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)

FISHERIES ENGINEERING MEASURES

Draft Final
December 1993

Shawinigan Lavalin (1991) Inc.
Northwest Hydraulic Consultants

in association with

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

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ACRONYMS AND ABBREVIATIONS

BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agriculture Research Institute
BBS	Bangladesh Bureau of Statistics
BDR	Bangladesh Rifles
BFRSS	Bangladesh Fisheries Resource System Survey
BJRI	Bangladesh Jute Research Institute
BRDB	Bangladesh Rural Development Board
BWDB	Bangladesh Water Development Board
DAE	Department of Agricultural Extension
DOF	Department of Fisheries
DPHE	Department of Public Health Engineering
DTW	Deep Tube Well
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environmental Management Plan
EPWAPDA	East Pakistan Water and Power Development Agency
ERR	Economic Rate of Return
FAP	Flood Action Plan
FCD/I	Flood Control, Drainage and Irrigation
FFW	Food for Work
FPCO	Flood Plan Coordination Organization
FRI	Fisheries Research Institute
FW	Future With project scenario
FWO	Future Without project scenario
GOB	Government of Bangladesh
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
MAF	Maximum Area Flooded
MPO	Master Planning Organization
MSY	Maximum Sustainable Yield
NERP	Northeast Regional Water Management Project
NFMP	New Fisheries Management Policy
NGO	Non-governmental organization
NHC	Northwest Hydraulic Consultants
NPV	Net Present Value
PD	Person-day
PDB	Power Development Board
PWD	Public Works Department
RHD	Roads and Highways Department
RCC	Reinforced concrete
SLI	SNC-Lavalin International
SRTI	Sugarcane Research and Training Institutes
STW	Shallow Tube well

US $1 = Tk 38

EXECUTIVE SUMMARY

The purpose of the initiative described here is to maintain and improve fisheries habitat through structural measures incorporated into new and existing FCDI projects, or built as stand-alone fisheries projects. Specifically, maintain or re-establish migration routes by providing fish pass structures in embankments; and protect selected *beels* from sedimentation and increase *beel* water storage by constructing protective embankments.

Traditionally, water resources infrastructure on the floodplain has been oriented solely towards improving agriculture. In the process, the openwater fishery has suffered negative impacts in the form of reduced floodplain and *beel* habitat, delay of flood onset (and therefore of spawning activity), and closure of fish migration routes at embankments, which in some cases has eliminated critical access between floodplain, *beel* and river habitats.

New and existing FCDI projects can be made less inimical to fish by providing fish passes at key points in embankments, and, where appropriate, by providing protective embankments, with structures at outfall channels, around selected *beels* to increase water volume and decrease sediment deposition. Fish passes (a vertical slot design appears most appropriate) will first require a pilot project to verify designs and impacts.

Such measures have already been incorporated in many of the new FCDI initiatives proposed under NERP, and are included in costs for those projects. For example, the Kushiyara-Bijna Interbasin Development Project contains a *beel* bunding component.

Costs estimated at US$ 7.7 million would cover provision the package of measures identified within this prefeasibility study which includes construction of 27 fish passes and construction of beel embankments/structures around 36 key beels and development of 100 community beels within existing FCD/I projects. It should be noted, however, that these measures could be introduced at any scale and in any combination and that the estimated cost of a single fish pass structure is US$ 160,000; the estimated cost of developing a single key beel is US$ 58,000 and a community beel is US$ 12,500. These projects would be developed jointly by BWDB and DOF.

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

Haor basin (Sylhet Depression)	6000 sq km
Lowland floodplains	13260 sq km
Piedmont floodplains	960 sq km
Alluvial fans	1490 sq km
TOTAL (Upper Meghna River floodplain)	21710 sq km
Catchment in India	45574 sq km
Total river channel lengths	2150 km
River channel surface area	832 sq km
- Upper Meghna River	336 sq km
- other rivers	496 sq km
Number of beels	6149
Total area of beels	635 sq km

1.2 Scope and Methodology

This is a study that was undertaken to a pre-feasibility level over a period of several months in 1993. The study team consisted of three fisheries specialists. Additional analytical support was provided by a fisheries engineering design specialist, a water resources planner and an economist.

1.3 Report Layout

A description of the biophysical features of the project area is provided in Chapter 2. Chapter 3 describes the current status of fisheries production including a summary of the impacts of FCD/I projects. Chapter 4 briefly reviews previous studies directed towards evaluating FCD/I impacts on the fisheries resources and Chapter 5 lists trends which are occurring and which will continue if no interventions are made. Chapter 7 provides an analysis of the proposed project. The annexes consist of detailed information to support the main body of the report.

2. BIOPHYSICAL DESCRIPTION

2.1 Location

The proposed fisheries engineering measures would impacts throughout a gross area of 21,710 km^2 in the northeastern part of Bangladesh, between latitude 23° 30' and 25° 15' N, and longitude 90° 00' and 92° 30' E. The project region is approximately bordered by the Indian frontier in the north, east and south, and the Old Brahmaputra River channel to the west.

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 selected BWDB rain gauges in the area. 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.

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 area as a whole is best represented by data for Sylhet. Data are available for 1957-91 (35 years). 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 arises.

2.3 Physiography

The topography of the Northeast region consists of a large central depression (Sylhet Depression) flanked by lowland floodplains, then gently sloping piedmont floodplains, and bordered distally by alluvial fans, terraces and uplands extending into India. Approximately 25% of the total region area of 24,180 sq km lies below 5 m elevation and 50% lies below 8 m elevation. Four landforms with a total area of 21,710 sq km are liable to flooding, and these compromise the Upper Meghna River floodplain (senso lato). The Sylhet Depression is a bowl-shaped basin. Almost all land is in this unit is below 8 m (PWD datum). The depression is deeply flooded during the monsoon to depths of 5 m. The Lowland Floodplains are the deposition and erosion arenas of the major rivers of the region. Land elevations range between 9 and 16 m on the Surma/Kushiyara floodplain, 9 and 22 m on the Old Brahmaputra floodplain and less than 7 m on the Meghna floodplain. The Piedmont Floodplains are found along tributary streams in the southeastern part of the region. Land elevations range between 9 and 24 m. Alluvial fans are found along the foot of the Meghalaya Plateau in the northern part of the region. Land elevations range from 12 to 16 m in the west and from 9 to 11 m in the east.

The uppermost part of the Upper Meghna River floodplain extends into India as part of the Barak River catchment. It is called the Cachar Plain and has a surface area of less than 1000 sq km.

Terraces occur along the western edge of the region that are not inundated and these terraces confine portions of the Old Brahmaputra River. Land elevations range between 8 and 10 m. Uplands occur as outliers from the Tripura Hills in the eastern part of the region. Elevations reach 30 m.

2.4 Hydrology

2.4.1 Runoff Patterns

The region is "water-rich". Because of its special topographical and hydrological conditions it can be regarded as "unique" in Bangladesh. Most of the region is a self-contained drainage basin (with catchment extending into India) separate and distinct from the other large river systems of Bangladesh (Jamuna, Padma). The region is drained by a single major river channel in the southwest: the Upper Meghna River. This river receives inflow from two large tributaries, the Baulai River coming from the north, and the Kushiyara River from the northeast. The Baulai itself is formed by the confluence of the Kangsha River (which flows from west to east) and the Surma River (which flows east to west). The Surma and Kushiyara share a common origin at the bifurcation of the Barak River, which flows into Bangladesh from India at the extreme eastern part of the region at Amalshid. The Kangsha, Surma and Kushiyara receive lower order tributary inflows from numerous small rivers and streams draining the Meghalaya and Tripura Hills, such as the Luba, Jhalukhali, Manu and Khowai Rivers. The western boundary of the region is defined by the Old Brahmaputra channel, which no longer conducts major discharge volumes due to siltation at its origin. The current meagre bank overspill of the Old Brahmaputra has reduced the water supply of rivers to the east (such as the Mogra) which discharge into the Sylhet Depression. The region is crisscrossed by numerous khals and silted up old river beds which conduct drainage flows rather than mainstream discharges.

All external streamflow into the region comes from 21 catchments that extend into India. They fall into three groups:

- Meghalaya River catchments which discharge southward into the Kangsha and Surma. Their drainage area is 13,466 km^2.

- Barak River basin which discharges westward into the Surma and Kushiyara at Amalshid on the Indo-Bangladesh border. Drainage area is 25,263 km^2.

- Tripura River catchments which discharge northward into the Kushiyara. Their drainage area is 6,845 km^2.

These Indian catchments produce about 60.5% of the total water supply of the region, mostly in the form of flash floods from April to September. The flash floods of the Meghalaya are particularly ferocious. Mean monthly streamflow entering from India varies from over 7,000 m^3/sec in July to a low of about 220 m^3/sec in February. Streamflow generated directly within the region from rainfall and ground water discharge constitutes a significant part of total streamflow (between 30% and 80% of the inflow from India during the February to April dry season months).

The total surface area of water in river channels during the dry season is 832 km^2. The Upper Meghna River surface area is 336 km^2 and other rivers in greater Sylhet and Mymensingh Districts cover 496 km^2.

2.4.2 Flooding

During the rainy season, all rivers overflow on to the lateral floodplain, except for those portions of the Surma, Kushiyara, Khowai, Manu and Kangsha which have full flood embankments. Low order affluent tributaries flowing into Bangladesh from the Indian hills, such as the Luba River, become spate streams, and attract spawning migrations of carp and other species.

The annual flood pattern has two distinct phases in the region:

- The early flood (pre-monsoon) phase occurs during the early monsoon season when river and beel water levels are relatively low. It can begin as early as April and extend as late as June. Flash floods occurring in the piedmont rivers flowing from India spill water into haors through khals and as river overbank spill. Unembanked haors thus act to attenuate flood conditions in rivers (conversely, embanking of haors tends to increase river water levels and accentuates flooding in unembanked hoars or further downstream). When the flood recedes, water stored in the haors drains back into the rivers.

- The deeply flooded (monsoon) phase begins when backwater from the Meghna system causes deep flooding throughout the Sylhet depression and extends into the haor areas of the Surma-Kushiyara floodplain. The haor areas remain as a large deeply flooded "lake" until the Meghna levels recede at the end of the monsoon season.

2.4.3 Drainage

Post-monsoon drainage of the entire region is via a single outlet channel, the Upper Meghna River. Tidal back water of the Upper Meghna causes a reduction in current velocity and sedimentation of its channel. This creates a bottleneck at Bhairab Bazar and impedes post-monsoon drainage of the floodplain. During the dry season the Upper Meghna River, the Baulai, the Surma as far as Chhatak and portions of the Kushiyara have greater water depths (although discharge is minimal) and are used by large metal hulled transport boats which come up from Bhairab Bazar. The greater water depths in these rivers during the dry season and the existence of deep scour holes (*duars*), make them important dry season overwintering refuge habitats for the brood stock of some commercially important species, particularly major carps and large catfish. In contrast, the upper parts of the Surma (upstream from Chhatak), Kushiyara and Kangsha conduct little discharge during the dry season and water depths can drop as low as <1.0 m in some places. It is therefore important to distinguish between the tidally-influenced and non-tidally-influenced section of major rivers. Parts of the former's river beds are below sea level, especially the *duars,* and can be thought of as arms of the sea. Preliminary computer simulations indicate that even without affluent discharge from the catchments and without direct rainfall on the region, approximately one-third of the region would still be inundated annually due to tidal backing-up of the Upper Meghna into the Sylhet Depression. This has major implications for the long term economic prospects of the region - particularly, that fish production would appear to have an assured and substantial role in the region's long term economic production endowments and possibilities.

2. 4. 4 Water Bodies

Open water bodies

Of the total surface area of the region of 24,180 km^2, approximately 90% (21,710 km^2) is occupied by the four landform units which are subject to annual flooding (Sylhet Depression, lowland floodplains, piedmont floodplains, alluvial fans). Together these form the larger floodplain of the Upper Meghna River. The extent and duration of flooding varies from year to year depending on flood intensity (the result of rainfall and river discharges).

Flood land elevation variations are typically very small, and the very flat river gradients have led to the formation of a dominant morphological feature in the region called *haors*. Essentially, a haor is a small internal drainage basin located on low-lying land between two or more rivers. Haors form as a result of sediment-laden water spilling over the river banks and building up natural levees which eventually enclose the land. Characteristically, there is one or more small lakes *(beels)*, at the centre of the haor. The beels are usually connected to the rivers surrounding the haor by one or more drainage channels *(khals)*. Haors are particularly prevalent in the region, and may be unique to it. They occur throughout the region but are most numerous in the topographical trough running east-west along the foot of the Shillong plateau and containing the flood plains of the Surma and Kangsha, and on the flood plains of the Baulai and Kushiyara. A few are also found on the flood plain of the Barak river in the contiguous Cachar district of Assam, India. They are rarely, if ever, found on lands having an elevation greater than 10 m above sea level; this indicates that very flat river gradients are essential to their formation.

Characteristically, haors fill with water during the pre-monsoon and early monsoon periods, and empty during the early dry season. During the late monsoon they are essentially full, and in the late dry season they are essentially empty. When empty in the late dry season (February-March) the beels may be dry, or nearly so, depending on their bed elevation relative to the ground water table, the elevation of which is partly controlled by water levels in adjacent rivers. In this condition there is very little, if any, exchange of water between the haor and its surroundings as rainfall, evaporation, spill or seepage. During filling (April-July) water enters the haor as rainfall, as overbank spill from adjacent rivers, and by seepage of river water through the ground. All this water collects at the centre of the haor to form one or more beels, depending on the micro-topography of the haor bed. In the late monsoon season (August-September) the entire haor is usually flooded, and the river levees are usually completely submerged. The depth of inundation is commonly as much as 6 m above the haor bed. During emptying (October-January), water leaves the haor as evaporation, and by seepage through the ground back to the rivers. Drainage will also occur through khals on the haor bed if these cut through the levees into the adjacent rivers. Depending on the intensity of the wet and dry seasons in any year and on the topography of a particular haor bed, filling and emptying may or may not be completed in some years.

The total number of beels in the region is 6,149. They cover 635 km^2 and have a mean size of 10 ha. Some 58% of the beels in the region are permanent, while 42% are seasonal, or temporary. Sunamganj District has the largest number of beels of any district in the region and in Bangladesh. About half are large (over 8 ha in area). About 400 are permanent. Of the remainder, 500 are likely to desiccate completely each year, and 500 might still retain some water at the end of the dry season.

Closed water bodies

There are about 0. 201 million ponds in the region with a total area of 18,700 ha. Many of these are borrow pits resulting from homestead site preparation. The DOF classifies ponds as cultured (49.1% by area), culturable (22. 8%) and derelict (28. 1%). Another important microfishery real estate are the borrow pits running along road embankments. These are owned by the Roads and Highways Department and are leased out for fishery purposes. Their water supply is dependent on river overspill flooding and rainfall, while their fish resource is dependent on movement of fish on to the floodplain during the monsoon season. The stocks of mainly miscellaneous species are exploited for subsistence and minor commercial sale. During the early dry season katha are installed to harvest the larger species. Borrow-pits are often subdivided by fish fences with basket traps or bunds. Later the entire pit may be drained to remove all fish. Borrow pits are vulnerable to water deficits. As many are < 1 m deep, they are prone to desiccation by the end of the dry season (if they have not previously been artificially drained, which is the usual practice when harvesting the fish). A constraint on improving the water storage capacity is that borrow pits cannot be excavated to deepen them because this might endanger the road embankment. Borrow pits created during the course of FCD/I construction works are owned by the BWDB and are also leased out for fish production by auction.

2. 5 Ecology and Swamp Forest

2. 5. 1 Floodplain Limnology and Water Quality

Although high turbidity due to silt and clay loads characterizes flood waters during the monsoon, the water gradually clears during flood recession. This allows good growth of algae and aquatic macrophytes in beels and some river stretches during the dry season. Apart from providing a source of food to secondary trophic producers, algae (*shawla*) in the form of periphyton also constitute the most important pathway for fixing of atmospheric nitrogen, upon which good yields of rice in the haors are partly dependent. In shallow rivers during the dry season (such as the Surma near Kanaighat), algae grows directly on the sandy river bed, as well as on the brush and bamboo used in kathas. Sometimes algal growth is excessive. In Halir Haor fishermen complain that it forms large mats at the bottom of beels which interfere with fish movement and nets.

Infestation and overgrowth of smaller water bodies with *kachuri pana* (Water hyacinth, Eichhornia crassipes) appears to be a problem almost everywhere. Some domestic uses (fertilizer, fuel, cattle feed) and fisheries (mat for covering katha) are made of kachuri pana, but extensive overgrowth depresses fish production. It lowers water quality, plankton production and dissolved oxygen content (which many species cannot tolerate), and interferes with fishnets, thus reducing catchability of the stocks. Water lettuce (Pistia stratoides) also occurs in the region but is not particularly abundant, and therefore not a pest.

Water buffalo are plentiful in some areas and spend much time wallowing in borrow pits. Their dung undoubtedly directly contributes to the fertility of water bodies. Cattle graze on fallow rice fields and pasture lands of haors during the dry season and cattle fattening is an important economic activity. The importance of cattle dung for increasing the productivity of flood lands is limited because much of it is collected and dried for use as fuel.

Some water quality problems exist in the region. Serious problems of water pollution exist in the Surma River due to discharge of effluent from the bleach kraft pulp mill at Chhatak, and in the Kushiyara due to the urea fertilizer plant at Fenchuganj (although the latter is now scheduled to be shut down). Increasing use of insecticides may be reducing environmental quality and affecting fish catches. Moderate use of fertilizers probably has a beneficial effect on fish production. Moreover, the roots and cut stems of rice plants also contribute after decomposition to the bioproductivity of the floodplain. Excessive eutrophication and deterioration in water quality due to these factors has also been recorded however.

2. 5. 2 Swamp Forest Trees

Historically, much of the region was covered with inundation resistant tree species and bushes. An Agricultural Officer from Kishoreganj has reportedly identified 21 species of flood tolerant tree species. Two species are dominant: *hijal* Barringtonia acutangula and *koroch* Pongamia pinnata. Others common trees are *mandair, mera* and *barun.* These species grow in many haors (especially in Sunamganj District), often in plantations or gardens. In addition to wetland trees, several water resistant herbs and grasses occurs in the region: *Nol Khagra* (Phragmites karka), *Tara* (Alpinia sp.), *Chailla* (Arundo donax), *Echor*, *Bon Tulshi* (Lippia geminata), *Phaloi* and *Kashya*

Information from various parts of the region indicate that *hijal/koroch* trees and plantations serve at least six environmental and economic functions:

- They serve as a wave break to protect homesteads during the flood season;
- They provide shade during the dry season;
- They are a source of fuel during the flood season (straw and cow dung is normally used during the dry season);
- They provide a source of income through sale of branches for katha;
- They create upland by enhancing sedimentation around the planted area; and
- They increase fish production.

Trees and bushes which become submerged during the monsoon apparently act like a natural katha. Beels with *hijal* are known to have much more fish present than beels without. *Hijal* can grow into a large tree, but most examples seen are short with a thick trunk. This is because the branches are coppiced periodically for use in pile fisheries.

Because of the various benefits that flood tolerant trees yield to fisheries, homestead protection, fuelwood and income, there is widespread interest in the region in afforestation at individual, and community levels.

Clearing land for rice culture has caused massive deforestation of wetland trees in the region. This constitutes a major and severe environmental modification of the region. About 19,968 km^2 (83%) of the region is under rice. Allowing for other crops such as tea and pineapples, it is likely that less than 5-10% of the region is still forested, and a portion of this is not original floodplain/wetland forest. Little relatively undisturbed floodplain forest remains in the region. This massive deforestation has meant a severe reduction in the environmental and economic functions that floodplain forests serve. Of particular concern are the benefits to fisheries. It is difficult to quantify lost production because of deforestation, but it seems likely that this has taken place (given the widespread opinion that fish abundance is higher around inundated tree stands). Shortages of *hijal* branches for *katha* raises the cost of fish production.

2. 6 Sedimentation

Because of their steep gradients, the piedmont affluent rivers arising in the Indian catchment area carry large quantities of sand, gravel and stone. Stone and gravel is deposited in the alluvial fan zones. Most of the sediment that is deposited on the floodplain is silty washload.

Sedimentation is occurring in various parts of the region and is a problem for both fisheries and agriculture. The northern part of the Sylhet Depression and the lower part of the Kushiyara River are the most severely affected. Infilling of beels reduces mean depth and cubic meter months of dry season aquatic habitat, and converts some beels from permanent to seasonal status. River duars are also being filled in. It is widely believed that this reduction in water volume and elimination of deeper water habitats is negatively impacting fish production.

Management of river sediments is a major constraint in the planning and design of water management projects in the region. Huge quantities of sand and silt are washed down from the hills in India due to deforestation. As a result, the downstream sections of rivers, haors, floodplains and beels are gradually silting up. The Upper Meghna River near Bhairabazar is the only outlet of the entire haor area. Slow drainage of the Upper Meghna at Bhairabazar is due to siltation and prevents flushing of sediment out of the region.

Sediment processes include:

- Formation of natural levees adjacent to the river channel and the characteristic basins and khals between rivers. An example of this is the Upper Surma/ Kushiyara system where levees have formed along side the river channels and the overflow collects within the intervening basin which is drained by Sada Khal in a direction more-or-less parallel to the main rivers.

- Braided channel pattern and periodic shifting of piedmont streams. These rivers exist in a "perched" condition in which the river beds are higher than the floodplain and therefore when the river overtops its banks it may experience a wholesale shift in location. An example is the Someswari River where the original course of the river has been substantially abandoned since the 1970s.

- Reduction in channel size and capacity in the downstream reaches. This is illustrated by the Khowai. Prior to embankment construction, the rivers' capacity decreased from 700 m^3/s at Ballah to 100 m^3/s near Habiganj due to overbank spill.

3. SETTLEMENT, DEVELOPMENT, AND RESOURCE MANAGEMENT

3.1 Human Resources

3.1.1 Land Use and Settlement Pattern

Land Use
Approximately 16,100 km^2 (74.2%) of the Upper Meghna floodplain is used for rice cultivation. The remaining floodplain area is covered with beels and rivers or is too deeply flooded during the monsoon to allow rice cultivation.

Settlements
Villages are mainly found along river levees and along road sides. Individual isolated homesteads on raised mounds are not common. Fishermen live in three types of community situations:

- Permanent fishing villages, where most or all of the inhabitants are involved in fishing;
- Permanent agricultural villages, where only a minor proportion of inhabitants are involved in commercial fishing (although many more may carry out occasional subsistence fishing);
- Temporary fishing camps *(Khola)* situated near beels in haors and in deeply flooded areas. Typically fishermen live here for only five months during the dry season, and move back to permanent villages during the monsoon season. The temporary buildings are re-erected each year after the flood recedes using materials brought in from outside.

3.1.2 Demographic Characteristics

The total population of the Upper Meghna floodplain and adjacent uplands in the Northeast Bangladesh region is estimated to be 17. 66 million of whom 48. 78% are female. The gender ratio is calculated to be 105 (males to 100 females). The total households are estimated to be 4.92 million within 21,114 villages. The population increased by 23% between 1981 and 1991.

The cohort distribution for males is: 32.5% are below 10 years of age, 61.2% are between 15 and 59 years of age, and 6.3% are above 60 years of age. The corresponding distribution for females is 34.1%, 60.7%, and 5.2%.

The average population density is 730 persons per km^2, with density ranging from a maximum of 6019 persons per km^2 in Bandar to 235 persons per km^2 in Companiganj. The average household size in the area is estimated to be 5.34 persons.

3. 1. 3 Quality of Life Indicators

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

Literacy
In the project area the literacy rate is very low. According to the 1981 census, the literacy of the population at 5 years of age and above varied from 31.5% in Palash Thana to 9% in Companiganj Thana. The corresponding figures for females were 22. 2% and 3. 8% respectively for the same thanas. The rate appears to have increased significantly over the last 10 years. According to the 1991 census, the literacy rate for all people of the region is recorded as less than 20% for both male and female.

