is considered acceptable. By controlling inflow to the project basins through the spill channels, river water levels will also experience some rise at lower than the peak stages. Since these water levels would be below the flood stage, there would be no negative effect on adjacent areas.

Flood levels in the Kushiyara River may also increase since some of the pre-monsoon spills will be diverted back into the river. However, if the proposed "Upper Surma Kushiyara Project" is constructed[1], the net increase is not expected to be significant since there will be no spill from the Surma River via the Kura Gang.

Given our present understanding of the system, the expected increases in the pre-monsoon flood levels are above 0.3 m on the upper Surma and below 0.3 m on the upper reach of Kushiyara.

7.8.2 Social

The key areas of social impact for this project are described below.

Employment
There will be an overall decrease in employment of 3.12 million person-days per year. This is composed of:

- an increase in agricultural labour employment of 1.25 million pd/yr:
  - owner-labour employment + 0.69 million pd/yr, of which very roughly 20% is post-harvest processing activities traditionally done by women of the household.
  - hired labour +0.56 million pd/yr, of which about 10% is for post-harvest processing traditionally done by women hired in (mainly by larger farmers) for the purpose.
- a net decrease in employment opportunities for landless people of 4.37 million pd/yr, mainly in fishing labour due to reduced openwater fish production. 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.

Displacement impacts due to land use changes
Households whose homestead land is acquired, for proper cash compensation, by the project may have difficulty relocating. This is because suitable homestead lands are so scarce that availability of replacement land for purchase is not assured.

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[1] *Upper Surma Kushiyara Project*, FAP 6, April 1993.

Two mitigation options bear consideration. Embankments could be constructed with berms at strategic locations to support homesteads. Alternatively, provision could be included for the construction of raised housing platforms to facilitate relocation. The experience of BWDB in resettling landless people on embankments in the Cyclone Protection Project may be relevant to the requirements of this project area.

Conflicts
Improved drainage will encourage farmers to extend cultivation further into Maijail Haor in the east and Deker Haor beels in the north of the project area. This will bring them into conflict with fishermen who will find the fishing area reduced. This conflict will affect the proposed re-opening of the Panda Khal for revival of the lost fisheries in the Deker Haor area.

Households that are left outside the embankment can also be a source of conflict. When water levels are high, river side residents may cut the embankment in an attempt to relieve flooding in their area. Detailed settlement surveys will be required to assess the magnitude of this problem in this area.

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

- Landowners, in proportion to landholdings, benefit directly from investment in agriculture production. This is the main benefit (83% 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. *Progressive*; provided the proposed fisheries projects (improved management and mitigating measures) are carried out.

- Families displaced from their homesteads by project land acquisition. Insofar as more wealthy families can influence infrastructure siting/alignment, this is *regressive*.

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

Gender Equity
The net equity impact would appear to be *regressive*. While employment opportunities for women are expected to increase in agriculture, they will decrease in fisheries, and in wetland gathering. Given that overall employment is expected to decrease, it is also reasonable to assume that employment for women will decrease by a proportionate amount.

The adverse effects of acquiring 49 ha of homestead land (2450 households involving an estimated 7400 women) will be substantial given that most village women spend most of their lives within the homestead and are responsible for homestead-based productive tasks.

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Table 7.11: Qualitative Impact Scoring

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

Notes on Qualitative Impact Scoring
The qualitative criteria shown in Table 7.11 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 7.12. 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, etc). Here, each score sums across five equally weighted logical (true/false) criteria, with each "true" counting for a value of one and each "false" for zero. The sign reflects whether the impact is positive or negative.

7.8.3 Economic

The project has an economic rate of return of 35.1%, which compares well to the required rate of 12% as prescribed by government. It is a relatively high capital investment project, at Tk 1,398 million, but the unit cost is reasonable at Tk 5,502 per hectare. It covers a large geographic area (319,289 ha gross). The rate of return remains above the required 12% under different economic scenarios (a 20% increase in capital costs would reduce the rate of return to 29.5%), and a delay in benefits by two years would reduce the ERR to 22.8%.

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

Most of the benefits of the project relate to increased rice production. Average crop yields would increase mostly as a result of shifts to HYVs and reduced flood damage. The cropping intensity is assumed to remain constant at 1.3. Non-cereal production would increase by 14.3%.

Total fish production would decrease by an estimated 18% of future-without-project production. The value of the loss in fish production would amount to about 28% of the value of incremental agricultural output.

Substantial benefits in transportation could result if the Sylhet by-pass road to Chhatak and Sunamganj were constructed. However, as these benefits have not been quantified in the pre-feasibility study, the cost of the road has not been included in the ERR calculations.

About 3% of the project benefits would result from partial replacement of some of the existing haor projects with the proposed project based on a new design concept. About Tk 10 million may be saved in annual repair of about 125 km of the internal submersible embankments.

The disbenefits that result from loss of food, shelter, and tree products that are currently harvested from the seasonal wetlands are comparatively small though they impact the population group which is most vulnerable to a loss in resources.

A summary of salient data in provided in Table 7.12.

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

A significant caution is that the economic 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

From a multi-criteria perspective (Table 7.13), the project is not attractive:

- A number of households would lose their homestead land to project land acquisition.
- Kushiyara and Surma flood levels would increase.
- Conflicts between farmers and fishermen, and between families living within and outside the embankment, would increase.
- The net employment impact is negative.
- The project has a high dependency on central government for implementation.
- There would be a decline in fisheries production.

The positive aspects of the project would be:

- Benefits derive from agriculture 97%, and savings in maintaining existing infrastructure 3% (of total benefits).

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- The project would not affect adversely regional biodiversity.
- Rate of return is acceptable.
- Substantial increase in rice production.
- Increased economic returns to land owners.
- Small increment in non-cereal production.
- Project responds to public concerns.

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Table 7.12: Summary of Salient Data

Economic Rate of Return (ERR)	35.1			
Capital Investment (Tk million)	1,398			
Maximum O+M (Tk million / yr)	23			
Capital Investment (Tk/ha)	5,502			
Foreign Cost Component	6			
Net Project Area (ha)	254,069			
Land Acquisition Required (ha)	699			

AGRICULTURAL IMPACTS		Present	FWO	FW
Incremental Net Econ Output (Tk million / yr)	456.76			
Cropping Intensity		1.3	1.3	1.3
Average Yield (tonnes/ha)		2.1	2.1	2.4
Average Gross Margins (Tk/ha)		10,967	11,065	12,408
Owner Labour (md/ha)		113	113	114
Hired Labour (md/ha)		28	29	30
Irrigation (ha)		113,261	147,439	147,709
Incremental Cereal Prod'n (' 000 tonnes / yr)	79			
Incremental Non-Cereal (' 000 tonnes / yr)	11			
Incremental Owner Labour (' 000 pd / yr)	690			
Incremental Hired Labour (' 000 pd / yr)	561			

FISHERIES IMPACTS		Flood plain	Beels	Channels
Incremental Net Econ Output (Tk million / yr)	-130.88	-49	-69	-131
Impacted Area (ha)		231,064	14,300	8,200
Average Gross Margins (Tk/ha)		1,606	38,500	14,000
Remaining Production on Impacted Area, %		80%	80%	82%
Incremental Fish Production (tonnes / year)	-3,900	-2,039	-1,573	-288
Incremental Labour ('000 pd / yr)	-4,371	-4,078	-197	-96

FLOOD DAMAGE BENEFITS				
Households Affected				
Reduced Econ Damage Households (Tk M / yr)				
Embankments/Roads Affected (km)	250			
Reduced Econ Damage Roads (Tk M / yr)	10.11			

OTHER IMPACTS				
Wetland Incr Net Econ Output (Tk million / yr)	-0.015			
Wetland Incremental Labour ('000 pd / yr)	negl.			
Acquired Cult & Homestead Lands, Incr Net Econ output (Tk million / yr)	-3.0			
Persons Displaced by Homestead Acquisition	15,000			

Table 7.13: Multi-Criteria Analysis

Economic		
Indicator	**Units**	**Value**
Economic Internal Rate of Return (EIRR)	per cent	35.1
EIRR, Increase Capital Costs by 20%	per cent	29.5
EIRR, Delay Benefits by Two Years	per cent	22.8
EIRR, Decrease in Agr/Fish Production by 20%	per cent	29.0
Net Present Value	'1000 Tk	1,159.9

Quantitative Impacts			
Indicator	**Units**	**Value**	**Percent[1]**
Incremental Cereal Production[2]	tonnes	81,538	13.0
Incremental Non-Cereal Production	tonnes	11,487	14.0
Incremental Fish Production	tonnes	-3,900	-17.9
Change in Floodplain Wetland/Fisheries Habitat	ha	+248	1.7
Homesteads Displaced Due to Land Acquisition	homesteads	2,450	5.1
Homesteads Protected From Floods	homesteads	0	
Roads Protected From Floods	km	0	
Surma Flood Levels (Pre-monsoon)	m	>0.3	
Kushiyara Flood Levels (pre-monsoon)	m	<0.3	
Owner Employment	million pd/yr	+0.69	1.9
Hired Employment (Agri+Fishing+Wetland)	million pd/yr	-3.81	-12.1

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

[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); project affected (displaced) haor embankments; Kushiyara and Surma water levels; and total employment for owners and hired labourers.

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

ANNEX A

ENGINEERING DATA AND ANALYSIS

ANNEX A
ENGINEERING DATA AND ANALYSIS

A.1 Climatic Data

The weather stations within the Surma-Kushiyara-Baulai Project area are listed in Table A1. The monthly averages of the climatic parameters are presented in Tables A2 and A3, and the extremes of records in Table A4.

Table A1: BWDB Weather Stations Relevant to The SKB Project Area 1961-90

Name of Station	Number	Location Relative to Project Area
Manumukh	R-119	Peripheral, to the southeast
Kaliajuri	R-113	Peripheral, to the west
Markuli	R-120	Peripheral, to the southwest
Tajpur	R-129	Inside, east central
Sylhet	R-128	Peripheral, to the northeast
Gobindaganj	R-109	Peripheral, to the north
Chhatak	R-107	Peripheral, to the north
Pagla	R-124	Inside, north central
Sunamganj	R-127	Peripheral, to the northwest

Table A2: Average Rainfall Over The SKB Project Area, 1961-90 (mm)

Period	Manumukh	Kaliajuri	Markuli	Tajpur	Sylhet	Gobindaganj	Chhatak	Sunamganj
	(SE)	(W)	(SW)	(EC)	(NE)	(N)	(N)	(NW)
Jan	11	9	7	13	10	8	6	6
Feb	24	20	26	24	31	28	28	26
Mar	88	52	63	85	119	97	101	82
Apr	256	205	341	337	378	373	388	287
May	482	402	558	550	548	550	572	548
Jun	640	578	823	856	903	878	1110	1060
Jul	497	550	673	737	804	910	1200	1402
Aug	416	550	465	583	622	715	885	1088
Sep	317	636	393	424	513	531	730	734
Oct	159	232	145	197	234	242	279	264
Nov	23	37	24	35	37	35	34	23
Dec	10	8	11	11	12	10	6	11
Year	2898 (100%)	3325 (115%)	3501 (121%)	3876 (134%)	4202 (145%)	4366 (151%)	5278 (182%)	5539 (191%)

Table A3: Climatological Averages
Sylhet 1957-91

Month	Sunshine (hrs)	Temperature			Humidity (%)
		Mean Max (°C)	Mean Min (°C)	Mean (°C)	
Jan	8.3	25.1	12.4	18.9	73
Feb	8.4	27.2	14.2	20.8	65
Mar	8.0	30.6	18.0	24.4	66
Apr	6.8	31.0	21.1	25.8	76
May	6.2	30.7	22.7	26.7	82
Jun	3.9	30.5	24.5	27.8	88
Jul	3.6	30.8	25.1	27.9	88
Aug	4.7	31.3	25.1	28.3	88
Sep	4.7	31.0	24.7	27.7	88
Oct	7.4	30.5	22.4	26.6	84
Nov	8.5	28.9	17.9	23.5	77
Dec	8.3	26.0	13.9	20.1	75
Year	6.4	31.3	12.4	24.9	79

Month	Wind		Rain (mm)	PET (mm)	Surplus/ Deficit
	Speed (km/hr)	Direction			
Jan	2.1	ENE	8	106	-98
Feb	7.3	E	39	124	-85
Mar	8.5	SE	130	162	-32
Apr	8.8	SE	378	157	221
May	7.3	SE	597	153	444
Jun	7.3	SE	805	125	680
July	7.3	SE	802	125	677
Aug	7.3	SE	643	131	512
Sep	6.9	ESE	563	121	442
Oct	6.9	E	240	128	112
Nov	6.9	ENE	31	115	-84
Dec	6.9	ENE	17	103	-86
Year	7.3	ESE	4253	1550	2703

Station: Location 24°54'N, 91°53'E
Elevation 35.1 m

Source: BMD
BARC for PET

Table A4: Climatic Extremes of Record
Sylhet 1957-1992

Month	Daily Temperature		Monthly Rainfall		Maximum Daily	
	Max (°C)	Min (°C)	Max (mm)	Min (mm)	Rainfall (mm)	Wind Speed (km/hr)
Jan	28.5	5.7	62	0	31	67
Feb	35.0	6.8	510	0	508	104
Mar	37.4	10.0	323	2	84	130
Apr	40.5	14.1	759	38	346	168
May	39.3	16.5	893	317	274	155
Jun	36.4	18.9	1294	414	336	133
Jul	36.7	21.7	1322	277	218	148
Aug	37.9	19.9	964	256	201	43
Sep	35.6	20.6	714	104	241	67
Oct	35.2	15.7	608	26	220	83
Nov	32.8	10.9	94	0	56	67
Dec	30.1	8.3	33	0	18	41
Period	40.5	5.7	1322	0	508	168

Source: BMD

A.1.1 Rainfall Runoff Analysis

The Surma-Kushiyara-Baulai Project is designed for the protection of crops against floods which occur during winter and during the pre-monsoon season until the 15 th of May.

Flood embankments constructed along the boundary rivers are to restrict the entry of river floodwater into the basin, while the internal drainage system should have a sufficient capacity to evacuate the local rainfall runoff without causing damage to the crops. Following a rainstorm, the runoff (excess rainfall) should be drained out from the paddy lands within 3 days to a water depth not exceeding 0.3 m.

A 5-day rainfall with 10-year return period occurring in May has been adopted as the design rainfall. (No analysis of winter rain storms were carried out due to insufficient data).

The basin runoff estimates are based on a simplified water balance analysis with the basin rainfall assumed to be 80% of the station rainfall. The adopted basin parameters are listed in Table A5.

A summary of rainfall runoff analysis for the four selected stations in the basin, based on data from 1962 to 1989, are shown in Table A6.

Table A5: Basin Climatic and Soil Parameters

Item	Paddy Land	Non-Paddy Land
Per cent	70	30
Depression Storage	100 mm	25 mm
Initial Soil Loss	0 mm	13 mm
Subsequent Soil Loss	1 mm/hr	1 mm/hr
Evapotranspiration	5 mm/day	5 mm/day

Table A6: Surma-Kushiyara-Baulai Basin Runoff Analysis

Rainfall Station	5-Day, 1:10-Year Point Rainfall Depth (mm)	Equivalent Basin Rainfall (mm)	Net Basin Runoff	
			(mm)	(l/s/km2)
Markuli R-120	399.0	319.2	92.8	0.215
Pagla R-124	437.0	349.6	123.2	0.285
Sylhet R-128	389.0	311.2	84.8	0.196
Tajpur R-129	391.0	312.8	86.4	0.200

A.2 Topographic Data

The Surma-Kushiyara-Baulai Basin Project covers a gross area of 319,289 ha, which extends about 100 km from the hills in Golapganj thana in the east to the Baulai River channel in the west. The two main dominant landforms are the Sylhet Plain and the Sylhet Basin. Uplands are a small percentage. The topographic characteristics of the project are quite diverse. To facilitate carrying out the agro-engineering and fisheries analysis, the project basin has been divided into five catchments as shown in Figure 4. The Area-Elevation and Storage Volume Relations for each catchment are given in Table A7.

Table A7: Basin Elevation vs Area-Storage Volume Relation

Elevation (m PWD)	Area (ha)	Storage (ha-m)	Elevation (m PWD)	Area (ha)	Storage (ha-m)
Catchment 1			Catchment 2		
5.2	100.9	0	4.7	201.2	0
5.5	201.8	39.4	5.0	301.8	75.5
6.0	1312.2	417.9	5.5	1308.1	478.0
6.5	3331.0	1578.7	6.0	4528.2	1937.0
7.0	7671.5	4329.4	6.5	11270.2	5886.6
7.5	14131.7	9780.2	7.0	19722.8	13634.9
8.0	20491.0	18435.8	7.5	26766.6	25257.2
8.5	27657.8	30473.0	8.0	34011.7	40451.8
9.0	34723.6	46068.4	8.5	42263.1	59520.5
9.5	40275.4	64818.2	9.0	48200.1	82136.3
10.0	45928.1	86369.0	9.5	54137.0	107720.6
10.5	50268.5	110418.2	10.0	58464.0	135870.9
11.0	52489.2	136107.6	10.5	60376.0	165580.8
11.5	53498.6	162604.6	10.8	60879.0	187406.7
12.0	54407.1	189581.1			
12.5	54709.9	216860.3			
13.0	55012.7	244291.0			
13.5	55416.5	271898.3			
14.0	55517.4	299631.8			
14.5	55820.3	327466.3			
15.0	55921.2	355401.7			
15.5	56123.1	383412.8			
16.0	56123.1	411474.3			
16.5	56224.1	439561.1			
16.7	56325.0	451378.8			

Table A7 (cont.): Basin Elevation vs Area-Storage Volume Relation

Elevation (m PWD)	Area (ha)	Storage (ha-m)	Elevation (m PWD)	Area (ha)	Storage (ha-m)
Catchment 3			Catchment 4		
3.7	101.0	0	2.6	200.7	0
4.0	1212.4	197.0	3.0	2107.7	427.0
4.5	5961.0	1990.4	3.5	7728.3	2886.0
5.0	13437.6	6840.0	4.0	16159.3	8858.0
5.5	21217.3	15503.8	4.5	30913.4	20626.1
6.0	31724.9	28739.3	5.0	43258.7	39169.2
6.5	41424.2	47026.6	5.5	52492.6	63107.0
7.0	51325.6	70214.1	6.0	57812.1	90683.1
7.5	59004.3	97796.5	6.5	60020.2	120141.2
8.0	65268.4	128864.7	6.9	60522.0	143646.9
8.5	69511.8	162559.7			
9.0	71734.6	197871.4			
9.5	72643.9	233966.0			
9.7	72846.0	248515.0			
Catchment 5					
1.0	101.2	0			
1.5	303.6	93.1			
2.0	1012.0	422.0			
2.5	4554.1	1813.6			
3.0	12954.0	6190.6			
3.5	25908.0	15906.1			
4.0	39469.3	32250.4			
4.5	48476.3	54236.8			
5.0	55965.4	80347.3			
5.5	62037.6	109848.0			
6.0	65579.7	141752.3			
6.5	67198.9	174947			
7.0	68615.8	208900.7			
7.1	68717.0	213707.3			

A.3 Hydrological Data

The hydrological regime of the Surma-Kushiyara basin is governed by external flows in the project boundary rivers; the Surma-Nawa-Baulai River and the Kushiyara-Kalni River, and by the local drainage system and the internal rainfall runoff. Good hydrological records are available from the gauging stations maintained on the boundary rivers, but there are no hydrometric stations inside the project basin. Location of the stations with the type of observations are indicated in Table A8.

