Government of the People's Republic of Bangladesh
Bangladesh Water Development Board
Water Resources Planning Organisation

FLOOD ACTION PLAN

NORTHEAST REGIONAL WATER MANAGEMENT PROJECT (FAP 6)

FINAL

FISHPASS PILOT PROJECT

COMPLETION REPORT

Volume 1: Main Report

October 1998

SNC ♦ LAVALIN International
Northwest Hydraulic Consultants

in association with

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Bangladesh Engineering and Technological Services

Canadian International Development Agency

2

COVER PHOTO: A typical village in the deeply flooded area of the Northeast Region. The earthen village platform is created to keep the houses above water during the flood season which lasts for five to seven months of the year. The platform is threatened by erosion from wave action; bamboo fencing is used as bank protection but often proves ineffective. The single *hijal* tree in front of the village is all that remains of the past lowland forest. The houses on the platform are squeezed together leaving no space for courtyards, gardens or livestock. Water surrounding the platform is used as a source of drinking water and for waste disposal by the hanging latrines. Life in these crowded villages can become very stressful especially for the women, because of the isolation during the flood season. The only form of transport from the village is by small country boats seen in the picture. The Northeast Regional Water Management Plan aims to improve the quality of life for these people.

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AOP	Actual Operation Period
ASA	Association for Social Advancement
BRAC	Bangladesh Rural Advancement Committee
BRTA	Bangladesh Rural Telecommunication Authority
BT&T	Bangladesh Telephone and Telegraph
BWDB	Bangladesh Water Development Board
C/S	Countryside
CAS	Catch assessment survey
CBA	Cost-benefit analysis
CIDA	Canadian International Development Agency
CO	Community Organizer
D/S	Downstream
DFO	District Fisheries Officer
DOF	Department of Fisheries
DWM	Dominant Water Mass
EUS	Epizootic Ulcerative Syndrome (a fish disease)
FAP	Flood Action Plan
FCDI	Flood Control, Drainage & Irrigation Project
FPCO	Flood Plan Coordination Organisation
FPG	Fish Processors Group
FPP	Fishpass Pilot Project
FWC	Family Welfare Centre
FWV	Family Welfare Visitor
GB	Grameen Bank
GOB	Government of Bangladesh
HBB	Herring-bone Bond
IRR	Internal rate of return
KHFA	Kawadighi Haor Fisheries Association
LCC	Local Consultative Committee
LFM	Length at first maturity
LGED	Local Government Engineering Department
MCH	Maternal Child Health
MCM	Million of cubic metres
MF	Monsoon Flood
MFL	Ministry of Fisheries and Livestock
ML	Maximum length
MRIP	Manu River Flood Control & Irrigation Project
NE	North East
NERP	Northeast Regional Water Management Project
NFMP	New Fisheries Management Policy
NGO	Non-government Organization
NOP	Non Operation Period
NPV	Net present value
NSW FRI	New South Wales Fisheries Research Institute
PMF	Pre-monsoon Flood
PMP	Project Monitoring Program

POP	Potential Operation Period
PRA	Participatory rural appraisal
PWD	Public Works Department standard level (reference 0 m is at mean sea level)
R/S	Riverside (= Kushiyara River)
SADP	Second Aquaculture Development Project
SOB	Survey of Bangladesh standard level (reference 0 m is at 0.46 m PWD)
TFP	Third Fisheries Project
U/S	Upstream

GLOSSARY OF TERMS

aaratdar	Trader with a space for storing commodities
abadi	Outside settler
akai	Gleaning of submerged rice
aman	Monsoon rice crop harvested in November/December
barga	Share cropping
barman	Hindu sub-caste whose major profession is fishing
beel	Floodplain lake which may hold water permanently or dry up during the winter season
bepari	Harvester of *boro* rice who generally comes from outside the area
bhagi	Share cropping
bhasha	One method of fishing
bigha	Local unit of land measurement (one *bigha* = 0.13 ha)
bisra	Area adjacent to a homestead and intermediate in height between the homestead and rice fields, on which vegetables are grown
biyash	A tree species used as fuelwood (Salix tetrasperma)
boro	Rice grown in the dry season and harvested in April/May
boromaach	big fish
borun	A tree species used as fuelwood (Crataera nurvala)
chailla	A long grass grown in lowlands (Hematheria potensa)
chada	Contribution
changari	Platform made to dry fish
chhon (*ululbinna*)	A grass used to thatch house rooves
chhora	small hilly streams
chukti	Seasonal lease of agricultural land with an agreed fixed amount of the produce to be paid after the harvest
chula	Cooking place (oven)
concurrent	Movement of fish in the same direction as water current
countercurrent	Movement of fish in the opposite direction as water current
dair/chhit	Terrace of shallow channels within a rice field
dalal	Commission agent
deta	Rice straw
dhara	Bamboo mat
doba	Smaller water body
don	An indigenous method of manual irrigation
duar	Deep scour hole in a river, usually at a bend or a confluence
durba	A kind of grass (Cynodon dactylon)
ejmali	Jointly owned by co-sharers/villagers
gola	Granary
haal	Local unit of land measurement (1 *haal* = 12 *kare* = 1.44 ha)
haor	Depression on floodplain, located between two or more rivers, which functions as a small internal drainage basin
hati	Continuous group of homesteads occupied by a social group sharing lineage and/or other factors
hizal	A wetland tree species used for fuelwood and *katha* (Barringtonia acutangula)
hydrological year	From beginning of first pre-monsoon flood to end of dry season in next calendar year
icha	Collective name for several species of small prawns