According to the 1981 census, school attendance in the project area for all children five to nine years of age varies from 39.7% in Beanibazar thana to 11.1% in Companiganj thana. Attendance for females in this age cohort in these two thanas varies from 36.6% to 8.3%, respectively. Attendance for all youths between the ages of five and 24 is 31.6% and 8.6% for these thanas while the corresponding attendance for females is 26.1% and 5.2%.

The situation is worse for the rural poor. They can not afford to send their children to school. Moreover, many villages have no primary schools. The average number of primary schools per 10,000 population is estimated to be 6. 39.

Access to Health Services
Each district has a district/sadar hospital and each thana has a thana health complex. Access to health services is generally limited for rural villagers and is out of reach of the poor. According to the Directorate General of Health Services (1992), there is one hospital for every 220,682 persons and one doctor for every 21,596 persons in the region. One hospital bed is meant for 5,256 people. The rate of immunization coverage of children below two years of age varies from 10% in Mymensingh thana to 65% in Golapganj thana (1990).

Rural Water Supply
DPHE (for 1991-92) reports the availability of one working tube well for 122 persons in the region. Most tube wells are located in the houses of the rich. This results in the poor having very limited access to potable water.

Sanitation
Sanitary latrines are more widely used in Moulvibazar and Sylhet Districts, the proportion of households possessing sanitary latrines being 33% and 29%, respectively. In most other districts in the region the proportion of households using sanitary latrines is less than 10%

From the available information it is not clear that permanent fishing villages differ substantially from agricultural villages and general rural norms in terms of quality of life/living conditions (health services, potable water, energy, roads, housing, electrification, child mortality, nutrition, life expectancy and so on). Hygienic conditions in *Kholas* appear to be better than in permanent villages, possibly because of the shortage of time for accumulation of refuse, annual flood flushing of the site, and greater care because of the need to reduce the vulnerability of the fish drying operations to rodents and other pests. In general fishing communities are extremely poor. The majority of fishermen are illiterate. Fishermen often do not want their sons to become

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fishermen. The value of education for getting better jobs is clearly recognized although many fishing families do not have access to schools. Low incomes prevent capital accumulation or expenditure on human development (ie education for children).

3. 1. 4 Employment and Wage Rates

Four general occupational categories within the production sector are recognizable (apart from caste/ethnic groupings):

- Professional fishermen, who earn their livelihood entirely from fishing. Under the NFMP, these are called "genuine fishermen".

- Part-time fishermen, who fish for only part of the year to supplement their income, and are engaged in other employment (agriculture and so on) during the rest of the year.

- Occasional fishermen, who fish irregularly, and mainly for subsistence rather than income.

- Fish farmers, who own ponds and operate at various levels of production intensity.

There are several castes of highly experienced Hindu fishermen, the most important being the *Koibarta*. These "traditional" or "genuine" fishermen in the project area are decreasing. However, fishing is now practised as a profession by many poor people, particularly during monsoon months when they can fish in open water. Such "non-traditional" fishermen are increasing and they are larger in number in the low lying beel areas. Many enter fisheries as a "last resort" because they are landless. Because of their marginal economic situation, their fishing practices are short-run, income-maximizing in nature, and not conservationistic. Production support industries include boat building and net making (artisanal hand weaving, factory mechanized weaving). In the post harvest sector employment categories include fish vendors/traders (wholesale and retail), processors (artisanal sun-drying, export factories), and transporters (collector boats, insulated trucks). Business investment interests include jalmohal leaseholders and moneylenders. During the dry season when there is no free access to fishery resources, many genuine fishermen have to work as fisheries wage labourers. In Hakaluki Haor, the fishermen work for leaseholders as wage labourers, getting paid Tk 20-25 per day. Fishermen receive no shares of the catch. But this employment is only during the dry season. Sometimes the leaseholder brings fishermen labourers from far away villages (possibly to undermine any strengthening of local labour organizational power). During the monsoon season, when the entire haor is flooded out, the fishermen are free to fish anywhere on the floodplain. They prefer the monsoon season because they are independent and can sell their catch directly at the market. It is during the flood months of June and October that seasonal labour absorption capacity peaks in fisheries. During the four months of the flood season, a fisherman can earn about Tk 40-50 per day selling his fish. During the dry season which lasts six months, fishery wage earning work for leaseholders is not continuous and pays only Tk 20-25 per day.

No reliable data exists on the numbers of persons employed in the fisheries sector in the region. Studies of many artisanal inland fisheries in different parts of the world has shown that limitations on the physical capacity of individual artisanal fishermen to handle their catch, as well as lack

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of efficient gear and adequate infrastructure, restrict output per commercial fisherman to about 1 to 4 tons per year. Assuming the lower value to be appropriate for the region (given the high intensity of exploitation), the overall production of 1987/88 (115,402 tons) suggests that the number of fishermen, in terms of equivalents to commercial fishermen units, might be 115,000. The actual number of persons involved in fishing activity is however much greater as 24% of overall production results from occasional subsistence fishing. Over 70% of all households in the region participate in some type of fishing activity. Furthermore, the production sector creates employment both upstream (boat building and net making) and downstream in post harvest (processing, transport, marketing). Studies elsewhere indicate that for every job in the production sector, two to three jobs are automatically created in the post harvest sector. Direct employment in fisheries in the region might be in the order of 345,000 - 460,000 persons (or 6. 8% to 9. 0% of the regional labour force of 5. 1 million). Self-provisioning subsistence fishing might be carried out by several million individuals in the region. Expansion of the labour force will increase the demand for employment. Annual population growth rates are expected to diminish from 2. 2% in 1991 to 1. 2% in 2015. The labour force could increase by an additional 3. 4 million persons. If the fisheries sector is to maintain its current share, an additional 340,000 jobs will have to be created in fisheries over the next 20 years. There is also increasing incidence of landlessness among the poor because small holders are short of funds and sell out. This increases the supply of agricultural wage labourers. Because they have a low opportunity cost, many are drawn into fishing, which puts even more pressure on the fish resources. Potential areas for creation of new jobs are:

- processing
- marketing and transport
- net making and repair
- boat building and repair
- construction works supporting fisheries (such as embankments around beels, excavation of borrow pits and ponds, and fish passes)
- pond culture production

Little direct information is available on income levels within the fisheries sector of the region. At an estimated average current retail price of Tk 60 per kg, the total value of fish production from the region is about Tk 6.9 billion. Assuming that 76% of this pertains to commercially marketed produce (the remaining 24% is an equivalent market value for subsistence produce), a total of Tk 5.2 billion is shared out among the 500,000 persons estimated to be directly employed in the fisheries sector. Mean per capita income is therefore Tk 10,400. However, jalmohal lease holders, money lenders and government taxation capture a large share of total income, leading to severe inequality of income distribution in the fisheries sector. Actual hands-on "genuine" fishermen and artisanal and factory processing labour undoubtedly earn considerably less than the mean income. BBS (1991) gives data from the 1988/89 household expenditure survey for all of Bangladesh. Average monthly income per rural households are:

- 39.3% are farming households: Tk 3,129
  - owner farming: Tk 3,696
  - owner-cum-tenant: Tk 2,737
  - pure tenant: Tk 1,968

- 21.1% are agricultural wage labour households: Tk 1,565

- 1.6% are fishing households: Tk 2,068

Although these figures may not be accurate for the region, they do indicate that fishing is more remunerative than agricultural wage labouring or tenant farming. Genuine fishermen are apparently now better off than before NFMP. In Habiganj, NFMP fishermen are said to earn up to Tk 4,000 per year, whereas before they earned less under the jalmohal lease system. Implicit daily wage rates determined by BCAS (1989) for NFMP fisheries range between Tk 57 and Tk 167, but these are high season averages, not annual means. Given the range of retail trader markups, the retail prices of fish and the quantities of fish sold per trader, it would seem likely that a small fish trader's income might exceed that of a fishermen by a modest margin.

3. 1. 5 Situation of Women

The role of women in fisheries is limited. They are employed mainly in processing and net weaving/repair, and may also carry out pond feeding. Girls often participate in fish harvesting in rice fields and borrow pits.

3. 1. 6 People's Perception

Numerous interviews were conducted with fishermen, fish traders, leaseholders and DOF officials at district and thana levels. Many of those interviewed have stated that fish resources have declined significantly in the region over the last 10-15 years. The only boromaach species which appears to be increasing in production is Ilish. The region-wide decline in production is attributed to several factors:

- Siltation of river beds and deeper beels.
- Over exploitation of fishes, particularly the use of fine-meshed net in tributaries affecting small fish species and fingerlings (March-April), and harvesting of boromaach broodfish in rivers (March-May).
- Annual fishing of the beels by complete de-watering (the present short term leasing system motivates lease holders to seek short term returns).
- Deforestation in the haor area. Only in two areas (Hakaluki haor and Tangua haor) have large *hijal* plantations been started.
- Industrial effluents of Fenchuganj and Chhatak affect fish breeding.
- Poisonous plants used in India cause mass fish mortality in Sharighat and Juri Rivers.
- Barriers to fish migration during the breeding season caused by FCD/I projects.

2Y

3. 2 Water Resources Development

There are some 65 existing FCD/I projects in the region which were constructed through BWDB, including 27 full flood control projects, 33 partial flood control projects, and five drainage schemes. The total length of the embankments (full flood and submersible) for these projects is about 1,500 km. Many smaller FCD/I initiatives have been undertaken without BWDB sponsorship at thana, village and private landowner level. These are mainly in the form of smaller embankments, bunds, drainage works, and small water retention structures. A discussion on how FCD/I projects impact on fish production is given in Section 3. 3. 8.

3. 3 Fisheries Resources

3. 3. 1 Fish Biodiversity

Of the 260 species of freshwater fish known to inhabit Bangladesh, over 143 native plus eight exotic introductions are known or suspected to inhabit the water bodies of the region. Cyprinids and catfishes dominate the ichthyofauna. Virtually all species are of some commercial importance in so far as they appear in retail markets. Major carps and large catfish are the most commercially valuable, but other groups such as the knifefish, "livefishes" *(Koi, Magur, Singi)*, and herring (*Ilish*) are also important. Miscellaneous species are of the highest importance for subsistence and self-provisioning. It is significant that even these species are attaining market importance and entering commercial networks.

There are two fish group categories which are widely used:

- *Boromaach,* or large fish. This includes major carp, large catfish, *Chital,* Gangetic stingray, *Gazar, Shol* and *Ilish.* All *boromaach* are commercially important species. Most boromaach carry out longitudinal spawning migration. Thus, the group is defined by both ecological and economic factors.

- *Chotomaach,* or small fish. This includes the vast majority of species. Most are important for subsistence consumption, although a few are commercially in demand (such as *Rani*). Most *chotomaach* do not carry out spawning migrations, or at most move short lateral distances into shallow water.

Major carps
There are four cyprinid species which are commonly called the major carps:

- *Rui* Labeo rohita
- *Catla* Catla catla
- *Mrigel* Cirrhinus mrigala
- *Kalibaus* Labeo calbasu

Tor Mahaseer (Tor tor) and *Putitor Mohaseer* (Tor putitora) are very rare at present in the region.

The major carps are important commercial species. *Rui* is perhaps the most highly esteemed food fish in Bangladesh. *Kalibaus* and *Rui* are generally more abundant in catches than *Catla* and

Mrigel. *Rui*, *Mrigel* and *Kalibaus* feed at the bottom on plant matter and decaying vegetation. *Catla* is a surface and midwater feeder. *Mrigel* attains sexual maturity at 2 years of age, *Rui* at 2 to 3 years, and *Catla* and *Kalibaus* at 3 years.

All four species are thought to have similar reproductive strategies. Brood stock overwinter the dry season in large rivers and beels. Spawning migrations occur during the early monsoon. Typically brood stock from beels swim down the khals and out into the rivers, then upstream to reach shallower areas which are suitable spawning localities. Ox-bow bends in particular appear to be favoured, probably because they possess unique hydrological features (deep pools in the outer bend, turbulence, upwelling and backwater currents at the inner bend [Tsai et al, 1981]). Eggs are non-adhesive and drift with the current. The embryo hatches out in 5 to 24 hours, depending on the species. Yolk absorption takes 3 to 4 days, after which the fry begin feeding. Occurrence of drifting fertilized eggs and hatchlings is an indication of major carp spawning grounds nearby. Information on spawning localities in the region is fragmentary. Well known spawning localities (ie spawn collection sites) are in the Old Brahmaputra River where spawn and hatchlings are collected from May to July. Jhingran (1983) notes that in India major carp spawn is found in the headwater streams of the Surma (ie Barak River basin). This suggests that some of the Upper Meghna basin broodstock present in Bangladesh swims upstream into India to spawn and is thus an internationally shared stock. Local fishermen and fisheries officers in Bangladesh state that "major carp fry are available in many tributaries" (Tsai and Ali, 1985).

Large catfishes
Six species of large catfish occur in the region:

- *Boal* Wallago attu
- *Pangas* Pangasius pangasius
- *Air* Aorichthys aor
- *Guizza Air* Aorichthys seenghala
- *Baghair* Bagarius bagarius
- *Rita* Rita rita

Boal is the most common species seen in markets followed by *Guizza Air*, *Air* and *Rita*. A few large *Baghair* are regularly seen. *Pangas* is rare, at least in the upper parts of the region. It is very occasionally caught in the Kushiyara around Sherpur. *Boal* inhabits all manner of lotic and lentic water bodies. It breeds on floodplains during the pre-monsoon and monsoon. It is an extremely voracious piscivore. Its flesh is very tasty with few bones. *Air* and *Guizza Air* inhabit both rivers and beels. Spawning may take place from early April up to the end of August. A nest (breeding pit) is dug in the soft mud of river beds where the current is sluggish. Both males and females guard the nest. Egg incubation lasts about 26 hours. Yolk absorption takes 7 days. *Pangas* usually lives in large deep rivers. It carries out long distance spawning migration, from the brackish estuarine lower delta up the Jamuna and Ganga Rivers into India. It spawns early in the monsoon over the inundated muddy islands of the main river channel. There is no evidence that *Pangas* spawns in the region. Occasional individuals appear at markets, and originate from the Kushiyara. *Baghair* occurs in low abundance in the Surma, Kushiyara, Kangsha and Old Brahmaputra. It is a voracious predator. Large specimens have been landed from the Surma (150 kg from near the confluence with the Luba River) and the Kushiyara (120 kg from near the confluence of the Manu River). The latter specimen was sold in Moulvibazar market for Tk 15,000. *Rita* is found in muddy rivers and is carnivorous.

Minor carps
The most common of the minor carps is *Gonia* (Labeo gonius), followed by *Lasu* (Cirrhinus reba). *Nanid* (Labeo nandina) and *Angrot* (Labeo angra) were previously quite abundant but are now almost extinct in the region. *Lasu* feeds on plankton and detritus. *Gonia* breeds during the pre-monsoon on floodplains.

Ilish
Although *Ilish* is of the greatest economic importance in Bangladesh fisheries as a whole, *Ilish* (Hilsa ilisha) is of only secondary importance in the Northeast Region. The adults migrate from the sea far up rivers to spawn. Some stock enters the Upper Meghna and penetrate far up the Kushiyara and Surma. Thus, 1-2 kg females with eggs are caught in the Kushiyara River near Sherpur during the monsoon season. Two major spawning migrations of 4 and 5 year olds occur, peaking in March and August. Breeding, egg development and fry development take place in rivers. Eggs hatch after 18-26 hours. Yolk absorption is completed after 8 days. Small *Ilish* occasionally appear in markets in the region. Most adult *Ilish* sold is iced product originating from Chittagong and Chandpur.

Knifefishes
Chital (Notopterus chitala) is a *boromaach* of substantial commercial importance and is routinely seen at markets. It inhabits beels as well as rivers, but prefers clear water. During the rainy season it spawns in rivers. Breeding takes place in June and July. A nest is over hard structures. The adhesive eggs are deposited in the nest, on submerged aquatic plants or on branches of submerged trees. Both parents guard the nest. *Chital* is a carnivorous and predatory feeder. *Foli* (Notopterus notopterus) is a second but smaller species of knifefish. It is very abundant in stagnant as well as running waters. Breeding takes place in May and June. The eggs receive parental care. The diet is carnivorous.

Miscellaneous species
The remaining part of the indigenous ichthyofauna has been lumped together here as "miscellaneous" species. This includes both commercial and subsistence taxa.

Needlefishes: *Kaikka* (Xenentodon cutcutia) is a very common predator in beels and flood lands. It is usually marketed in sun dried form.

Minnows, Rasboras and Barbs: Various small cyprinids such as *Punti, Chela, Mola* and *Jaya* regularly appear in markets in both fresh and sun-dried form. These species are also very important for subsistence consumption. They occur widely in virtually every type of aquatic habitat. The previously important *Sarpunti* (Puntius sarana) has declined in recent years.

Loaches: *Rani* (Botia dario) is regularly seen at markets and is in demand for export. It occurs in the Surma and its tributaries around Sylhet, Chhatak, and Sunamganj. *Gutum* (Lepidocephalus guntea) is widespread and used for subsistence.

Anchovies and Sardines: *Phasa* (Setipinna phasa), *Kachki* (Corica soborna) and *Goni Chapila* (Gonialosa manminna) occur mainly in rivers, while *Chapila* (Gudusia chapra) is also found in beels, ditches and flood lands. They are important subsistence species and often sold in dry form.

Spiny eels: *Baim* (Mastacembelus aculeatus) is widely distributed in rivers, beels and flood lands. It is regularly seen at markets and is in demand.

Climbing Perch: *Koi* (Anabas testudineus) possesses a breathing organ and is usually sold as "livefish". It is tasty and popular, and sold at most markets. It is also a staple subsistence food item. It prefers stagnant water habitats and can travel overland. During the dry season it remains buried under the mud. Breeding lasts from May to July. Eggs float at the surface and there is no parental care. Hatching takes 18 hours, and yolk absorption 4 days.

Gobies: *Bailla* (Glossogobius giuris) is common in rivers, and caught at night during the dry season by constructing low bunds out from the shore. It is carnivorous and primarily of subsistence importance.

Mud Perches: *Bheda* (Nandus nandus) is occasionally seen at markets. It is predatory and common in ditches and on flood lands.

Glassfishes: *Chanda* (Chanda spp) is found in beels and is marketed in fresh and dry form.

There are other important fish species in the Northeast Region such as Dolphins, Snakeheads, Stingray, and Prawns. These and other species are described in the draft final report entitled *Fisheries Specialist Study, NERP, 1993.*

3. 3. 2 Migrations and General Floodplain Fish Ecology

In general, during the pre-monsoon and early monsoon period fish migrate into shallow areas. During flood recession fish migrate to deeper areas. Migrations are usually countercurrent during pre-monsoon and early monsoon. If rain falls in the upper catchment area (in India), rivers rise and water flows from the river up the khals and into the beels. Fish will tend to swim from the beels down the khals to the river. If rainfall is localized on the haor, the haor will drain into the beel and then water will flow from the beel down the khal into the river (but this is a less common event). In this case, fish will tend to swim from the river up the khal to the beels.

The "fish year" can be divided into four seasons:

The overwintering dry season (December to March): Broodstock and juveniles approaching recruitment size are concentrated in river duars and beels. No migratory movements take place at this time. These habitats (especially beels) are fished heavily during this season, and whatever fish survive enter the next season.

The spawning migration season (April to June): This season usually begins during the pre-monsoon flood phase of the hydrological year and can continue into the first part of the full monsoon flood phase. Fish generally move from deeper waters (such as duars) to shallower waters. Breeding takes place in shallower waters. Almost all fish species can be separated into two distinct groups:

- Species which breed in the river: Among *Boromaach* this includes the major carp *Rui, Mrigel, Catla* and *Kalibaus*, the knifefish *Chital* and the large catfish

Baghair and *Air* (see below for *Pangas* and *Ilish*). Among *Chotomaach* this group includes *Katchki, Batashi, Kajuli, Baim, Rani, Bailla*, and some others. Regardless of where these species have overwintered (and many of them are not very selective in this regard), all will attempt to migrate into river channels. Those individuals that overwintered in rivers are not inconvenienced. Those which overwintered in beels will have to swim out of the beel, down the khal (and this will be a countercurrent migration, because river water will already have begun to spill into the haor via the khals), and out into the river. Once in the river, it is assumed all species will swim upstream (countercurrent) until they reach spawn grounds which they find suitable for their requirements. The specifications of suitable spawning grounds varies from species to species. Major carp apparently prefer river bends. *Chital* prefer submerged structures such as trees and artificial structures such as submerged canoes. *Air, Guiza* and *Rita* make pits on the river bed as breeding "nests". The common requirement for all these species is that they need to be able to swim out from beels into the rivers (ie countercurrent). Bypass structures in FCD/I project embankments need to allow this to happen.

- Species which breed on the floodplain: The great majority of *Chotomaach* breed on the floodplain once inundation starts during the pre-monsoon floods. There is evidence that some *Chotomaach* species breed several times during the monsoon flood. Thus they migrate only a short distance laterally, from the beels (where they overwintered) out on to the floodplain. However there are also some *Boromaach* which breed on the floodplain, specifically *Boal* and *Ghonia*. Those individuals who overwintered in beels also only have to carry out a short lateral migration on to the flood plain. However *Boa*l and *Ghonia* (and some *Chotomaach* species as well) which overwintered in rivers have to swim up the river (ie countercurrent), until they find a khal they can enter (ie then changing to swimming with the current) to get to a beel and up on to the now expanding floodplain. The requirement for these species is that they need to be able to swim from rivers into beels/floodplains. Bypass structures in FCD/I project embankments need to allow this to happen.

The nursery/grow-out season (June to September): This fish season corresponds to the hydrological height of the monsoon flood season. The fingerlings of those fish which bred on the floodplain are already on the nursery grounds so they do not have an access problem. But the fingerlings hatched from river breeding species need to get up on to the floodplain, and this can only happen in one of two ways: either they are passively swept on to the floodplain when the river overflows its banks (or overtops a submersible embankment) or are passively swept through a bypass structure such as a regulator when it is opened to effect controlled flooding of a haor. This is the season of rapid fish growth. Habitat hectarage increases enormously. In the region the dry season (river plus beel) water surface area is 1,467 sq km. During the height of the flood season this expands by a maximum factor of 15 to 21,710 sq km. Food availability probably increases by a similar factor. However fingerlings suffer a high mortality rate from piscivores, insects, snakes, frogs, otters, turtles, birds, disease, parasites and fishermen. Not withstanding this larvicide, the full flood season is still the best period for fast fish growth. Though fish movements may not be entirely random on the floodplain, there is little evidence of the mass migrations of the previous season. Schooling behaviour is more likely related to feeding tactics or a defence against predation.

The flood recession season (September to December): Flood waters start receding. Drainage starts as sheet flow and eventually transitions to channelized flow by the end of this season. As water hectarage shrinks, fish move into deeper waters, navigating along khals and river channels, and with the currents which flow along these bottom topographies. The migrations are thus concurrent with the objective of leaving shallow water areas so as to avoid being stranded and killed by desiccation. A few species are able to aestivate (ie KOI, Channna spp), but the majority migrate to deeper water during flood recession. A fish moving from the floodplain laterally to a deep beel does not encounter much of a problem. A fish moving from the floodplain out into a river will normally move along a khal. FCD/I embankment bypass structures need to allow this to happen. The flood recession/crowding season holds some fairly severe events for the fish stocks. Juvenile fish continue growing but their numbers decrease tremendously. This is because predation by piscivorous fish species such as *Boal*, *Air*, *Kaikka*, *Guizar*, as well as dolphins, now reaches a maximum. Most of the forage fish have not yet grown large enough to escape predation. There is a fairly direct correlation between predator and prey size. A prey species can escape the danger of being eaten by a particular predator once it grows large enough in size to pass outside of the prey size range limits of the predator. As flood water recession gradually changes from sheet flow to channelized flow, and water volume becomes reduced, the density of predators (both in terms of number per water area and number per water volume) increases and crowding together of prey results in extremely heavy predation. There occurs, therefore, a massive natural mortality of fish during this period, which is augmented by fishing mortality. The carrying capacity of the overwintering grounds is limited and sharply defined, and any "excess" ichthyomass will be eliminated.