Table A8: Surma-Kushiyara-Baulai Project Hydrometric Stations

Station No.	Name of Station	Type of Observations	Latitude	Longitude	Available Records
Kushiyara-Kalni River					
172	Amalshid	S	25°52.13'N	92°28.54'E	1947
173	Sheola	S,Q	25°39.50'N	92°11.44'E	1949
174	Fenchuganj	S,Q	24°42.12'N	91°56.48'E	1947
175	Sherpur	S,Q	24°37.69'N	91°40.98'E	
270	Markuli	S	24°41.62'N	91°22.87'E	1949
271	Ajmiriganj	S	24°33.22'N	91°13.73'E	
272	Madna	S	24°20.14'N	91°14.26'E	1949
272.1	Austagram	S	24°16.30'N	91°06.00'E	1962
Surma-Nawa-Baulai River					
266	Kanaighat	S,Q	25°00.00'N	92°15.55'E	1952
267	Sylhet	S,Q	24°53.24'N	91°52.26'E	1938
268	Chhatak	S	25°02.15'N	91°39.93'E	1949
269	Sunamganj	S	25°04.53'N	91°24.84'E	1949
72 B	Sukdevpur	S	24°52.76'N	91°09.94'E	
72	Khaliajuri	S	24°41.30'N	91°07.33'E	1945
73	Itna	S	24°31.83'N	91°05.63'E	
74	Dilalpur	S	24°11.22'N	90°58.59'E	

Table A9: Recorded Discharges along the Kushiyara, 1964-91

Station	Years of Record	Mean (m^3/s)	Minimum (m^3/s)	Maximum (m^3/s)	Range (m^3/s)
Sheola	27	681.7	27.7	2960	2932
Sherpur	10	1101.2	45.6	3950	3804

Table A10: Recorded Discharges along the Surma, 1964-91

Station	Years of Record	Mean (m^3/s)	Maximum (m^3/s)	Maximum (m^3/s)	Range (m^3/s)
Kanairghat	22	548.5	2.2	2730	2728
Sylhet	22	562.5	2.6	2480	2477

Table A11: Recorded Water Levels along the Surma-Nawa-Baulai, 1964-91

Station	Years of Record	Mean (m PWD)	Maximum (m PWD)	Maximum (m PWD)	Range (m)
Kanairghat	27	8.32	3.93	15.04	11.11
Sylhet	28	6.34	1.99	11.94	9.95
Chhatak	28	5.43	1.10	11.16	10.06
Sunamganj	28	5.23	1.34	9.46	8.12
Sukdevpur	10	4.44	0.80	8.08	7.28
Kaliajuri	26	4.66	0.98	8.99	8.01
Itna	27	4.39	1.20	8.69	7.49
Dilalpur	27	3.83	1.02	8.15	7.13

Table A12: Recorded Water Levels along the Kushiyara-Kalni, 1964-91

Station	Years of Record	Mean (m PWD)	Minimum (m PWD)	Maximum (m PWD)	Range (m)
Amalshid	28	10.73	5.94	17.91	11.97
Sheola	28	8.76	3.92	14.22	10.30
Fenchuganj	28	6.61	2.06	11.30	9.24
Manumukh	16	5.58	1.48	9.76	8.28
Sherpur	10	5.86	1.79	9.30	7.51
Markuli	25	4.85	1.34	8.50	7.16
Ajmiriganj	27	4.22	1.04	8.35	7.31
Madna	24	3.77	0.68	8.15	7.47
Austagram	25	3.52	0.28	7.97	7.69

Table A13: Monthly Distribution of Mean Discharges and Water Levels
Kushiyara at Sheola

Period	Discharge (m^3/s)	Volume		Water Level (m PWD)
		MCM	%	
Apr	317.9	824.0	3.8	7.20
May	620.9	1662.8	7.7	9.22
Jun	1240.1	3214.3	15.0	11.71
Jul	1621.4	4342.1	20.2	12.90
Aug	1510.5	4045.1	18.8	12.67
Sep	1279.6	3316.7	15.4	12.10
Oct	811.0	2171.9	10.1	10.46
Nov	291.4	755.3	3.5	7.49
Dec	144.0	285.6	1.8	5.91
Jan	97.3	260.6	1.2	5.18
Feb	85.7	207.3	1.1	4.93
Mar	115.0	308.0	1.4	5.13
Year	681.7	21493.7	100.0	8.76

Table A14: Monthly Distribution of Mean Discharges and Water Levels
Kushiyara at Sherpur

Period	Discharge (m^3/s)	Volume		Water Level (m PWD)
		MCM	%	
Apr	730.5	1893.5	5.4	5.00
May	1561.2	4180.9	12.0	6.64
Jun	1785.1	4627.0	13.3	7.59
Jul	2015.0	5396.2	1.5	8.31
Aug	2036.5	5453.7	15.6	8.38
Sep	1967.7	5100.3	14.6	8.19
Oct	1652.1	4424.3	12.7	7.60
Nov	683.7	1772.2	5.1	5.32
Dec	261.5	700.3	2.0	3.84
Jan	173.1	463.6	1.3	3.21
Feb	135.9	328.7	0.9	2.88
Mar	211.0	565.1	1.6	3.21
Year	1101.2	34905.9	100.0	5.86

Table A15: Monthly Distribution of Mean Discharges and Water Levels
Surma at Kanairghat

Period	Discharge (m^3/s)	Volume		Water Level (m PWD)
		MCM	%	
Apr	251.8	625.7	3.8	6.79
May	551.7	1477.5	8.5	8.80
Jun	1148.2	2976.1	17.2	11.72
Jul	1425.5	3817.5	22.1	13.07
Aug	1308.2	3503.3	20.3	12.56
Sep	1049.8	2721.1	15.7	11.71
Oct	598.2	1602.0	9.3	9.70
Nov	128.4	332.8	1.9	6.34
Dec	25.9	69.4	0.4	5.04
Jan	9.2	24.6	0.1	4.57
Feb	6.8	16.4	0.1	4.45
Mar	39.5	105.8	0.6	4.75
Year	548.5	17299.2	100.0	8.32

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Table A16: Monthly Distribution of Mean Discharges and Water Levels
Surma at Sylhet

Period	Discharge (m^3/s)	Volume		Water Level (m PWD)
		MCM	%	
Apr	250.9	650.3	3.7	5.01
May	543.0	1454.2	8.2	7.15
Jun	1171.4	3036.3	17.1	9.29
Jul	1458.7	3906.4	22.0	10.29
Aug	1331.9	3566.8	20.1	9.96
Sep	1080.7	2801.2	15.8	9.40
Oct	645.7	1729.2	9.7	7.91
Nov	136.0	352.5	2.0	5.20
Dec	33.3	89.2	0.5	3.63
Jan	12.7	34.0	0.2	2.75
Feb	8.2	19.8	0.1	2.46
Mar	38.0	101.8	0.6	2.85
Year	562.5	17741.7	100.0	6.34

A.3.1 Flood Frequency Analysis

The flood frequency analysis were carried out separately for the pre-monsoon floods expected before 15 May and for the maximum annual floods expected during the monsoon months. The pre-monsoon flood levels are needed for planning and design of flood protection for *bodo rice*, and the annual flood levels are needed for design of high flood embankments and for planning monsoon season cropping patterns.

The flood frequency analysis are summarized in Tables A17 to A20.

Table A17: Flood Discharges along the Kushiyara
(m^3/s)

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual (Monsoon) Series:							
Sheola	2162	2492	2652	2773	2806	2894	2963
Sherpur	2575	2771	2852	2905	2919	2952	2975
Pre-Monsoon Series:							
Sheola	754	1156	1485	1834	1954	2354	2802
Sherpur	1570	1947	2147	2309	2355	2482	2590

Table A18: Flood Water Levels along the Kushiyara-Kalni (m PWD)

Station	Return Period (years)						
	2	5	10	20	25	50	100
Annual (Monsoon) Floods:							
Amalshid	17.28	17.59	17.72	17.81	17.83	17.89	17.93
Sheola	13.95	14.12	14.19	14.24	14.25	14.28	14.30
Fenchuganj	10.64	10.85	10.96	11.06	11.09	11.18	11.25
Sherpur	9.10	9.25	9.32	9.38	9.40	9.45	9.49
Markuli	7.44	7.72	7.99	8.10	8.16	8.35	8.54
Ajmiriganj	7.15	7.54	7.76	7.95	8.01	8.17	8.31
Madna	6.98	7.40	7.62	7.80	7.85	7.99	8.10
Austagram*	6.79	7.24	7.49	7.71	7.77	7.95	8.10
Pre-Monsoon Floods:							
Amalshid	13.02	14.60	15.42	16.06	16.23	16.72	17.12
Sheola	11.14	12.37	12.94	13.36	13.47	13.76	13.98
Fenchuganj	8.10	9.09	9.54	9.86	9.94	10.16	10.32
Sherpur	7.28	7.83	8.12	8.35	8.42	8.60	8.76
Markuli	5.57	6.20	6.46	6.64	6.68	6.79	6.86
Ajmiriganj	3.98	4.55	4.78	4.94	4.98	5.07	5.14
Madna	3.08	3.47	3.71	3.92	3.98	4.17	4.35
Austagram*	2.94	3.27	3.45	3.59	3.63	3.74	3.83

* Gauge datum not corrected. Levels in other stations adjusted to the 1993 Second Order Levelling elevations.

Table A19: Flood Discharges along the Surma
(m^3/s)

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Annual (Monsoon) Series:							
Kanairghat	2157	2415	2532	2617	2640	2697	2741
Sylhet	2051	2251	2339	2400	2416	2456	2486
Pre-Monsoon Series:							
Kanairghat	946	1299	1468	1595	1628	1718	1787
Sylhet	853	1155	1281	1366	1387	1440	1478

Table A20: Flood Water Levels along the Surma-Nawa-Baulai
(m PWD)

Station	Return Period (years)						
	2	5	10	20	25	50	100
Annual (Monsoon) Floods:							
Kanairghat	14.77	15.03	15.13	15.20	15.22	15.26	15.29
Sylhet	11.25	11.56	11.71	11.82	11.84	11.92	11.98
Chhatak	10.03	10.50	10.73	10.90	10.94	11.07	11.17
Sunamganj	8.56	8.83	9.03	9.23	9.30	9.51	9.73
Sukdevpur	7.44	7.80	7.95	8.05	8.07	8.14	8.19
Khaliajuri	7.26	7.69	7.94	8.16	8.22	8.41	8.58
Itna	7.14	7.53	7.75	7.93	7.98	8.12	8.25
Dilalpur	6.81	7.24	7.57	7.64	7.69	7.82	7.93
Pre-Monsoon Floods:							
Kanairghat	11.46	12.90	13.57	13.89	13.99	14.23	14.40
Sylhet	8.62	9.68	10.12	10.41	10.48	10.66	10.79
Chhatak	6.92	7.74	8.08	8.30	8.36	8.50	8.59
Sunamganj	6.47	7.13	7.40	7.59	7.63	7.74	7.82
Sukdevpur	4.96	5.08	5.11	5.16	5.17	5.19	5.20
Khaliajuri	3.82	4.45	4.81	5.11	5.20	5.45	5.68
Itna	3.43	4.00	4.35	4.67	4.77	5.06	5.33
Dilalpur	2.93	3.28	3.48	3.65	3.70	3.84	3.96

Note: All levels adjusted to the 1993 Second Order Levelling gauge elevations.

A.4 Drainage Channels

The internal drainage channels should have a sufficient capacity to pass safely the pre-monsoon local runoff plus the design discharge of the head regulator(s). During the monsoon season the channels will remain submerged.

The required capacities of the channels to be improved are shown in Tables A21 to A23. The discharge estimates are based on the unit runoff values shown in Table A6 and the structure capacities shown in Table A25. The profiles of the channels are shown in Figures 18 to 20.

Table A21: Design Pre-Monsoon Flood Discharge

Channel A (Bhatta-Dahuka-Mora Surma)

Location (km)	Distance (km)	Watershed Area (ha)	Local Discharge (m^3/s)	Channel Design Capacity (m^3/s)
Bhatta Khal Offtake at Gobindaganj	0.0	0	0.0	180.0
Bhatta Khal	25.0	305	86.9	266.9
Dahuka River	45.0	380	108.3	288.3
Dahuka River + Moha Singh R. (Channel B)	45.5	850	242.3	422.3
Surma River	50.0	950	267.3	447.3
Surma River	118.0	1350	353.3	533.3
Surma River + Channel C	118.5	2850	660.0	1165.0
Outfall into Baulai	124.0	2900	670.0	1175.0

Note: The channel design capacity includes the pre-monsoon flood relief from the Surma River through the Bhatta Khal Regulator (180 m^3/s).

Table A22: Design Pre-Monsoon Flood Discharge

Channel B (Moha Singh River)

Location (km)	Distance (km)	Watershed Area (ha)	Local Discharge (m^3/s)	Channel Design Discharge (m^3/s)
Mohasingh River	0.0	0	0.0	0.0
Mohasingh River + Hamhamia River	10.0	60	17.1	17.1
Deker Haor	30	300	85.5	85.5
Outfall into Dahuka (Channel A)	50	582	166.9	166.9

Table A23: Design Pre-Monsoon Flood Discharge

Channel C (Khasipur Khal-Sadipur Khal-Itakhola Nadi-Naljor River-Kamarkhali River-Kalni River-Darain River-Surma Channel)

Location (km)	Distance (km)	Watershed Area (ha)	Local Discharge (m^3/s)	Channel Design Discharge (m^3/s)
Barbhanga Nadi at Balaganj	0.0	450	90.0	290.0
Sadipur Khal at Sherpur	17.0	563	112.6	312.6
Itakhola Nadi	32.0	863	172.6	372.6
Naljor River	43.0	1020	204.0	404.0
Kamarkhali River	60.0	1170	234.0	434.0
Kalni River	81.0	1300	262.0	462.0
Darain River	86.0	1350	272.8	472.8
Outfall into Channel A	144.0	1500	305.0	505.0

Note: The channel design capacity includes the pre-monsoon flood relief from the Kushiyara River through the proposed structures (total 200 m^3/s).

A.5 Flood Embankments

The project designs provide for full flood protection against Surma River Floods) in the northeastern part and for a partial flood protection in the remaining part of the project.

The project boundary along the Surma-Nawa-Baulai Rivers is 202 km, out of which 145 km is embanked; 120 km with flood embankments and 25 km with local roads cum embankments. Out of the remaining 55 km, higher land covers about 45 km from Sylhet to Chhatak, and lowlands about 12 km between the outfall of the Piyain River and Khaliajuri.

The boundary along the Kushiyara-Kalni River is 115 km, out of which 72 km is already embanked. The unembanked sections are: about 5 km upstream from Balaganj, 23 km from Sherpur to Ranigonj Bazar and 15 km from the end of the existing Bhanda Beel embankment to the Bheramohona closure of the Mora Surma River.

High embankments exist along the left bank of Surma (0.0 to 25.0 km) and along the right bank of Kushiyara downstream of Fenchuganj (7.0 to 10.0 km) and from Balaganj to Sherpur (25.0 to 47.0 km). All the remaining embankments were originally designed as submersible embankments, but later on some sections were upgraded to road cum embankment and the height was raised to above average annual flood level (Surma left bank from Chhatak to Nilpur).

It is proposed that the existing Surma high embankment be upgraded to 1 in 20-year annual flood protection level. There is no need to upgrade the high embankments along the Kushiyara, as the Kushiyara right bank floodway is needed for passing monsoon floods. However, there may be some benefits from extending high embankments upstream of Fenchuganj, and it needs to be examined during feasibility study.

Submersible embankments designed for 1 in 10-year pre-monsoon flood are proposed along the remaining project boundaries with the Surma-Nawa-Baulai and the Kushiyara-Kalni Rivers.

The Surma embankments would extend from Moulavi Bazar Regulator to the outfall of the Surma Khal into Baulai at Dhanpur. The Kushiyara embankments would extend from Manikkona to 1 km downstream from the Bheramohona closure near Ajmiriganj.

The proposed embankment works are as follows.

- **Construction of new embankments (99.5 km):**
  - along the left bank of Surma River between the offtake of Bahia Gang at Darsa and Chhatak (44.5 km),
  - along the left bank of Baulai from the outfall of Piyain River to Khaliajuri (12 km),
  - along the right bank of Kushiyara upstream from Balaganj from 20 to 25 km (5 km) and from Sherpur to Ranigonj Bazar (23 km), and

- along the right bank of Kalni from Protappur to 1 km downstream from Bheramohona closure near Ajmiriganj (15 km).

- **Re-sectioning of existing embankments (217.5 km):**

  - along the left bank of Surma River from Maulavi Bazar to the offtake of Bahia Gang at Darsa (high embankment, 25.5 km),

  - along the left bank of Surma, Nawa and Baulai from Chhatak to below the outfall of Piyain River (total 108 km) and from 190 to 202 km (12 km), and

  - along the right bank of Kushiyara from 0 to 20 km (20 km) and from 25 to 47 km (22 km).

  - along the right bank of Kushiyara from 70 to 100 km (30 km) (existing embankments of Naluar, Tangua and Bhanda Haors).

Alignment of Embankments

Flood embankments are constructed at a certain distance from the river banks called an *embankment set back distance*. The purpose of the embankment set back is to ensure a reasonable degree of protection against river erosion and against foundation failure. River erosion is governed by natural channel development processes, and it intensifies with increases in flow velocity under greater depth in a confined channel. Detailed analysis are required to determine the progressive channel erosion under both the natural conditions and in a confined channel with embankments.

High embankments cause greater confinement, and the confinement effect of submersible embankments is lower as they are overtopped at a certain level. For this reason the submersible embankments are constructed closer to the river channel than the high embankments. However, many embankments which originally were constructed as submersible embankments are being raised and upgraded to road cum embankment. These embankments practically become high embankments with insufficient set back distance, and their stability is undermined. This has to be taken into account while planning the alignment of flood embankments. Also the volume of earthworks and resettlement of homesteads which usually are constructed close to the river are taken into account.

High and low (submersible) embankments are proposed under the project, including both upgrading of existing and construction of new embankments. The present set back distance of the existing embankments varies. In some sections it appears to be sufficient while in other sections the embankments are right on the river bank threatened by erosion.

The proposed minimum set back distance for new and retired embankments is,

- 30 m for submersible embankments, and

- 50 m for high embankments.

The existing embankments will need to be examined closely during the feasibility study survey. If the present alignment is found acceptable, the upgrading and re-sectioning work should be carried out by building up the embankment section on the country side. This way, the river side of the embankment which is more exposed to the river erosion would remain undisturbed.

Embankment Crest Elevation

According to BWDB guidelines submersible embankments in haor schemes are designed for 1:10-year pre-monsoon flood level with a nominal freeboard of about 0.30 m. Currently the same specifications are used in the design of the river and the internal khal or haor embankments. High embankments are designed for 1:20-year annual flood level increased by the anticipated confinement. A nominal freeboard of up to 0.9 m for minor rivers and up to 1.5 m for major rivers is added to the future with project flood levels.

At this stage of study, the exact estimates of the future flood levels in the rivers within the project are not available. However, from preliminary estimates, using the existing rating curves and the historic flood data, the pre-monsoon flood levels in the Surma are expected to increase by 0.2 to 0.8 m. The flood levels would increase by 0.8 m if all the spill channels were closed, and by only 0.2 m if all the gates in the proposed embankment structures (on the spill channels) were open. It would be possible to limit the increase to 0.3 m by regulating the spill inflows into the project through the proposed regulators.

Data on the pre-monsoon spills from the Kushiyara River are insufficient to determine the river confinement with regulated inflows into the basin. However, it may be assumed that the increase will be limited to less than 0.3 m. This is because the future Kushiyara discharges will be lower than the historic discharges. The present spills from the Surma River into the Kushiyara River through Kakura Khal will be regulated (Refer to NERP Upper Kushiyara Project Pre-Feasibility Report).

In general, the following freeboard heights have been adopted,

high embankments	1.8 m
submersible embankments	0.8 m

The above freeboards include the anticipated increases in flood levels due to the future confinement effects. The high embankment crest levels are based on 1:20-year annual flood and 1:10-year pre-monsoon flood levels for the high and submersible embankments respectively.