jagli	An indigenous variety of *boro* rice
jal	Fishing net
jala	Seedlings
jalmohal	Fishing ground
jangal	Dyke-cum-road across crop fields
kaiborta	Hindu sub-caste whose major profession is fishing
kamla	Wage labourer
kanda	Ridges that are higher than the *haor* basin but lower than homestead land
katha	Branches of trees or bamboo piles placed in water to provide shelter for fish
kare	Local unit of land measurement (one *kare* = 0.12 ha)
khal	Drainage channel running across a *haor*, connecting a *beel* to a river
khalashi	Sluice gate operator
kharif	Monsoon crop season, including *Aus* and *Aman* crop season
khas	Government-owned land
katha	Bush park type fish production system
khet	Agricultural land
khola	Temporary dry season fishing camp
kona jal	A kind of seine net
koroch	A wetland tree species used as fuelwood and for *katha* (Pongamia pinnata)
mahajan	Local money/rice lender
maimol	Muslims whose major profession is fishing.
majhi	Boatman
maund	Local unit of measurement (one *maund* = 37.5 kg)
mehagani	A tree species with high timber value
mera	A tree species used as fuelwood
mother fishery	An area with a dense concentration of diverse high quality fishery habitats which controls fish abundance over a much larger area
namasudra	Hindu sub-caste with low status
nara	Rice straw
nikari	Fish retailer
nolkhagra	One type of wild plant used for homestead protection
paharadar	Guard
parishad	Council
patam	Wooden platform of boat
patni	Hindu sub-caste whose major profession is boat plying
pon pratha	Dowry system
purdah	Seclusion
rabi	Dry season
rangjama	Seasonal lease of agricultural land with an agreed advance in cash
rotenone	Poison derived from a plant used to kill fish
samity	Cooperative society
sampad	Resource
shail	A variety of *boro* rice
shak	Leafy vegetable
shidal	Semi-fermented fish
shutki	Sun-dried fish
singra	A type of water chest nut (Trapa maximawiczee)
sona bang	A frog species (Rana tigrina)
tab	Bamboo poles to shelter fish
thana	Smallest administrative unit; below district (formerly *upazila*)

tole	Unofficial fishing tax or fishing permit fee
ujaiya	Movement of fish against water current
union *parishad*	Local government council at union level
uthan	Courtyard
Year 1	First year of fishpass operation (ie hydrological year 1995)
Year 2	Second year of fishpass operation (i.e.: hydrological year 1996)
Year 3	Third year of fishpass operation (i.e.: hydrological year 1997)
zamindar	Feudal landlord
zirati	Immigrant cultivators

Calendar conversion

Bangla calendar	International calendar From middle of-	To middle of
Baishakh	April	May
Jaishthya	May	June
Ashar	June	July
Sravan	July	August
Bhadra	August	September
Ashwin	September	October
Kartik	October	November
Agrahayan	November	December
Poush	December	January
Magh	January	February
Falgun	February	March
Choitra	March	April

EXECUTIVE SUMMARY

1. The purpose of the fishpass pilot project (FPP) is to assess the technical feasibility of using the vertical slot type of fishpass to provide passage to migrating fish stocks across flood control embankments in Bangladesh, and acquire information about economic and socioeconomic impacts on the communities.

2. A vertical slot fishpass was constructed at Kashimpur, Moulvibazar District, to test the feasibility of using such a structure to partly mitigate the negative impact of the Manu River Irrigation Project (MRIP) on the fisheries of Kawadighi Haor.

3. The design of the structure was based initially on Canadian structures built for salmon, and then modified based on Australian experience with warm-water fish species. It consists of a single jet vertical slot design, with 61.85 m long concrete section, maximum height of 6.54 m, and maximum width of 5.00 m. There are 17 pools and two observation chambers. Slot width is 410 mm. Maximum design head drop across the structure was 3.78 m, resulting in maximum head loss per baffle from pool to pool of 24 cm. Average maximum design velocity at the slot was 1.62 m/s.

4. The structure was constructed during January-May 1995, and was operational from May 1995 to September 1997.

5. The hydraulic performance of the structure was studied during the three years of operation. Water velocity and turbulence at the slot was constant across the entire structure only when water surface profile was parallel to structure bed surface slope. When water profile was steeper than bed slope, increased velocities occurred at the downstream portion. Conversely, when water profile was milder than bed slope, increased velocities and turbulence occurred at the upstream portion. Water velocity remained above 1.5 m/s for 27-41% of the time for river to *haor* flow, and 11-36% of the time for *haor* to river flow.