The overwintering dry season (December to March): The annual cycle comes full circle. The floodplain has dried out and the only water left is in rivers and beels, where the entire fish population of the region is lodged. Prey species have generally grown large enough to avoid being eaten by predators. Juveniles mature into adults and gonads begin ripening in anticipation of the coming breeding season.

To summarize, for the majority of fish species in the region, the following principal fish migrations take place (in chronological order):

- Active breeding migration of broodstock from overwintering grounds to breeding grounds;
- Passive hatchling/fingerling migration from breeding grounds to nursery/grazing grounds;
- Active migration of juveniles and broodstock from breeding and/or grazing grounds to overwintering grounds.

There are three important species which differ from this pattern:

- *Pangas*: This large catfish spawns in major rivers during the early monsoon and the fry remain in the fast midstream of the river. They are washed down to brackish water coastal areas, where they mature. Eventually the adults swim up the major rivers (Padma/Ganges, Lower Meghna, Jamuna/Brahmaputra) to spawn over flooded chars. This is a long range migration of 1,000 - 2,000 km. The life cycle of *pangas* would appear to be restricted entirely to large rivers and the coastal estuarine environment. It would appear not to require access to floodplains during any part of its life cycle and thus does not have to be accommodated by embankment bypass structures.

- *Ilish*: This large herring constitutes about 1/3 of the total fish production of Bangladesh, so it is of strategic importance to the country's food supply. Juvenile Ilish grow to maturity in the sea, and adults ascend rivers to spawn twice each year. The major spawning runs are in June(early monsoon) and September (late monsoon). The fingerlings and juveniles (*jatka*) remain in the rivers and over the space of 4-5 months make their way downstream to the sea. Like *pangas*, the life cycle of *Ilish* appears to be restricted to the riverine habitat and completely detached from floodplains (although *jatka* do enter haors in small numbers occasionally). Thus *Ilish* does not have to be accommodated by embankment bypass structures.

- *Golda Chingri*: Adults of this large prawn inhabit mainly rivers. In the pre-monsoon season (February to April) there is a mass migration of adults downstream to estuarine and brackish water areas, where spawning takes place. The juveniles metamorphose into post larvae in brackish water and then begin a slow migration upstream into freshwater during the full monsoon (June to September). The juveniles disperse on to floodplains lateral to rivers to feed and grow. The adults return to the larger river channels. FCD/I embankment bypass structures have to allow juveniles on to the floodplains during the full monsoon and the adults back into the rivers during the flood recession period.

A special "problem" which has not yet been definitely resolved is the question of homing behaviour in *boromaach,* in particular major carp. One underlying assumption behind the use of the three year katha pile harvesting system (and a belief held by many fishermen) is that individual fish return to the same duar or beel (and the katha installed there) each year during flood recession to overwinter. Harvesting katha only once every three years allows the *boromaach* to grow to adult size and breed at least once before being caught. The homing hypothesis was tested by the leaseholders and fishermen of the Rangchapur and Tangua Haor fisheries. Fish were "marked" by cutting off one lobe of the tail fin and then returned to the water. Three years later these marked fish were recaptured in the same place at the time of the pile fishing. The implications of possible homing behaviour in *boromaach* for fishing practices and fisheries management are fairly profound:

- If *boromaach* home back to the same duar or beel year after year, it becomes worthwhile for the katha owner to delay harvesting until the third year, because the price per kg of adult size *boromaach* is significantly higher than for juveniles of the same species

- On the other hand, if *boromaach* do not home back to the same katha, the incentive to delay harvesting is reduced, because any individual fish not caught in a particular year might overwinter in another beel or duar the following year and be harvested by some other *katha* owner or fisherman.

A *boromaach* tagging program needs to be carried out to establish definitively whether or not homing exists. In the event of a positive result, homing should be incorporated into the regional fisheries management strategy.

A second fish migration problem that requires attention is the movement of *boromaach* stocks across the border into India. Such movements can be expected to take place in all three catchment areas of the region (Meghalaya, Barak River, Tripura). Fishermen of the Amalshid area maintain that *boromaach,* particularly carp, migrate towards the Barak River during the month of April-May and are caught by the Indian fishermen. It is also claimed that in the upper reach of the Barak (near the proposed Tipaimukh dam site), there is a spawning ground of carp. The movement of migrating broodstock up lateral tributaries of the Meghalaya and Tripura catchments is also important because some of the rivers are selected as spawning grounds due to their high water quality. Some of the boromaach stocks of the region should therefore be designated as internationally shared fish stocks which use Bangladesh waters as overwintering grounds and the Upper Barak (in India) and smaller tributaries (in Bangladesh and India) as breeding grounds. Bangladesh fishermen regard the broodstock of carp as a common property of both countries and suggest that a bilateral program is required to maintain and manage these stocks.

3. 3. 3 Spawning Patterns and Locations

Except for major carp, *Pangas* and *Ilish*, most fish species breed more or less everywhere in the region. The species can be separated into two groups based on their preferred breeding habitat:

- <u>Floodplain and beel breeders</u>: *Boal, Ghonia, Sarputi, Shingi, Magur, Koi, Bheda, Puti, Icha, Chanda, Mola, Ghonia, Boal, Sarputi, Gulsha, Tengra, Laso, Kholisha, Along.*

- <u>River breeders</u>: *Chital, Ghagot, Kalibaus, Catla, Rui, Mrigel, Chital, Air, Rani, Pabda, Pangas, Basa, Ghagot, Garua, Shilon, Baspata, Kajuli.*

Floodplain and Beel Breeders

Breeding begins during the pre-monsoon flood. Depending on the rain and water volume in the river and floodplain, most of the catfish, live fish and other species (*Magur, Singhi, Koi, Tengra, Pabda, Air, Boal, Gazar, Shoal*) start breeding at the end of March and early April. Piscivorous species (*Boal, Shoal, Gazar*) breed earlier than the non-piscivorous species. The optimal meteorological conditions for fish breeding are tempestuous. Flash floods, heavy continuous rain and thunder together stimulate fish breeding, particularly for *Boal, Ghonia, Pabda, Koi, Batashi, Puti* and *Laso*. When the first pre-monsoon flood water *(goola)* enters into the beels, fish begin moving against the current to search for suitable spawning habitat. *Ghonia, Boal, Foli, Pabda, Shoal, Gazar, Lati, Cheng, Koi* and *Laso* prefer to breed on newly inundated grassy areas on kanda where the current is slow, water depth is low (about 0. 5 m) and bush/reeds (*Chailla bon, Nol Khagra, Bon tulshi, Parua, Binna bon, Hugol bon*) are present. These species are called *Jangal* breeders. *Boal, Pabda* and *Ghonia* also breed in the canals connected with beels. During the spawning period, the following species form groups or schools which are called *Jaak dhora: Boal, Ghonia, Kangla, Laso, Koi, Puti, Shingi, Magur, Tengra, Cirka, Batashi, Kholisha, Bheda, Pabda.* The migration of a typical *jaak* toward a spawning place is called *Uijja.* At the time of mating, fish behave incautiously and can even be caught by hand. No aggressive behaviour is exhibited. The mating pair bend against each other when expelling eggs and milt.

Normally the schools are segregated by species. Usually the schools move at night during the new or full moon phase. Except for the snakeheads, most species do not have parental care of their offspring.

River breeders

Reproductive patterns are more diverse among river breeders. *Air, Rita, Ghagot* and *Guizza* make pits in the shallower part of the river in April and May. They are also known to breed around katha. Each pit is about 1 m in diameter and 0. 6 m in height. They choose an area with clay soil and excavate the pits with their mouths. A single female uses one pit, but one male can service 3-5 females. Local fishermen know their behaviour and brood fish are caught by the anglers with bait. *Chital* and *Foli* prefer to breed in shallower parts of the river over hard structures such as stones, bamboo or submerged tree branches. A sunken boat under a katha is an excellent artificial breeding site. Eggs are sprayed over the structures and adults carry out brood care. The breeding period of *Chital* and *Foli* is May and June. A number of *chotomaach* breed in rivers, including *Batashi, Bashpata, Chela, Kachki, Bailla* and *Baim*. Shallow areas are selected and breeding takes place in April. *Rani* prefers to breed in the rivers particularly in any quiet undisturbed shallower place where water current is weak and the river bed consists of course sand. They shelter in the holes of bamboo *(chong)* during the breeding period. The occurrence of substantial jatka schools in the Upper Meghna, Baulai and Kushiyara Rivers suggests that *Ilish* probably spawn in the region. Spawning likely takes place in the rivers during the pre-monsoon (March) and monsoon (August) floods. Spawning sites in the region have not yet been identified.

Major carp are thought to spawn mainly in rivers. The breeding period of most species is in early April to June and depends upon rainfall. From June to September, large numbers of fry, fingerlings and juveniles are present in the beel areas (5-13 cm size). *Kalibaus* is more abundant than *Rui* and *Catla*, while *Mrigel* is becoming rare. The following areas are suspected or known to contain important carp breeding grounds:

- Tangua Haor,
- Pashuar Haor,
- Laudi and Bawa Beels of Companiganj area,
- Erali Beel,
- Hakaluki Haor,
- Luba River,
- Sarigowain River,
- Old Brahmaputra River.

Fishermen of the region record that carp spawn occurs in the following areas:

- Kawnai River near Daulatpur and Milanpur (Dharmapasha thana),
- Boroiya River near Shanbarir bazar (Dharmapasha thana),
- Baulai River near Mukshedpur (Dharmapasha thana),
- Alamduarer area in Tangua haor,
- Surma River near Sunamganj town,
- Dhanu River near Ranichapur and Dhalimati (Kaliajuri area),
- Kalni River near Markuli (Derai thana),
- Khoiltajuri River near Dighirpar (Companiganj area).

3. 3. 4 Mother Fisheries

Discussions with fishermen revealed the existence of several major centres of fish production and dispersal within the region. These areas are called mother fisheries by the fishermen. The concept (or phenomenon) of a mother fishery does not appear to been previously identified or its importance recognized in floodplain fisheries literature. Functionally, a mother fishery exerts a controlling influence on fish abundance over a wide area. Thus, if fish abundance is high in a particular mother fishery in a particular year, fishermen expect fish abundance also to be high in the surrounding areas. The reverse would also be expected: low fish abundance in the mother fishery would result in low catches in the surrounding areas.

Structurally, a mother fishery could consist of a single beel, or duar or spawning locality. For example, there are 25 important jalmohals in Purbadhala thana. Out of those, six jalmohals are considered important as mother fisheries: Mora nadi jalmohal, Bonduk khali (in the Kangsha River), Rajdhala beel, Bais dar duba (in the Kangsha River) and Bagruar duba (in the Kangsha River)

But the concept of mother fishery is more commonly used in the region to describe a larger geographical area possessing a dense concentration of diverse high quality fish habitats and supportive flora (deep river duars, clear tributary streams, deep beels, sediment-free khals, wetland forest stands, reedbeds, floodland with wetland grasses). There appears to be a general consensus among the many individuals involved in the field that there currently exist four important mother fisheries in the region:

- Tangua Haor
- Hakaluki Haor
- Kaliajuri area
- Companiganj area

Previous to the construction of the Manu River Irrigation Project, Kawadighi Haor was also a major mother fishery. Unfortunately, this FCD/I project has seriously reduced Kawadighi Haor as a mother fishery.

Tangua Haor (80 km^2) is considered to be the single most important mother fishery in the Northeast region. There are relatively few villages and little agriculture in the haor area and virtually no use of fertilizers and pesticides. Water enters the haor as low turbidity hillside runoff from the adjacent Indian hills to the north, and as back flow from the area to the south. This two-way water supply system (hillside runoff water, back flow flushing) provides circulation which helps to maintain the natural environment. The water entering the haor contains a high amount of organic nutrient but little sediment as the there no major khals or rivers flowing to the haor. The haor contains a few hundred beels which are inter-connected by small canals. About 25 permanent beels are used as over-wintering grounds by fish. Clear water increases the survival of fish spawn. Natural reeds and other vegetation provide a natural ecological balance. The three year pile fishery system is used and harvesting rotates among different beels in the haor. This plays an important role in maintaining production levels.

3. 3. 5 River Duars

The recession of flood water after the monsoon leads to a large reduction in water surface area during the winter dry season. Almost the entire fishery resource of the region becomes crowded and confined to two major habitats: rivers and beels. Because shallow beels and the upper reaches of rivers are prone to partial or complete desiccation, most fish (and broodstock in particular) seek out deepwater habitat locations to overwinter in. Only two such habitat location types exist in the region: *duars* in the larger rivers, and the deeper permanent beels in the haors. The concentration of commercially valuable fish in a limited and circumscribed number of locations during the winter is well known to fishermen and has given rise to the existing pattern of intensive dry season fish harvesting. In particular, the *katha* harvesting method is a technical response to the overwintering crowding of fish. The extremely high vulnerability of broodstock to fishing mortality during overwintering means that the winter season is a critical period during the annual fish life cycle and that the river *duars* and deeper beels are critical fish habitats. Protection of overwintering broodstock and regulation of harvesting in overwintering refuge localities must figure as central elements in a regional fisheries management strategy. Field studies indicate that *duars* are more important than deeper beels for survival of the region's broodstock during the winter. Except for the northernmost part of the Sylhet Depression (Tangua Haor area), most beels in the region are affected by siltation, resulting in a general region-wide decrease in the maximum depth of beels, and in some cases in a change from permanent to seasonal status. The widespread practice of extracting beel water in mid-winter to irrigate *boro* crops further reduces beel water volumes. Complete de-watering of beels is now routinely carried out in many areas in order to obtain total fish harvests, thus producing the greatest possible short term return to *jalmohal* leaseholders. Increasing the frequency of *katha* harvesting from triennially to annually has put further pressure on fish stocks overwintering in beels. The combination of sedimentation, boro irrigation, de-watering and annual *katha* harvesting has resulted in the virtual elimination of beels as secure overwintering refuge habitat for broodstock in most of the region. River *duars* are thus by default the only important overwintering refuge habitat in the region for broodstock. The sustainablity of fish production in the region is thus almost entirely dependant on the degree to which natural and fishing mortality act on broodstock overwintering in the region's *duars*. While they are not invulnerable to certain threats, most *duars* are fairly stable morphological structures, and are more difficult to fish out due to high current velocities and turbulence, and great depth.

3. 3. 6 Production Trends

Nominal BFRSS statistics for the six year period 1983/84 to 1988/89 show the following apparent trends in the region:

<u>Overall fish production</u> in the region has shown an average annual growth of 3.8%, increasing from 95,895 to 114,273 tons (18,378 tons or 19.2% increment). Openwater capture fisheries grew by 3.0% per annum, from 83,555 to 96,198 tons (12,643 tons or 15.1% increment). Species composition of capture fisheries production is dominated by miscellaneous species, which increased from 48,018 tons (57.5% of total) to 58,331 tons (60.6% of total). Ilish and livefish production also increased. Carp and catfish production decreased over most of the period, but recovered in 1988/89. Large shrimp also declined.

<u>Rivers</u> are the most important harvesting habitat in the region, accounting for 31. 6% of overall production in 1988/89. Mean annual growth was 3.2%. About 40% of riverine production

comes from the Upper Meghna (mainly the stretch in greater Dhaka and Comilla Districts), and 60% from its tributaries (ie Surma, Kushiyara, Kangsha, etc, which are collectively termed other rivers). Upper Meghna production grew by a mean annual rate of 6.9%. Miscellaneous species and Ilish dominate the catch, the latter increasing significantly. Production from other rivers grew by 3.1% annually. There has been a major increase in catches of miscellaneous species, and severe declines in carp and catfish (although a significant carp recovery was recorded in 1988/89).

Beel production constitutes 29.3% of overall production. Mean annual growth in output was 3.7%. It is widely reported in the region that 1991/92 catches are down compared to 1990/91. A possible explanation of this is that the production boom resulting from the extensive floods of 1987 and 1988 was fished out in 1988/89, 1989/90 and 1990/91. Thus in 1991/92 fish biomass was reduced. Around Sunamganj beel fishing began late in 1992 because of high water levels due to heavy un-seasonal rains in December 1991. Seasonal beels are termed annual fisheries. During the dry season in March-April they are completely harvested. Katha are sometimes installed in annual beels. Often the water is drained out to facilitate capture of all fish. A whole village may participate in the annual fish out, which has a festive air (community fishing). Permanent beels are termed pile fisheries and are supposed to be fished only once every 3 years in order to allow fish to grow to maturity. Since such beels cannot be drained, katha brush parks are installed to attract fish and facilitate their capture. Katha appear to selectively attract major carps *(Rui, Catla, Mrigel, Kalibaus)* and especially the minor carp *Gonia* as shown by the difference in species composition of annual and pile fishery catches. Carp constitute 29.1% of pile fishery production, but only 8.4% of annual fishery production. The aggregate percentages for large catfish *(Boal, Air)* and for small prawns are similar for the two beel fishery types. The other species not listed in the tables are much more important in the annual fishery (62.1%) than in the pile fishery (37.1%).

Commercial fishing on floodlands is substantial. BFRSS collects production data but has never included it in its annual statistics report. FAP 17 has analyzed this data set and concluded that its inclusion would approximately double the floodplain catch figure.

Subsistence fishing on floodlands constitutes 23.3% of overall production, and has grown annually by 5.7%. The World Bank (1991) considers that the BFRSS subsistence catch statistics underestimate the true level of subsistence harvesting. Miscellaneous species dominate the catch (of which snakeheads are an important component). Catfish, livefish and small shrimp are important secondary components. Carp are of only marginal importance. Much of the floodland subsistence fishing takes place during the monsoon when the floodplain is inundated. RHD and BWDB borrow pit production is not recorded separately from floodland production. Most of the catch consists of small species: *Singi, Puti, Baim, Ithca, Gutum, Kaikka, Koi, Magur, Foli, Taki* and *Kachki*.

Closed water (pond) culture production grew by 9.7% per annum, from 12,340 to 18,075 tons (5,735 tons or 46.5% increment). Ponds contribute 15.8% of overall production. Pond production in greater Mymensingh District is mainly major carps, while in Sylhet *Air, Punti* and other species are also of importance. Collection of natural carp spawn from the Old Brahmaputra River to supply ponds has declined steeply, but a small recovery took place in 1989. This is a lucrative business as spawn can sell for up to Tk 5,000 per kg. Pond culture is further supported by 16 carp hatcheries in and around the region. Many pond owners in the region release an uncounted number of fingerling into their ponds without undertaking other basic management activities such as predatory fish eradication and regular application of feed and fertilizer. Other pond owners rely on passive stocking of ponds by flood-borne seed. Monitoring the growth and health of the fish is also not done on a regular basis. The fish are usually harvested during the dry season. It should be noted that the many ponds that adjoin homestead land provide domestic water supply for a wide variety of activities (bathing, washing clothes and dishes, occasionally watering homestead vegetable plots, and so on).

Many fishermen and others related to the fisheries sector have stated that fish production in the region has declined significantly (see draft report *Fisheries Specialist Study, NERP, April, 1993*).

3. 3. 7 MSY and Yield Estimates

No estimates have previously been made of overall fish standing crop or potential yield for the region. Because fish stocks are on the whole not rigidly tied to any one major aquatic habitat and can still move relatively freely between rivers, floodlands and beels in much of the region, standing crop estimates for discrete habitats are limited in their usefulness from the prospectus of the entire floodplain (which still largely functions as a single holistic, dynamic and integrated system in the region). It is probably true to say that for many species any individual fish specimen represents a biological production composite originating from river, beel and floodplain habitats. An empirical approach to obtain a robust first approximation of MSY is to equate catch with maximum area flooded, or MAF. The relationship determined from catch and area data for 25 tropical floodplains exploited at a substantial level of intensity is:

$$C = 4.23 A^{1.005}$$

where: C is catch in tons
A is area in sq km

The range of yields fall between 40 and 60 kg/ha/yr.

The area of the region occupied by flood prone landforms is 21,710 sq km. Regional MSY is empirically predicted as 96,500 tons (yield of 45 kg/ha/yr). Nominal capture fishery production from the region is between 80,000 and 97,000 tons (nominal yield range of 37-45 kg/ha/yr). This encompasses the empirically predicted MSY, and would indicate that the region's fish stocks, based on BFRSS statistics, are being harvested at about the MSY level.

If it is accepted that subsistence and commercial floodland catch statistics underestimate the real level of yield then the real overall regional yield may currently be in the range of 55-70 kg/ha/yr. If yield has indeed been declining over the last two decades, then yields several decades ago may have been as high as 70-100 kg/ha/yr before overfishing and environmental degradation from FCD/I and non-FCD/I factors began impacting the fish stocks.

3. 3. 8 Impacts of FCD/I Projects on Fish Production

Conventional Wisdom on FCD/I Impacts on Fisheries

The conventional wisdom on FCD/I impacts on floodplain fisheries has been determined (sometimes, but not always) from actual case studies in Bangladesh, such as the Chandpur Project, Cauline Beel Project. The following impacts are attributed to FCD/I:

- open water fish production declines due to general reduction in the area (hectare-months) of floodlands and beels (such as reducing the area of nurseries and feeding grounds);

- regulators prevent migration and recruitment of migratory species, especially major carp;

- small sized fish and prawn species replace large sized species;

- elimination of oxbows by channelization destroys prime carp spawning grounds;

- cross dams on rivers prevent migration upstream, and consequently the upstream fishery disappears;

- embankments cut off channels (khals) which connect beels to rivers thus preventing both water and fish stock replenishment of beels.

- submersible embankments delay spawning migrations, resulting in resorption of ova and milt in frustrated brood stock. (This may be a non-issue. Tsai et al (1981), for example, witnessed 11 spawning episodes of major carp in one river bend locality between 21 April and 25 June. Submersible embankments designed to overtop in mid-May will still allow late spawning to take place. Carp which have overwintered in rivers are not inconvenienced as they can swim to spawning localities further upstream).

Status of fisheries in areas without FCD/I projects

As a basis for the evaluation of impacts of FCD/I projects on fishery resources and the supporting aquatic environment of the region, as well as for assessing the overall status of the fisheries sector in the region and formulating a strategy for regional fisheries rehabilitation and development, 16 field case studies were carried out at well defined fisheries areas not directly enclosed or impacted by FCD/I projects. The areas were selected based on their importance and relative contribution to the overall fish production of the region. Except for the Companiganj mother fishery, all the other fisheries studied have suffered production declines ranging from 30% to 80% (where quantitative estimates were put forward by interviewees). These figures should not be interpreted literally but as indicating the existence of significant problems at many non-FCD/I fisheries which require attention (mother fisheries in particular). The most common region-wide factors responsible for declining fish production are:

- Overfishing from use of current *jal* and other illegal nets;
- Siltation of beels and rivers;
- De-watering of beels for agriculture;
- Annual harvesting of *katha*;
- Deforestation.

Other factors contributing to declining catches are:

- Fish disease;
- Industrial water pollution;
- Plant poisons;

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- Decomposition of rice plant residue;
- Dynamite fishing (one case: Luba River);
- Short term *jalmohal* tenure (ie leasing);
- Reduced bird population;
- Poaching and conflicts with leaseholders.