For the Kushiyara embankment downstream from Sherpur the freeboard has been reduced to about 0.6 m. With 0.8 m added to the present flood level the embankment crest would coincide or be above the average annual flood level, which should be avoided in case of submersible embankments.

Then design embankment crest elevation is given in Table A24, and longitudinal profiles are shown in Figure 13, Kushiyara-Kalni right bank embankment and in Figure 14a and 14b, Surma-Nawa-Baulai left bank embankment.

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Embankment Cross Section

The crest width the of the existing embankments is, about 2.44 m in the submersible embankments and 4.27 m in high embankments and in submersible embankments upgraded to roads. The present side slopes vary from about 1:1 to 1:2 on both sides.

A uniform cross section is proposed for high and submersible embankments:

- crest width 4.27 m
- side slope (C/S) 1:2
- side slope (R/S) 1:3

Protective Measures for Embankments During Overtopping

The submersible embankments are most vulnerable to erosion during overtopping by the river flood. To reduce this hazard, in polder type haor schemes, water is flushed through regulators into the basin so the difference in the water levels (in and outside the haor) at the time of embankment overtopping is less than 0.3 m.

Although the structures provided on the Surma and Kushiyara spill channels will be used for flushing, their capacity is not sufficient to fill up the basin. Also, the large size and the topography of the project area makes the flushing through regulators for the purpose of equalizing water levels not practical.

To reduce the hazard of embankment overtopping at high hydraulic head the flood water can be flushed into the basin over the natural river banks. For this purpose it is proposed to provide overbank floodways. The overbank floodways would be nothing more than just a not embanked sections of the rivers where the natural ground is at about the expected design flood level, including the anticipated embankment confinement.

To prevent ground erosion the overbank flood relief ways should be protected with grass cover.

To reduce the hazard of scouring out of the Bheramohona closure during the flood inflow into the Old Surma channel the flood embankment should be extended 1 km downstream of the closure.

Table A24: Embankment Design Crest Elevations

Location	Section (km)	Flood Levels (m PWD)			Embank. Crest Level (m PWD)
		1:10-y Pre-Monsoon	1:2-y Annual	1:20-y Annual	
Surma-Baulai River					
Moulavi Bazar	0.0	10.85	11.69	12.15	14.00
Sylhet	18.0	10.12	11.25	11.82	13.65
Bahia Nadi	25.5	9.81	11.08	11.68	13.50 10.80
Chhatak	68.0	8.08	10.03	10.90	8.90
Sunamganj	110.0	7.40	8.56	9.23	8.20
Sukdevpur	162.0	5.11	7.44	8.05	5.90
Khaliajuri	190.0	4.81	7.26	8.16	5.60
Dhanpur	202.0	4.63	7.21	8.07	5.40
Kushiyara-Kalni River					
Manikkona	0.0	9.75	10.86	11.30	10.60
Fenchuganj	6.0	9.54	10.64	11.06	10.35
Balaganj	24.0	8.92	9.96	10.32	9.67
Sherpur	47.0	8.12	9.10	9.38	8.80
Markuli	90.0	6.46	7.44	8.10	7.10
Ajmiriganj	115.0	4.78	7.15	7.95	5.40

A.6 Structures

Hydraulic structures are proposed at the offtakes of the open khals to check the uncontrolled flood inflow into the project area during the pre-monsoon season: five structures along the Surma left bank, four structures along the Kushiyara right bank and one structure on the left bank of the Piyain River.

Three types of structures are proposed; Flushing Regulators, Flushing and Drainage Regulators, and Regulators combined with Navigation Lock. All the khals taking off from the Surma River are spill channels, and flushing regulators should be provided on these channels, with the exception of the Bahia Nadi which also drains back into the Surma and requires flushing/drainage regulator.

Regulators with locks will be provided on khals which at present are used for navigation. At this preliminary stage of planning, three sizes of locks are proposed, 3.0 m, 5.0 m and 6.0 m in width.

To prevent excessive rise of water levels in the boundary rivers and to maintain sufficient depth for navigation in the internal khals, the structures (and the channels) should be designed for a continual flow from the river into the channel. One or more regulator gates may need to remain open all the time. This will reduce the project impact on fisheries. In addition, each structure will be equipped with fish passage facility to allow fish migration.

The proposed discharge capacities of the structures were determined from the present discharges through the khals at the 1 to 10-year pre-monsoon flood levels in case of a spill channel, and verified with the drainage requirement in case of a drainage channel.

Discharge capacities of the Bhatta Khal and the Kazanchi Nadi Regulators have been reduced to about 0.6 of the present discharges. These khals have large cross sections at the offtake, but further downstream the sections decrease rapidly. With the bank levels dropping from 11.0 m PWD at the offtake to 6.0 m at about 20 km downstream most of the inflows spill overbank flooding the adjacent areas (Surveyed Cross Section Inventory, FAP 6, May 1993).

The proposed structures are listed in Table A25.

Table A25: Surma-Kushiyara-Baulai Project Proposed Structures

Location	Type of Structure	Structure Size	Design Q (m^3/s)
On Surma River Khals:			
Bahia Nadi	Lock/Regulator	5.0 m Lock + 2-2.0 x 6.0 m	100
Kazanchi Nadi	Regulator	4-2.0 x 6.0	80
Bhatta Khal	Lock/Regulator	5.0 m Lock + 6-2.0 x 6.0 m	180
Madhabpur Khal	Regulator	4-2.0 x 6.0	80
Old Surma River	Lock/Regulator	6.0 m Lock + 3-2.0 x 6.0 m	130
On Kushiyara River Khals:			
Kurkuchi Khal	Lock/Regulator	3.0 m + 2-2.0 x 6.0 m	85
Betari Nadi at Narayanpur	Lock/Regulator	3.0 m + 2-2.0 x 6.0 m	85
Betari Nadi at Hariyargaon	Regulator	2-2.0 x 6.0 m	40
Barbhanga Nadi	Lock/Regulator	5.0 m + 4-2.0 x 6.0 m	140
Piyain River:			
Kolkolia Khal	Regulator	3-2.0 x 6.0 m	60

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Table A26: Pre-Monsoon Depth of Flooding

Flood Depth (m)	Gross Area (ha)	
	Pre-Project	Post-Project
Catchment 1		
< 0.30	32100	51300
0.30-0.90	7125	3125
0.90-1.80	7925	1900
> 1.80	9175	0
Total	56325	56325
Catchment 2		
< 0.30	26879	56279
0.30-0.90	8500	3500
0.90-1.80	14500	1100
> 1.80	11000	0
Total	60879	60879
Catchment 3		
< 0.30	27846	56546
0.30-0.90	11800	9000
0.90-1.80	16900	7300
> 1.80	16300	0
Total	72846	72846
Catchment 4		
< 0.30	23022	44322
0.30-0.90	22800	10000
0.90-1.80	7200	6200
> 1.80	7500	0
Total	60522	60522
Catchment 5		
< 0.30	20117	29117
0.30-0.90	16600	17500
0.90-1.80	5500	17600
> 1.80	26500	4500
Total	68717	68717

Tabla A27: Reference Flood Water Levels in Surma-Kushiyara-Baulai Basin

Basin Catchment Number	1:10-Year Pre-Monsoon Flood Level (m PWD)		Average Annual Flood Level (m PWD)	
	Pre-Project	Post-Project	Pre-Project	Post-Project
1	8.7	7.0	9.8	9.8
2	8.3	6.3	8.9	8.9
3	7.0	5.5	8.7	8.7
4	6.0	4.3	7.5	7.5
5	6.0	4.3	7.8	7.8

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A.7 Fisheries

Table A28: Closed Water Bodies in the Project Area

Thana	% of Project Area	Total Number of Ponds	Total Pond Area (ha)	Average Pond Area (ha)	Pond Concentra tion (nos/km2)
Sunamganj	75	3814	295	0.07	8.47
Jamalganj	63	1684	130	0.07	8.71
Derai	92	3405	264	0.07	8.83
Sullah	100	2364	183	0.07	9.02
Kaliajuri	59	1395	156	0.11	8.12
Jagannathpur	78	2607	202	0.07	8.54
Itna	5	15	17	1.13	0.61
Balaganj	100	3534	273	0.07	9.06
Fenchuganj	30	301	35	0.11	9.11
Golapganj	37	927	72	0.07	9.18
Sylhet sadar	43	2156	163	0.07	10.06
Bishwanath	100	1958	151	0.07	9.19
Chhatak	80	3305	256	0.07	10.20
Dowarabazar	43	1037	80	0.07	8.12
Total		28,502	2277		

Source: BFRSS, 1986

Table A29: Open Water Bodies in the Surma-Kushiyara-Baulai Basin

Thana	Beel Area (ha)	Thana	Beel Area (ha)
Sunamganj	1674	Sylhet sadar	1114
Jamalganj	1344	Chhatak	1951
Derai	2962	Dowarabazar	645
Sullah	906	Balaganj	1069
Kaliajuri	1285	Fenchuganj	77
Itna	130	Biswanath	284
Jagannathpur	532	Golapganj	310
Total:	14,283 ha		

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

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Table A30: Duars Around the Project Area

Name of Duar	Depth During Dry Season (m)	Boramach Occurred *	Chotomach Occurred *
River: SURMA			
Birdhalpara	8-9	LC, MC	Ch,Ca,P,B
Astagram	8-9	As above	As above
Anantapur	8-9	LC,C,MC	As above
Sharpur	8-9	As above	As above
Digholi **	10-11	As above	As above
Shahibpur	10-11	As above	As above
Nowar dor	9-10	As above	As above
Khidirpur	11-12	As above	As above
Wazirpur	9-10	As above	As above
Rampur	9-10	As above	As above
Perkul	9-10	As above	As above
Bagairar dor	13*	As above	B,Ch,Ca,R
Muktigaon	16*	As above	As above
Boalir dor	12*	As above	As above
Thanar dor	17*	As above	As above
Baushar dor	18*	As above	As above
Baturar dor	13*	As above	As above
Dowarabazar dor	20*	As above	As above
Machimpurar dor	13*	As above	As above
Pandarmuk	15*	As above	As above
Dowarabazar2 **	26*	As above	As above
Sharifpur**	12-13	As above	As above
Damband	11-12	As above	As above
Nurpur	10-11	As above	As above
Brahmangaor dor**	12-13	As above	As above
Lalpurar koor	16-17	As above	As above
Ajkhalir dor	14-15	As above	As above
Puranlaxamansree	14-15	As above	As above
Paindar dor	10-12	As above	As above
Baburbazar	12-14	As above	As above
Amriar dor	15-16	As above	As above
Noagaor duar	15-16	As above	As above
Jamlabaz **	15-16	As above	As above

Table A30: Duars Around the Project Area

Name of Duar	Depth During Dry Season (m)	Boramach Occurred *	Chotomach Occurred *
River: OLD SURMA (within the project area)			
Jaykoloshar dor	10-11	LC,C,MC	B,Ch,Ca,T
Ghazinagar	10-11	As above	As above
Thakurbogar	10-11	As above	As above
Sujanagarar duar	10-11	As above	As above
Chandpurar dor 2	10-11	As above	As above
Narsingpur 2	10-11	As above	As above
Kartikpur	9-10	As above	As above
Katoir	9-10	As above	As above
Bheramonar duar	8-9	As above	As above
River: BRAHMONI (within the project area)			
Motokonar dor	4-5	LC, MC, C	Ch, Ca, P
Majorgoar	4-5	As above	As above
Khasir dor	4-5	LC, MC	As above
Naya dor	4-5	As above	As above
Gazirmokam	4-5	As above	As above
Kaliganga	4-5	As above	As above
River: DHANU/BAULAI			

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Table A30: Duars Around the Project Area

Name of Duar	Depth During Dry Season (m)	Boramach Occurred *	Chotomach Occurred *
Kalipurar dor	15-16	LC,C,MC	B,Ch,Ca,L
Gazariar duar	10-11	As above	As above
Chandpurar duar	10-11	As above	As above
Sonapurar duar	10-11	As above	As above
Lalpurar duar	12-13	As above	As above
Laxmipurar duar	12-13	As above	As above
Golakpurar duar	11-12	As above	As above
Santipurar duar	11-12	As above	As above
Mara Dhanu	13-14	As above	As above
Alipurar duar	12-13	As above	As above
Chandpurar duar	12-13	As above	As above
Gaglajur	15-16	As above	As above
Barantarar duar	8-9	As above	As above
Asadpurar duar	9-10	As above	As above
Saldighor	15*	As above	As above
Nawtana 2 **	14* & 12*	As above	As above
Faridpur	12*	As above	As above
Jagendrapur	12*	As above	As above
Jaganathpur loop	10*	As above	As above
Jaganathpur 2	10* & 13*	As above	As above
Kaliajuri goona	12*	As above	As above
Mara Dhanu 3	10*,12*,11*	As above	As above
Putir duar	8*	As above	As above
Karakhala	13*	As above	As above
Kalar duar**	17*	As above	As above
Ran duar	12*	As above	As above
River: KUSHIYARA			

Table A30: Duars Around the Project Area

Name of Duar	Depth During Dry Season (m)	Boramach Occurred *	Chotomach Occurred *
Rokonpurar dor	10-11	LC, MC, C	B,Ch,Ca,L
Dekapurar dor	10-11	As above	As above
Sonapurar dor	13-14	As above	As above
Sadapurar dor	10-11	As above	As above
Azampurar dor	10-11	As above	As above
Sheikhpurar dor	10-11	As above	As above
Islampurar dor	11-12	As above	As above
Berkurir dor	19*	LC,MC	As above
Shahpurar dor	15*	As above	As above
Korchar dor	17*	As above	As above
Chorkir dor	21*	LC,MC,C	As above
Jalalpurar dor	18*	LC,MC	As above
Jamirkonar dor	17*	As above	As above
Poradair	12*	As above	As above
Poradair	17*	As above	As above
Manumuk	14*	As above	As above
Bahadurpur	11*	LC,MC,C	As above
Brahmangaon	23*	As above	As above
Perkular dor	16*	LC,MC	As above
Kamarkheda	15*	As above	As above
Hossainpur	15*	As above	As above
Mirkhalir dor	17*	LC,MC,C	As above
Digholbag 4**	14,16,18,32*	As above	As above
Atghor	19*	As above	As above
Bara Pechi**	16*	As above	As above
Jalalpurar dor	14*	LC,MC	As above
Kaittar dor**	14*	As above	As above
Bagakhalir dor**	25*	LC,MC,C	As above
Alokdir dor	19*	As above	As above
Pilegaor dor	18*	As above	As above
Ranigangar dor**	22*	As above	As above
Alampurar duar	18*	As above	As above
Balichata	17*	As above	As above
Bagmaynar duar	19*	As above	As above
Roailar dor**	31*	As above	As above
Mohiskonar duar	15-16	As above	As above
Baushir duar	15-16	As above	As above
Galishalar duar	12-13	As above	As above
Markulir dor	12-13	As above	As above
Pratappurar duar	11-12	As above	As above
Bherar duar	12-13	As above	As above
Matidora	11-12	As above	As above
Badalpurar dor	11-12	As above	As above
Pirispurar duar	11-12	As above	As above

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Table A30: Duars Around the Project Area

Name of Duar	Depth During Dry Season (m)	Boramach Occurred *	Chotomach Occurred *
River: PIYAIN (within the project area)			
Rangchapur 9	9-14 *	MC,LC,C	B,Ca,L,S,G
Dhalimati 2	9-11 *	As above	As above
Rautala	10	As above	As above
Boiragir khaw	12	As above	As above
Shishur duar**	12	As above	As above
Shaintar duar	19	As above	As above
Auti	12	As above	As above
Chorkir duar	11	As above	As above
Lamba baid	10	As above	As above
Gangar khaw	9-10	As above	As above
Govindapur	9-10	As above	As above
Katwagara	10-11	As above	As above
Bagar duar	9-10	As above	As above
Pirarbathan	9-10	As above	As above
Elonguri	6-7	As above	As above
River: MORA DHANU			
Ballavpurar duar**	25-26	C,LC,MC	B,L,Ch,Ca

* Echo sounding data (all other depths from interviewing with fishermen).

** Duars proposed for fish sanctuaries.

B:Bacha; Ba:Bailla; C:Chital; Ca:Chapila; Ch:Chela; G:Golda Chingri; L:Laso; LC:Large catfish; MC:Major carp; Pa:Pabda; Pu:Puti; R:Rani; T:Tengra.

Source: NERP, 1992

Table A31: Surma-Kushiyara-Baulai Basin Fisheries

Type of Water Body	Area (ha)			Rate of Production (kg/ha)*
	Present	FWO	FW	
Beel	14,300	14,300	14,300	550
Floodplain	231,064	231,064	230,900	44
River/Channel	8,200	8,200	8,448	200
Pond	2,300	2,300	2,300	800

* FW Project production rates decreased approximately by 20%. See model in Annex C

Table A32: Fish Production in the Surma-Kushiyara-Baulai Basin (tonnes/year)

Year	Beel	Floodplain	Pond*	River/khal	Total
Present	7,865	10,167	1,840	1,640	21,512
FWO	7,865	10,167	2,116	1,640	21,788
FW	6,292	8,128	2,116	1,352	17,888

* Pond production estimated with an annual growth rate of 3% in the next five years.

Table A33: Fisheries Employment
('000 Person Days)

Year	Beel *	Floodplain*	Pond*	River/ Channel	Total
Present	982	20,334	204	547	22,067
FWO	982	20,334	235	547	22,098
FW	786	16,256	235	235	17,728

* **Beel** - 1 person day per 8 kg fish; **Floodplain** - 1 person day per 0.5 kg fish; **Pond** - 1 person day per 9 kg fish; **River/Channel** - 1 person day per 3 kg fish.

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ANNEX B

ENGINEERING COST ANALYSIS

ANNEX B
ENGINEERING COST ANALYSIS

B.1 Flood Embankments

Table B1: Surma-Nawa-Baulai River Left Embankment

Item	Quantity	Unit Rate ('1000)	Amount (Tk '1000)
Re-sectioning of embankments: Average H=1.5 m Average H=3.5 m	 120.0 km 25.5 km	 150 Tk/km 708 Tk/km	 18,000 18,054
Land Acquisition	106.5 ha	300 Tk/ha	31,950
Construction of new embankments: Average H=1.0 m Average H=1.5 m	 44.5 km 12.0 km	 203 Tk/km 350 Tk/km	 9,034 4,200
Land Acquisition	142.2 ha	300 Tk/ha	42,660
Total Embankments:	202.0 km		49,288
Total Land Acquisition:	248.7 ha		76,610

Table B2: Kushiyara-Kalni River Right Embankment

Item	Quantity	Unit Rate ('1000)	Amount (Tk '1000)
Re-sectioning of embankments	72.0 km	150 Tk/km	10,800
Land Acquisition	43.2 ha	300 Tk/ha	12,960
Construction of new embankments: Average H=1.0 m Average H=1.5 m	 28.0 km 15.0 km	 203 Tk/km 350 Tk/km	 5,684 5,250
Land Acquisition	109.9 ha	300 Tk/ha	32,970
Total Embankments:	115.0 km		17,234
Total Land Acquisition:	153.1 ha		40,530

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B.2 Drainage Channels

Table B3: Channel A

Item	**Quantity**	**Unit**	**Rate (Tk)**	**Amount (Tk '1000)**
1. Re-excavation of Bhatta Khal, 15.0 km				
Earthwork	1,050,000	m^3	25.35	26,617.5
Land Acquisition	22.5	ha	300,000	6,750.0
2. Re-excavation of Dahuka River, 32.0 km				
Earthwork	2,545,455	m^3	25.35	64,527.3
Land Acquisition	64.0	ha	300,000	19,200.0
3. Dredging of Mora Surma River, 42.0 km				
Earthwork	1,260,000	m^3	80.00	100,800.0
Land Acquisition	-	ha	300,000	
Total Earthworks:	4,855,455 m^3			191,944.8
Total Land Acquisition:		86.5 ha		25,950.0

Table B4: Channel B

Item	**Quantity**	**Unit**	**Rate (Tk)**	**Amount (Tk '1000)**
1. Excavation of Hamhamia River Link Channel, 2.0 km				
Earthwork	68,000	m^3	22.11	1,503.5
Land Acquisition	5.0	ha	260,000	1,300.0
2. Re-excavation of Mohasingh River, 12.0 km				
Earthwork	720,000	m^3	25.35	18,252.0
Land Acquisition	12.0	ha	260,000	3,120.0
Total Earthworks:	788,000 m^3			19,755.5
Total Land Acquisition:		17.0 ha		4,420.0

Table B5: Channel C

Item	Quantity	Unit	Rate (Tk)	Amount (Tk '1000)
1. Excavation of Patachatal Beel Link Channel, 0.5 km				
Earthwork	72,000	m^3	25.35	1,825.2
Land Acquisition	3.0	ha	300,000	900.0
2. Re-excavation of Muktarpur Haor Khals, 10.0 km				
Earthwork	740,000	m^3	25.35	18,759.0
Land Acquisition	20.0	ha	260,000	5,200.0
3. Excavation of, Sadipur-Itakhola Nadi Link Channel 8.0 km				
Earthwork	2,400,000	m^3	25.35	60,840.0
Land Acquisition	64.0	ha	300,000	19,200.0
4. Re-excavation of Naljor-Ratna-Kamarkhali River, 48 km				
Earthwork	2,880,000	m^3	25.35	73,008.0
Land Acquisition	57.6	ha	300,000	17,280.0
5. Dredging of Darain River, 40 km				
Earthwork	1,800,000	m^3	80.00	144,000.0
Land Acquisition	-	ha	300,000	
Total Earthworks:	7,892,000 m^3			298,432.2
Total Land Acquisition:		144.6 ha		42,580.0

The dredging volume estimates are based on an average dredging depth of 1.0 m and 1.5 m for the Mora Surma and the Darain River respectively.