6. The movement of fish through the fishpass was studied by taking samples from the observation chambers at either end of the structure. Adequate sampling gear was not available during Year 1, but large metal cages were used during Years 2 and 3 which allowed reliable estimation of fish traffic rates. A total of 516 samples were taken. The sampling periods constituted 11-20% of the entire annual operation period of the fishpass.

7. All samples contained fish, suggesting that there is a continuous fish traffic through the fishpass. Fish moved simultaneously in both direction (river to *haor*, and *haor* to river) and in both swimming modes (concurrent and countercurrent).

8. Three different methods were used to estimate the number of fish migrating through the fishpass. This resulted in the following annual traffic estimates:

Year 1: 0.34 to 0.54 million
Year 2: 1.24 to 1.30 million
Year 3: 1.71 to 1.80 million

The Year 1 estimate is likely a large underestimate due to unreliable sampling gear, while the Year 3 estimate is an incomplete estimate as sampling was not carried out during the last part of the monsoon (Oct-Nov 1997).

9. Traffic rates through the fishpass were highest during the premonsoon and early monsoon flood surges. The largest number of species (88) using the fishpass was recorded during Year 3. The species composition of the traffic was dominated by small prawns (*icha*), glassfish (*chanda*), small cyprinids (*mola*, *puti*, *chela*), small catfish (*batashi*, *bacha*, *tengra*), the sardine *chapila* and the giant river prawn *golda chingri*. The most common large species were the catfish *air*, the carp *kalibaush*, the spiny eel *baim*, and the common eel *bamosh*.

10. There was a general preference for fish and small prawns to move through the fishpass at night, although fish were more flexible and also moved during the day. Concurrent swimming mode appeared to be unaffected by water velocity at the slot. Countercurrent swimming however appeared to be affected at velocities above 1.5 m/s, and only three species were recorded at the highest observed velocity (2.49 m/s).

11. Various environmental issues affected the project. A fish sanctuary was declared in the access canal (Karadair Khal) of the fishpass to protect migrating stocks. This canal suffered from water hyacinth infestation at the end of the monsoon season. Low water quality (low dissolved oxygen, low pH) and dry season *beel* dewatering were also stressful to fish. Trial planting of wetland and hardwood trees was moderately successful.

12. Monitoring of fish production in Kawadighi Haor indicated that an overall average increase of 54.9% in catch occurred during the period 1992 to 1996 when comparing pre-project and with project time periods. Most of this increase can be attributed to the effect of the fishpass. Monsoon floodplain production increased by 34.2%, while dry season *beel* production increased by 201.7%. Fish biodiversity in the *haor* increased from 80 species to 95 after the fishpass began operation. Some species such as *bacha*, *bagair*, *gonia* and *lachu* appear to benefit directly from the access provided and have re-established themselves in the *haor*. Other species such as *air*, *golda chingri*, *kalibaush* and *mola* became more abundant year round since fishpass operation began.

13. A water balance model of the MRIP project and Kawadighi Haor was developed to elucidate the impact of fishpass discharges on *haor* hydrology. Average inflow through the fishpass during the premonsoon and early monsoon was 0.5 to 0.8 m^3/s, resulting in monthly average areas affected of 0.3 to 3.22 ha/day. Study of agricultural cropping patterns during the three years of fishpass operation failed to show any impact on rice production from the negligible volume of water discharged into MRIP through the fishpass.

14. Improvements in fishing income and fish consumption amongst most beneficiary groups in the project area were recorded. Inequities in distribution of the benefits of the fishpass are due to the fisheries leasing system imposed by the government.

15. Economic evaluation predicts that the project will generate a net present value of Tk 27.4 million over a 30 year lifespan. The internal rate of return was 48%, and the benefit-cost ratio was 3.4:1. The results compare vary favourably with the project alternative of floodplain stocking.

16. The Department of Fisheries (DOF) and Bangladesh Water Development Board (BWDB) participated in the project development and implementation, and also benefited from training workshops. The fishpass was handed over to the BWDB in January 1998. Arrangements were made for continued operation of the structure under the auspices of local Management and Operation Committees. An Operation, Maintenance and Management Manual was produced.

17. An attempt was made to unite the genuine fishermen of the *haor* under a single producer organisation - the Kawadighi Haor Fisheries Association (KHFA). A series of organisational and training meeting was conducted with the KHFA, and the group is undergoing official registration process.

18. Two floating cage trials were conducted to demonstrate and assess fish fattening and fingerling grow-out methods. The fish fattening trial using wild-sourced indigenous species (*air* and *kalibaush*) was reasonable successful, while the fingerling grow-out using non-indigenous hatchery-sourced species (carpio, *tilapia*, grass carp, Thai *pangas*) was largely unsuccessful. A number of suggestions were made to improve future cage culture trials.