All of these factors in combination can be regarded as a non-FCD/I factor complex which negatively affects fisheries. It might be possible to quantify the losses due to individual non-FCD/I factors, but it would be difficult to separate the effects of two or more factors operating simultaneously. Few fisheries in the region appear to be under only a single stress factor. Typically, most non-FCD/I fisheries are being impacted by several factors simultaneously.

An additional complication to evaluating the fisheries of non-FCD/I areas is the importance of remote effects of both nearby and distant FCD/I projects (singly and in combination). For example, an FCD/I project such as the Manu River Irrigation Project which damaged a carp spawning locality would exert a negative influence on all downstream non-FCD/I fisheries which depended on that carp spawning area for fry. Another remote effect of FCD/I projects is to 'channelize' boromaach broodstock during their spawning migrations. Thus the 15+ partial flood protection FCD/I projects in the northern part of the Sylhet Basin (Shanir Haor, Halir Haor, Matian Haor, and so on) prevent broodstock that are swimming up river during the pre-monsoon from moving laterally on to the floodplains prior to mid-May. The broodstock presumably continue to swim upstream, past the embanked haors, until they reach un-embanked haors/floodplains near the Indian border, such as Tangua Haor and the Companiganj area. A high density of FCD/I projects/embankments thus transforms rivers into corridors which 'lead' migrating fish to remote un-embanked areas further upstream. FCD/I projects also induce sedimentation in non-FCD/I fisheries, both upstream (through ponding) and downstream (through aggradation).

Monitoring of fisheries in Shanir Haor Project and Manu River Irrigation Projects
In order to gain a more comprehensive understanding of the impacts of the two main types of FCD/I projects existing in the region, long term monitoring of fisheries was carried out at:

- Shanir Haor Project, a partial flood protection (submersible embankment) project situated in the northern part of the Sylhet Depression,

- Manu River Irrigation Project, a full flood protection project with pumped drainage and irrigation situated in the southeastern part of the region on the Kushiyara floodplain.

Shanir Haor
Monitoring began in March 1992. The haor is located in the midst of several other haors (Matian, Angurali, Halir and Gurmar haors) and surrounded by the Baulai, Rakti and Nandia Rivers. The Shanir Project comprises 48 km of submersible embankments and one drainage regulator with fall boards (which are troublesome to operate in a timely manner). It also has 9 km of compartmental bunds which do not have adequate water inlet-outlet structures. The project planning objective was to protect the boro rice crop from pre-monsoon flood damage. The needs of the fisheries sector were not considered. As a result the beel fisheries in the haor have declined and suffered economic loss. During the pre-monsoon season, the submersible embankment prevents migratory fish from entering the haor and delays haor flooding (thus

reducing flood duration). Agriculture has also suffered due to inadequate regulator capacity causing post-monsoon drainage congestion.

In mid-June 1992, water levels overtopped the embankment and flooded the haor area. Water levels dropped to embankment crest level at the end of October 1992. This flood period (mid - June through October) was the most important season for fish production. The hydrological regime makes the haor a good grazing habitat for fish. But with the shortened flood period (starting in mid-June rather than April), the time available for fish to feed and grow in the haor is reduced. Congestion of migrating broodstock and juveniles in front of regulators and the trapping of fish at embankment cuts resulted in heavy fishing mortality.

Manu River Irrigation Project
Monitoring began in June 1992. The project is bounded by the Manu and Kushiyara Rivers and by the Battera hills. The terrain slopes from the east and south-east towards the north-west, where Kawadighi Haor is located. The project includes 59 km of full flood embankments along the Kushiyara and Manu Rivers. These embankments have closed a number of tributaries (Munia River, Karadhair River, Machua Khali River, and so on) which previously connected the Kushiyara River with Kawadighi Haor.

This haor was one of the most important fish breeding grounds in the region (a mother fishery). Implementation of the project has severely reduced fisheries in the area. Before implementation, large broodfish from the Sylhet Depression would migrate up the Kushiyara River to Kawadighi Haor during the pre-monsoon season. The importance of the Kawadighi fishery in the past is highlighted by the following information:

- Fish catches were so large that a helicopter was used to transport the fish out of the haor;
- The haor was regarded as having the highest fish abundance and greatest spawning activity in the region,
- The only locally managed fish festival in Bangladesh has been held annually at Manumuk for 150-200 years.

The haor's large fishery resource was due to its special hydrological and topographical features. It was the deepest haor within the region. It is the closest haor upstream of the confluence of the Manu River (which carries a heavy silt load) and the Kushiyara (which has deep duars harbouring large boromaach broodstock in its downstream reaches). Water entered the haor from two sources: the Battera hills, and backflow from adjacent rivers. Rainfall runoff from the Battera hills has little silt and no pollutants. The river backflows also had little silt. These different water sources produced a natural water circulation in the haor which created an ideal habitat for fish spawning.

Even 10 years after implementation of the project, broodfish still try to cross the embankment at Karadhair and Machua Khali River. The embankment has resulted in an enormous economic loss to the fisheries:

- Brood fish cannot enter into the haor and are easily harvested outside, in the Kushiyara;

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- The once fertile beels within the project have become unproductive;

- The agricultural lands are losing their natural fertility because of excessive aquatic plant growth caused by water stagnation.

- Targeted irrigated areas are not used for irrigation. Agriculture lands are being extended into the beel area causing local conflict between farmers and fishermen/leaseholders.

Many genuine fishing communities reside in the haor area. This is a good indicator of the magnitude of the earlier fisheries of Kawadighi Haor. It was observed during monitoring work that a large number of fish that were caught outside of the embankment, were not present within the project area. The fishes inside the project (mainly *chanda, mola, kaikka*) were observed to spawn throughout the monsoon. Carp broodfish were observed on the river side at the Kashempur pump house trying to get in through the pump.

Case studies of other FCD/I projects
Short duration field studies were undertaken to examine the impacts on fisheries of the other 65 BWDB FCD/I projects in the region. FCD/I projects were separated and examined in five main types. These categories are not completely distinct from each other, as any one project may include elements of another category. For example, some full flood protection projects include khal re-excavation to improve drainage. These case studies had difficulty separating the effects of FCD/I projects on fish production from non-FCD/I factors.

Partial Flood Protection Projects (30 projects, excluding Shanir Haor Project)
These projects typically consist of submersible embankments surrounding a haor, and one or more flushing/drainage regulators. Their purpose is to protect boro crop from pre-monsoon flooding by delaying haor flooding until mid-May. There are two major clusters of projects in the north/central and east Sylhet Depression, and outliers at Kalnar Haor, Chhatak area, Hail Haor, the Upper Kushiyara and the Lower Baulai. Submersible embankments may increase the surface area of beels during the dry season. They impede fish migration in either direction for about 10-20 days during the early monsoon season until the embankment is overtopped. As fish stocks likely include early spawners and late spawners, only the late spawners will cross the submersible embankments. Early spawners overwintering in rivers will probably swim further upstream to headwaters and tributaries.

Full Flood Protection Projects, (20 projects without pumped drainage or irrigation, one project with pumped drainage and irrigation, excluding Manu Project)
These projects typically consist of full flood embankments (often incorporating paved roads) surrounding a haor or other flood prone area, with one or more flushing/drainage regulators. Full flood protection projects (both with and without pumped drainage) have either negative impacts on fisheries — caused by reduction in flooded area and obstruction of fish migration — or no impacts on fisheries (frequently because the area was not important as a fish producing area prior to project implementation).

River Channelization Projects (5 projects)
Two types of projects are included in this category:

- Rivers which have been "confined" by the construction of full flood embankments along one river bank (Konapara) or both on both river banks (Khowai, Manu). The former is generally carried out for larger rivers, and the latter for spate-type tributaries. The objective is to protect rice crops planted on the hinterland behind the embankment(s);

- Rivers which have been straightened by eliminating meanders and loops (by loop-cutting), such as the middle Kushiyara River. Loops are cut not by excavation, but by gouging a shallow channel across the base of the loop and allowing the monsoon flood to excavate the bypass channel. This results in large masses of sediment (much of it bedload) being transported downstream. No embankments are erected.

River channelization projects can have mixed impacts. River loop-cuts have a severe negative impact on carp reproduction as ox-bow bends are a favoured spawning habitat. Sedimentation of duars is another negative impact.

River and Khal Re-excavation Projects (6 projects)
This type of project removes sediment from drainage khals and rivers which have become silted up. This improves drainage flows in the late monsoon and relieves drainage "congestion", thus permitting early planting of boro seed beds. River and khal re-excavation projects have positive or no impacts on fisheries. Benefits are probably due to greater fish habitat depth, better flow regime, and improved connection with other channels and their fish stocks. Greater use is probably made of the re-excavated khals by migrating fish stocks.

Water Retention Structures Projects (3 projects)
This type of project consists of a large regulator built across a stream, and lateral embankments. The purpose is to pond river water behind the regulator for irrigation during the dry season. Water retention schemes have little impact on fisheries.

To summarize, negative impacts of FCD/I projects centre on interference with fish migration/reproduction and general reduction/disruption of aquatic habitat quality and area. Many of these conventional impacts have been observed or reported on from the region. However, given the high number of partial flood protection projects as a percentage of total projects in the region, FCD/I impacts on fisheries would not appear to be as catastrophic as may be the case in other regions of Bangladesh. In evaluating the impacts of the FCD/I projects in the region, it is of importance to bear in mind that many FCD/I projects do not behave according to the design plan. Problems frequently seen are:

- too early overtopping of submersible embankments;

- frequent breaching of submersible and full embankments either by floods or by public cuts (farmers and/or fishermen trying to drain out fields or to flood them for various and frequently conflicting purposes);

- too many drainage and irrigation structures inoperable due to mechanical damage and siltation;

- river channel siltation contributing to the above and limiting navigation.

The relevance to fisheries of these failures is profound because it implies partial reversions to pre-FCD/I conditions. Clearly, the impact of any particular FCD/I project has the potential to vary from one year to the next. In conceptualizing and assessing the impacts of FCD/I projects it is necessary to distinguish between what might happen over the long term if the structures perform perfectly, and what has actually transpired given their imperfect behaviour.

It is clear that the effects of FCD/I projects on flooding are complex and difficult to track on a regional basis from year to year. Submersible embankments do not reduce the area flooded but hectare-months of inundation and flood water residence time are reduced. Full flood embankments severely reduce the latter two inundation indices, as well as area flooded, but even under full flood protection conventional paddy field flooding is carried out. This highly restricted form of inundation still yields some fish production. Intentional cutting of embankments and embankment/regulator failures are non-design events which counteract flood protection restrictions on natural flooding, thus increasing inundation areas and pushing inundation indices upwards.

3. 4 Agriculture

3. 4. 1 Floodplain Cropping Patterns

Approximately 19838 sq km (91.4%) of the Upper Meghna floodplain are currently under some form of agricultural production. The area flooded in excess of 0.9 m in Northeast region (58%) is considerably higher than for Bangladesh as a whole (29%). This highlights the need to acknowledge that flooding is a major factor in determining agricultural practices in this region as compared to other parts of the country. Farmers have adjusted their crop production practices to accommodate this hydrologic regime. More than 100 crops are grown in the Northeast region. The region is highly suitable for rice production, so not surprisingly, as elsewhere in Bangladesh, rice has emerged as the dominant crop. It is produced on an estimated 86% of the cultivated area, and it is grown in all the three cropping seasons (*kharif* I, *kharif* II, and *boro*).

Rice is characterized by the season in which it is grown. Photoperiod insensitive varieties grown in the *kharif* I season are generally called *aus* rice and are produced on 0. 476 million hectares in the region. About 80% of this area is covered by more than 350 local varieties (b *aus*). The remaining 20% is covered by 13 high yielding varieties (hyv *aus*) recommended by BRRI for this season. *Aus* production in the region was 0.508 million tonnes during 1990-91 contributing 15% of total rice produced in the region.

During the *kharif* II season, assorted varieties of *aman* rice are grown on 1.007 million hectares in the region. About 25% of this area is cropped by more than 500 varieties of deep-water rice (b *aman*). Slightly more than 50% of the *aman* rice area is cropped by local transplanted *aman* (lt *aman*). Over 600 varieties have been identified by BRRI to date. Both b *aman* and lt *aman* are photoperiod sensitive. The remaining 24% of the *aman* rice area is covered by nine high-yielding rice varieties (HYV *aman*) which have been recommended by BRRI for this season.

These include two photoperiod sensitive hyv *aman* varieties released recently. *Aman* production in the region was 1.341 million tonnes during 1990-91 contributing 41% of total rice produced in the region.

Photoperiod insensitive varieties of *boro* rice are grown on 0.697 million hectares in the region, about 75% of which is covered by 16 high yielding varieties (hyv *boro*) recommended by BRRI for this season. The remaining 25% of the *boro* rice area is covered by a more than 400 local varieties (l *boro*). The region produced 1.427 million tonnes of *boro* rice in 1990-91 constituting 44% of total regional rice production.

Rice production increases during the last decade occurred mainly because high yielding varieties were introduced for *boro* rice production under irrigated conditions. Compare rainfed (*aus, aman*) with irrigated (*boro*) rice production trends. *Aus* production in the region increased from 0.5 million tonnes in 1960-61 to 0.6 million tonnes in 1983-84, then decreased to 0.4 million tonnes in 1991-92. *Aman* production increased from 1.4 million tonnes in 1960-61 to 1.6 million tonnes in 1986-86, and then dropped to 1.3 million tonnes in 1990-91. In contrast, *boro* production increased from 0.3 million tonnes in 1960-61 to 1.4 million tonnes in 1990-91, a five-fold increase.

3.4.2 Agricultural Impacts/Conflicts with Fisheries

A principal source of conflict between farmers and fishermen within existing FCD/I projects is related to land reclamation for paddy. This results in a reduction of water area in the beels due to more people claiming agricultural lands within the beel area. While farmers may want to drain beels to create more agricultural land, fishermen often want to retain higher water levels for their katha production system. A second area of conflict relates to surface water storage for mid-winter irrigation, and beel de-watering for total fish harvesting. Jalmohal leaseholders and/or fishermen often want to drain beels to facilitate total harvesting of fish, while farmers want to retain water for their boro crop irrigation needs. Regulator operation is under the control of the BWDB. In cases of conflict, BWDB tries to arrange compromises between fisheries and agriculture. Complete de-watering is extremely destructive to the fishery resource. Timing of draining or flooding also causes conflicts. Fishermen often want to cut embankments or open regulators in mid-May to allow pre-monsoon flood water into the haors so that fishing can begin. Farmers may resist this if all the *boro* crop has not been harvested, or if they are expecting to harvest an additional *boro* crop *(demi)*. Social tensions between farmers and fishermen often revolve around the fishery resource itself. Fishermen brought in from outside by leaseholders are resented by local farming populations. Fishermen catch fish which would otherwise be available to farmers when their land is seasonally flooded. Farmers claim customary rights to unimpeded fishing in water bodies.

Pesticides

The increasing use of pesticides in the region parallels the introduction of hyv rice. This presents a threat to floodplain fisheries as it leads to contamination of fish flesh by pesticides which have moved up the food chain, rendering it unsafe for human consumption. Statistics for 1988-89 show that 538 t of pesticides were distributed to the region (10.7% of the national total). The total area of rice cultivated in the region is 1,996,755 ha (19.1% of the national total). The average application rate in the region is thus 0.27 kg/ha. This is 44% less than the national average of 0.48 kg/ha. Some 0.16 kg of pesticide is applied per ton of rice produced in the region, compared to 0.28 kg/t for all Bangladesh. As some pesticides are used on non-rice crops, the real quantities of pesticide applied per ton of rice produced are somewhat lower. A first approximation of annual pesticide loading of the aquatic environment can be made for the region. Assuming an annual water supply of 173.3 km^3, the maximum possible dissolved pesticide concentration (assuming complete solubility and no losses) would be 3.104 micrograms per l. A more realistic index would be the amount applied to rice fields (that is 0.27 kg/ha). Assuming an average inundation level of one meter of water, the maximum possible dissolved pesticide concentration is 27.0 micrograms per litre. In higher elevation areas with lower water inundation levels, and where two or three crops are grown each year, pesticide concentrations could be much higher. Residue analysis of fish tissue from representative markets needs to be undertaken to establish the magnitude of the fish flesh contamination problem at regional level. Case studies of residue levels in fish caught in selected rice fields also need to be undertaken, and this needs to be related to pesticide usage in the fields.

Fertilizers

Chemical fertilizers can increase fish production, but in large doses lead to negative impacts because of excessive aquatic macrophyte growth and direct chemical effects. There has been an increasing trend of fertilizer use for crops in the region. Urea (70.4% of total) is by far the most commonly used fertilizer in the region, followed by triple super phosphate (22.4%) and potassium oxide (4.7%). Average loading of the environment in 1987/88 was 95 kg/ha for the region as a whole (2,418,000 ha), or 115 kg/ha for rice hectarage only (1,996,755 ha). Some 60-70% of nitrogen fertilizer may remain residual in the soil and become dissolved in flood or irrigation water. Other ions may be more efficiently taken up by crops. Assuming that about 30% of applied fertilizer remains in the environment, the concentration of fertilizer dissolved in the water column would be 0.4 mg/l for the region as a whole (173.3 cu km annual water supply). A more realistic index would be the amount applied to rice fields (about 115 kg/ha). Assuming an average inundation level of one meter of water, the maximum possible dissolved residual fertilizer concentration would be about 35 mg/l. In higher elevation areas with lower water inundation levels, and where two or three crops are grown each year, the annual loading would be greater. Nutrient-rich runoff would eventually make its way to beels and rivers, and cause eutrophication. Case studies have shown that this is indeed taking place, and that where FCD/I projects result in stagnation of surface waters (ie increase the water mass residence time) problems of low water quality and fish disease increase.

3. 5 Wetland Resources Utilization and Management

The wetlands of the Northeast Region provide many valuable goods and services to local residents, to the region as a whole, and to the nation, including:

- *Hydrological and physical values.* Flood control, sediment trapping, ground water recharge, water purification, swamp forest trees that protect homesteads from erosion.

- *Economic production and employment.* In addition to fisheries production, local people harvest wild (undomesticated) plants for fuel, animal fodder, and housing materials. Some wetland plants make a critical contribution to the diets of the poor, especially in seasons when employment is low and after poor harvests. Trees and brush also play an extremely important role in providing shelter and food for fish. Industries based on wild plants have been proposed - for example, making paper pulp. A number of animal species are harvested, legally or illegally, for consumption, use, and export in the form of food products, skins, and so on; these include frogs and lizards. Some animals play an important role in keeping insect pest populations under control.

- *Biodiversity conservation.* Biodiversity refers to the variety of types of plants and animals. The region still supports internationally important numbers of ducks and other water birds. Despite the ban on hunting, these animals also provide food and income for local people - in addition to sport hunting by rich locals and urban visitors.

- *Social and cultural values.* The wetlands of the Northeast have current or potential value for education, research, recreation, tourism, and so on.

Nine internationally important sites have been identified, and field studies are being carried out to characterize these. In addition, sites of national importance for overwintering of fish broodstock ("mother fisheries") are being identified and studied. Each key wetland site identified is unique in terms of overall physical characteristics, plant and animal communities, and human activities.

In the future rice cultivation will continue to be a major primary use of large areas of the Northeast Region. But for areas where rice cultivation is too risky or yields are too low, other primary uses such as open water fish production, harvesting natural products, swamp forests provide greater economic and social benefit to the region's people. Enhancing conditions for secondary and tertiary uses can yield additional benefits. The challenge is to integrate the varied knowledge and efforts of local people, technical experts, and national policy makers, so as to enable each wetland system and site to be used as wisely as possible.

4. PREVIOUS STUDIES

4.1 Technical Report No. 17, Fisheries and Flood Control, Drainage and Irrigation Development, MPO, 1985.

The impacts of FCD/I projects on floodplain fisheries were studied in a comprehensive manner in this MPO benchmark report. Findings of investigations of the two FCD/I projects (Chandpur Irrigation and Flood Control Project; Muhuri Irrigation Project) were presented. Although no studies were reported on from the haor basin, it was speculated that, because of the general prevalence of submersible embankments, "If the natural cycle of fish dispersion from the beels in flood season and concentration in the dry season could be preserved, it would be possible to attain perpetually a high harvest of fish from beels within the haors of Sylhet and Mymensingh regions. " The report suggested three approaches for preventing and mitigating fishery losses and as modes of development:

- Allocation of lands for controlled flooding. In May-June, a specific area of low lying land within each planning area would be shallowly flooded (to a depth of 20-40 cm) for 30-40 days. This would allow fish fry to enter from the rivers, and present opportunities for beel fish to access shallowly flooded land.

- Mitigation through the design and operation of water development projects. Two concepts were proposed. The first proposal included protective embankments around beels, re-excavation of khals connecting the beels, and installation of fish friendly regulators across the khals. The second proposal, primarily for submersible embankment projects in the Northeast Region, was for regulators to remain closed during the post-monsoon period from September to November to increase hectare-months of inundation and fish production. Larger capacity regulators are required to provide for rapid drainage after November so that boro transplantation can begin.

- Mitigation through replacement measures. The loss of openwater fish production would be mitigated through artificial restocking.

Assessment of study: Controlled flooding is not relevant to partial flood protection projects, since they flood "automatically" every year in any case. Controlled flooding in full flood control projects would be incompatible with present project objectives. A limited amount of beel embankments have been introduced to the region. They have proved to be effective in increasing water storage and preventing sedimentation of beels. Longer water retention during the post-monsoon season for submersible embankment projects would be incompatible with boro production, since slow drainage is already a problem in many projects and such a measure would shorten the boro season still further. Artificial floodplain stocking has been taken up throughout Bangladesh in large projects funded by the World Bank, UNDP and, in the Northeast Region, by the ADB.

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4.2 Pre-feasibility Study for Northeast Rivers Flood Protection, BWDB, 1986.

In Appendix A of the BWDB study (Agriculture and Fisheries), several possible provisions for mitigating fishery losses from FCD/I projects were reviewed. These are similar to those of the above MPO study: controlled flooding of a selected fish reserve area, beel embankments, haor water retention, and artificial stocking. Other provisions are:

- Fish passes. Fish passages would be incorporated into existing water regulation structures for fish migration. Structures should be operated to accommodate fish migration, when possible.

- Spawning grounds. Lateral expansion zones designated as sensitive spawning grounds would be kept totally free of flood control measures.

Assessment of study: Some of the measures proposed are similar to those discussed for the MPO study. Fish passes and fish friendly design and operation of regulators appear to be viable approaches. Exclusion of sensitive spawning grounds (as fish sanctuaries) from FCD/I projects is necessary.

4.3 Towards Sustainable Development: Fisheries Resource of Bangladesh, IUCN/MEF/BARC, 1991.

The report reviews the impacts on floodplain fisheries of the Chandpur and Muhury FCD/I projects, and presents findings from other projects: Chalan Beel Project, Naogaon Polder-I Sub-Project, Madhumati Nabagonga Subproject, Horai River Subproject, and several river closure and barrage projects (River Kumar, Faralla Barrage, and Boral River). A hypothesis is advanced that the sharp decline in abundance of major carps in the beels of the Northeast Region may be due to the interference of submersible embankments with breeding and feeding migrations. The study recommends that fishery interests be accommodated and integrated into FCD/I projects. Mitigation measures proposed are similar to those in the preceding studies: 1) regulator operation to be compatible with fish migrations, and 2) artificial floodplain stocking.

Assessment of study: The study presents new impact study findings and supports the mitigative solutions proposed by the earlier studies.

4.4 Design of "Fish Friendly" Regulators within the Flood Action Plan, FAP 17, Fisheries Study, 1993.

This study focuses exclusively on the problem of the barrier to fish migration presented by embankments. It considers the concept of fish ladders to enable fish migrating against current to surmount permanent large variations in water levels. It concludes that such structures are not appropriate for Bangladesh as there are no major structures which induce large water level differences. The study assesses the design of existing water regulators of FCD/I projects and their effectiveness as regards "fish friendliness". The study assumes that the migration of adult and juvenile fish across embankments in both directions is not an important problem, because: 1) water flowing from a river across an embankment into a compartment does not attract many fish as the current is flowing in the wrong direction (fish would not want to swim downstream), and 2) "wild major carp . . . are not abundant in enclosed beels." It is assumed that any migrating adult fish attempting to pass through regulators, under normal flood levels, are most likely to be successful.