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B.3 Structures

Navigation Locks and Regulators

Table B6: Surma-Kushiyara-Baulai Project Structures

Location	Type of Structure	Structure Size	Unit Cost (Tk '000)
On Surma River Khals:			
Bahia Nadi	Lock/Regulator	5.0 m Lock + 2-2.0 x 6.0 m Fl. Reg.	23,268
Kazanchi Nadi	Regulator	4-2.0 x 6.0 m Fl. Reg.	10,142
Bhatta Khal	Lock/Regulator	5.0 m Lock + 6-2.0 x 6.0 m Fl. Reg.	27,816
Madhabpur Khal	Regulator	4-2.0 x 6.0 m Fl/Dr Reg.	10,142
Old Surma River	Lock/Regulator	6.0 m Lock + 3-2.0 x 6.0 m Fl. Reg.	28,605
On Kushiyara River Khals:			
Kurkuchi Khal	Lock/Regulator	3.0 m Lock + 2-2.0 x 6.0 m Fl/Dr Reg.	19,668
Betari Nadi at Narayanpur	Lock/Regulator	3.0 m Lock + 2-2.0 x 6.0 m Regulator	19,668
Betari Nadi at Hariyargaon	Regulator	2-2.0 x 6.0 m Regulator	7,868
Barbhanga Nadi	Lock/Regulator	5.0 m Lock + 4-2.0 x 6.0 m Fl/Dr Reg.	25,542
On Piyain River Khal:			
Kolkolia Khal	Regulator	3-2.0 x 6.0 m Fl/Dr Reg.	9,005
Total Structures:		10 Nos	181,724
Total Land Acquisition:		15.0 ha	4,500

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B.4 *Project Buildings*

Table B7: Project Buildings

Description	Nos.	Cost (Tk '1000)	Land Req. (ha)	Total Cost (Tk '1000)	
				Buildings	Land Acq.
Structure Operator	10	250/unit	3.0	2,500	900
Embankment Guard	10	250/unit	3.0	2,500	900
Project Monitor	3	250/unit	1.0	750	300
Project Office (200 m^2)	1	$5/m^2$	1.0	1,000	400
Staff Quarters (500 m^2)	1	$5/m^2$	1.0	2,500	400
Total:			9.0	9,250	2,900

B.5 Sylhet-Sunamganj By-Pass Road (Costs not included in the EIRR Analysis)

Table B8: Proposed New Road

Item	Quantity	Unit Rates	Amount (Tk '1000)
Feeder Road from Sripur to Kazirgaon: Total Length 6.00 km Crest Width 7.32 m Embankment Height 2.00 m Side slopes 1:2			
Earthwork	6.0 km	774 Tk/m	4,644
Pavement	6.0 km	1220 Tk/m	7,320
Land Acquisition	24.6 ha	300000 Tk/ha	7,380
Total Civil Works:	6.0 km		11,964
Total Land Acquisition:	24.6 ha		7,380

Table B9: Bridges and Culverts

Location	Type	Size (m)	Unit Rate (Tk/m)	Total Cost (Tk '1000)
Kazanchi Khal at Sripur	RCC Bridge	30.0	354,000	10,620
Amirpur	RCC Box Culvert	6.0	118,000	708
Kurikhal	RCC Box Culvert	6.0	118,000	708
Total:				12,036

B.6 Capital Cost Summary

Table B10: Capital Cost Summary

Item	Quantity	Cost ('000 Tk)
Structures	10 Nos	181,724.0
Embankments	Re-sect. 217.5 km New emb. 99.5 km	66,522.0
Channels	Excavation 10.5 km Re-exc. 117.0 km Dredging 82.0 km	510,133.0
Buildings	1 office 1 off. quarters 23 field quarters	9,250.0
Land Acquisition	Structures 15.0 Embankments 426.4 Channels 248.1 Buildings 9.0 Total: 698.5 ha	204,870.0
BASE COST		972,499.0
Physical Contingencies (25%)		243,124.7
SUBTOTAL		1,215,623.7
Study Cost (15%)		182,343.6
TOTAL:		**1,397,967.3**

The estimated direct cost of the proposed Sylhet-Sunamganj by-pass road is about Tk 24.0 Million. The total capital project cost including the road is about Tk 1,432.5 Million.

ANNEX C

INITIAL ENVIRONMENTAL EXAMINATION

ANNEX C
INITIAL ENVIRONMENTAL EXAMINATION

C.1 Introduction

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

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

C.2 Alternative 1: Proposed 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: 319,289 ha.
Impacted (net) area: 254,589 ha.
Impacted area outside project: Peak pre-monsoon flood levels could increase in the upper reaches of Surma by 0.2 to 0.8 m, and in Kushiyara by 0.2 to 0.5 m, depending on the rate of inflow released into the project through the proposed regulators. The confinement effect in the lower reaches of the rivers is expected to be below 0.3 m. During feasibility studies, these impacts need to be assessed.

Temporal:

Preconstruction: years zero through year three (see Table 7.6).
Construction: year one through year four (see Table 7.6).
Operation: year four through year thirty.
Abandonment: after year 30.

Cumulative impacts:

With other floodplain infrastructure: This will be looked at in the context of the Regional Plan.

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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 openwater fisheries production impacts were estimated with a simplified model. The limitations of the model mirror the limitations in our current understanding of and information about the system. Results of the analysis are summarized below and Table 7.13 of the main report (multi-criteria analysis).

The major system processes about which we have some insight are:

- Migration access and timing. It seems to be accepted that:
  - a multiplicity of access points is desirable (i.e. that closing any or some channels is still deleterious),
  - the most important channels are those at the downstream end (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 suspected 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 is lacking it has been neglected in the model.]

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

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

The foregoing is represented quantitatively here as:

FWO production =

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

FW production =

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

Thus,

Impact = FW - FWO production =

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

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

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

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 200, 550, 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.

Estimated values for this project are shown in the Table below. 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.

Table C1: Fisheries Indicators

Var	Value	Stnd value	Comments
M	0.8	1	
Q	1	1	
R_0	8200	1	Peripheral rivers included
R_1	8448	1	Excavation of internal channels
B_0	14300	1	
B_1	14300	1	
W_0	231064	1	
W_1	230900	1	Construction of embankments
P_{RO}	200	1	BFRSS average yields for Mymensingh and Sylhet Districts
P_{BO}	550	1	
P_{WO}	44	1	
A_M	0	1	

The total annual openwater fisheries production impact is - 3,900 tonnes, which is about 20% of the FWO annual production of 19,672 tonnes. This implies decrease in the openwater-source fish availability from 18 to 15 gm per person per day after the project implementation.

C.2.8 Environmental Management Plan (Step 8)

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

Mitigation and enhancement. Documented in Section 7.3.5.

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

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

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

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

People's participation. There is a need at regional, institutional, and project levels to maintain enthusiasm for people's participation, and to develop effective and efficient public participation modalities.

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

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

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

Reporting and accountability framework. At a national or regional scale, there is a need to develop satisfactory reporting/accountability arrangements involving BWDB and DOE, probably through an Environmental Cell within BWDB linked to DOE. At the project level, the client committee and local BWDB staff should develop reporting/accountability arrangements satisfactory to themselves. Project implementation should be contingent upon development of satisfactory arrangements at the local level, at a minimum.

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

Table C2: Environmental Screening Matrix

Screening matrix / PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Preconstruction	Normal	Surveys & instrumentation: landmark, topographic, benchmark, hydrologic, climatic, socio-economic, land use, natural resource										
		Land acquisition	-						-			
		People's participation activities							-			
	Abnormal											
Construction	Normal	Site preparation: vegetation removal, infrastructure removal/relocation, resettlement, levelling, temporary structure installation (access roads, godowns, accommodations, garages and parking sites, cooking and eating facilities, waste disposal sites, water supply, drainage, sanitary facilities)	-						-			
		Canal excavation: labor and materials mobilization, crossdam construction, spoil transport, spoil disposal							+			
		Embankment construction: labor and materials mobilization, topsoil removal, soil taking and transport, compaction, turfing, paving							+			
		Structure (sluice gate, culvert, pump house, and so on) construction: labor and material mobilization, de-watering, excavation, pile driving, foundation works, structure construction, earthwork filling, turfing, paving		+					+			
		Tube well installation: boring, distribution facilities, electrification										
	Abnormal	Suspension of construction before completion, construction delays										
		Incorrect construction practices or techniques										
Construction (continued)	Abnormal (cont'd)											

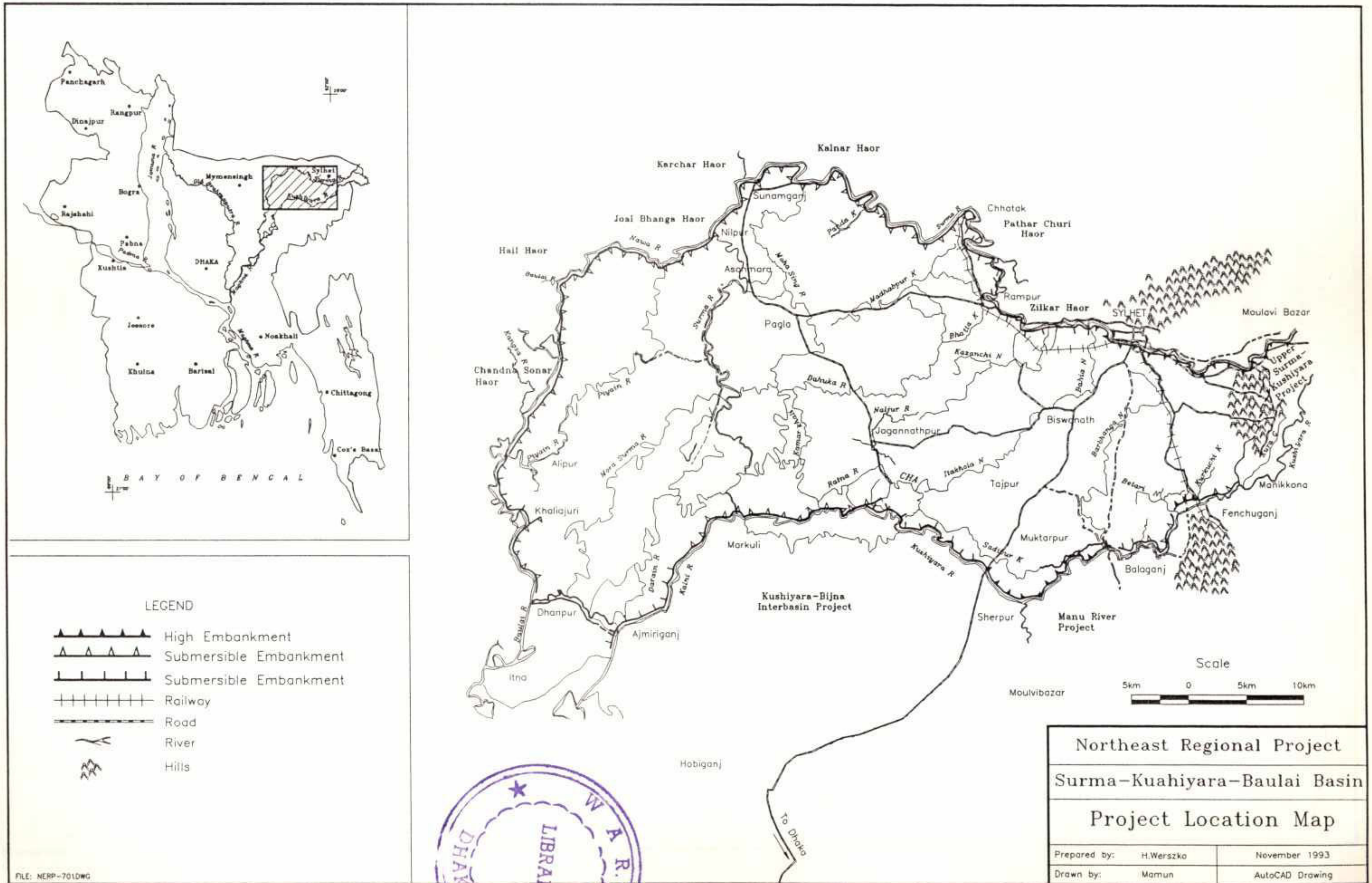
Table C2: Environmental Screening Matrix

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
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

FIGURES

Figure 1


Northeast Regional Project
Surma-Kuahiyara-Baulai Basin
Project Location Map
Prepared by: H.Werszko
November 1993
Drawn by: Mamun
AutoCAD Drawing
LEGEND
High Embankment
Submersible Embankment
Submersible Embankment
Railway
Road
River
Hills
Scale
5km 0 5km 10km
FILE: NERP-70I.DWG
Kalnar Haor
Karchar Haor
Joal Bhanga Haor
Hail Haor
Chandna Sonar Haor
Pathar Churi Haor
Zilkar Haor
Chhatak
Sunamganj
Nilpur
Asamara
Pagla
Rampur
SYLHET
Moulavi Bazar
Upper Surma-Kushiyara Project
Biswanath
Jagannathpur
Tajpur
Muktarpur
Balaganj
Fenchuganj
Manikkona
Sherpur
Manu River Project
Moulvibazar
Kushiyara-Bijna Interbasin Project
Markuli
Khaliajuri
Alipur
Dhanpur
Ajmiriganj
Itna
Hobiganj
To Dhaka
BAY OF BENGAL

268

Figure 2

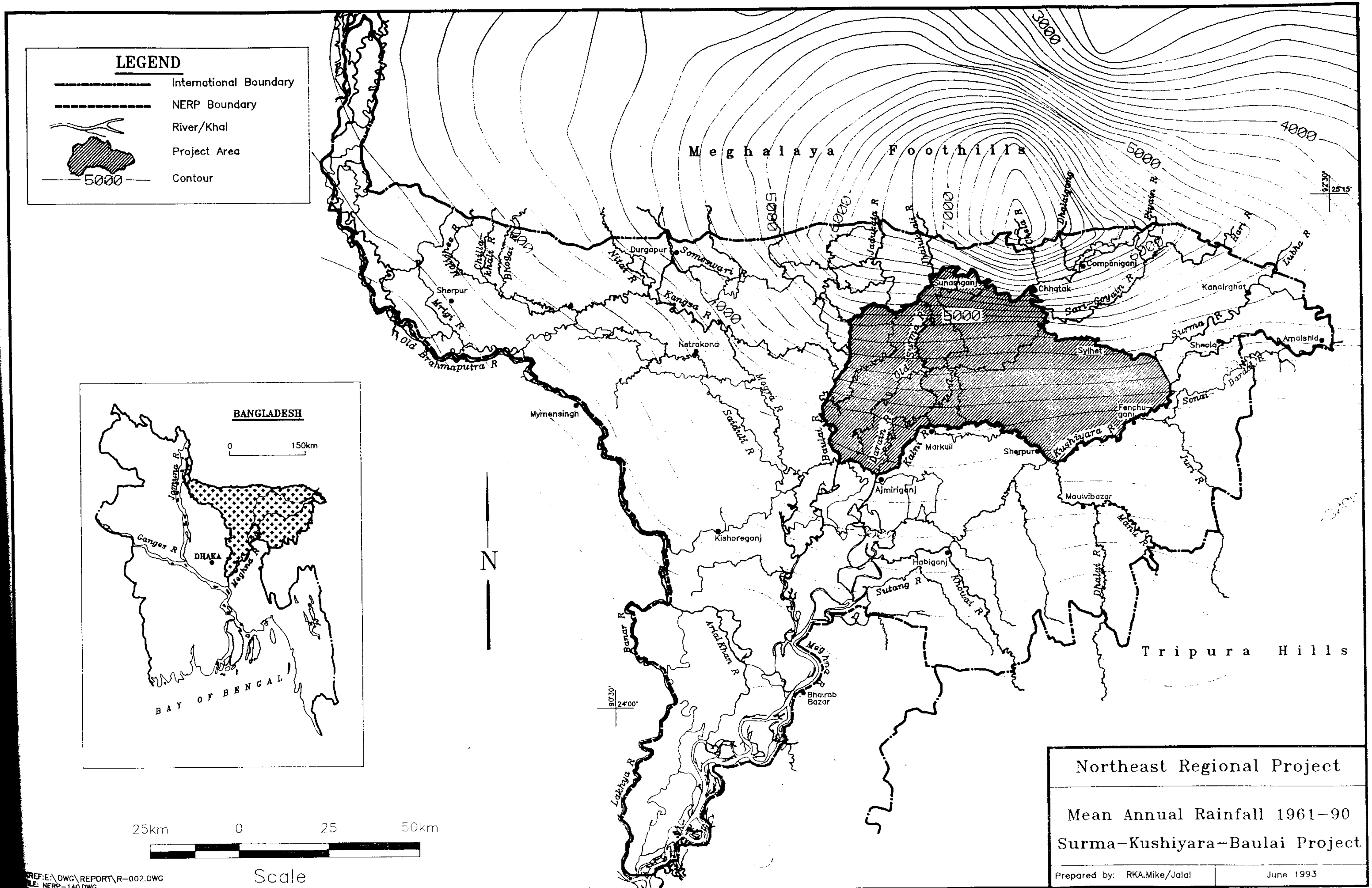
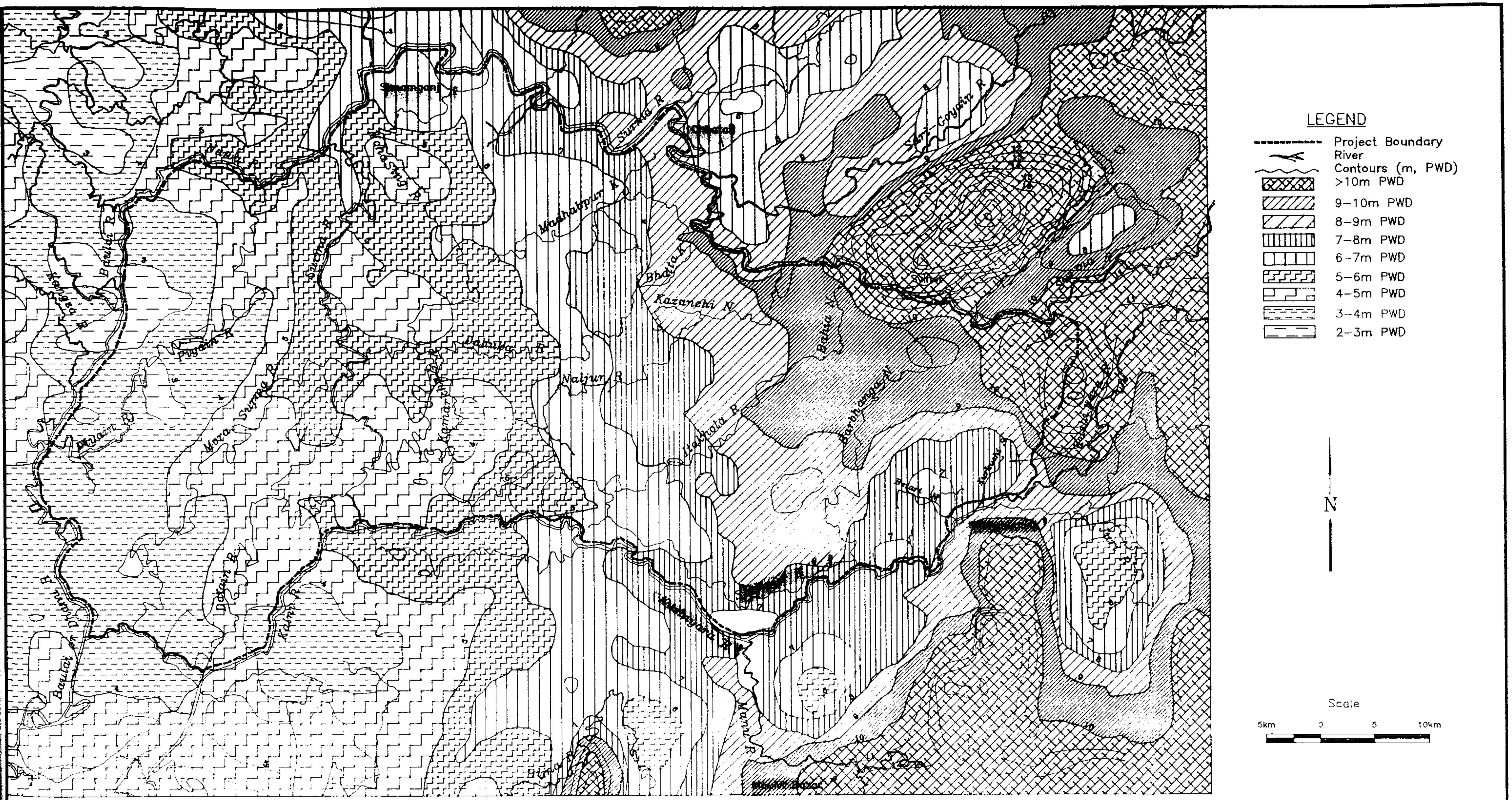