19. Training was provided to women fish processors in solar drying and better fish handling methods.

20. It is concluded that the vertical fishpass type of design is suitable for use as a mitigation measure in flood control, drainage and irrigation (FCDI) projects. The structure could be constructed in other parts of the country but its technical and socioeconomic viability (size, storage volume and crop damage) must be given due considerations during the selection and evaluation of the project. Some modifications to structure design are desirable to reduce high water velocities and turbulence during certain periods.

21. Fishpass projects should be nested inside larger more comprehensive fisheries development projects to rehabilitate and modernise the fisheries sector inside FCDI projects. Such comprehensive fisheries projects should include other components such as environmental improvement, fisheries management, and fisheries technology upgrading, with emphasis given to equity and also gender issues.

22. Lead implementation for fishpass projects should rest with the Ministry of Fisheries and Livestock and the Department of Fisheries. Civil engineering construction work should be carried out under the supervision of the BWDB and Local Government Engineering Department (LGED).

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

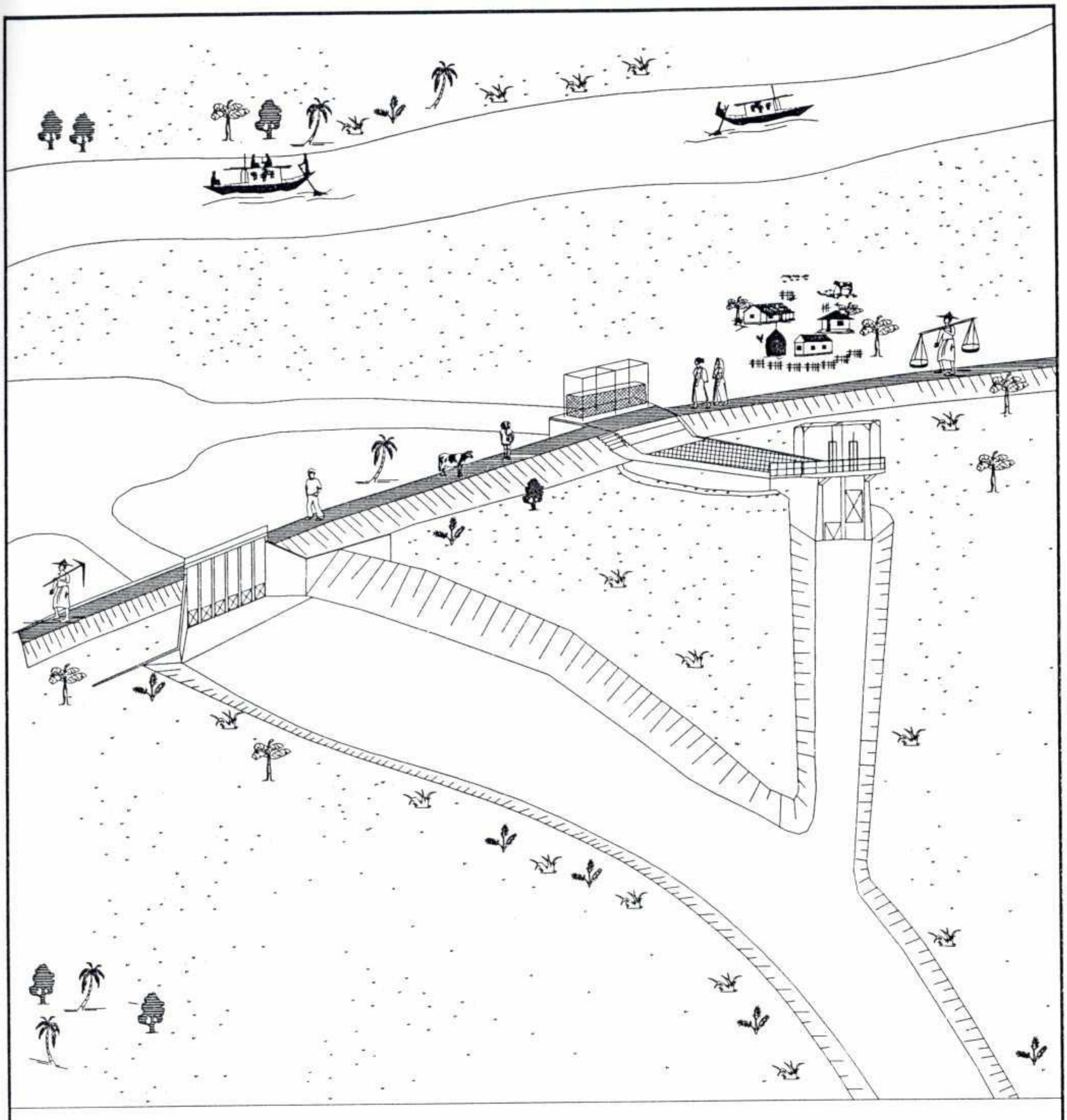
LIST OF FIGURES

LIST OF TABLES IN ANNEX

List of Tables

22

CONTENT OF VOL 2: APPENDICES



Northeast Regional Project

Rendering of the Fishpass at Kashimpur

Prepared by: Salahuddin	December 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-250.DWG

PREAMBLE

This document reports on the activities and results of an undertaking to test the feasibility of using a fishpass to mitigate the negative effects of full flood-protection embankments on floodplain fisheries. As this was the first such attempt in Bangladesh, there was at the time of project approval some uncertainty about the eventual outcome. The results however are very positive and previously unknown phenomenon for fishpasses have been recorded for the first time. Many species of fish were observed migrating through the structure, both to and from the floodplain. The biodiversity and number of migrating fish was significant, causing the yields of the monsoon season floodplain fishery and the dry season beel fishery to increase appreciably.