The main problem associated with fish bypasses at regulators is identified as the danger to fish fry and hatchlings passively drifting downstream from spawning grounds during the early monsoon season (assuming the regulator is opened at least partially):

- Fish may be physically damaged by contact with the structure;
- Damage may occur to the swim bladder through rapid changes in pressure;
- Damage may arise from turbulence downstream of the structure. This is not yet proven, but the study suggests it is preferable to minimize turbulence in any case.

The report notes that contact damage most likely occurs at small culvert type regulators possessing impact energy dissipators, and that fish movement at such culverts is common. Swim bladder damage is most likely to occur at undershot vertical lift gates when gates are operated at small openings. Free surface flow, which occurs with overshot or fully open gates, would minimize this problem. The principal recommendation of the report is that main hydraulic regulation be carried out using undershot gates (as this is likely to provide the most convenient method of smoothly controlling downstream water levels). Provision should be made at the sides of the regulator for overshot flow expressly for fish passage. The unit discharge of the overshot section should be smaller than that of the main gates so as to minimize turbulence downstream.

Assessment of study: The study presents a detailed consideration of one aspect of the fish migration interference problem (ie access of passively drifting fry and hatchlings from river to floodplains during the early monsoon season). A reasonable working solution is proposed for overshot flow, but this does not solve all access problems for partial flood protection projects in the Northeast Region. Field studies indicate that broodstock are in a state of active migration during the pre-monsoon season, and that spawning migrations occur in both directions (ie from beel to river, and from river to beel), depending on species. Undershot flow velocities across regulators under differential heads of 3-4 m are in the order of 6.5-9 m/sec, which exceeds the countercurrent swimming abilities of probably all fish species in the region. Hence the problem of broodstock migration out of beels into rivers most likely cannot be solved by hydraulic regulator design and operation. Some form of fish ladder is required.

Migration of broodstock from the river into the haor during the pre-monsoon season needs further review. Ripening and harvesting of the boro rice crop takes place in late April and early May. Design elevations of submersible embankments generally provide for pre-monsoon flood protection up to mid-May. However, pre-monsoon spawning migrations begin well in advance of this date (in March/April). In order for broodstock that have overwintered in rivers to access the floodplains for spawning, some controlled flow would have to be allowed into the haor in March/April. Because of the need to strictly protect the boro crop at this time, only a small volume of water could be introduced into the haor, depending on beel storage capacity. If the water is passed through a small undershot opening, the velocity would be excessive and swim bladder pressure damage might result. Fish in the river might try to avoid being sucked through the undershot opening. With overshot flow, the head differences could create high turbulence and damage.

The report describes various types of small and large fish pass structures. However, the vertical slot type fish pass is not included and this structure may be appropriate for the Northeast Region.

4. 5 Conclusion

Previous studies describe the several structural as well as non-structural measures which could act as mitigative solutions to the negative impacts of FCD/I projects on fisheries. The principal non-structural measure - artificial stocking - is currently being implemented, and its impact is being evaluated.

The most promising structural measures are beel embankments and fish passes at hydraulic regulators. Beel embankments have been successfully used at Medhol Beel and Chatla Beel in the Northeast Region. Fish passes have yet to be tested.

5. WITHOUT-PROJECT TRENDS (NULL OPTION)

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

- Continuing sedimentation of rivers, haors, and beels in certain parts of the region: The total surface area affected is likely to increase. The loss of deeper water habitats will likely affect stocks of *boromaach* more severely than *chotomaach*. Available evidence suggests that one species of major carp *(Nandina)* has already become extinct in the region because of deepwater habitat loss. More loss of fish biodiversity can be expected if the trend of sedimentation continues.

- Changing flood patterns: Flood stages are getting higher due to sedimentation and flood duration is becoming longer due to earlier pre-monsoon flooding. Total surface water volumes are also increasing due to increasing rainfall. These hydrological changes are shifting fish breeding migrations earlier in the calendar year. The timing of the *boro* growing season is, however, remaining relatively stationary in haor areas, and shifting to later in the year in full flood control projects where HYV *boro* is grown. This increasing de-synchronization between the pre-monsoon fish reproduction period and the *boro* rice cultivation season will result in less opportunity for floodplain breeding fish species to have access to breeding grounds, and poorer access to floodplain nursery/grazing grounds for fry and hatchlings of river breeding species. The overall result will be declining recruitment and yields.

- Continuing slow drainage and early flooding: Slow drainage of haor areas in the post-monsoon is expected to continue. Failure to close cuts promptly during the dry season allows flood waters to enter the haor areas early in the pre-monsoon season and increases hectare-months of inundation. The result will be a longer growing season for fish on the floodplains. This should result in more *chotomaach* breeding episodes and some increase in production. However slower drainage in the post-monsoon and water stagnation can result in massive fish kills from disease outbreaks, and a consequent reduction in yield.

6. FISHERIES INFRASTRUCTURE DEVELOPMENT OPTIONS

6.1 Summary of Problems

The most important problems affecting floodplain fisheries that might be mitigated by structural measures are loss of deepwater habitat due to sedimentation, loss of hectare-months of inundation due to FCD/I projects which mainly service agricultural interests, and interference with fish migrations by flood control embankments.

6.2 Fisheries Infrastructure Development Options

There are four basic options for fisheries infrastructure development in the project area:

- *Provision of fish passes.* This option would allow migrating fish to "move through embankments" against a water head differential, thus permitting fish inside embanked haors to move into rivers during the pre-monsoon season. All of the fish pass options (vertical slot fishway, undershot vertical lift gate, overshot gate, and so on) must operate with a limited volume of water entering the haor so that boro crops are not endangered. Fish pass development and adaptation to meet Bangladesh FCD/I conditions through pilot projects must precede any wider introduction of fish passes in the region and country. Fish pass developments are described in Chapter 7.

- *Embankment of beels to prevent sedimentation and retain more water.* Embankments at Chatla Beel in Hakaluki Haor, Boro Haor and Medhol Beel have successfully reduced the inflow of bed load sediments and increased dry season water retention. This option appears to be technically feasible, and apparently cost-effective as embankment maintenance at Chatla Beel and Medhol Beel is carried out under local private sector initiatives. The large number of beels in the region (6000+) requires that beel embankment projects must be selective, as well as act in a strategic catalytic manner. This option is described in Chapter 7.

- *Controlled flooding.* This is already being carried out at partial flood protection projects in so far as the haor is intentionally flooded through the regulator prior to overtopping of the submersible embankment in order to equalize water levels on each side of the embankment and minimize embankment erosion. Some flow could be introduced into full flood control projects through the regulators. Whatever water storage capacities exist in beels and khals within the project boundaries will likely be automatically replenished during the monsoon by direct rainfall and drainage within the project area, and resorting to river inflows is probably not necessary. This option is not further discussed in this report.

- *Formation of artificial river duars.* Experiences with spur dykes at loop cuts in the Kushiyara and Baulai Rivers indicate that these structures can re-mobilize sediments locally and create artificial scour holes or duars. However stone rip-rap spurs would be expensive, and could initiate erosion on the opposite river bank and create shoals which would obstruct navigation. Hence large scale use of spur dykes does not appear appropriate. They may be attractive for localised habitat replacement for mitigating the loss of deepwater habitat due to water resource works. This option is not discussed further in this report.

7. PROPOSED FISHERIES ENGINEERING MEASURES

7.1 Rationale

The Fisheries Engineering Project provides for the construction and monitoring of fish passes, and construction of beel embankments. The fish passes will mitigate the obstruction to fish migration caused by flood control embankments, and result in increased production of spawn and increased catches in floodplain and river fisheries. Beel embankments will prevent entry of bed load sediments into the beel during the flood season and/or increase the water storage capacity during the dry season.

7.2 Objectives

The objectives of the measures are:

i) to provide for migration of fish across embankments to increase production of spawn and fish production;

ii) to prevent sedimentation of beels and increase the beel dry season water storage capacity

7.3 Description

There are three components to the fisheries engineering project:

- Fish Pass Structures: This includes the installation of two pilot fish pass structures (of the vertical slot type) at a FCD/I project for design optimization and short term impact monitoring. Following the pilot project, a further 25 vertical slot fish pass structures will be constructed at selected FCD/I projects in the region and monitor their impacts;

- Embankments around Key Beels: Protective embankments will be constructed around key beels to protect the beels from sedimentation;

- Embankments around Community Beels: As part of a self-help programme in rural villages, low embankments or bunds would be constructed around community beels in order to increase their water storage volume and thus enhance fish production during the dry season.

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7. 3. 1 Fish Pass Structures

Fish Migration

The evaluation of fish passages covers mainly the pre-monsoon period of April and May when mature adult fish migrate from rivers to haors and some move from haors to rivers. The natural pattern of fish migration during the pre-monsoon period is for adult fish, mainly carp and catfish, to move from the river to shallow areas within the haor for breeding purposes (in-migration). Breeding areas include streams within the haor, beels and other shallowly flooded areas.

Other adult fish which overwinter in the haor area, mainly within beels, migrate in the opposite direction from the haor to the river for spawning (out-migration). Before construction of embankments and control structures for flood protection purposes around haors the migrating adult fish were able to swim freely in and out along the natural flow channels (khals) between rivers and haors. Through field studies and interviews in the field, it was concluded that without flood control works there is an extensive in-migration of adult carp and catfish from the river to haor areas during the pre-monsoon season and likewise an out-migration from the haor to the river.

During the pre-monsoon migration period with regulator gates closed, water levels on the river side are often as much as 3.5 m above water levels within the haor area. Where fish are blocked or delayed at partial or full flood regulators, special fish pass facilities should be provided to overcome the problem and ensure maintenance of future fish production. Special fish passage facilities are required for moving fish across the project boundary in both directions.

The migration pattern during the post-monsoon period (mid-September to mid-November) is a reversal of conditions for the pre-monsoon season. Older mature adult, and young new adult fish move from their spring and summer breeding/rearing grounds to overwintering areas. Thus fish from the haor move into the rivers and some move from the river to beels within the haor for overwintering. During the post-monsoon period the differences in water levels between rivers and haors are normally very minor (maximum 0.3 m). With adequate and <u>open</u> control gates the adult fish are able to migrate freely in either direction. As long as control gates are open, no fish passage facilities are required for the post-monsoon period.

Swimming Characteristics of Fish

For fish pass structure planning the speed and endurance of migratory fish was examined. Three aspects of swimming speeds, which vary with fish species, can be defined:

- Cruising speed: one that can be maintained for long periods of time (hours)
- Sustained speed: one that can be maintained for minutes
- Darting speed: a single effort, not sustainable (Estimated maximum duration, 10 seconds)

Normally fish employ *cruising speed* for movements such as migration, *sustained speed* for passage through difficult river reaches and *darting speed* for feeding, leaping or escape purposes. The force on the fish may be considered equivalent to that associated with any object moving within the water or stationary in moving water. Only limited information on the relative swimming speeds of fish such as carp and catfish are available. The swimming speeds for carp (cyprinus carpio) common to Japan, China, Central Asia and parts of Europe (M. C. Bell,1973) is 0.46, 1.22, and 2.59 m/sec for cruising, sustained, and darting speeds, respectively for a 76 cm long fish.

There is no data available on the swimming speeds of catfish. Biological information indicates that catfish are a more vigorous fish in comparison with carp and likely a faster fish. Normally fish are able to swim for hours at the upper ranges of their cruising speeds and it is assumed that no oxygen deficiency occurs at that level. At higher speeds fish are apparently not capable of passing water over their gills at the proper rate to obtain the increased oxygen required for additional energy expenditure. For movement through a fish pass structure with baffles and resting pools, fish would normally utilize all three levels of speed at different stages during their ascent.

Successful passage of skin carp (40 cm), catfish (30 cm) and dase (30 cm) was observed through a vertical slot fishway at the Hazama River Irrigation Dam Japan (R. Sato, 1990). At this 10 pool, 11 baffle fishway, the flow velocity through the baffle slots was estimated at 1.6 m/s.

Fish Behaviour - Distribution
Behaviour of fish is critical in fish passage design and is often a function of the individual species. Important parameters which may influence planning are the shore and depth orientation of the fish during migration, where they rest, how they respond to river barriers such as gated control structures and associated hydraulics, how do they react to light and enclosures, and possible diurnal variation in migration.

Knowledge about the distribution of migratory fish within the river or haor system is equally important in planning the location of access channels to or from the fish pass structure. Poorly located access channels will delay rather than attract migrants.

Design Considerations
One important biological parameter in the design of fish pass structures is that the facility must accommodate the weakest fish within the weakest species requiring passage. A further requirement is that the size of the facility should be based on the expected numbers of fish which need passage and the expected hourly or daily rate of ascending migrants.

Information needed for design of fish pass structures includes site specific data such as tailwater rating curves, local topography, magnitude of flow and velocities and water surface profiles along each bank upstream and downstream of the proposed fish pass location. Combined with biological requirements and hydraulics these physical parameters will determine the type of fish pass facility which will suit a specific flood control regulator.

Actual site observations and possibly modelling will be required to locate fish pass entrances and exits and determine the scale of the facility and passage flow in combination with biological requirements. Observing the behaviour of fish and the flow pattern downstream of existing structures are often the best method of locating a successful fish entrance to a bypass. Fish entrances based on theoretical hydraulic considerations alone often need modifications after construction.

Model studies can be a valuable tool in helping the designer understand the fish pass and fish entrance setting. There should be no excessive turbulence at the outflow from the fish entrance and an adequate depth for fish to readily enter. High velocity sluice water or hydraulic jumps adjacent to fish entrances make fish seek the acceptable velocities through a bypass.

Preliminary Layouts of Fish Pass Facilities

Fish passes or fishways are channels or a series of pools installed to aid fish in overcoming natural or artificial obstacles to migration. A small amount of water is diverted from the river or forebay of a dam upstream of the obstacle. The diverted flow is controlled throughout the length of the fish pass by means of baffles, weirs or orifices so as to reduce the velocity to the point where the fish, in their upstream migration, can swim without too much exertion. Resting spaces between baffles or weirs are provided so fish can recover after darting or bursting from pool to pool.

The main concern in the hydraulic design of fish passes is to determine the best way to control the water flowing through the structure so as to dissipate its energy most efficiently without hindering the swimming ability of the fish. There is however, no rational approach to the problem of energy dissipation in a fish pass and most existing structures built have been copied from original designs made with the aid of hydraulic model studies. The pilot design would be a large scale model where flow patterns, energy dissipation and surface profiles can be observed with live fish and improvements made if necessary.

Apart from acceptable hydraulics, other general requirements are:

- Sediment bedload, debris and polluted water must not interfere with the flow
- The fish pass should be designed so that the least amount or at best no manual control would be required for maintenance of flow through the structure
- The operating water level range must satisfy fluctuations in headwater and tailwater
- The flow through the fish pass must be adequate to attract fish at the downstream end (fish entrance)
- The upstream end of the fish pass (fish exit) must be located so that fish leaving will not be swept down over obstructions or dams.
- The size of the fish pass must be based on the numbers of fish expected to use the facility.
- This last and probably most important aspect of fish pass design is the location of the fish entrance. Other than adequate attraction flow, the entrance should be located and aligned so that the migrating fish will not be delayed unduly by turbulence which confuse direction and cause “traffic jams”. See Figure 1 for examples of poorly and well located fish entrance locations at dams.

In general, fish pass designs are of four main types: vertical slot fishways, pool and weir fishways, Denil fishways, and fish locks (Figure 2). These structures are described in Annex C. At specific sites, design may incorporate aspects from a combination of the above fish passes.

At embankments and regulators in the Northeast Region the forebay levels normally vary independently of tailwater (haor side) during the pre-monsoon period. Under these conditions a vertical slot fishway appears to be the better option. Sizing of vertical slot fishways is normally based on hydraulic considerations from model tests and by the required capacity for moving fish over an obstruction.

Proposed Fishways
Fish passes located at regulators between rivers and haors would have to accommodate fluctuations in head water levels of up to 3-3.5 m during the pre-monsoon period. Fish migrating from the haor to the river (out-migration) would ascend from low to high water levels whereas in-migrating fish would move downstream in the opposite direction (from river to haor).

Out-migration (upstream moving fish) can be accommodated by a vertical slot fishway which operates at variable water depths as proven on many occasions (Figures 3 and 4). However, downstream passage of fish (in-migration) at the same time is questionable. Small fish, fry and fingerlings have been known to enter upstream ends of fishways and either get flushed or swim with the flow. No records are available indicating that adult fish will do the same or if they would be adversely delayed and possibly injured by moving down a fishway. Because of this unknown factor it is suggested that fish migrating from the river to the haor be provided an alternate bypass through a fish friendly underflow sluiceway structure. Vertical slot fishways and sluiceway passage facilities will be assessed and incorporated in the same layouts.

Plans and general details for an 11 pool, 12 baffle fishway structure, fish sluiceway passage and fence for guiding the migrants are shown for two configurations. Alternate I layout (Figures 5 and 6), is a straight alignment with the fish entrance and exit a distance away from the regulator. In-stream fencing using bamboo, steel or other suitable material would guide out-migration from the haor at the downstream end and in-migration from the river at the upstream end (down fish exit). It is proposed that a fish sluice gate be incorporated with the regulator control if adult in-migrating fish will not enter the fishway and move down with the flow. The fish sluiceway layout includes allowance for a stilling basin at the tailwater end. The stilling basin or deep pool at the tailwater end of the fish sluiceway (Figure 7), will dissipate the high velocity flow under the gate and provide a transition for the migrants to swim down the khal into the haor. The fish sluice gate or any other regulator sluiceway gate should be fully open when fish are present to avoid injuries to the migrants. Flow out of the stilling basin across slots in the wall will be adjusted by stoplog control. After initial setting to suit tailwater conditions no further adjustments should be needed.

Upstream (and downstream) passage of migrant fish through the fishway depend on adequate depth of water over the forebay and fishway invert levels. Adequate passage is expected with submergence of one metre.

Ideally for a vertical slot fishway which is self regulating the forebay (fish exit) and tailwater (fish entrance) levels change by equal amounts and the water depths and flow are the same at each baffle slot. However, at regulator structures at haors the forebay in the initial flood stages rises faster than the tailwater. To prevent hydraulic drawdown in the upper pools when water starts flowing through the fishway, the water levels at the fish entrance need to be adjusted. The adjustment can be made by telescoping weir(s) at the fish entrance operated by float control at the forebay or otherwise by manually correcting using stoplogs in the fish entrance slots.

The stream channel (khal) downstream of the fish entrance might have to be trenched and/or provided with berm weirs to facilitate a channel with adequate depth of water for fish to swim to or from the fishway.

The flow through the fishway would be 0.85 m^3/s at one metre of depth at the forebay of the regulator dam. At 5 m depth the flow would be 3.57 m^3/s. The flow down the fish sluice way through the 0.7 m wide x 2.0 m gate fully open would be approx. 8m^3/s. If not used for passing fish the sluice gate could be used to provide attraction water at the fish entrance. Such additional flow would also benefit fish migrating up or down the khal within the haor.

Fishway layout, Alternate II, (Figures 8 and 9) depicts a folded alignment of the vertical slot structure shown for Alternate I. Hydraulically the structures are similar. Alternative II provides a more integrated structure with the regulator, and provides downstream fish passage (river to haor) exclusively through a fish sluiceway on the river side opposite the vertical slot fishway. The stilling basin at the downstream end of the fish sluice is similar for both layouts (Figure 7). The fish migrants are guided by fences constructed using bamboo, steel or other suitable materials.

It is apparent that the fish entrance and exit areas, the pools within the fishway and the finger gate openings in the fences upstream and downstream of the structure would be attractive locations for catching fish. Therefore, it will be imperative that rules and regulations are adopted to prohibit any commercial or subsistence fishery or fishing by individuals in the vicinity near the fish pass facilities. Effective policing and enforcement will be required.

Pilot Project
Little information is available on the passage of freshwater adult carp and catfish through an artificial fish pass structure. Present studies indicate that the hydraulics of a vertical slot fishway in general are conducive to moving fish up over an obstruction such as flood embankments and regulators. It is recommended that a pilot project be implemented and monitored before a large number of fish structures be constructed. Such a pilot project would include a number of full scale vertical slot fishways and a fish sluice way at a location where adult carp and/or catfish are known to congregate and require passage over an obstruction. The internal configuration of pools, baffles and slots should be designed so that on-site modifications can be made to improve hydraulic performance.

Verification of migration routes and timing require further study. It is suggested that recent techniques such as radio tagging and electronic imprinting be used in conjunction with enumeration by fish counts at temporary fish fences. Research should include information on daily and, if possible, hourly movement of migrant fish along channels between rivers and haors, in both directions. Rate of migration is an important parameter in determining the physical size of a proposed fish pass structure.

It is probable that some optimization of design will be required, and this would be best accomplished by construction and monitoring over a two/three years period of a pilot project of two fish passes prior to general and widespread building of fish passes throughout the region. This project component addresses this need.

Project activities would be as follows:

- Several BWDB design engineers will receive training in fish pass design;
- Site will be selected for construction and community sensitization/ participation in project formulation will be encouraged;
- An engineering design for the fish pass will be finalized based on local conditions;
- The fish passes will be constructed and the BWDB field staff will be trained in the operation and maintenance of the fish passes;
- DOF field staff will monitor the species and number of fish using the fish pass, and the impact on fish catches inside the FCD/I project and in the adjacent khals and rivers;
- NERP project staff will monitor the impact of the fish pass on agricultural production and on social aspects;
- Optimizing baffle design will be based on monitoring results during the first year of operation.

Required action by GOB: The following actions are required by GOB in order to allow this project component to proceed:

- BWDB to select staff design engineers to undergo training in fish pass design and to appoint field staff for operation and maintenance of the fish passes;
- DOF to appoint field staff for monitoring impacts of fish passes on fish migrations and fish catches;

Construction of 25 Vertical Slot Fish Passes
Once design optimization has been accomplished under the pilot project, widespread construction of fish passes in the region can proceed. Initially, some 25 FCD/I projects will be selected for fish pass construction. The locations of these projects are shown in Figure 10 and are listed in Table 1, Annex B. The general provision of bypass facilities for fish at FCD/I projects will result in a marked increase in fish production.

7.3.3 Embankment of Key Beels

Rationale: A number of large beels in the region are threatened by bed load sedimentation during the flood season (Annex B: Table 2). There are existing beel projects in the region where embankments have been constructed around the beel which have successfully protected the beel from transported sediments. This proposed project provides for such protective works at key threatened beels in the region. Tentative locations for embankment projects are shown in Figure 11.

Project activities: The following is proposed:

- An inventory will be prepared of all key beels and their sedimentation threat. From this inventory a short list of threatened beels will be drawn up for protective works;

- Concerned parties in the general beel area (land owners, fishermen, farmers) will be contacted and their input sought during planning and implementation;

- Embankment construction will be carried out, as a joint activity between BWDB and the local community beneficiaries;

- Following construction, embankments will be planted with hizal and other inundation tolerant tree species;

- The effectiveness of the embankments in protecting against sedimentation, and the social impacts of the beel embankments will be monitored.

The GOB would be required, where necessary, to make *khas* land available for embankment construction.

7. 3. 4 Embankment of Community Beels

Rationale: The fish production of many small village beels, which is of dietary subsistence benefit to rural communities, could be improved by structural works to increase water storage volume and by ancillary developmental activities. Local communities might be motivated to formulate and implement a package of structural and non-structural measures for beel improvement if the benefits seem realizable and a support system is put in place. Communities proposed for inclusion in the Community Beel Embankment Project are listed in Table 3, Annex B.