LEGEND
International Boundary
NERP Boundary
River/Khal
Project Area
5000
Contour
BANGLADESH
0
150km
DHAKA
BAY OF BENGAL
Meghalaya Foothills
Tripura Hills
Old Brahmaputra R
Sherpur
Durgapur
Netrakona
Mymensingh
Kishoreganj
Sunamganj
Chhatak
Companiganj
Kanairghat
Sylhet
Sheola
Amalshid
Fenchuganj
Markuli
Sherpur
Ajmiriganj
Maulvibazar
Habiganj
Bhairab Bazar
Surma R
Kushiyara R
Sonai
Meghna
Sutang R
Khowai R
Dhalai R
Manu R
Juri R
Kangsa R
Someswari R
Baulai R
Kalni R
Lakhya R
Banar R
Arial Khan R
3000
4000
5000
6000
7000
N
25km
0
25
50km
Scale
REF:E:\DWG\REPORT\R-002.DWG
FILE: NERP-140.DWG
Northeast Regional Project
Mean Annual Rainfall 1961-90
Surma-Kushiyara-Baulai Project
Prepared by: RKA.Mike/Jalal
June 1993

Figure 3



Northeast Regional Project

Surma–Kushiyara–Baulai Basin Project
Topography

Prepared by:	Mike	June 1993
Drawn by:	Mamun	AutoCAD Drawing

FILE: NERP–648.DWG

Figure 4

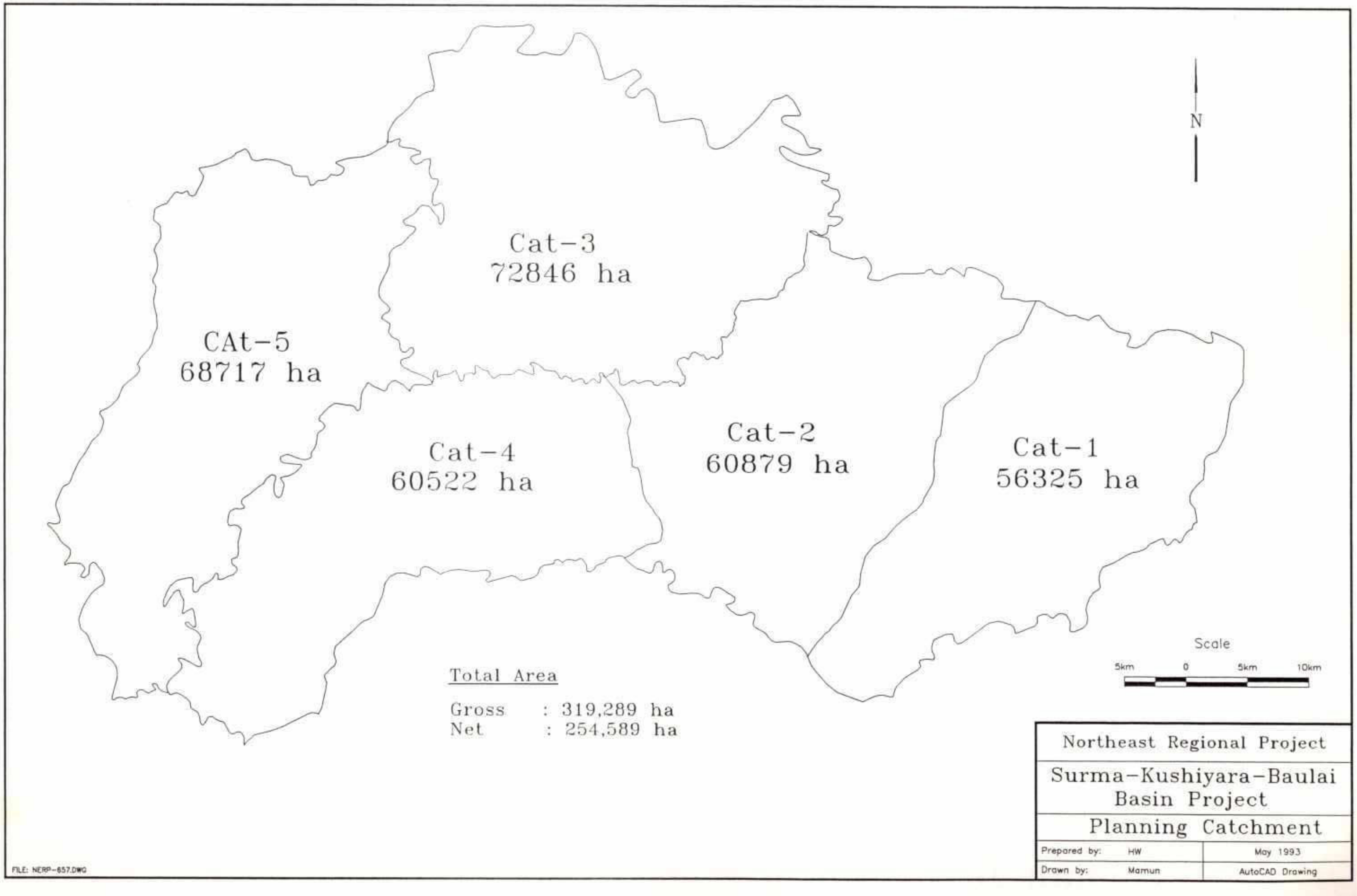
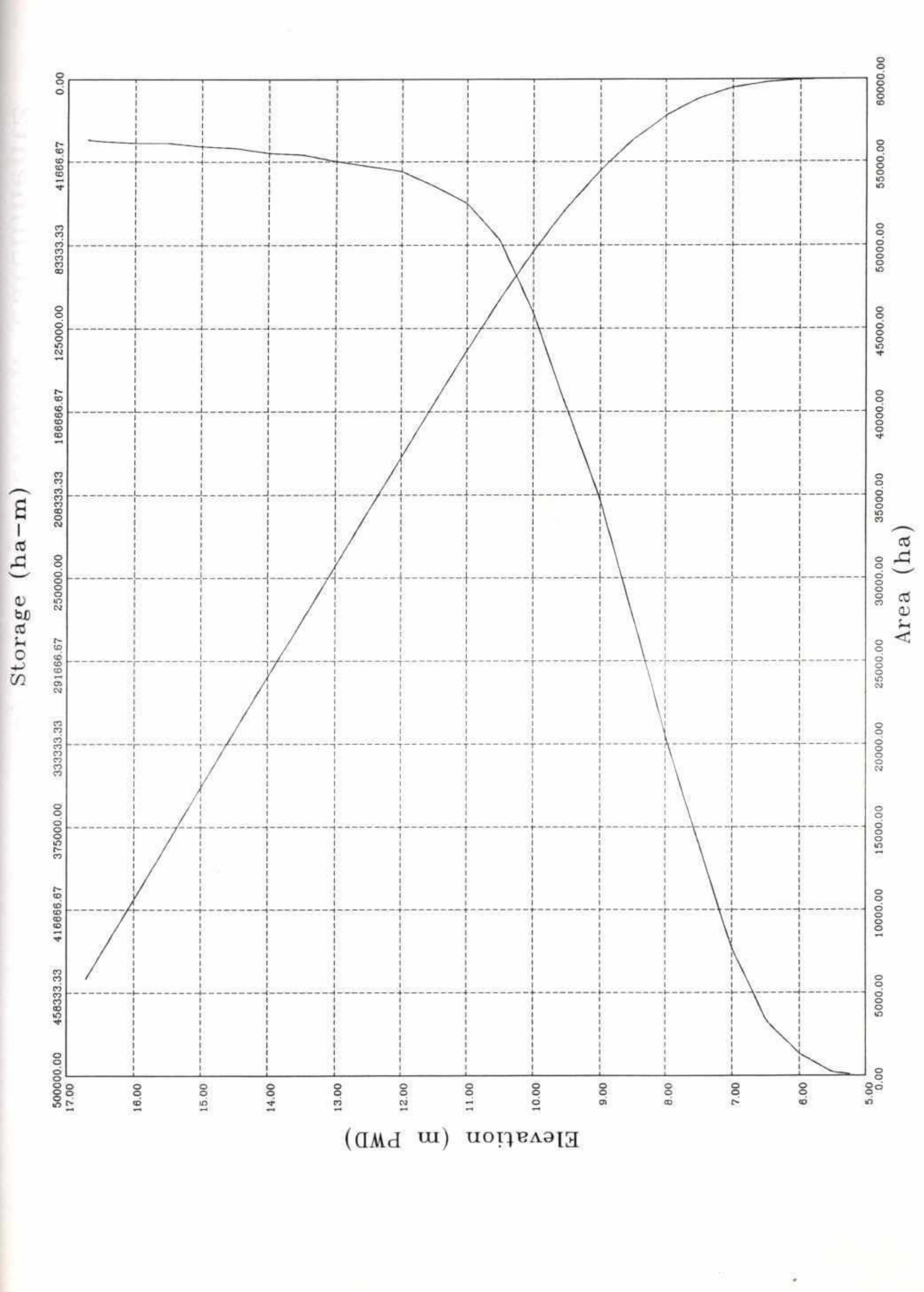
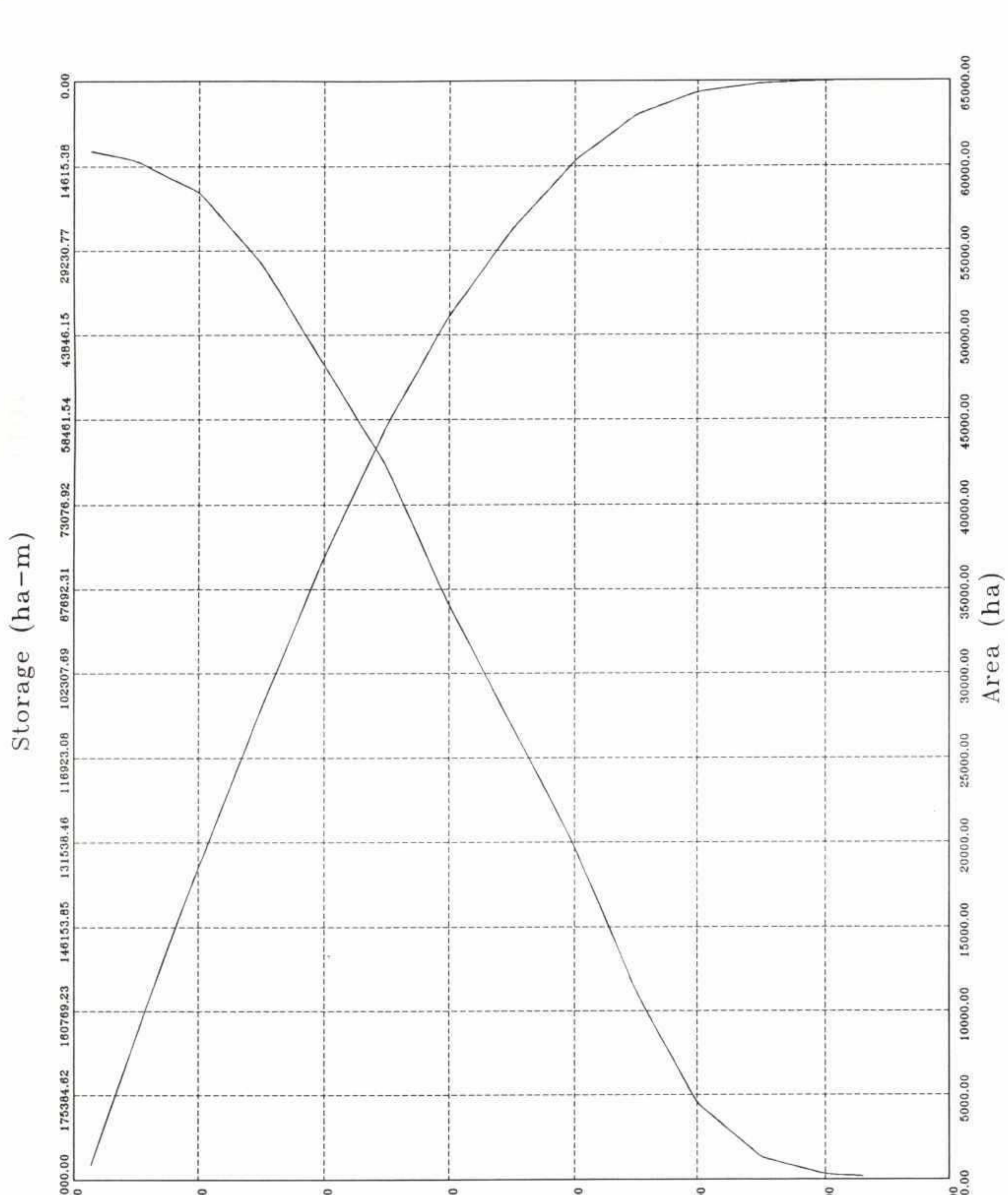

N
Cat-3
72846 ha
CAt-5
68717 ha
Cat-4
60522 ha
Cat-2
60879 ha
Cat-1
56325 ha
Total Area
Gross : 319,289 ha
Net : 254,589 ha
Scale
5km 0 5km 10km
Northeast Regional Project
Surma-Kushiyara-Baulai Basin Project
Planning Catchment
Prepared by: HW
May 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-657.DWG