The prospect exists for installation of fishpasses at other full flood control schemes in Bangladesh and other countries. The high responsiveness of the migrating fish stocks to an open embankment bypass route observed at Kashimpur suggests that fishpasses of the vertical slot design type are likely to be equally successful elsewhere in similar situations. However, some circumspection is advisable in applying the results from the Kashimpur fishpass project to other locations. FCDI project conditions (economic, environmental, engineering and social) vary widely and are themselves often beset with deficiencies and inefficiencies (i.e: at Manu River, pumping capacity was underdesigned and entrenched absentee landlordism reduces cropping intensity below the target level). The design and operation of a fishpass would have to take into account the specific conditions prevalent at any particular location. The Manu River Irrigation project is one of a set of large full flood control projects in Bangladesh which also includes Chandpur, Muhuri, Pabna and Karnafuli FCDI projects (among others). However, even within this set of projects, the fishpass design and operational regime adopted at Kashimpur (where there is an especially large haor and beel area, and a powerful pumping station) is not necessarily the optimal or likely to be the most successful at other large FCDI projects. Medium and small size full flood control projects may impose stringent limitations on the volume of discharge that would be acceptable through the fishpass into the FCDI project area, and appropriate changes to fishpass design and operation may have to be considered.

Economic tradeoffs also need to be taken into account between fish production value, agricultural production value and water excavation (pumping) costs. This may be more difficult for fishpass projects which are retro-installed at existing FCDI projects as the fishpass might be viewed as a new installation which 'disturbs' or impacts the existing situation. A fishpass that is installed at the same time as construction of other structures (ie embankment, regulator, pumphouse, barrage) is more likely to be regarded as an integral and normal component of the FCDI project. In general, fish production value may be increased by discharging more water into the FCDI project area through the fishpass. This might result in crop damage at the margins of beels if there is no vacant storage capacity available in the beels and khals at the time of water entry. In spite of this, if there is a net marginal increase in economic production, such an arrangement may be workable. Water excavation (through installation of a pump equal in capacity to the discharge volume passing through the fishpass) might also be economically feasible to recover the lost agricultural production if this emerges as a problem.

Clearly, a thorough site-specific feasibility study of the economic, environmental and social conditions and likely impacts of a fishpass needs to be undertaken to optimize design and operation to ensure that the maximum net benefits are achieved, and any disbenefits are mitigated and acquitted.

1. INTRODUCTION

1.1 Background

Following the disastrous floods of 1987 and 1988, the Government of Bangladesh (GOB) undertook a comprehensive review of its flood policy and launched the Flood Action Plan (FAP) to formulate and implement technically, financially, economically and environmentally sound solutions to the flooding problems of Bangladesh. During the first three years of FAP (1990-93), regional water resources development planning studies were undertaken to identify and assess various water resources management strategies for different regions of the country. The regional studies were followed by feasibility studies of selected investment projects. In addition, a number of complementary technical, social, economic and environmental studies were undertaken to improve the understanding of the impact of flooding and flood control, drainage and irrigation projects, to improve the data base, and to develop guidelines and planning criteria for use in the preparation and implementation of the FAP Studies.

One of the regional studies was the Northeast Regional Water Management Project (NERP), also known as FAP 6, which was funded by the Canadian International Development Agency (CIDA). Under FAP 6, a Northeast Regional Water Management Plan was prepared using a strategic planning process which consisted of a combination of structural and non-structural components. The plan identified 45 initiatives for the Northeast Region, and pre-feasibility level studies and other studies were completed for these initiatives. The initiatives identified in the Plan fall into two broad categories: flood control, drainage and irrigation projects (FCDI) and other non-FCDI projects. These initiatives conform to the water management strategy proposed for the region and have undergone multi-criteria analysis as specified by Flood Plan Coordination Organisation (FPCO).

Non-FCDI initiatives were identified based on investigations which began with the preparation of sectoral or Specialist studies. The list of initiatives was further refined on the basis of the outcome of subsequent steps in the planning process, including development of an interpretive description of the region, identification of driving forces, regional analysis, and strategy formulation.

The Fishpass Pilot Project (FPP) originated from the NERP study 'FISHERIES ENGINEERING MEASURES'. It is a structural initiative which is designed to mitigate negative impacts of FCDI projects on fisheries, specifically to allow normal breeding migrations to take place during the premonsoon and monsoon. This is expected to result in an increase in fish biodiversity, abundance, and yield, and thus help to meet regional planning objectives of poverty alleviation, food self-sufficiency and economic development.