Project activities: Two activities will be undertaken:

- A general package of structural and non-structural measures will be formulated by three pilot projects carried out at selected villages. This will focus on embanking or bunding community beels to increase storage capacity, removal of aquatic weeds and planting of inundation resistant trees. The community will be encouraged to participate in all stages of the pilot project cycle: planning, construction/implementation, management, monitoring, appraisal.

- A project extension network will be established to disseminate the package and provide technical support to communities that choose to implement the package.

The GOB would need to possibly legalize and otherwise reaffirm the access and tenure rights of rural communities to small beels in their vicinity.

7.4 Project Operation and Maintenance

Fish Passes

Fish pass structures will be the property of BWDB, which will be responsible for their physical maintenance. BWDB field staff will be trained to carry out these functions. DOF field staff will be responsible for the monitoring of fish migrations through the fish pass and the impact on fish catches. Operational authority will be jointly shared by the BWDB, DOF and the local fishing community. DOF will enforce measures to protect fish stocks in the vicinity of the fish pass. The cooperation of local communities in protecting fish stocks will be actively sought.

Beel Embankments

Embankments around larger beels will be regarded as part of the jalmohal. BWDB will be responsible for major repairs to the embankment, if breached. Routine maintenance will be the responsibility of the party possessing tenure and access rights to the jalmohal.

Embankments around community beels will be maintained entirely by the community.

7.5 Organization and Management

During the early part of the feasibility study and pilot project process, a number of client groups would need to be organized to oversee project development. These client groups would be composed of representatives from the local fishing community representatives, local fisheries officers, local public representatives, and relevant departmental officers. The groups would ensure that the problems of the fisheries sector 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 for the fishing community. They would be continually briefed as the feasibility work was carried out and would need to confirm the conclusions of the exercise.

BWDB would be responsible for undertaking technical work related to implementation of structural works in accordance with current practice but would be responsive to the client groups described above. The DOF is responsible for the provision of extension services to the fishermen within the project.

7.6 Project Cost Estimates

Total project costs are estimated at Tk 307.67 million. The breakdown by project components is as follows:

	Tk million
27 (25+2) Fish Passes	175. 33
Key Beel (36) Embankment	82. 72
Community Beel (100) Embankment	49. 62

Cost details are provided in Annex E.

7. 7 Project Phasing and Disbursement Period

Four years are required to implement the project. Two years are required for completion of feasibility studies, pilot projects, and conducting field surveys. Preparation of detailed designs should start in year one and be completed in year two. Construction activities for pilot work could start in year one. Construction should be complete by year four.

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 F, Initial Environmental Evaluation.

Fish Pass Structures
The project is expected to increase the reproductive success of fish stocks by reducing the barrier-to-spawning-migration effect of flood embankments by the construction of fish passes. Particularly important will be the restoration of spawning runs of major carp, including that to the Kawadighi Haor mother fishery. The fish passes will also improve the access of fish fry to floodplain and beel habitats. Quantification of benefits are difficult to define before the pilot fish pass structures are in place and further studies are carried out. Initial work suggests that fish passes will substantially increase fish production in partial flood control projects and full flood control projects (very preliminary estimates indicate a more than 50% increase of FW production over FWO condition).

Beel Embankments
Embankment of key beels will act to reduce sedimentation and increase water levels. Fish production in key beels should increase because they will become relatively more secure as fishery habitats with better habitat quality attributes, thus attracting more migratory species. Quantification of benefits are difficult at this stage. Preliminary work suggests that production increases in the order of 20% can be expected. Embankment and non-structural development of community beels will improve their fish production substantially (very preliminary estimates predict an increase of at least 50%).

Wetland Habitats and Grazing Area
Fish passes will allow some water flows into haors/beels during the pre-monsoon. This will replenish some evaporation and irrigation extraction losses, and will have a very limited beneficial impact on the aquatic habitat.

The impact of the key and community beel embankments would be beneficial in preventing sedimentation and increasing dry season storage volumes. The accompanying non-structural inputs (tree and reed plantations on and near the embankments) will generally enhance and improve environmental quality. The embankment/tree/reed belts around beels will also create a fixed demarcation boundary between wetlands and croplands, and act to deter encroachment.

Agriculture
The project will have little direct effect on agricultural production. Fish passes will be provided with vertical drop gates, so that water flows into haors during the pre-monsoon season can be

regulated in the event that flows become excessive and threaten boro crops. Beel embankments will be erected within beel perimeters and therefore will not encroach on agricultural land.

7. 8. 2 Social

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

Employment
There will be an overall increase in continuing employment of 200,000 person-days per year. This is composed of an increase in employment of DOF/BWDB supervisory/management staff to oversee the fish passes, an increase in employment opportunities for landless people who look after the tree/reed plantations at beel embankments, and an increase in employment in routine maintenance of beel embankments.

Conflicts
Fish passes will require protection from poaching during the pre-monsoon spawning migration period. Furthermore, a protected zone in the adjacent 250 m downstream section of the river and the upstream section of the adjacent khal (as far as the beel) will have to be created in order to protect migrating broodstock. The enforcement of a ban on fishing at the fish pass and in the protected zone will initially be the responsibility of the DOF. Once the beneficial impacts of the fish pass becomes evident, it is anticipated fishermen will participate in enforcement and should be included in the fish pass management system.

Beel embankments will prevent late season planting of rice along beel shorelines, and this will be a source of conflict with some of the landless population.

Equity
The net equity impact is progressive. Fish passes will benefit virtually the whole fish harvesting and/or fish consuming population through increased production.

Embankment of key beels will increase general haor fish production, but where key beels are under investor tenure the equity shift from fishing will be regressive. Conversely, those key beels under NFMP will experience a progressive equity shift. Assuming that all embankment tree/reed plantation will come under landless population stewardship, a strong progressive equity shift can be expected.

Gender Equity
The net equity impact would be somewhat progressive. Greater production of fish would be realized by fishing communities and thus greater demand for net weaving and fish processing - both of which are activities primarily carried out by women. A second gender equity impact could be in the management of embankment tree/reed plantations, as these could come under a high proportion of women stewards.

Qualitative Impact Scoring
The qualitative criteria shown in Table 7. 1 are scored on an 11 level scale of -5 to +5. 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.

Table 7. 1: Qualitative Impact Scoring

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

7. 8. 3 Cost/Benefit Considerations

As described in the preceding chapters the objectives of this project are necessary, desirable, and of high priority. To achieve these objectives, technical options were evaluated and in the case of fish passes will be tested by pilot projects. From these studies the most cost-effective and technically acceptable option would be implemented. No economic analysis was carried out for the project as quantification of benefits are difficult to define at this stage.

Almost all of the benefits of the project relate to increased commercial and subsistence fish production. A second important source of benefits is tree/reed production. The value of the lost agricultural output on high risk beel shorelines is a small fraction of the increase in fish production.

7. 8. 4 Summary Analysis

From a multi-criteria perspective the project is attractive:

- Benefits derive almost entirely from increased commercial and subsistence fish production and secondarily from wetland tree/reed production (at only a small expense in rice production). This reverses the current trend of accelerating loss of fishery and lowland forestry production.
- There would be a small loss in rice growing area from beel shorelines;
- The net employment impact is positive, but not major.
- The project has a high dependency on central government for implementation.
- A mother fishery (Kawadighi Haor) would be restored.

- The project would positively affect regional biodiversity by facilitating fish reproduction (and thus allowing threatened species more opportunity to breed) and generally enhance wetland quality, thus improving wetland habitat space for wetland dependant fauna and flora.

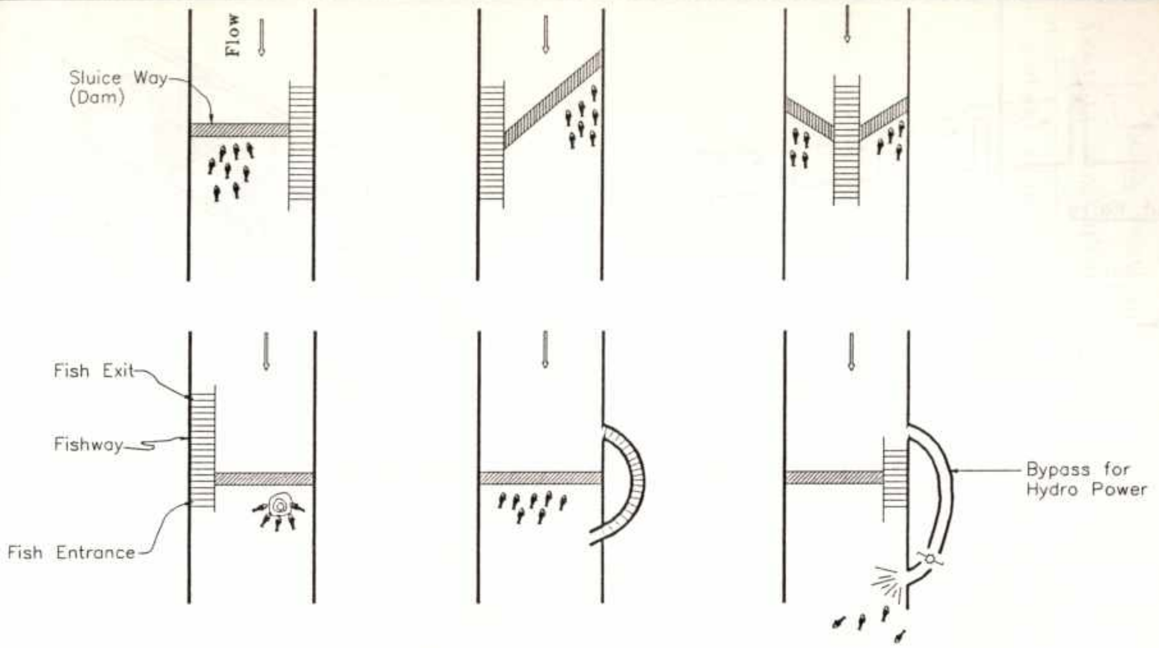
- Gender equity impacts are progressive.

- Project responds to some public concerns.

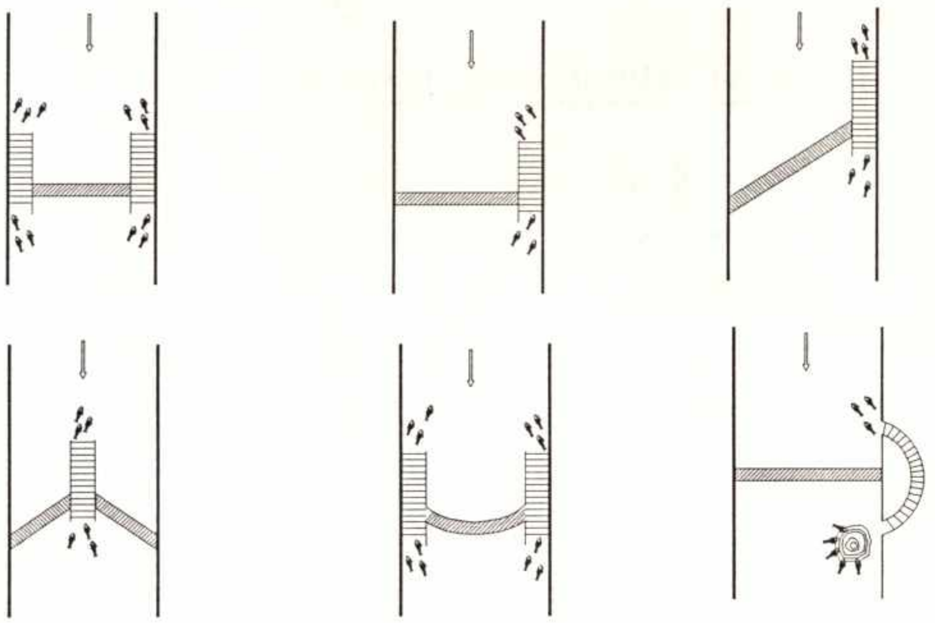
ANNEX A

FIGURES

Figure 1



Examples of poorly located Fish Entrances



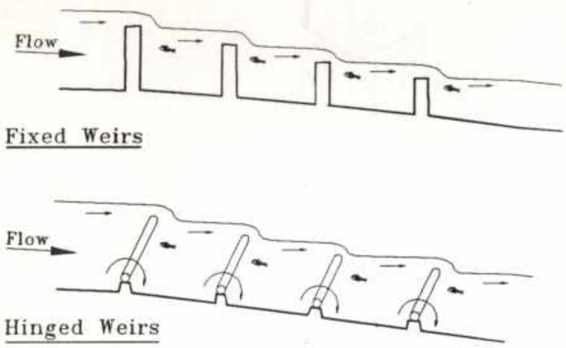
Examples of well located Fish Entrances

Note:
Modified from Design of Fishways, Toshio Torase and Shunroku Nakamura October, 1991

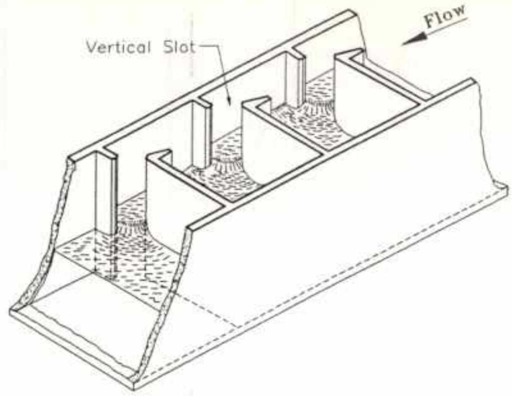
FILE: FISH-81.DWG

Not to Scale

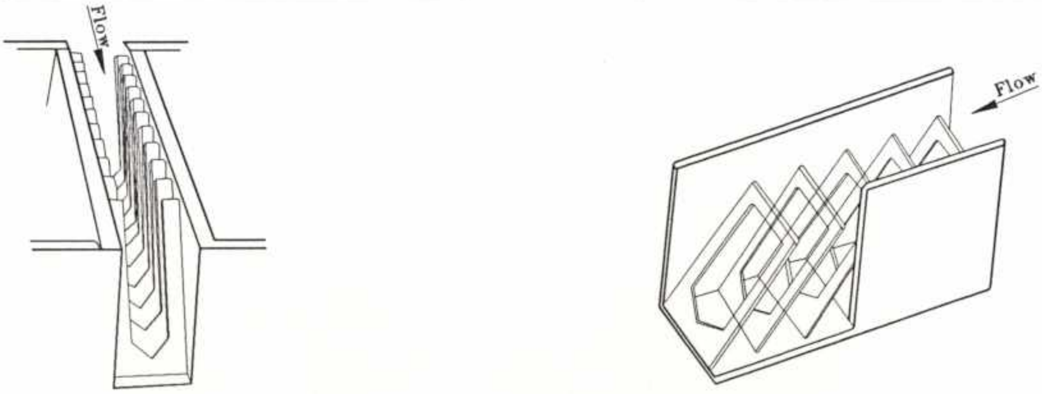
Northeast Regional Project			
Fish Entrances			
Prepared by:	PBS	June 1993	
Drawn By:	Mamun	AutoCAD Drawing	



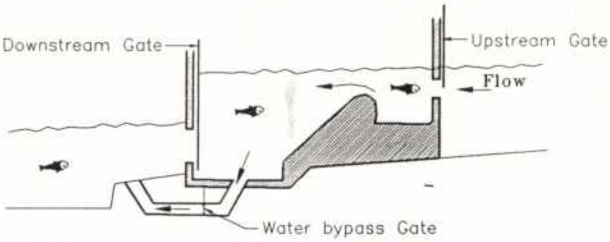
Pool and Weir Fishway



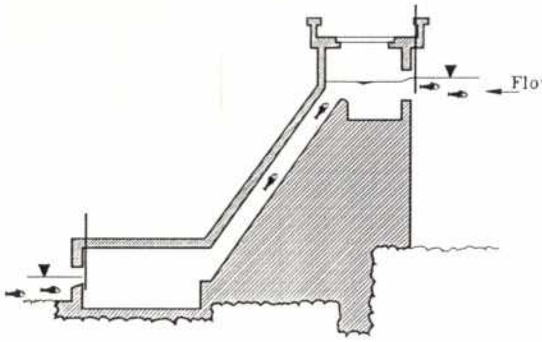
Vertical Slot Fishway



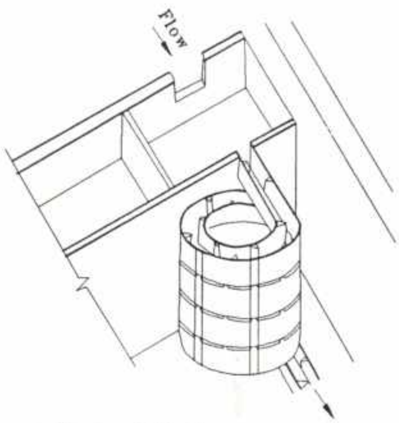
Denil or Steep Pass Fishway



Fishlock with bypass



Fishlock (Borland)



Circular Fishway
(Ver. slot or pool & weir)

Not to Scale

Northeast Regional Project

Fishways–Alternative Structures
Schematic Views

Prepared by:	PBS	June 1993
Drawn By:	Mamun	AutoCAD Drawing

FILE: FISH-89.DWG

Figure 3

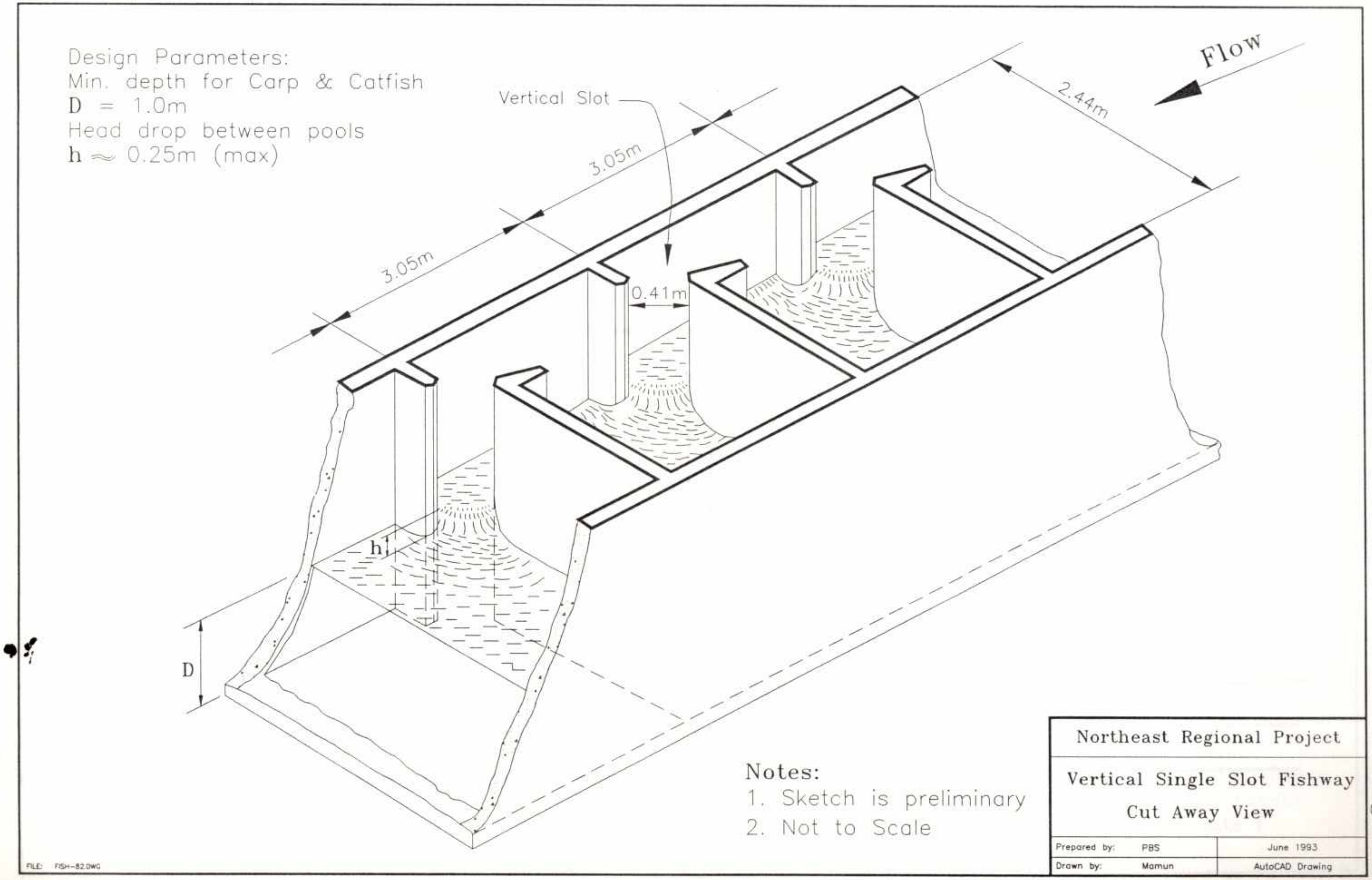
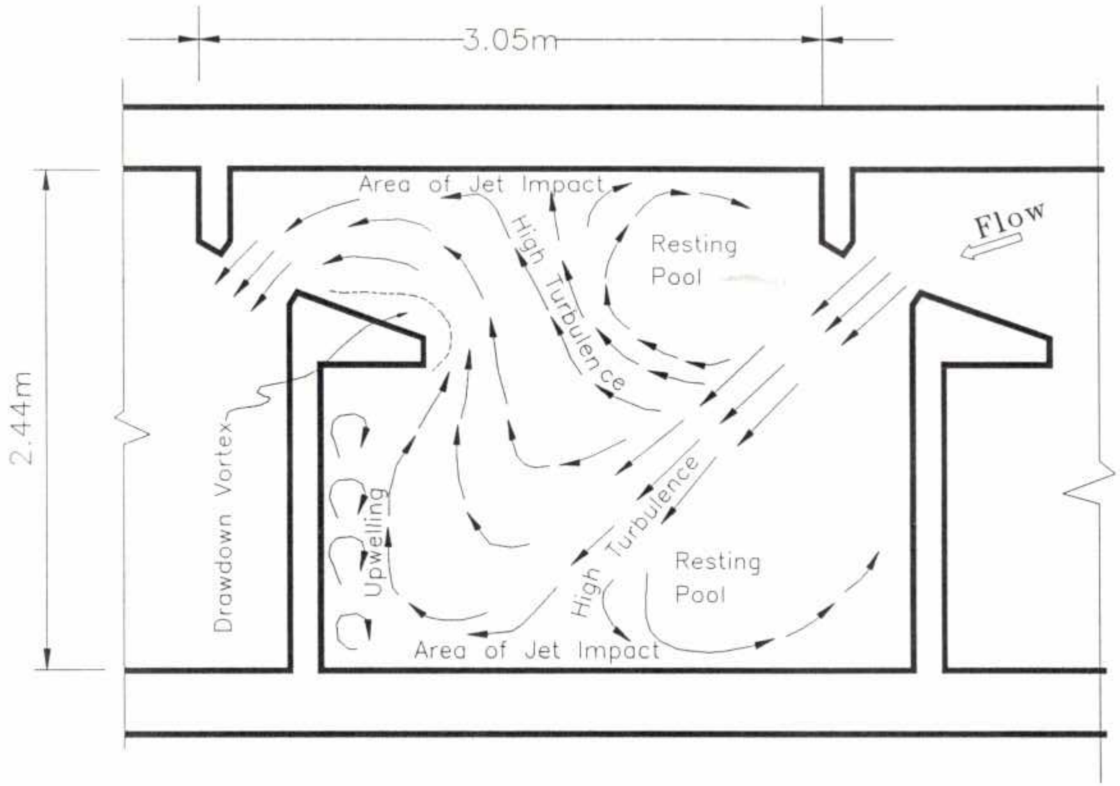
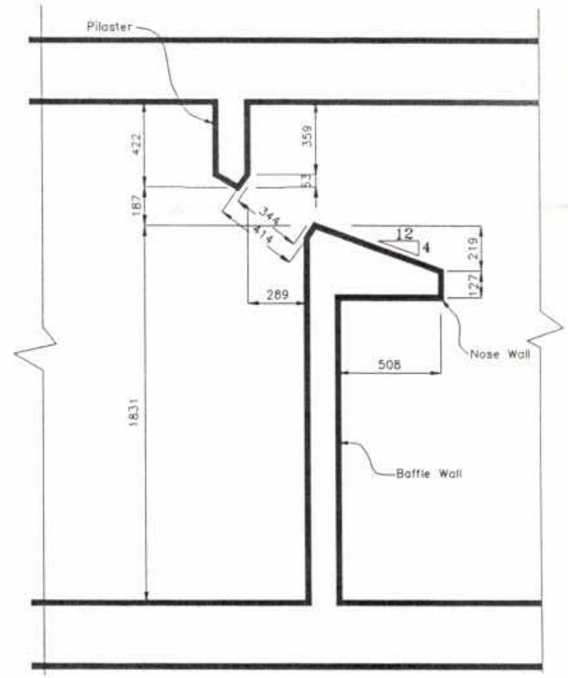