Figure 5



Elevation vs Area/Capacity Relation-Catchment1

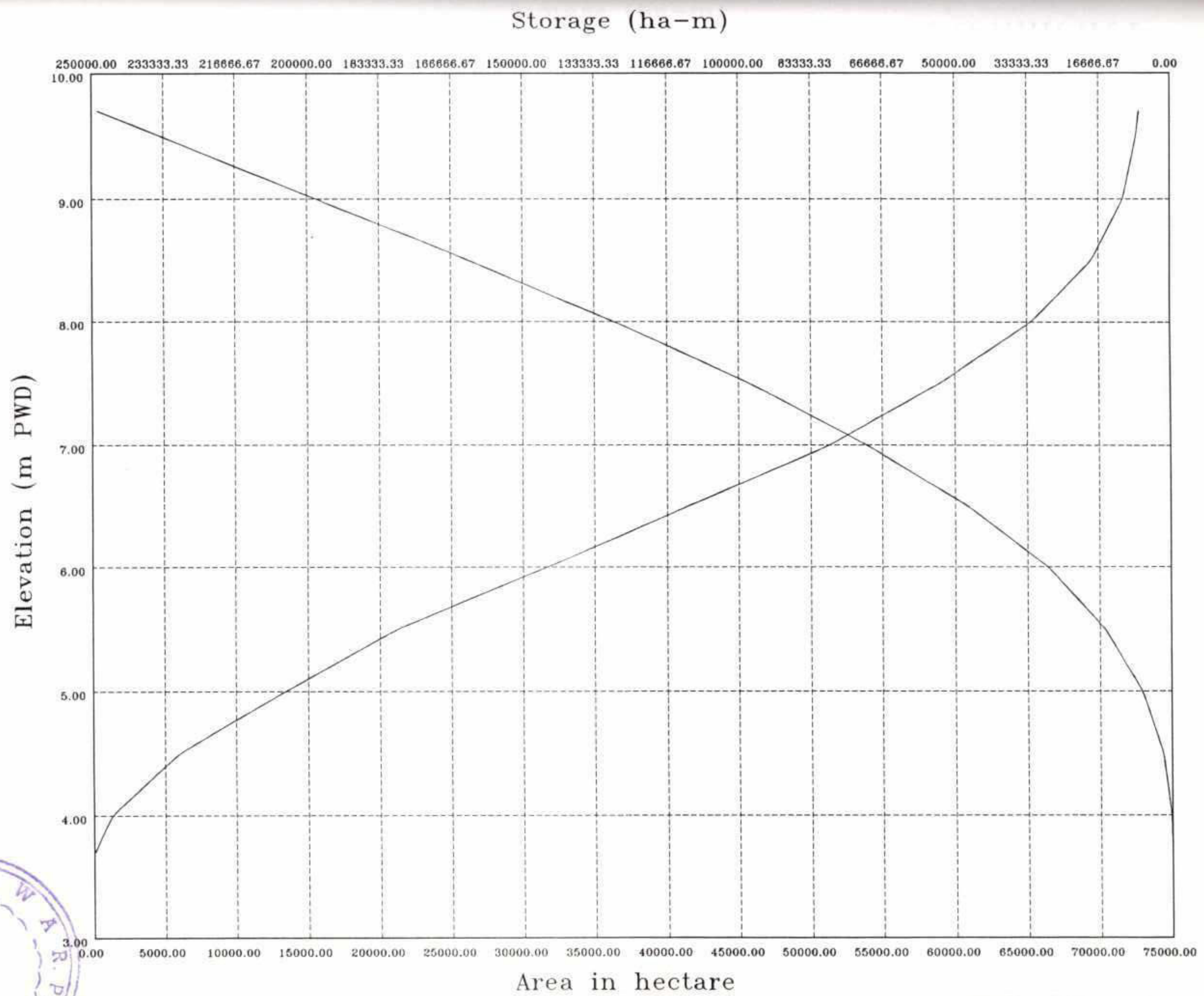
Figure 6



Elevation vs Area/Capacity Relation-Catchment2

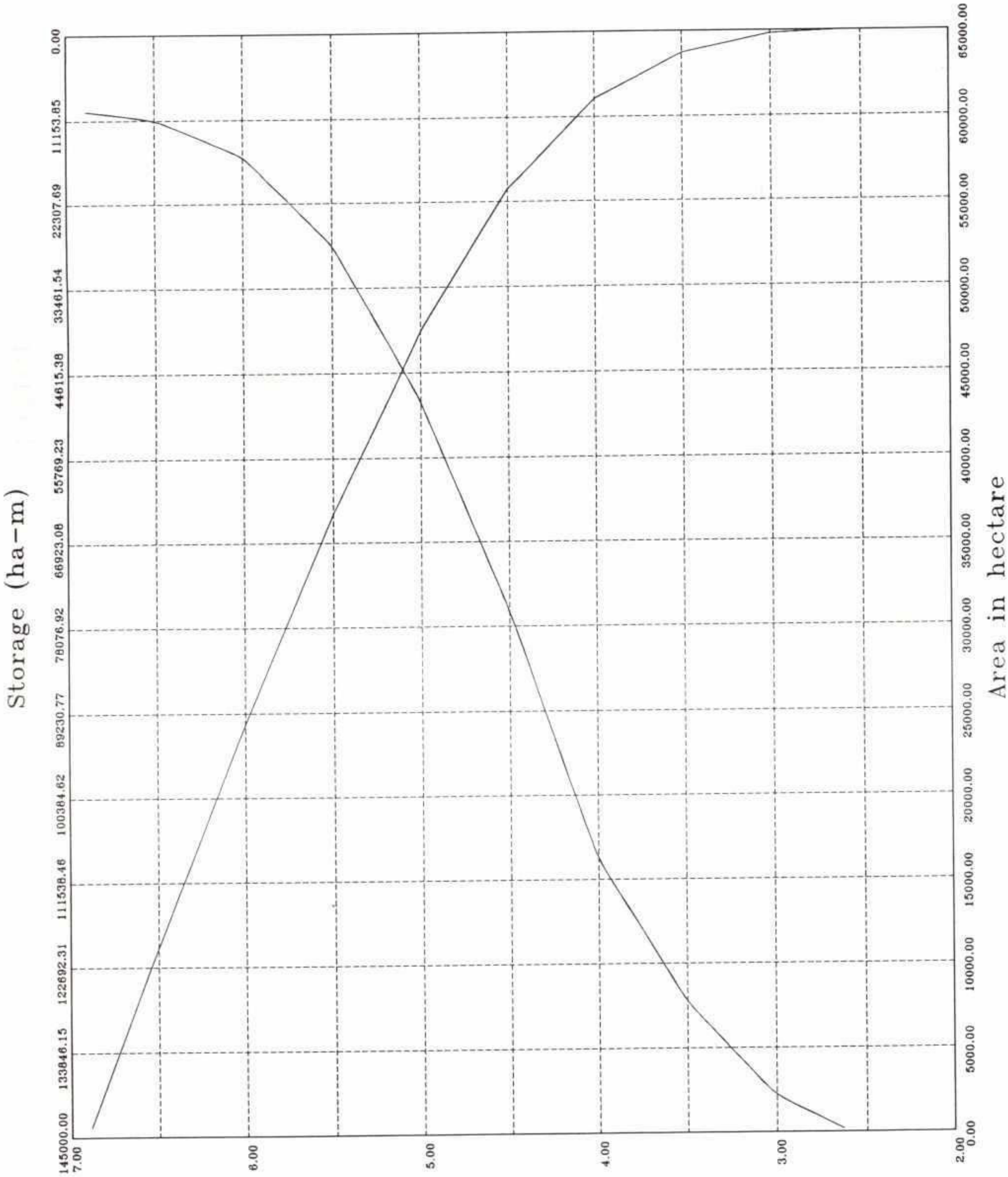
Figure 7

280



Elevation vs Area/Capacity Relation-Catchment3

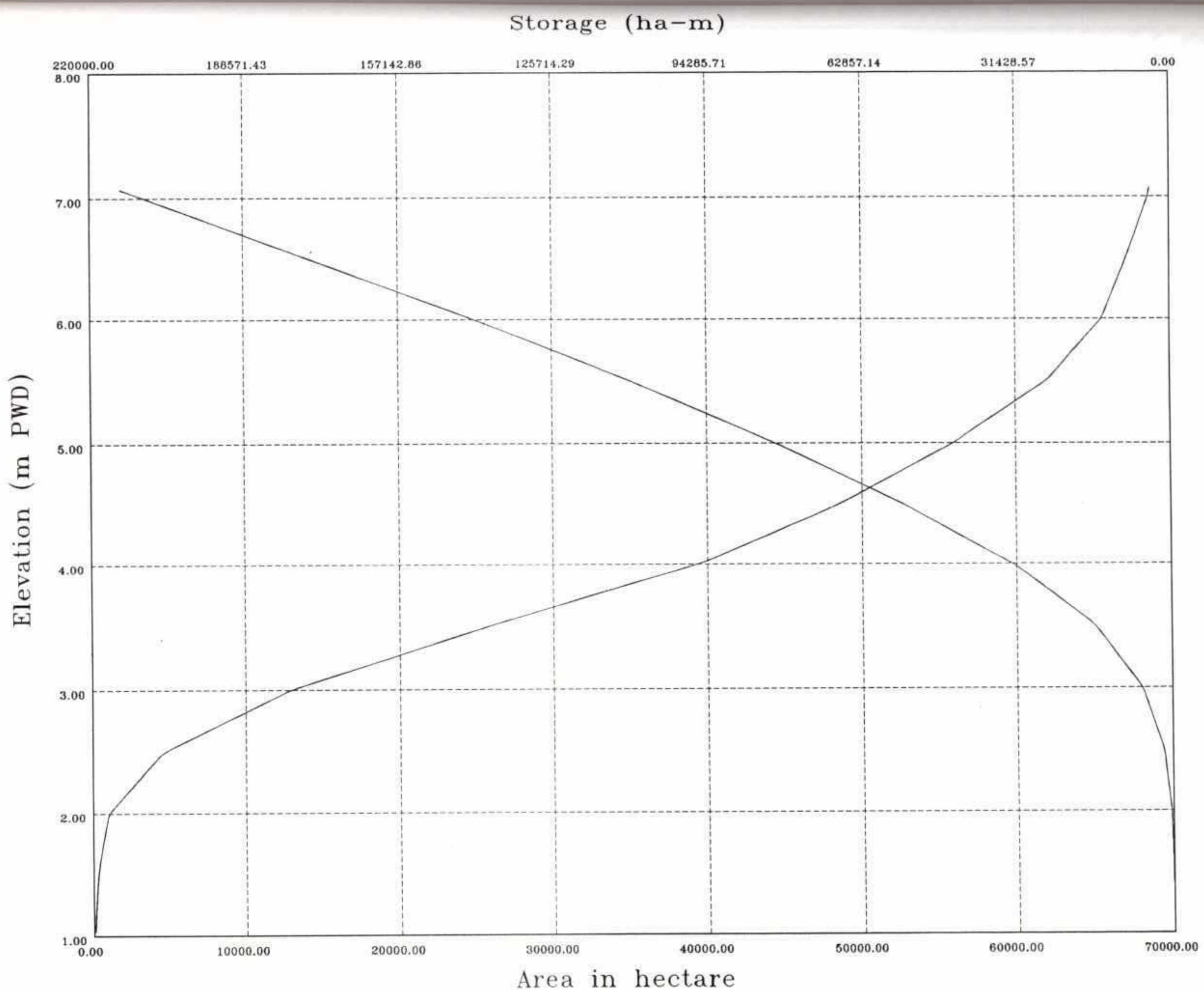
Figure 8



Elevation vs Area/Capacity Relation–Catchment4

Figure 9

282



Elevation vs Area/Capacity Relation-Catchment5

Figure 10

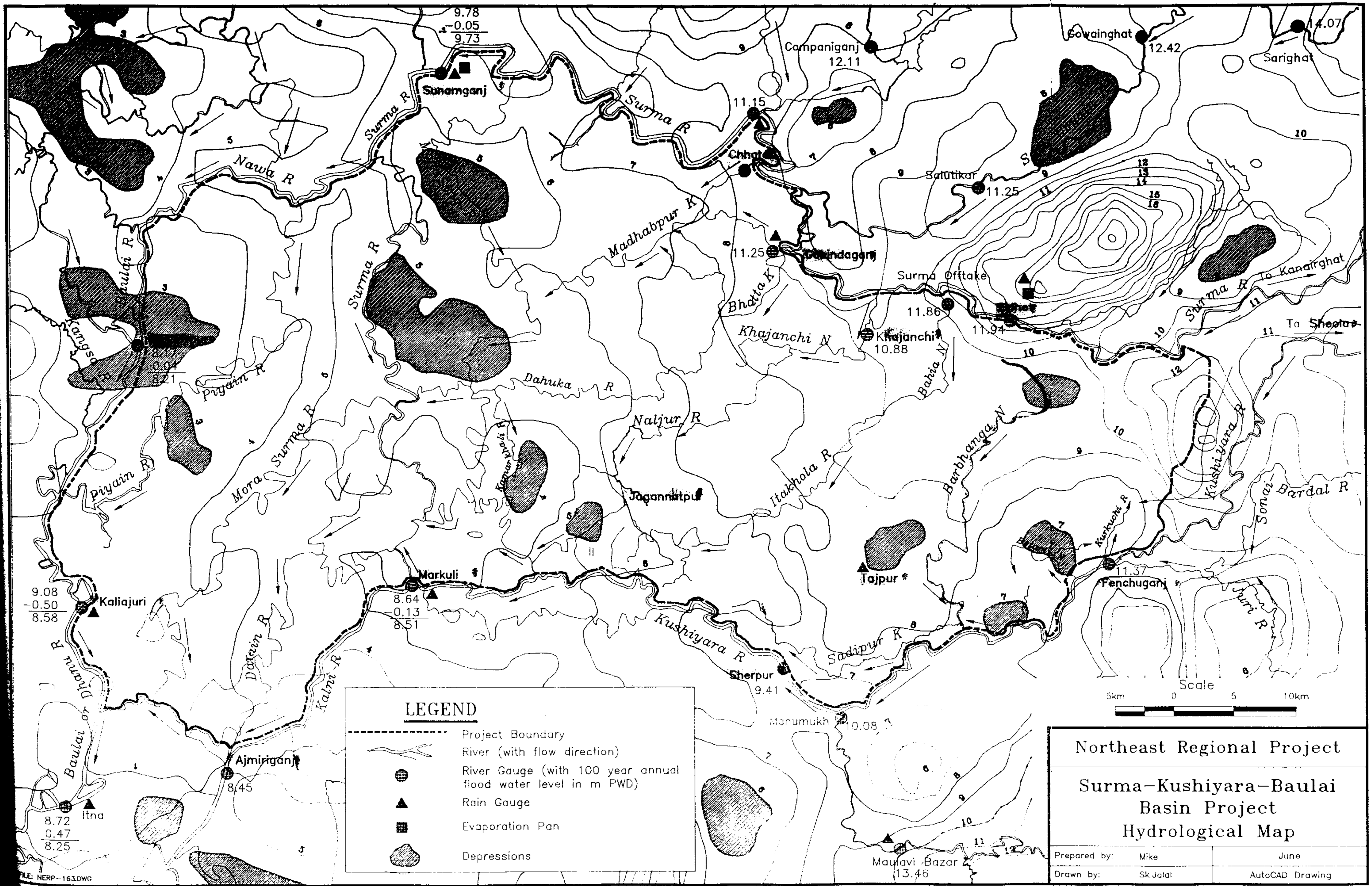

LEGEND
Project Boundary
River (with flow direction)
River Gauge (with 100 year annual flood water level in m PWD)
Rain Gauge
Evaporation Pan
Depressions
Northeast Regional Project
Surma-Kushiyara-Baulai Basin Project Hydrological Map
Prepared by: Mike
June
Drawn by: Sk.Jalal
AutoCAD Drawing
Scale
5km 0 5 10km
Sunamganj
9.78
-0.05
9.73
Companiganj
12.11
Gowainghat
12.42
Sarighat
14.07
Chhatak
11.15
Salutikar
11.25
Gobindaganj
11.25
Surma Offtake
Sylhet
11.86
11.94
Khajanchi
10.88
Kaliajuri
9.08
-0.50
8.58
Itna
8.72
0.47
8.25
Ajmiriganj
8.45
Markuli
8.64
-0.13
8.51
Sherpur
9.41
Manumukh
10.08
Maulavi Bazar
13.46
Fenchuganj
11.37
Jagannathpur
Tajpur
Surma R
Nawa R
Baulai R
Kangsa R
Piyain R
Mora Surma R
Dahuka R
Naljur R
Madhabpur K
Bhatta K
Khajanchi N
Bahia N
Barbhanga N
Itakhola R
Kushiyara R
Sadipur K
Kalni R
Darain R
Baulai or Dhanu R
Kamar khali R
Kurkuchi R
Juri R
Sonai-Bardal R
To Kanairghat
To Sheola
FILE: NERP-163.DWG

Figure 11

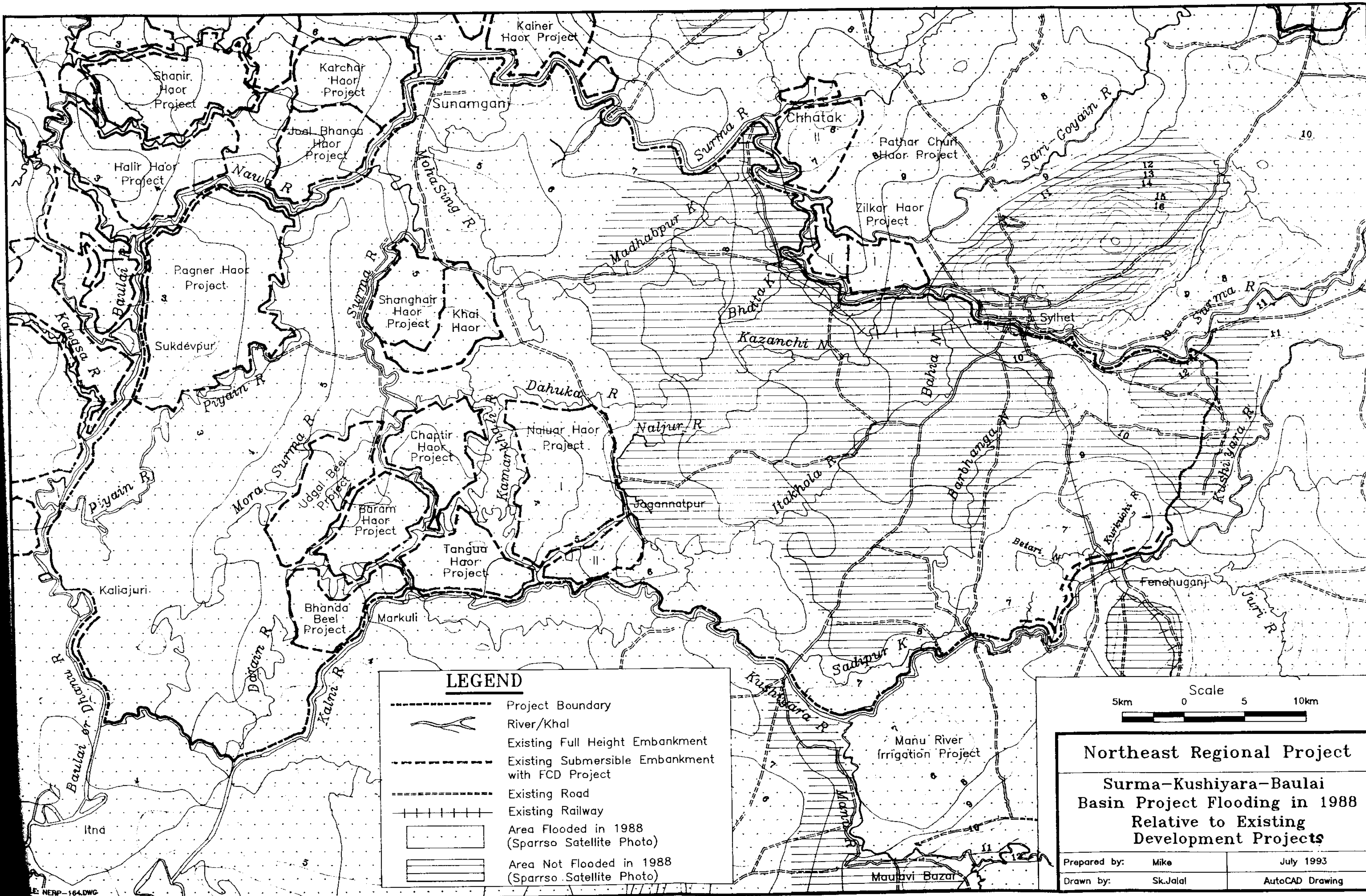
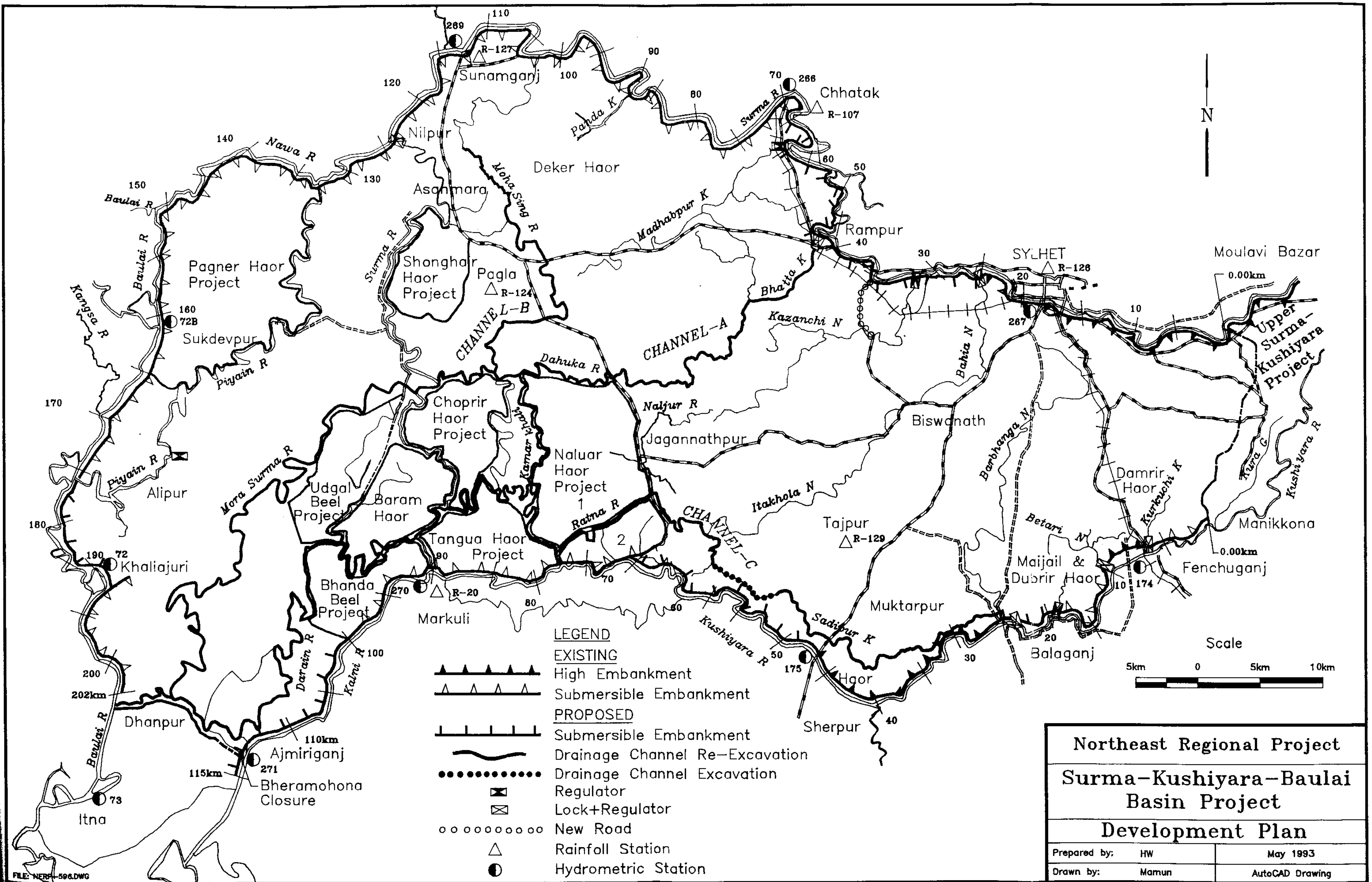
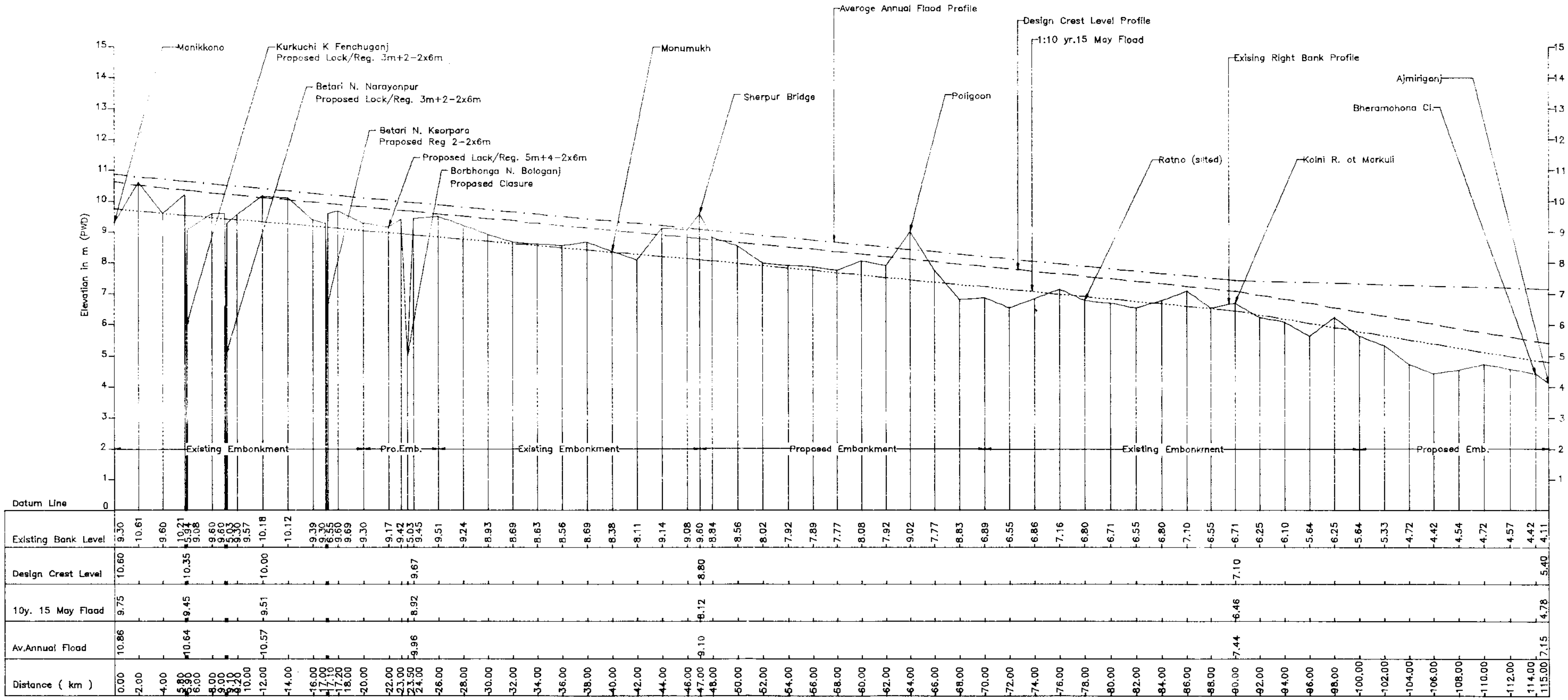