A second NERP study 'FISHERIES MANAGEMENT PROGRAM' identified a number of non-structural measures that could be initiated to achieve further development gains within the fisheries sector. Although this program was not implemented in its entirety, some of its components were incorporated into FPP on a trial basis.

FPP was financed by the Canadian International Development Agency (CIDA). The FPCO of the Ministry of Water Resources (MOWR) coordinated the project for the Government of Bangladesh.

2

1.2 Project Rationale

1.2.1 General Considerations

The aim of the project was to test the utility of a vertical slot fishpass for providing a functional access channel between a river and floodplain (*haor*) across a full flood control embankment. Fishpasses have not previously been constructed as environmental mitigation measures for flood control embankments in Bangladesh, or elsewhere in the world. It is a reasonable assumption that re-establishing annual fish migration events from river to *haor* would be of benefit to the fisheries still existing in the *haor*.

As the cost of a fishpass structure is significant, and its projected useful lifespan more than two decades, it seemed justifiable to aim the project objectives at a higher goal than simply establishing whether or not fish would migrate through a fishpass set on a Bangladeshi floodplain. It was decided that the development impact of the fish migration through the fishpass (assuming such migration would be successful) should have at least as high a purpose as pilot testing of the structure. Accordingly, the *haor* that appeared to be the most severely affected by an FCDI embankment in the northeast region was selected as the project location. Kawadighi Haor inside the Manu River Irrigation Project (MRIP) was chosen. The importance of this *haor*, and the need for its rehabilitation is discussed below.

1.2.2 Impact of MRIP on Kawadighi Haor

Kawadighi Haor was one of the most important fish breeding grounds in the region (a mother fishery) and was completely destroyed by the implementation of MRIP (Figure 1). Large broodfish from the Sylhet Depression used to migrate up the Kushiyara River to Kawadighi haor during the premonsoon as the *haor* possessed an excellent natural environment for spawning. During the Pakistani period fish catches were occasionally so large that a helicopter was used to transport the fish out of the *haor* to Dhaka. 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 the last 150 to 200 years.

The previously large fishery resource of the *haor* was due to the combination of its location and 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 *duar*s harbouring large boromaach broodstock downstream). It was the first and only *haor* which possessed substantial pure runoff rain water coming directly from the Bhattera Hills and having little silt. It had less silt due to backflow of river water as well as by the counterflow from the Bhattera Hills. These different water sources produced a natural water circulation in the *haor* which created a high quality habitat for fish spawning. Even 10 years after implementation of the project, broodfish still try to cross the embankment at Karadhair and Machuakhali River.

A detailed description of the civil engineering structures of MRIP is presented in Appendix A. The embankment has resulted in an enormous economic loss to the fishery of the *haor* as well as the nation. Brood fish cannot enter into the *haor* and become easily harvested outside in the Kushiyara River, resulting in a large loss of fish population within the region. The once fertile *beel*s within the project have became unproductive. The agricultural lands are losing their natural fertility because of excessive aquatic plant growth caused by water stagnation. Irrigated agriculture areas are not used for crop production, but agriculture lands are being extended into the *beel* area causing local conflict between farmers and fishermen. The water sources (local rainfall from Battara Hills) of the *haor* and land use patterns of absentee land owners living abroad were not considered during project planning, which lowers its viability considerably. At present agricultural costs appear to be increasing faster than agricultural production. The MRIP goal of achieving high net benefits through increased agricultural production has not been fully realised and it has destroyed one of the best fish spawning grounds in the region.

An exceptional number of genuine fishing communities reside in the *haor* area. These fishing communities produced an elite group which dominated local politics and administration. This is a good indicator of the previous magnitude and dominant importance of the fisheries sector of Kawadighi *haor* in the area.

1.2.3 Options for Rehabilitation of Kawadighi Haor and Project Alternative

The construction of a fishpass was judged to be the most viable option for rehabilitation of the Kawadighi Haor fishery. A number of observations and events provided a concrete basis for making a selection among various options:

- It was observed during NERP field work in 1992 that a large number of fish species were caught outside of the embankment, but which were not present on the project side. The species inside the project were floodplain resident species that do not carry out extensive migrations and were observed to spawn throughout the monsoon. This suggested that the flood control embankment had severely decreased fish biodiversity inside MRIP;

- Carp broodfish were observed on the river side at the Kashimpur pump house trying to get in through the pump. This suggested that river fish would readily migrate into the *haor* if access in the form of a fishpass was made available, and

- Massive failure of the embankment in 1993 near Machuakhali and elsewhere resulted in entry of Kushiyara River fish into Kawadighi Haor. A large increase in fish catch resulted. This event mimicked the operation of a fishpass, and gave an indication of the magnitude of the benefit that could be expected to be realised by the fisheries sector if premonsoon fish migrations from the river into the *haor* could be re-established by a fishpass.