Design Parameters:
Min. depth for Carp & Catfish
D = 1.0m
Head drop between pools
h ≈ 0.25m (max)
Vertical Slot
Flow
2.44m
3.05m
3.05m
0.41m
h
D
Notes:
1. Sketch is preliminary
2. Not to Scale
Northeast Regional Project
Vertical Single Slot Fishway
Cut Away View
Prepared by: PBS
June 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: FISH-82.DWG

Figure 4



Typical Flow Pattern



Slot & Baffle Details
Dim in mm

Not to Scale

Northeast Regional Project			
Vertical Single Slot Fishway Flow Pattern			
Prepared by:	PBS	July 1993	
Drawn by:	Mamun	AutoCAD Drawing	

FILE: FISH-92.DWG

Figure 5

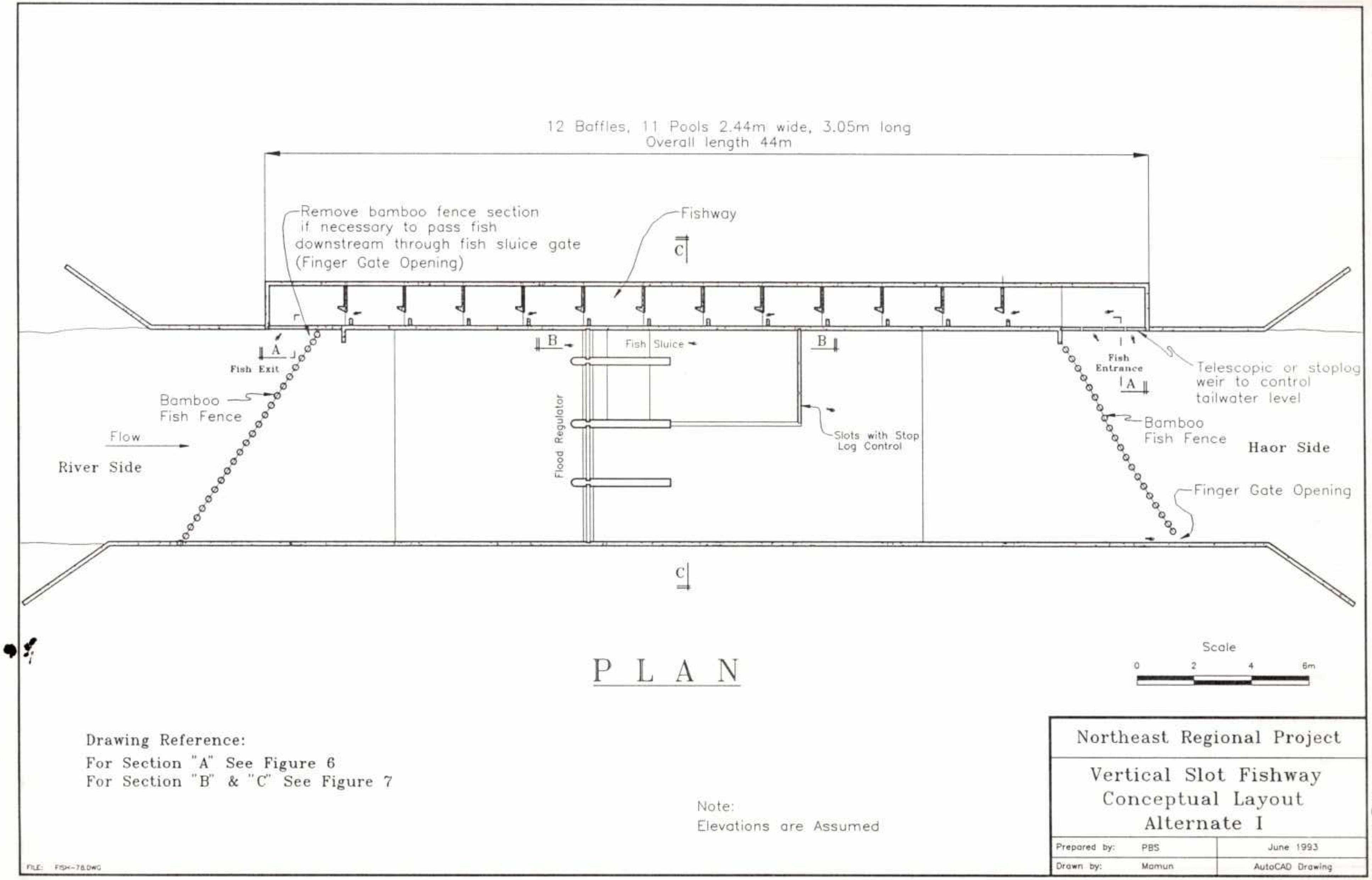
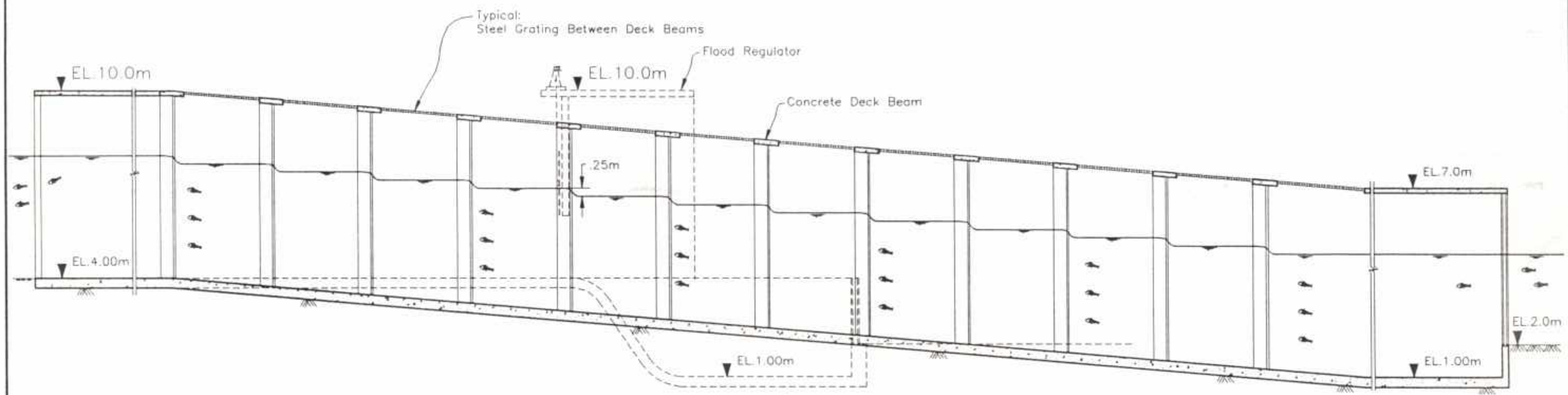
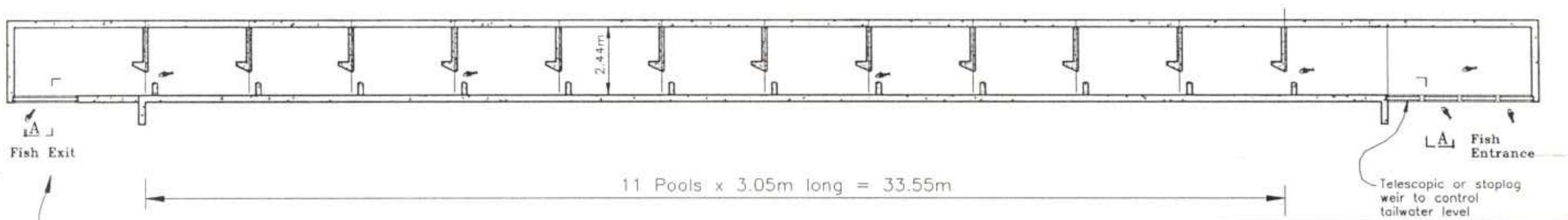

12 Baffles, 11 Pools 2.44m wide, 3.05m long
Overall length 44m
Remove bamboo fence section if necessary to pass fish downstream through fish sluice gate (Finger Gate Opening)
Fishway
C
A
Fish Exit
Bamboo Fish Fence
Flow
River Side
B
Fish Sluice
Flood Regulator
B
Slots with Stop Log Control
Fish Entrance
A
Telescopic or stoplog weir to control tailwater level
Bamboo Fish Fence
Haor Side
Finger Gate Opening
C
PLAN
Scale
0
2
4
6m
Drawing Reference:
For Section "A" See Figure 6
For Section "B" & "C" See Figure 7
Note:
Elevations are Assumed
Northeast Regional Project
Vertical Slot Fishway
Conceptual Layout
Alternate I
Prepared by: PBS
June 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: FISH-78.DWG

Figure 6



SECTION: A–A



For Dewatering or Shut off of flow thru Fishway install Stop Logs or Sluice gates at Fish Exit

PLAN

Scale

0 2 4 6m

For Baffle Details See Figure 4
For Layout See Figure 5
Elevations are Assumed

Northeast Regional Project			
Vertical slot Fishway Alternate I Plan & Section			
Prepared by:	PBS	June 1993	
Drawn by:	Mamun	AutoCAD Drawing	

FILE: FISH-77.DWG

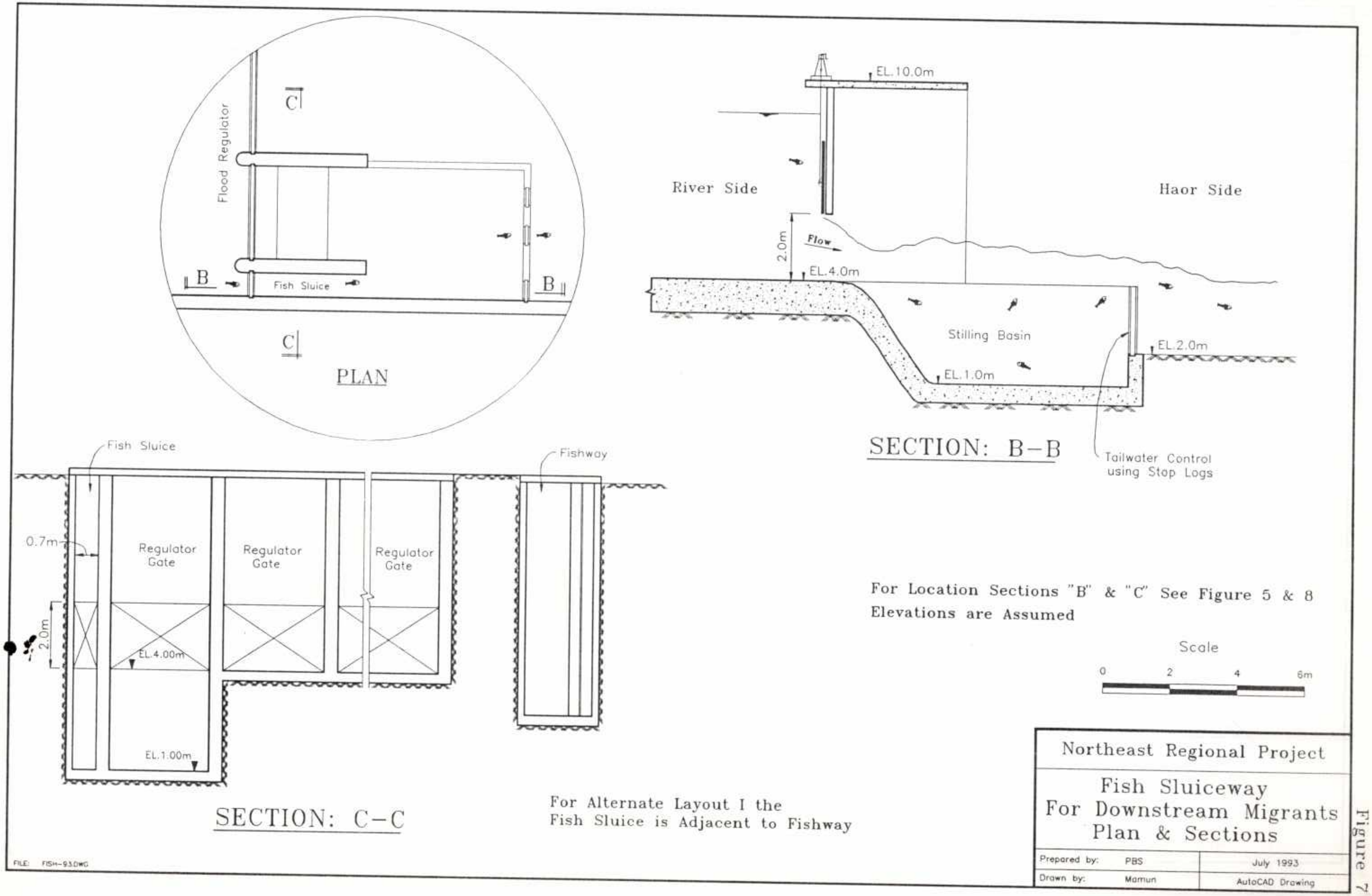
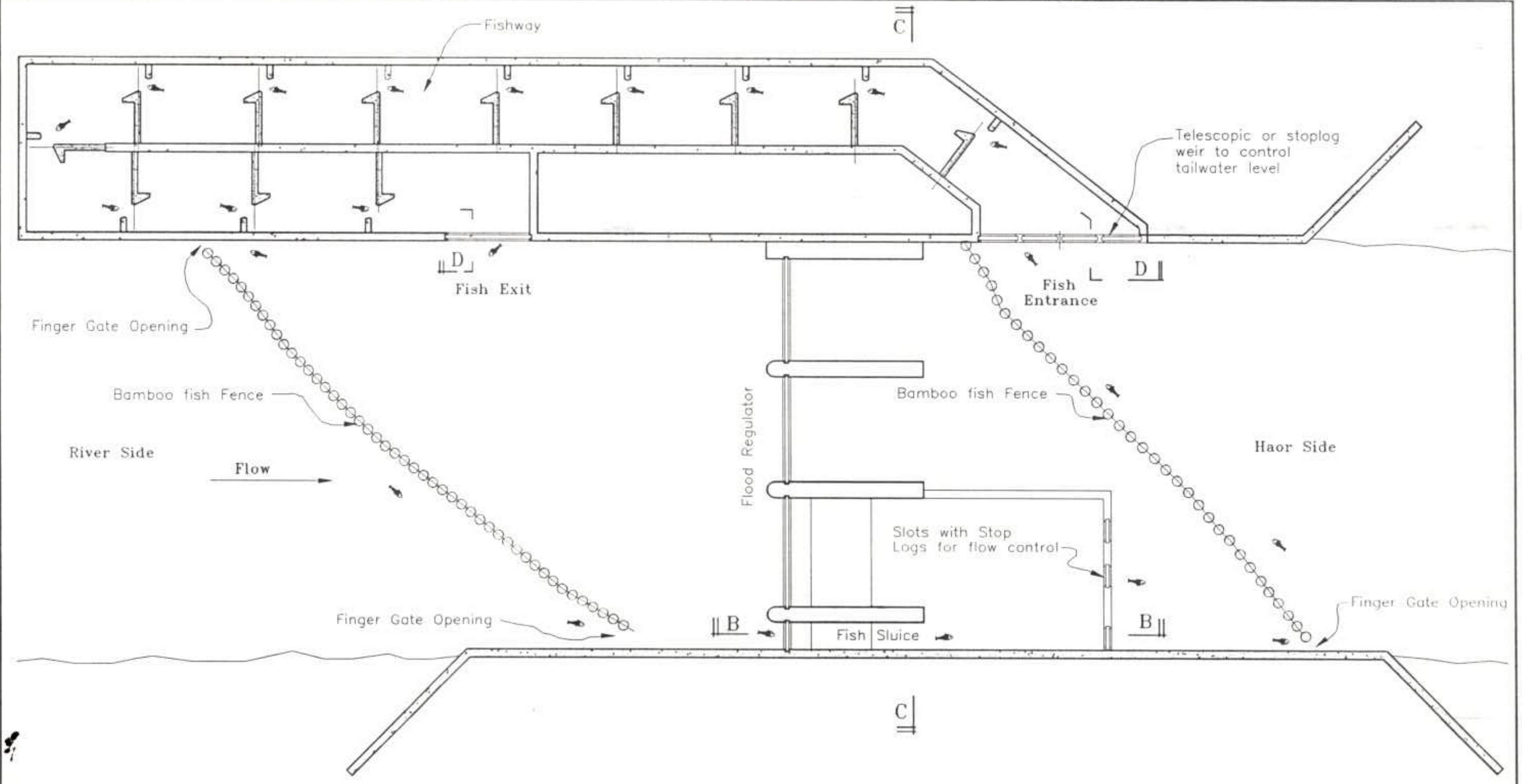

Flood Regulator
C
Fish Sluice
B
B
C
PLAN
EL.10.0m
River Side
Haor Side
2.0m
Flow
EL.4.0m
Stilling Basin
EL.2.0m
EL.1.0m
SECTION: B-B
Tailwater Control
using Stop Logs
Fish Sluice
Fishway
0.7m
Regulator Gate
Regulator Gate
Regulator Gate
2.0m
EL.4.00m
EL.1.00m
SECTION: C-C
For Alternate Layout I the
Fish Sluice is Adjacent to Fishway
For Location Sections "B" & "C" See Figure 5 & 8
Elevations are Assumed
Scale
0 2 4 6m
Northeast Regional Project
Fish Sluiceway
For Downstream Migrants
Plan & Sections
Prepared by: PBS
July 1993
Drawn by: Mamun
AutoCAD Drawing
FILE: FISH-93.DWG

Figure 7



PLAN

Note:

For Sections "B" & "C" See Figure 7
For Section "D" See Figure 9
For Baffle Details See Figure 4
Elevations are Assumed

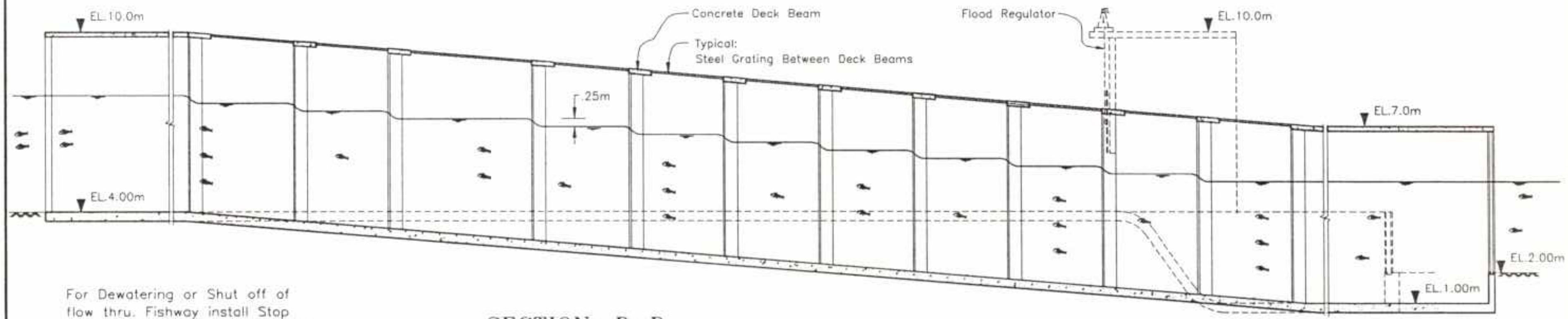
FILE: FISH-79.DWG

Northeast Regional Project

Vertical Slot Fishway
Conceptual Layout
Alternate II

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

Figure 8



For Dewatering or Shut off of flow thru. Fishway install Stop Logs or Sluice Gates at Fish Exit

SECTION: D-D

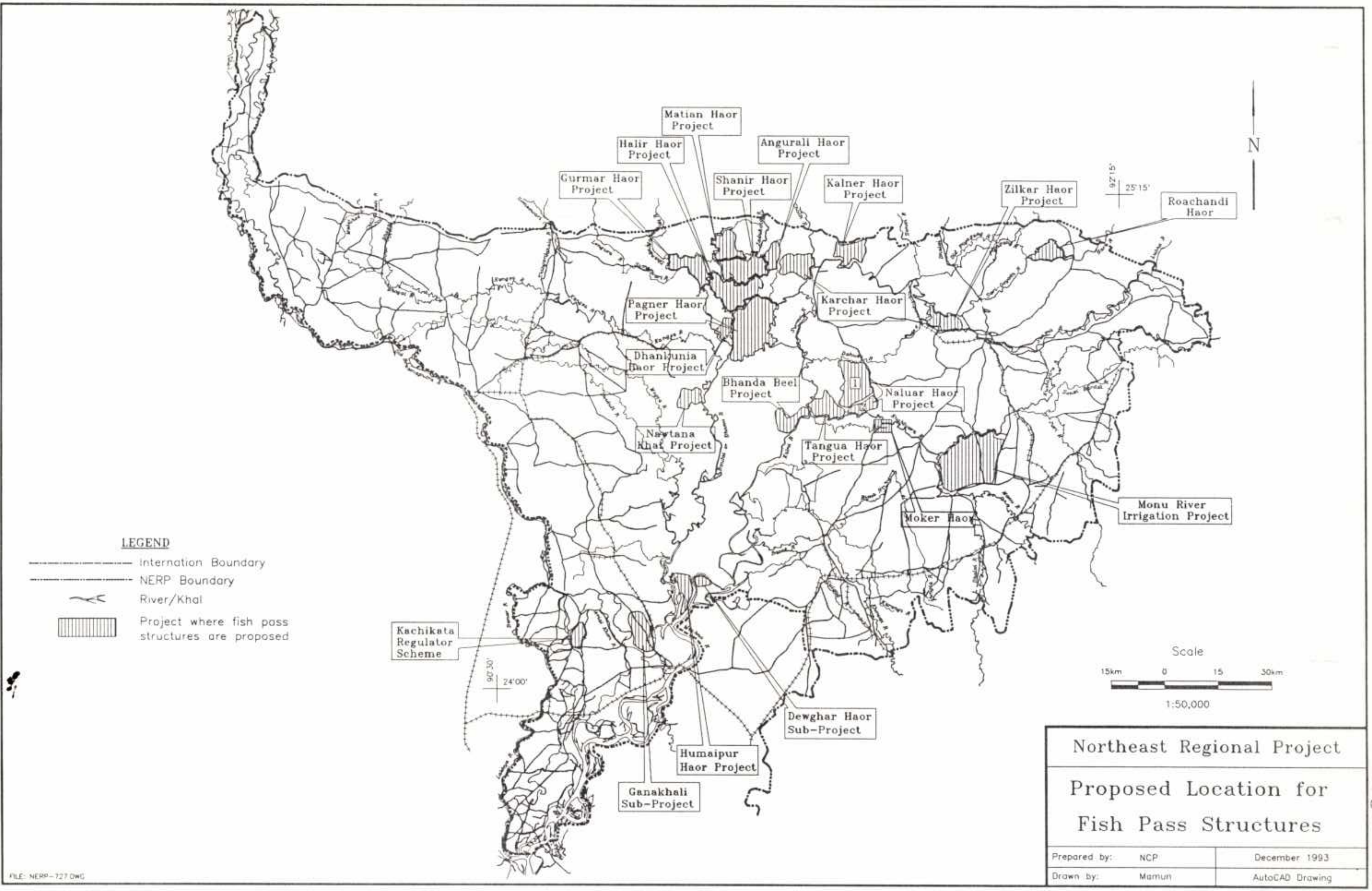
Note:
For Alternate II Plan See Figure 8
Elevations are Assumed