Kalner Haor Project
Karchar Haor Project
Shanir Haor Project
Sunamganj
Chhatak
Joal Bhanga Haor Project
Halir Haor Project
Pathar Churi Haor Project
Sari-Goyain R
Surma R
Nawa R
Moha Sing R
Zilkar Haor Project
Madhabpur K
Pagner Haor Project
Baulai R
Shanghair Haor Project
Khai Haor
Bhatta K
Sylhet
Kazanchi N
Kangsa R
Sukdevpur
Piyain R
Dahuka R
Bahia N
Chaptir Haor Project
Naluar Haor Project
Naljur R
Mora Surma R
Udgal Beel Project
Kamarkhali R
Itakhola R
Barbhanga N
Kushiyara R
Baram Haor Project
Jagannatpur
Tangua Haor Project
Betari N
Kurkuchi R
Fenchuganj
Kaliajuri
Bhanda Beel Project
Markuli
Juri R
Dhalai R
Sadipur K
Kalni R
Baulai or Dhanu R
Manu River Irrigation Project
Manu R
Itna
Maulavi Bazar
LEGEND
Project Boundary
River/Khal
Existing Full Height Embankment
Existing Submersible Embankment with FCD Project
Existing Road
Existing Railway
Area Flooded in 1988 (Sparrso Satellite Photo)
Area Not Flooded in 1988 (Sparrso Satellite Photo)
Scale
5km 0 5 10km
Northeast Regional Project
Surma-Kushiyara-Baulai Basin Project Flooding in 1988 Relative to Existing Development Projects
Prepared by: Mike
July 1993
Drawn by: Sk.Jalal
AutoCAD Drawing
FILE: NERP-164.DWG

Figure 12



Northeast Regional Project	
Surma-Kushiyara-Baulai Basin Project	
Development Plan	
Prepared by: HW	May 1993
Drawn by: Mamun	AutoCAD Drawing

Figure 13



KUSHIYARA-KALNI RIGHT EMBANKMENT PROFILE

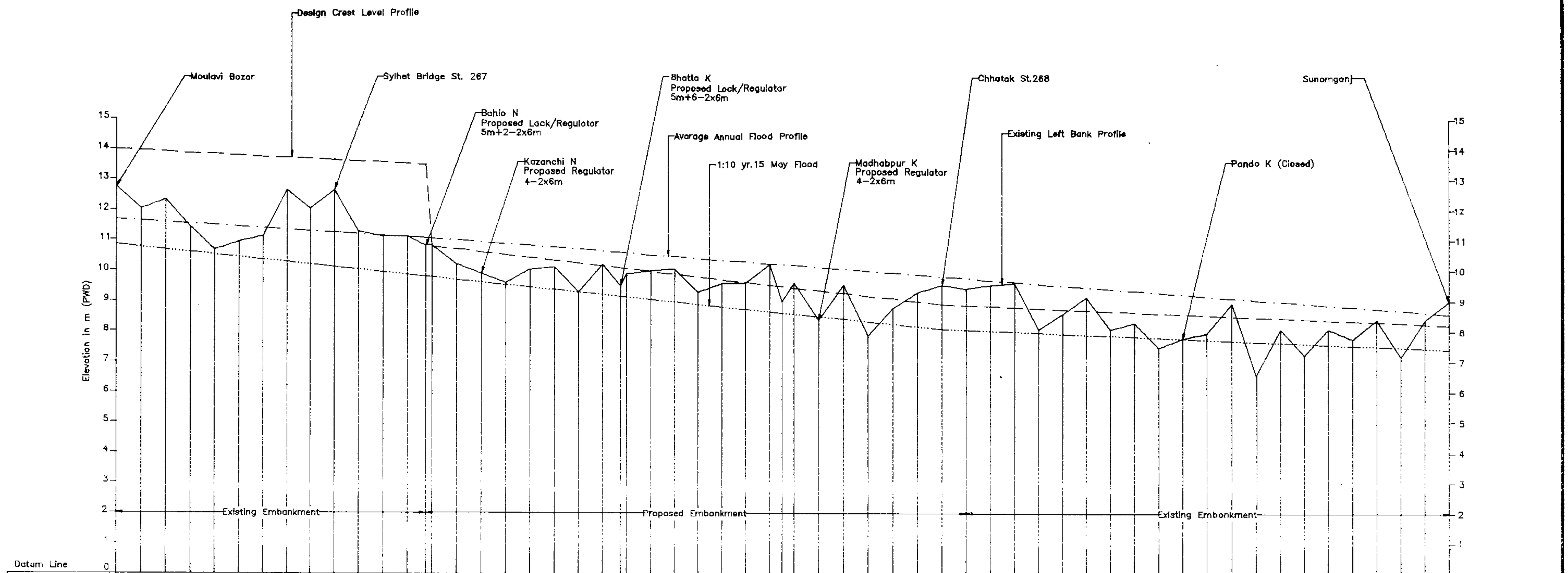
Northeast Regional Project

Kushiyara-Kalni Right Embankment

Prepared by:	H.Werszke	June 1993	
Drawn by:	Sk. Jalal	AutoCAD Drawing	

FILE: NERP-147.DWG

Figure 14a



Distance (km)	Existing Bank Level	Design Crest Level	10y. 15 May Flood	Av.Annual Flood
0.00	12.77	14.00	10.85	11.69
2.00	12.04			
4.00	12.34			
6.00	11.43			
8.00	10.67			
10.00	10.64			
12.00	11.13			
14.00	12.65			
16.00	12.04			
18.00	12.65	13.65	10.12	11.25
20.00	11.28			
22.00	11.13			
24.00	11.13			
25.50	10.82	13.50	9.81	11.08
26.00	10.82	10.80		
28.00	10.21			
30.00	9.91			
32.00	9.60			
34.00	10.06			
36.00	10.12			
38.00	9.30			
40.00	10.21			
41.50	9.50			
42.00	9.91			
44.00	10.00			
46.00	10.06			
48.00	9.30			
50.00	9.60			
52.00	9.60			
54.00	10.21			
55.00	8.99			
56.00	9.60			
58.00	8.38			
60.00	9.54			
62.00	7.86			
64.00	8.78			
66.00	9.30			
68.00	9.54	8.90	8.08	10.03
70.00	9.42			
72.00	9.54			
74.00	9.60			
76.00	8.08			
78.00	8.60			
80.00	9.14			
82.00	8.08			
84.00	8.29			
86.00	7.47			
88.00	7.77			
90.00	7.96			
92.00	8.93			
94.00	6.55			
96.00	8.08			
98.00	7.22			
100.00	8.08			
102.00	7.74			
104.00	8.38			
106.00	7.16			
108.00	8.38			
110.00	8.99	8.20	7.40	8.56

SURMA-NAWA-BAULAI LEFT EMBANKMENT PROFILE

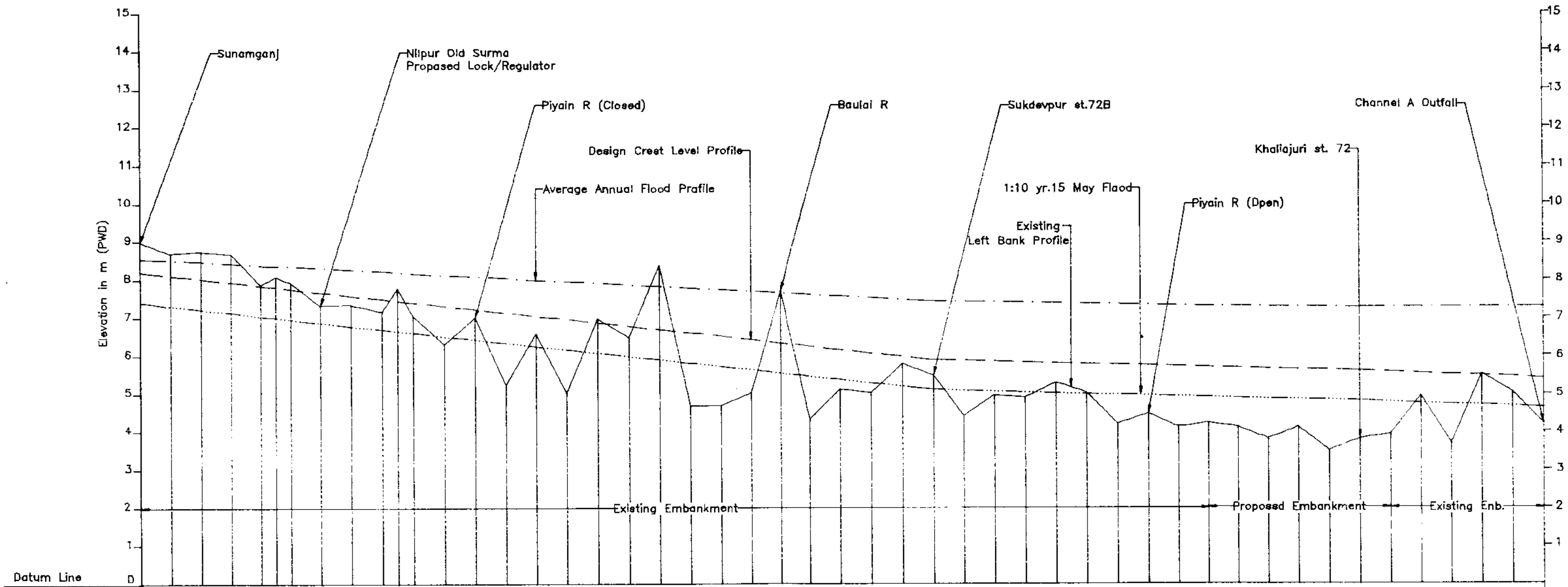
Northeast Regional Project

Surma-Nawa-Baulai
Left Embankment

Prepared by:	H.Werszke	June 1993
Drawn by:	Sk.Jalal	AutoCAD Drawing

FILE: NERP-14B.DWG

Figure 14b

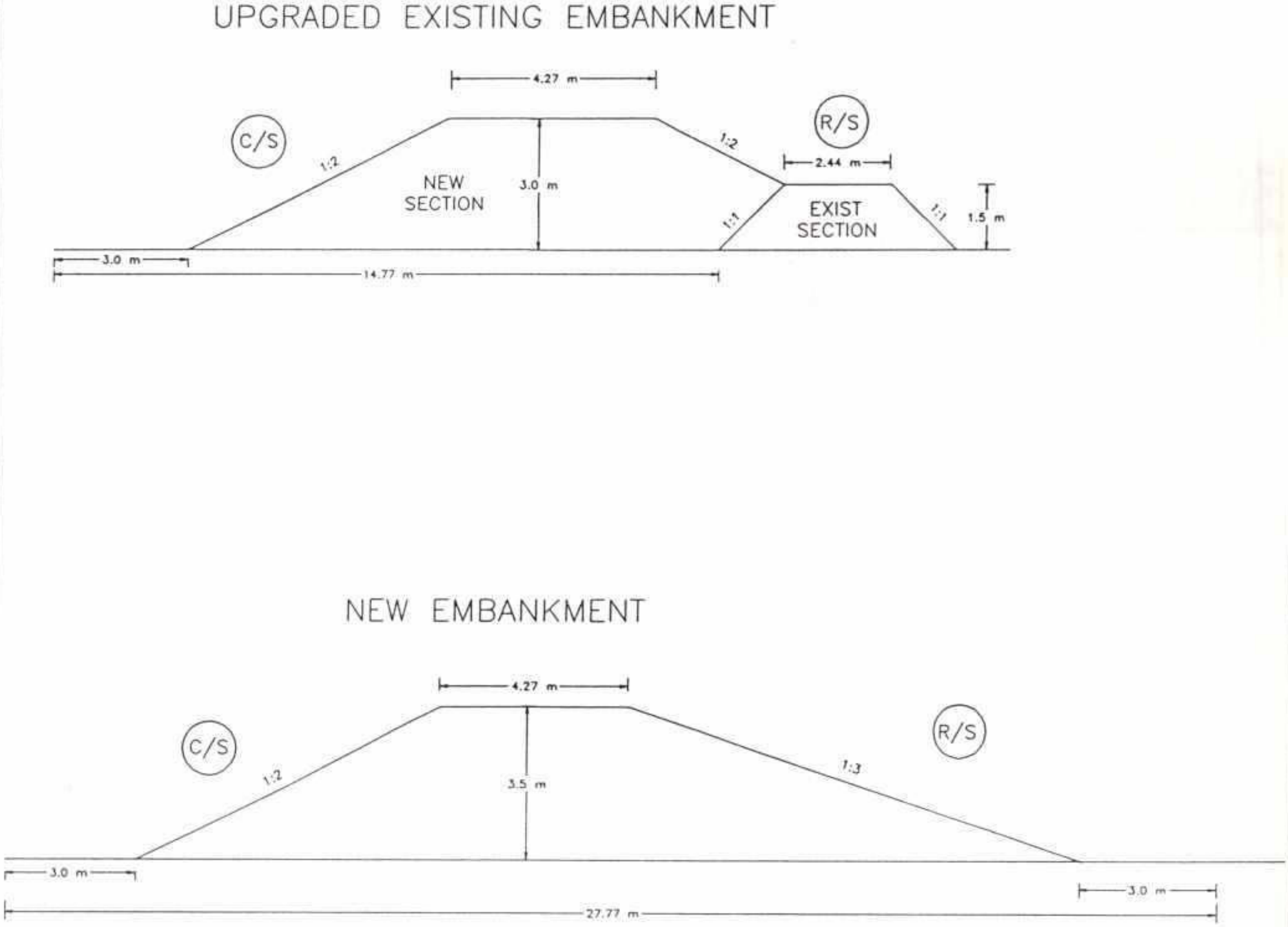


Distance (km)	Existing Bank Level	Design Crest Level	10y. 15 May Flood	Av.Annual Flood
110.00	8.99	8.20	7.40	8.56
112.00	8.96			
114.00	8.75			
116.00	8.69			
118.00	7.86			
119.00	8.08			
120.00	7.92			
122.00	7.32			
124.00	7.35			
126.00	7.16			
127.00	7.77			
128.00	7.04			
130.00	6.31			
132.00	7.01			
134.00	5.24			
136.00	6.58			
138.00	5.03			
140.00	6.98			
142.00	6.49			
144.00	8.38			
146.00	4.66			
148.00	4.69			
150.00	5.03			
152.00	7.71			
154.00	4.33			
156.00	5.12			
158.00	5.03			
160.00	5.79			
162.00	5.49	5.90	5.11	7.44
164.00	4.42			
166.00	4.97			
168.00	4.91			
170.00	5.30			
172.00	5.03			
174.00	4.21			
176.00	4.48			
168.00	4.11			
180.00	4.24			
182.00	4.11			
184.00	3.81			
186.00	4.11			
188.00	3.51			
190.00	3.81	5.60	4.81	7.26
192.00	3.93			
194.00	4.94			
196.00	3.69			
198.00	5.52			
200.00	5.03			
202.00	4.21	5.40	4.63	7.27

SURMA-NAWA-BAULAI LEFT EMBANKMENT PROFILE

Northeast Regional Project	
Surma-Nawa-Baulai Left Embankment	
Prepared by: H.Werszko	June 1993
Drawn by: Sk.Jalal	AutoCAD Drawing