Sufficient evidence existed therefore to support the contention that the presence of a fishpass which was properly designed to allow the local fish species to successfully negotiate it would likely result in both an increase in biodiversity and fish production inside the *haor*.

The main alternative for rehabilitating the Kawadighi Haor fishery is floodplain stocking. This alternative was considered less attractive than the fishpass option. Floodplain stocking with carp was being carried out at Kawadighi Haor and elsewhere in Bangladesh. Although some useful increases in carp catches were recorded, the stocking program was not sustainable and incurred an annual stocking cost. Both the practice of rotenoning *beel*s and the meagre biodiversity of stocked species was open to criticism. Stocking could not improve biodiversity directly. Stocking also increases the risk of disease transmission from hatcheries.

Another option considered was pond aquaculture. However, widespread pond aquaculture inside Kawadighi Haor was not considered feasible due to the high level of flooding which persists in spite of the embankments and pumped drainage. Most ponds inside the *haor* could be expected to be flooded each year and result in escapade of pond fish into the surrounding *haor*.

Construction of a fishpass appeared to be the best option because it addressed concerns about biodiversity and disruption of life cycles. It also appeared to be the most sustainable as it would not require any substantial additional investment after construction (apart from a small annual maintenance expenditure). The structure would go on yielding benefits for more than two decades before being decommissioned and replaced.

1.3 Project Objectives

The purpose of the fishpass pilot project (FPP) is to assess the technical feasibility of using the vertical slot type of fishpass to provide passage to migrating fish stocks across flood control embankments in the *haor* region of Bangladesh, and acquire information about economic and socioeconomic impacts on beneficiary communities.

If successful in meeting its objectives, it was anticipated that this would result in an increase in fish production inside MRIP. In effect this would restore a part of the fish production lost from this mother fishery due to damage from MRIP.

Because a structural measure cannot normally proceed in isolation from social, economic and environmental parameters, a strategy was devised for trials of other interventions, including:

- Establishment of a fish sanctuary along the main fish migration route to protect migrating broodstock and juveniles;
- Establishment of a single fisheries association for the *haor* composed only of genuine fishermen whose long term aim could be to acquire with ownership (or at least secure tenure) of the resource and full fisheries management authority and capability;
- Mobilisation of the DOF and other government agencies to support the general objective through various actions;
- Improvement of environmental conditions for fisheries in the *haor*, and
- Provision of training to the fishing community in fisheries management and postproduction technology in order to increase efficiency and income.

Given the nature of the contractual agreement between the cooperating parties of the project, it was not always possible to give primary emphasis to these strategic initiatives, and in some cases implementation was not rigorous.

1.4 Location and Site Selection

Kawadighi Haor and MRIP were selected as the site for the pilot fishpass construction based on its importance for regional fisheries development, as discussed in the previous section. The suitability of the site was also assessed using a set of rational criteria. Principal criteria for site selection were as follows:

- There must be evidence (local public opinion, DOF/NERP studies) that the FCDI project has had negative impacts on fisheries, specifically that fish migration has been disrupted (usually manifested as low abundance or absence of *boromaach* in perennial *beels*);
- The FCDI project area should be medium to large in order to maximise the benefit to the fisheries sector (and also to minimise opposition from farmers to release of water through the fishpass into the project area);
- The river channel opposite the fishpass should be perennial;
- Reliable and abundant populations of migratory fish should occur in the river;
- A number of the *beels* inside the FCDI project area should be perennial;
- During the time of the premonsoon, there should be no open embankment breeches or public cuts, and
- There should be no cross dams in the *khal* which connects to the fishpass.

Kawadighi Haor and MRIP generally meet these criteria. MRIP is a large and complex full flood control project with pumped drainage and gravity irrigation. The Manu River FCDI Project lies between longitudes 91°40' and 92°00'E and latitudes 24°55'and 24°40'N. It is situated about 175 km northeast of Dhaka and about 80 km southwest of Sylhet. Administratively, it falls within Moulvibazar District of the Greater Sylhet District. The Manu River Irrigation Project lies in Chandnighat, Akhikura, and Ekatuna union *parishads* of Moulvibazar Thana, and in the Rajnagar, Mansurnagar, *Uttar* Bhagh, Panchgaon, Munshibazar, Fatehpur, and Tengra union *parishads* of Rajnagar Thana. The municipal area of Moulvibazar, located mainly on the left bank of the Manu River, is not within the project area. MRIP is easily accessible by road and river and it is logistically supportable.

The options for fishpass location (Kashimpur, Machuakhali) are directly on the Kushiyara River which is a major regional fish migration route. There is evidence of migrating broodfish congregating at these locations (i.e.: the Machuakhali LLP inlet, Kashimpur pumphouse and 6 vent regulator) and attempting to enter the *haor* during the premonsoon and monsoon. Both locations were studied with respect to the above selection criteria. The Machuakhali location was discarded because, at present, the Machuakhali Khal does not have direct connection with the Kawadighi Haor. The Manumukh Irrigation Canal separates the *Khal* from the *haor* about 1.5 km east from its original outfall into the Kushiyara River, and the western part of the *Khal* has silted. This area is also prone to embankment breeching (either from river scouring or cutting by local residents, as occurred in 1993) and would not be a secure site for a large structure such as the fishpass.