Northeast Regional Project		
Vertical Slot Fishway Alternate II Section		
Prepared by:	PBS	June 1993
Drawn by:	Mamun	AutoCAD Drawing

FILE: FISH-80.DWG

Figure 9

Figure 10

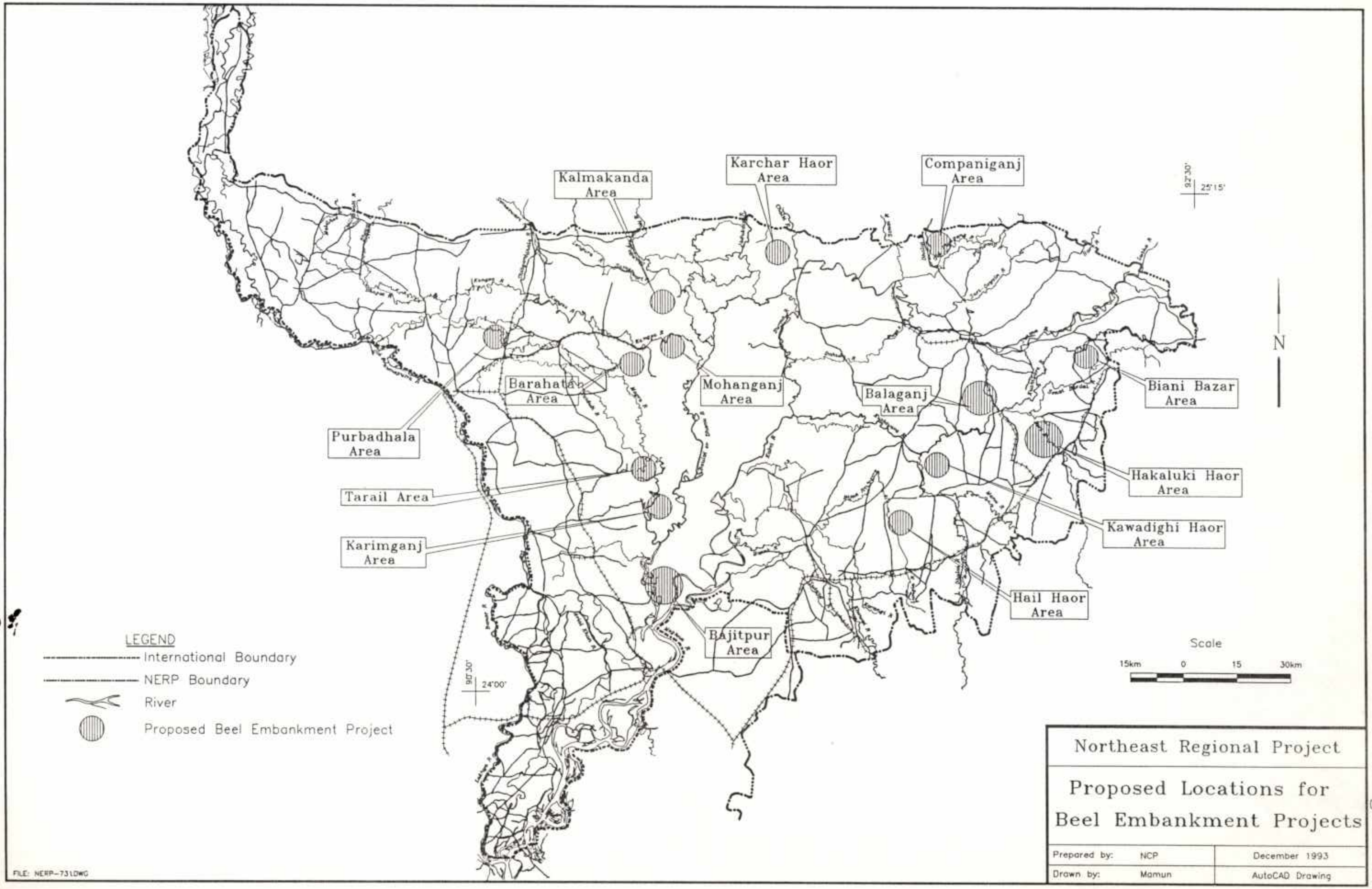


Northeast Regional Project

Proposed Location for Fish Pass Structures

Prepared by:	NCP	December 1993	
Drawn by:	Mamun	AutoCAD Drawing	

Figure 11



Northeast Regional Project			
Proposed Locations for Beel Embankment Projects			
Prepared by:	NCP	December 1993	
Drawn by:	Mamun	AutoCAD Drawing	

ANNEX B

TABLES

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Table 1: Proposed Locations for Fish Pass Structures

Location	Haor	Thana
Borabari beel regulator	Dewghar haor	Astagram
Bibiana river closser	Moker haor	Jaganathpur
Bora khal regulator(Boali-shibpur)	Humaipur haor	Bajitpur
Kaira River regulator	Humaipur haor	Bajitpur
Angurali Haor regulator	Angurali haor project	Bishambharpur
Dhankunia beel	Dhankunia Haor Proj.	Jamalgonj
Katakhali khal regulator	Ganakhali Subproject	Kuliarchar
Jagannathpur regulator	Gurmar Haor	Dharmapasha
Pashua regulator	Gurmar Haor	Dharmapasha
Kachikata regulator	Kachikata Regulator Scheme	Monohardi
Bausa khal regulator	Kalner haor	Sunamgonj
Ghalia Regulator	Karchar Haor	Bishambharpur
Hariya beel	Tangua Haor	Dirai
Ratla Khal	Halir Haor	Jamalganj
Suchia Khal	Halir Haor	Jamalganj
Nawtana regulator	Nawtana haor	Kaliajuri
Machuakhali Closser	Kawadighi Haor/Manu Project	Moulvibazar
Dhumkhal regulator	Zilkar haor	Sylet Sadar
Ahmmak khali Khal, Marala	Shanir Haor	Tahirpur
Main regulator(Barakhal	Matian Haor	Tahirpur
Gajaria Regulator	Pagner haor	Jamal pur
Phatabeel Regulator	Naluar Haor	Jagannathpur
Betawka Regulator	Naluar Haor	Jagannathpur
Hiderkhal	Roachandi haor	Goainghat
Bhandabeel		Sallah

Table 2: Key Beels Threatened by Sedimentation

Name of Beel	Embank. Length (m)	Area (ha)	Location
Rajdhala beel	4933	52.6	Purbadhala
Deghai beel	2131	36.2	Bianibazar
Magura beel	2359	44.3	
Barobeel	2182	37.9	
Meda beel	3910	121.9	Karchar Haor
Hoogla beel/ Rui beel	3996	127.3	
Benglachara doda	8825	620.9	Bajitpur
Maijchar Jalmohal	2626	54.9	
Jawar Makram beel	2666	56.7	Tarail
Karati beel	2589	53.4	Karimganj
Hail haor			Hail Haor
Kalabhanga beel	3040	73.7	Barhata
Barang & Tamasa beel,	4341	150.2	Hakaluki haor
Ranchi beel,	2942	69.0	
Chenguni kalapani beel,	3814	116.0	
Pulubhanga beel	4249	143.9	
Pinglar chepti beel	5344	227.6	
Barajalla Farjalla beel	7784	483.0	
Pliaula beel	5099	207.3	
Gunga beel/ Roail beel			Khaliajuri
Patasingra beel	4933	194.0	Moulvibazar
Phatakuri	6135	300.0	Companiganj
Laukuri beel			
Rauti beel			
Burohingai beel			
Panichara beel	2743	60.0	
Dulainhaori beel	3168	80.0	
Gajaria beel			Mohanganj
Patachatal beel,	3332	88.5	Balaganj
Maijal beel	4186	139.7	
Karacha gr. fishery	2931	68.5	
Harin Petya gr Fishery	2690	57.7	
Dubria gr fishery	4428	156.3	
Kalasara beel	2714	58.7	

Note: Total area of key beels exceeds 4000 hectares.

Table 3: Proposed Locations for Community Beel Embankments

Thana	Proposed Area for CJMS	Thana	Proposed Area for CJMS
Khaliajuri	Jhinachi beel, Komar khoda beel, Sewlai beel, Payra beel, Dighi beel, Phada beel.	Itna	Kaisma beel, Naipta beel, Hawa beel, Koisma-digma beel, Gool beel,
Kalmakanda	Baizar beel, Barkita beel, Chapai beel, Gajaria beel	Purbadhala	Hasma beel, Ichha mati beel, Kuma beel, Khoila beel.
companiganj	Khailtajuri beel,	Jointapur	
Goainghat	Roachandi beel	Balaganj	
Nabiganj		Baniachang	
Madan		Durgapur	
Dharmapasha		Taherpur	
Jamalganj		Astagram	
Bajitpur		Gauripur	
Atpara	Pairadanga gang	Karimganj	
Nikli		Tarail	
Doarabazar			

Note: CJMS is Community Jalmohal Management Systems

ANNEX C

DESIGN CONSIDERATIONS

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ANNEX C

DESIGN CONSIDERATIONS

Four fish pass structures were reviewed as follows:

Vertical Slot Fishways. These structures operate over a wide range of water levels without adjustments. Upright vertical panels and vertical full height slots are placed at intervals between fish entrance and exit and dissipate flow energy, and allow resting in pools between vertical panels. Short jets of water at low head through the slots enable the fish to dart or burst very short distances (about 1m) from pool to pool. Vertical slot fishways are used extensively in Europe, North America and Japan to bypass river obstructions, diversion dams and power dams.

Pool and Weir Fishways. These structures resemble staircases of water and are usually built when water levels at upstream and downstream ends do not fluctuate widely during the period that fish are migrating. A series of partitions or weirs are installed across the fish pass channel with water cascading over the crest from pool to pool. The head across the weirs is designed to suit the fish type(s) which require passage assistance. The overflow could be free fall or submerged. Fish will jump over the weirs from pool to pool or orifices could be provided in the baffle wall for swim-through. The pool and weir type of fishways could be adapted for variable head and tailwater levels by telescoping weir crests or adjustable hinged weirs. Adjustable weirs require continuous mechanical or manual operation and are costly.

Denil Fishway or steep pass fishways are narrow channels with closely spaced baffles on both sides and bottom and set at an angle to the axis of the aligned structure. The baffles form secondary channels at an angle with the main central flow and the energy is dissipated by intense mixing. This fishway type is generally used with a small run of fish, on a temporary basis and are not conducive to variable head or tailwater levels.

Fish Locks as the name implies will move fish in and out as well as up or down over obstructions and dams. The structure requires entry, exit and bypass gates or sluiceways by mechanical or manual operation. The main drawback is interrupted passage and lack of attraction flow.

For conceptual and possible pilot project purposes in aid of fish passage across embankments or dams in the Northeast Region a copy of the pool and slot configuration for a fishway at Seton River Dam in British Columbia, Canada has been adopted. The Seton River Dam Fishway layout was originally model tested and has proven very successful. A similar fishway built at Hell's Gate in the Fraser River, British Columbia in 1989 (P.B. Saxvik, 1990) proved by visual count to pass about 12500 migrating adult salmon (each weighing about 2.2 kg) per hour up through a 9 pool structure with a total head of 3 m. The single vertical slot fishway proposed as a pilot project is a 10 pool structure with 12 baffles, each with a max head drop of 0.25 m to overcome the total forebay to tailwater difference of 3.0 m.

The basic configuration of the vertical slot fishway pool and slots are shown in figures 3 and 4. Each resting pool between baffles is 2.44 m wide x 3.05 m long. The clear width of each vertical baffle slot is 0.41 m. The discharge through the vertical slot varies with depth and is calculated by Equation I:

$$Q = C_d(D+h)W\sqrt{2gh}.$$

Where

Q=discharge (m^3/s)
C_d=coef. for discharge through orifices $\approx$ 0.75
W=total width of slot (m)
D=depth of water at downstream side of battle (m)
h=drop in water surface from the upstream to the downstream side of a baffle (m)

The calculated discharge is approximate only since approach velocities are not accounted for. The velocity of the water jet through the vertical slot in the baffle is determined by Equation II:

$$V = C_d\sqrt{2gh}$$

Based on Equation I the discharge through the vertical slot fishway at one metre of depth under head of 0.25 m is 0.85 m^3/s. The velocity of the water jet through the slot is independent of water depth and based on Equation II equals 1.66 m/s.

The minimum volume of water through the fishway or min. depth of water depend on species of fish which migrate. For carp and catfish the minimum depth is assumed as one metre. For this minimum depth for migrating fish, the water volume within one fishway pool would be 7.44 m^3.

The migration capacity of a fishway depends on the acceptable density of fish within a pool during ascent and the swimming ability of the fish (rate of travel in m/minutes) through the structure. The pool volume recommended for fish is about 0.025 m^3/kg. For large carp or catfish at 30 kg weights the minimum pool volume per fish would be 0.75 m^3 and the acceptable density at minimum operating depth of one metre would be 10 fish. For the average size carp or catfish weighing about 7.5 kg, the acceptable density would be 40 fish at minimum flow through the structure. Without actual tests or recording of swimming abilities of carps or catfish through a vertical slot fishway the estimated rate of travel will be conservatively assumed based on values for other fish. The rate of travel for Sockeye Salmon through a fishway has been recorded at approx. 4 m per minute (P. Saxvik, Dec. 20, 1990) equivalent to passing through a 3.05 m long pool in 0.76 minutes. Earlier data (C.H.Clay, 1961) indicated travel time for salmon in the range 2-5.8 minutes per pool. Adopting the conservative speed of 6 minutes of travel time for carp or catfish through the pool the capacity in the proposed fishway at min. depth (1.0 m) would be 100 fish per hour based large (30 kg) fish and 400 fish per hour based on the average size (7.5 kg).

At periods of maximum river flood levels when forebay/tailwater differences at regulator dams would be approximately 3 m and depth of water flowing through the fishway about 5 m, the capacity for large and average size carp or catfish will be 500 and 2000 fish per hour respectively.

A poorly located fish entrance which is avoided by or delaying the migrants could reduce these theoretical capacity numbers. Conversely good location and alignment choices could possibly improve the capacity.

ANNEX D

ANALYSIS OF PRESENT CONDITIONS

ANNEX D

ANALYSIS OF PRESENT CONDITIONS

Example of Existing Embankment Project at Key Beels

There are some embanked beels developed by the leaseholder in the region to protect the beel from sedimentation. Two such beels are: 1) Ruila beel, Medhol Haor, Jaintapur, Sylhet, and 2) Chatla beel, Hakaluki Haor, Moulvibazar.

Ruila Beel

Ruila beel is one of the most important beels with pile fishery in Medhol Haor. The entire beel was embanked by a 3-5 feet high submersible embankment. The embankment was constructed in 1945 after the construction of the Sylhet-Tamabeel road. The fishery was leased out for a 16 year period.

The Sarigoyain River is the main source of water for Medhol Haor. The Sari River water enters into the haor through the Line River (Pabijuri River) near Chatal bazar at the eastern side. This river later branches into the Kushi, the Khorish and the Khapa Rivers. These rivers again enter into the Sarigoyain River near Goyainghat thana.

The Medhol haor is under the pile fisheries management system. The leaseholder stated that larger fish were only available by the third year. He said that it is more profitable to harvest fish every three years than to harvest them annually. Changes in fish composition over a three yeaar period are given below.

Change in Fish Composition due to Beel Embankments

Year of fishing	Big fish	Small fish
1st year fishing	10%	90%
2nd year fishing	40%	60%
3rd yr. fishing(pile)	70%	30%

It is assumed that fish always try to return to their previous habitat for overwintering. Following this initiative people residing on the eastern side of the Medhol beel have planted a large number of Hizal trees to protect their village from wave action and as a source of income.

ANNEX E

COST AND PRODUCTION ANALYSIS

ANNEX E

COST AND PRODUCTION ANALYSIS

Table E1: Estimated Cost of One Fish Pass Structure

Items of Works	Quantity	Unit	Unit price	Amount (Tk'000)
Excavation (Foundation)	2500	m^3	30.00	75.00
Excavation (Diversion)	4200	"	21.75	91.35
Back filling	1935	"	20.00	38.70
Sand filling	390	"	148.00	57.72
CC work	12	"	1804.00	21.65
RCC work	296	"	2495.00	738.52
Form work	1215	m^2	223.00	270.94
MS Reinforcement	35	t	32360.00	1132.60
PVC Water stop	50	m	1040.00	52.00
Graded Filter	26	m^3	339.54	8.83
CC blocks	65	"	1829.00	118.86
Steel grating(cover	97.5	m^2	1000.00	97.50
Dewatering LS				300.00
Mobiulization LS				150.00
Material Carriage Est.				300.00
Subtotal				3453.70
Land aquisition	0.5	ha	20000	100.00
Physical contengencies (25%)B				888.42
Engineering costs (15%of B)				666.32
Total				5108.44

Note: Total cost for 27 Fish Pass Structures (@ Tk 5,108,440/ Structure = Tk 137.93 Million

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Table E2: Estimated Support Costs for Fish Pass Structures

Item of cost	Unit	Unit cost	Years	Amount Tk '000
Training cost	5P			2500.0
Temporary sheds	27	30.0		810.0
Country Boats	27	5.0	7	135.0
Office and Supplies	LS			840.0
Vehicles and misc.	LS			8702.5
Monitoring Equipment	LS	470		470.0
Monitoring Staff	27x2	2.5	7	11340.0
Technical/Management Staff	16		7	12600.0
T o t a l				37397.5

Notes:Staffing would likely be through BWDB and DOF.
Support and Management would be over a period of 7 years.

Table E3: Preliminary Analysis of Fisheries Production for Fish Pass Structures

Production Source	FWO (Yearly Prod'n)		FW (Yearly Prod'n)		Production Increase (mt)	Yearly increased value of production (m Tk)
	Kg/ha	m Tk	Kg/ha	m Tk		
Floodplain	40	108.00 (30/Kg)	60	162.00	1800	54.00
Beel(4000 ha)	175	35.00 (50/Kg)	260	52.00	340	17.00
TOTAL	143.00m		214.00m		2140mt	71.00 m

Notes:Production is for 27 FCD/I projects.
Estimated area of coverage is 90,000 ha

Table E4: Employment Analysis for Fish Pass Structures (Person days in million/yr)

Status	Floodplain	Beel	Total
FWO	7.20	0.09	7.29
FW	10.80	0.13	10.13

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Table E5: Estimated Costs of Key Beel Embankment Projects.

Item	Quantity	Unit	Unit price.	Cost (Tk.m)	O & M Cost(Tk.m)
Earth Work Cost	1122500	m3	24.27	27.24	@6% 1.63
Fine dressing & Turfing cost	1161250	m2	2.27	2.64	@1% 0.02
Land Acquisition	341.25	ha	150000	51.19	
T O T A L	**Tk 82.72 Million**				

Table E6: Preliminary Analysis of Production for Key Beel Embankment Projects

Area	FWO (Yearly Prod'n)			FW(Yearly Prod.)		
	Kg/ha	Tk/Kg	Tk.m	Kg/ha	Tk/Kg	Tk.m
Beel Prod. (4000ha)	425	60	102	550	60	132
Flood Plain Prod. (96% = 100,000 ha)	50	30	150	70	30	210

Note: Yearly increase in value is Tk. 90 Million (Tk.342 -Tk.252 million)

Table E7: Employment Analysis for Beel Embankment Project (person days in million/yr)

Status	Floodplain	Beel	Total
FWO	10.0	0.21	10.21
FW	14.0	0.27	14.27

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Table E8: Estimated Costs for Community Beel Embankment Projects

Item	Quantity	Unit	Unit price (Tk)	Cost (Tk.M)
Re-excavation (0.7m) cu.m embankment	1400000	m3	25	35.00
Plantation Cost	200	ha	500	0.10
Small Structures	200	No.	30000	6.00
Sub-total	**41.10**			
Training	3000	PD	150	0.45
Local Management	6000	M	50	0.30
GOB Office Support	2880	M	1000	2.88
Management office				3.24
Vehicles				0.75
Management Support Cost	36	M	25000	0.90
Total cost (41.10 + 8.52)				**49.62m**

Table E9: Preliminary Production Analysis for Community Beel Embankment Projects

	Price of fish (Tk/kg)	Annual FWO			Annual FW		
		Kg/ha	mt	Tk.M	Kg/ha	mt	Tk.M
BEEL (200ha)	60	100	20	1.2	1000	200	12

Note: Yearly increased production is 180 tonnes (Tk 10.8 m)

Table E10: Employment Analysis for Community Beel Projects (million person days)

Status	Beel
FWO	0.025
FW	0.250

ANNEX F

INITIAL ENVIRONMENTAL EXAMINATION

ANNEX F

INITIAL ENVIRONMENTAL EXAMINATION

F.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.

F.2 Alternative 1: Proposed FCD Project

F.2.1 Project Design and Description (Step 1)

As in Section 7.3, Project Description.

F.2.2 Environmental Baseline Description (Step 2)

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

F.2.3 Scoping (Step 3)

Technical:

Literature review: Presented in Chapter 4, Previous Studies.

Local community: As described in Section 3.1.6, People's Perception.

F.2.4 Bounding (Step 4)

Physical:

Gross area: 190,200 ha.

Impacted (net) area: 190,200 ha.

Impacted area outside project: Floodplain fisheries production will be enhanced and will have a positive impact on the outside area. Regional biodiversity will be enhanced. No negative impacts are expected.

Temporal:

Preconstruction: year zero through year one.

Construction: year one through year four.

Operation: year one through year 20.

Abandonment: after year 20.

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Cumulative impacts:

With pre-existing no-project trends. Described in Chapter 5.

F.2.5 Field Investigations (Step 5)
Field investigations were limited to seven to ten days of informal reconnaissance by a multi-disciplinary team and by several weeks of field work by the fisheries specialist team.

F.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 7.8.1.

F.2.7 Quantify and Value Impacts (Step 7)
Quantification and evaluation of impacts is documented in Section 7.8.

F.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. No mitigation measures are required.

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

- Compensation for persons other than landowners who are impacted negatively by land acquisition and construction/infrastructure-related land use changes.

Monitoring. There is a need to define monitoring needs and methodologies at regional, institutional (BWDB and DOF), 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 fisheries measures are operational, investment in fisheries will likely rise. This increases the total amount of fishermens' assets that are at risk should an extreme flood event occur at the fish pass structure or the embankment.

Currently in Bangladesh, these risks are borne by individual investors.

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

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

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

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

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Environmental Screening Matrix

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

Environmental Screening Matrix : C

Screening matrix PHASE	Normal/ Abnormal	Activity / Important Environmental Component	Land Use	Agri-culture	Fisheries	Water Quality	Water Quantity	Human Health	Social Issues	Wild Plants & Animals	Hazards	Other
Construction (continued)	Abnormal (cont'd)											
Operation	Normal	Pre monsoon operation			+	+	+		∓		+	
		Monsoon										
		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 (due to extreme event, infrastructure failure)		−	+				∓			
		Monsoon (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											