FILE: NERP-149.DWG



Northeast Regional Project

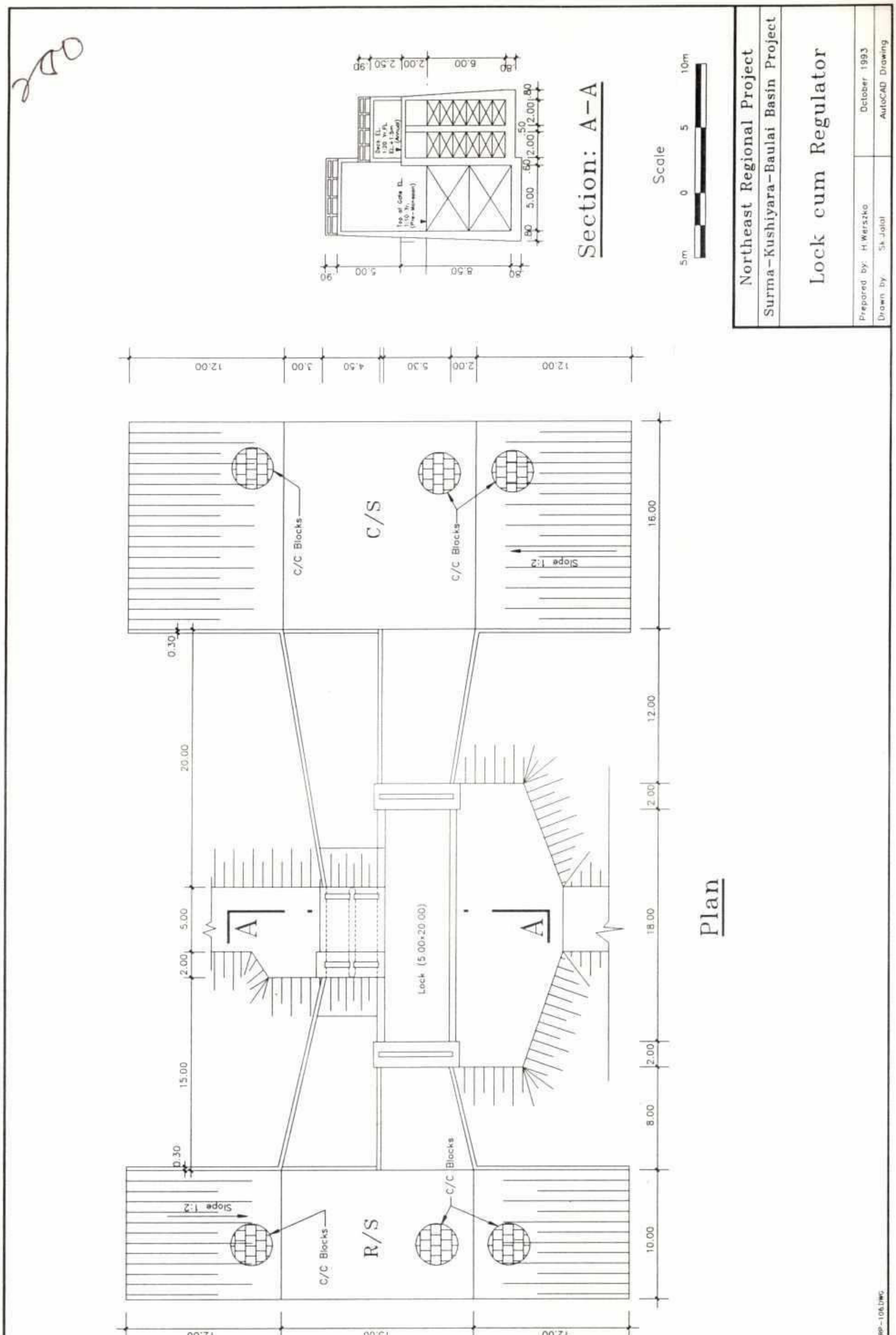
Surma-Kushiyara-Baulai

Typical Cross Section
of Flood Embankments

Prepared by: HW/Nasim	March 1993

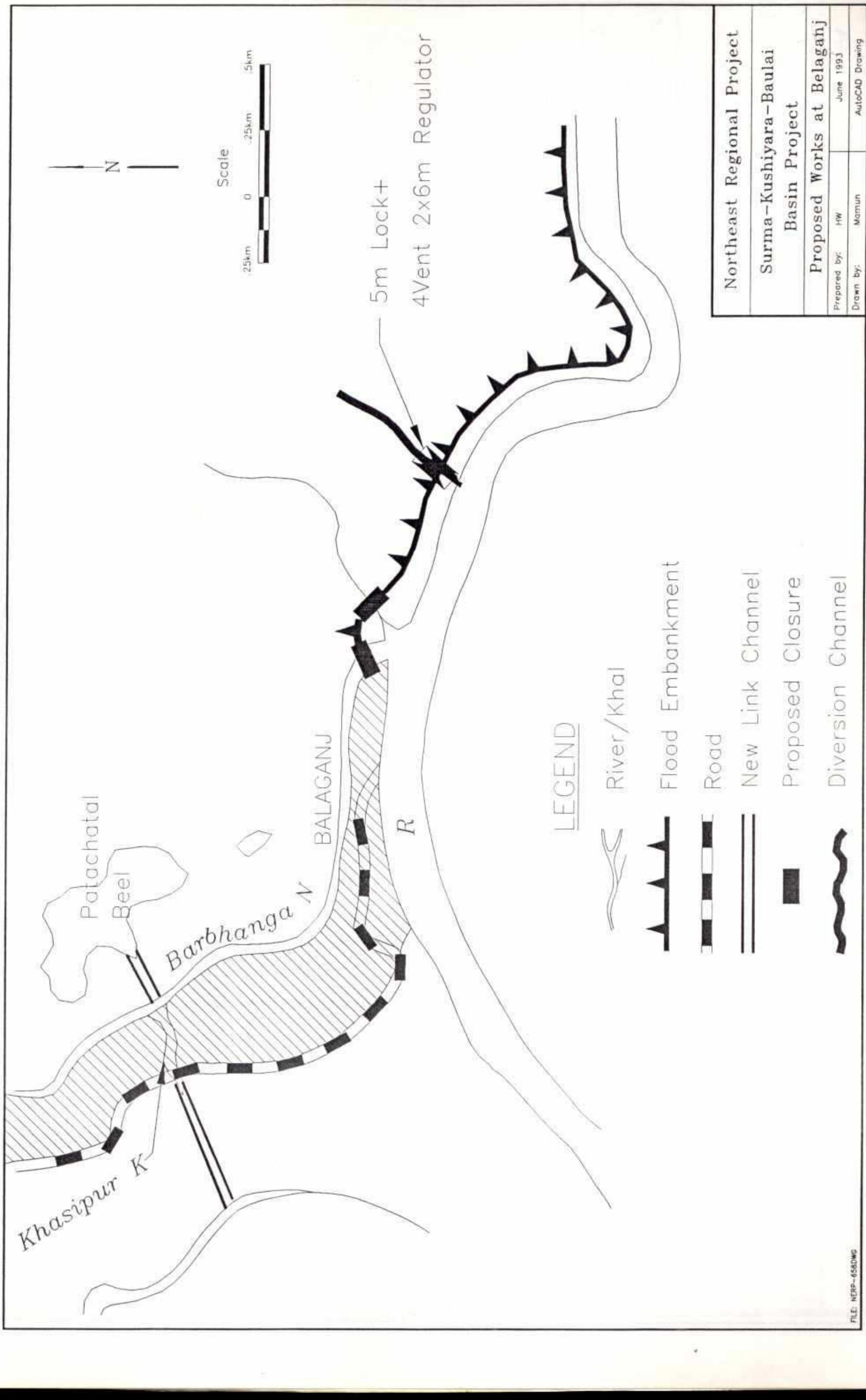
FILE: HENRY.DWG

Figure 16

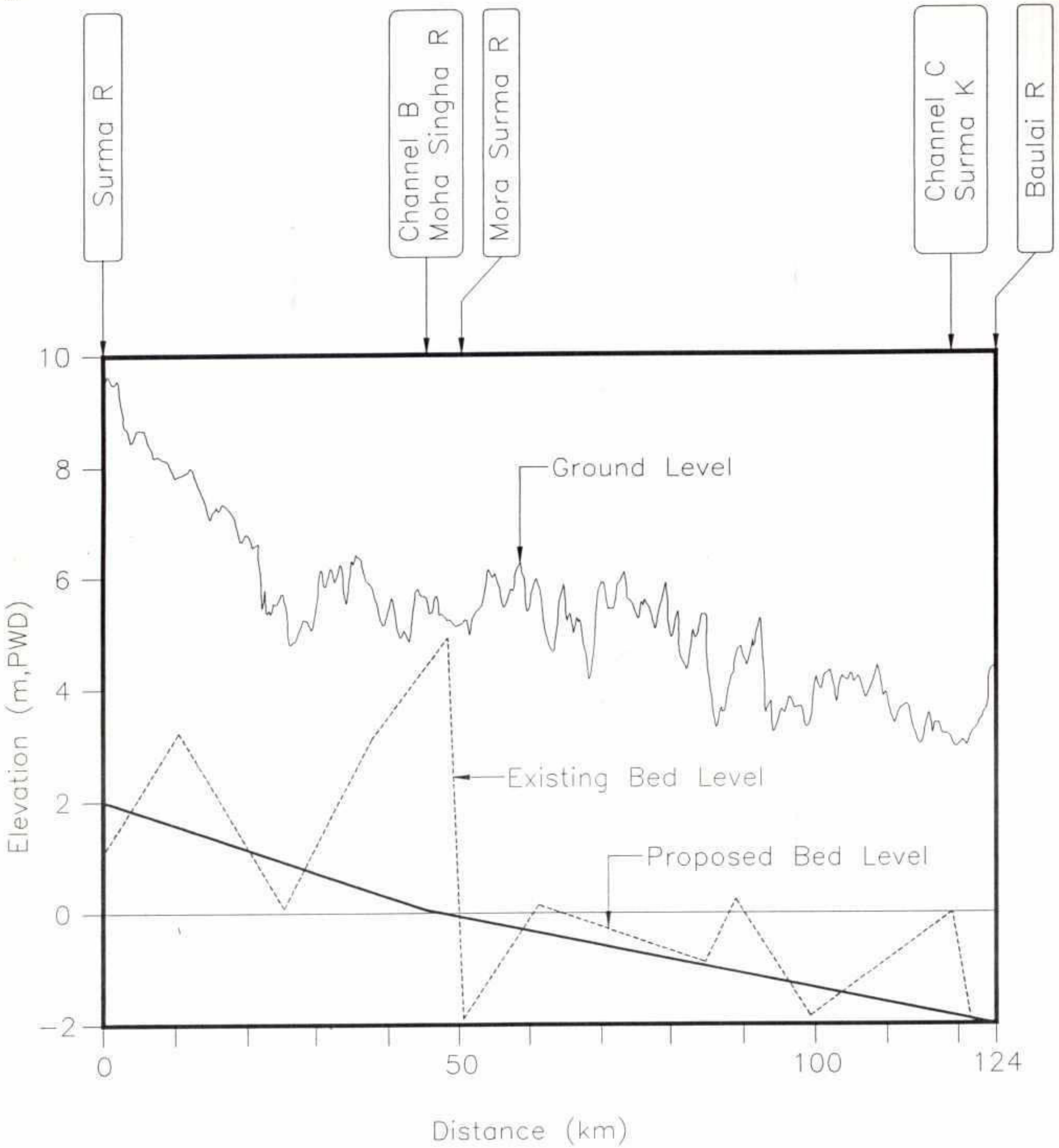


Northeast Regional Project
Surma-Kushiyara-Baulai Basin Project
Lock cum Regulator
Prepared by: H.Werszko
October 1993
Drawn by: Sk Jalal
AutoCAD Drawing
Section: A-A
Scale
Plan
C/S
R/S
C/C Blocks
Slope 1:2
Lock (5.00x20.00)

Figure 17



N
Scale
25km
0
.25km
.5km
5m Lock+
4Vent 2x6m Regulator
Patachatal
Beel
Barbhanga N
BALAGANJ
R
Khasipur K
LEGEND
River/Khal
Flood Embankment
Road
New Link Channel
Proposed Closure
Diversion Channel
Northeast Regional Project
Surma-Kushiyara-Baulai
Basin Project
Proposed Works at Belaganj
Prepared by: HW
June 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: NERP-658DWG

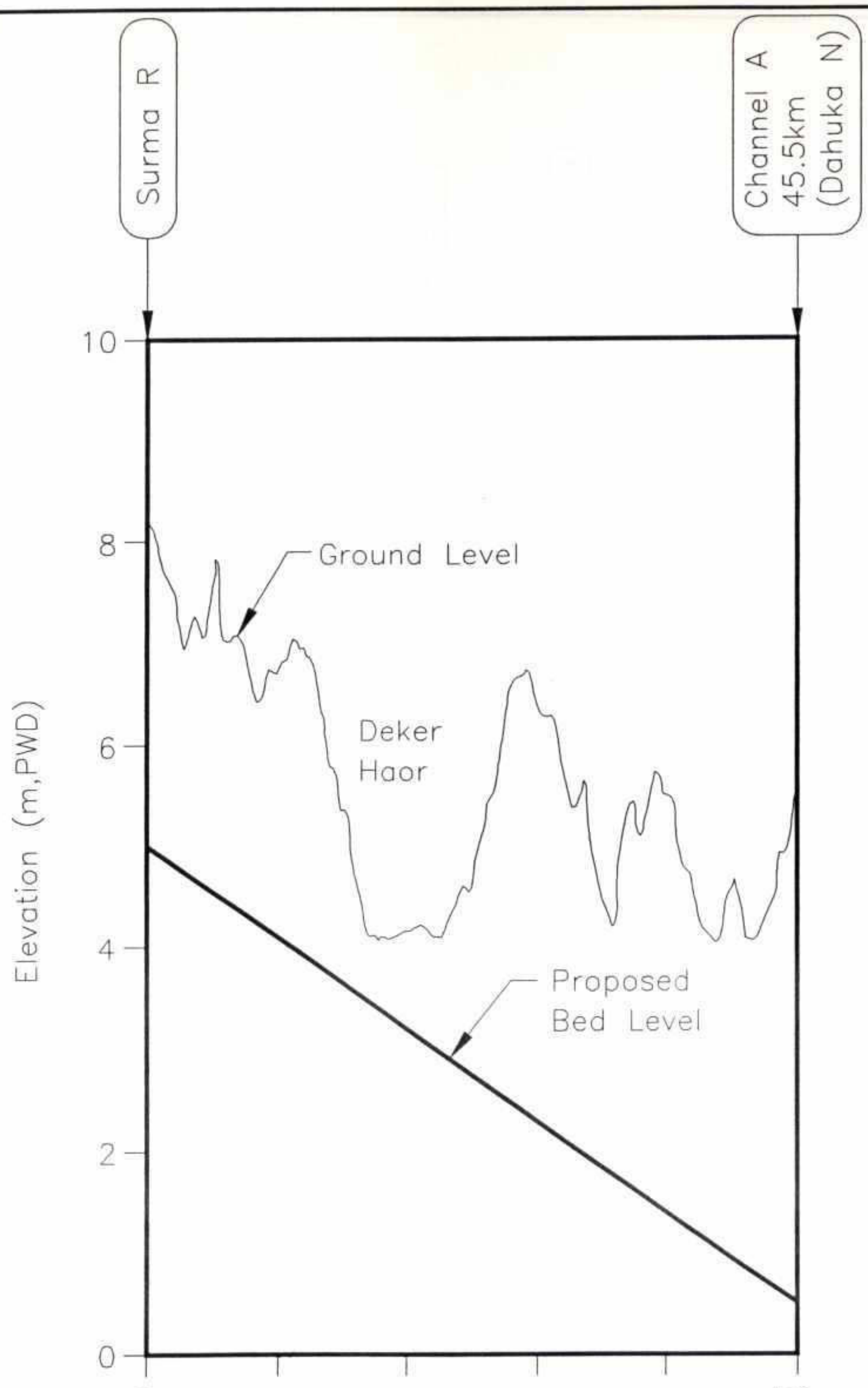


Northeast Regional Project		
Channel A Longitudinal Profile		
Prepared by:	H.Werszko	November 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-698.DWG

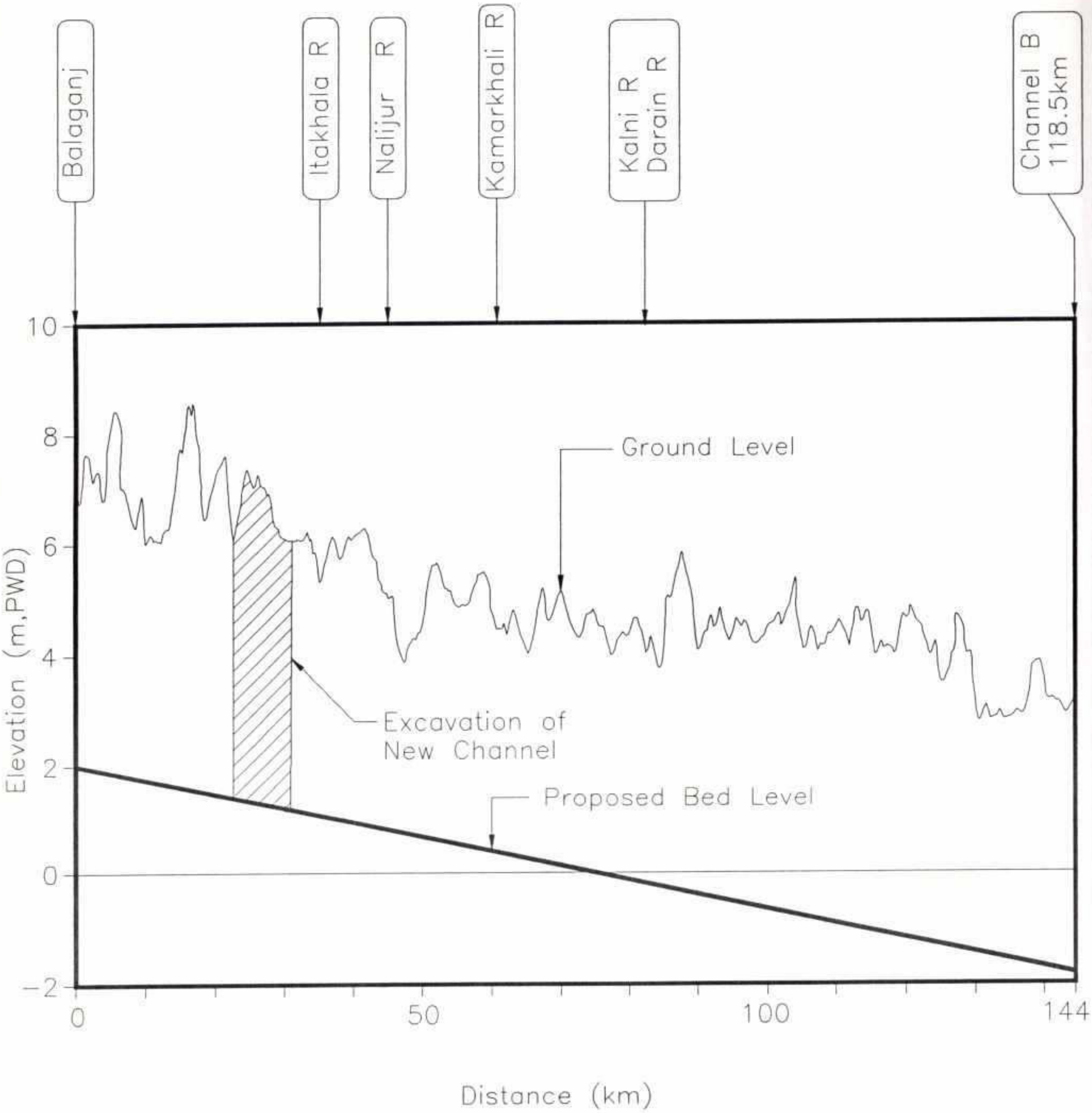
Figure 19

226



Northeast Regional Project		
Channel B Longitudinal Profile		
Prepared by:	H.Werszko	November 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-697.DWG



Northeast Regional Project

Channel C
Longitudinal Profile

Prepared by:	H.Werszke	November 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: NERP-698.DWG