The Kashimpur location was selected as best fulfilling the selection criteria. Two possible sites were considered for construction of the fishpass structure at Kashimpur:

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Site 1: on the west side of 3-vent drainage regulator which has been constructed in an excavated channel connecting the Kushiyara River with Karadair Khal.

Site 2: on the east side of 6-vent drainage regulator which has been constructed in the original Karadair Khal channel (Figure 2, and Appendix B, Drawing B.2).

On 12 June 1994 the proposed fishpass sites were inspected by Executive Engineer (Moulvi Bazar BWDB Division I) and NERP fisheries biologists. During this visit, an initial proposal was made to construct the fishpass next to the 3-vent regulator (Site 1). As the BWDB was planning to repair the 3-vent regulator, the possibility of combining the construction of the fishpass with the regulator repair work was explored. On 14 August 1994, the site was inspected by NERP biologist and fishpass designer. The designer, however, was aware of the siltation of the outfall channel having personally observed a completely silted outfall of the channel in March 1992. During major floods (including the premonsoon floods) the channel of the 3-vent regulator gets silted at the outfall into the Kushiyara, and needs to be re-opened almost every year. To avoid interruptions in operating the fishpass caused by siltation of the channel it was recommended to shift the fishpass close to the 6-vent regulator with link canal to the Karadair Khal (Site 2). The present fishpass site was finalised on October 16, 1994 during a joint field inspection by the Chief Engineer (NE Zone, BWDB Comilla), Superintending Engineer (BWDB Moulvi Bazar Circle), the NERP Fisheries Specialist and the NERP Design Engineer.

The fishpass structure is located 60 m east of the 6-vent drainage regulator and 60m west of the 3-vent drainage regulator of MRIP. There is a pumping station 100 m to the left of the fishpass. All these structures and the pumping station are constructed on the left bank of the Kushiyara River which is 600 m away from the embankment. The main inlet channel of these structures is known as Koradair Khal which diverges into four sub-inlet channels. The outlet channels of the 6-vent regulator, pumping station and fishpass combine at some distances and the unified *khal* falls into the Kushiyara. The outlet channel of the 3-vent regulator falls independently into the Kushiyara.

1.5 Information Database

1.5.1 Pre-Project Baseline Studies

The impacts of FPP over its three years of operation were compared to a three year baseline. NERP conducted a 2 year study (May 1992 to May 1994) of MRIP under its Project Monitoring Program (PMP). The study involved comprehensive monitoring by a multidisciplinary team of experts of the physical, operational, economic, financial, environmental and social impacts of MRIP. In June 1994 it was decided to proceed with FPP, and PMP studies were accordingly continued onward into FPP construction (February-May 1995) and operational (May 1995 - September 1997) phases.

1.5.2 Fishpass Sampling

The fishpass structure was designed with observation chambers at either end. This allowed the deployment of various sampling devices and the collection of information on fish types and quantities migrating through the structure. Full descriptions of sampling procedures, schedules and bias/error are presented in Sections 4.3.1 to 4.3.3. Comprehensive hydraulic studies inside the structure during different time periods and under different flow conditions were also carried out. Hydraulic measuring methods are described in Section 4.2.1.

1.5.3 Impact Monitoring

Assessment of the impact of FPP on fish production was done through catch assessment surveys (CAS), sampling of fish stocks by NERP, and developing an index of abundance for each species. Methods are described in Section 5.1.1.

Hydrological impacts of FPP were studied using river water levels, *haor* water levels, discharges and velocities at fishpass, inflow from Bhattera Hills, outflow through regulators, rainfall, evaporation, percolation, and topography of the project area.

In order to observe and analyse community response and social dynamics to FPP, a team of community organisers (COs) was deployed in the field. A participatory rural appraisal (PRA) method was used to obtain data and to gain insight about the situation. The method includes formal and informal interviews, group discussions, use of key informants, and similar subjective information acquisition.

1.6 Activities Carried out by Project

The FPP implementation plan consisted of six principal components:

- Management. Pilot project planning, administration, procurement, reporting and liaison with other projects;
- Pilot Design. Field studies at the pilot site and at functioning vertical slot fishpasses in Australia would be used to develop a design appropriate to local species and physical conditions;
- Pilot Construction. One concrete vertical slot fishpass to be constructed at MRIP;
- Pilot Operation. The pilot fishpass at MRIP would be operated during the premonsoon. Movement of fish through the structure would be monitored, and additional optimising adjustments would be made to the structure;
- Impact Monitoring. A comprehensive baseline and impact monitoring program would be put into place at MRIP which would focus on fisheries, agriculture, hydrology and socioeconomic factors. It would build on previous monitoring results obtained by PMP, and
- Institution Building. Training in fisheries engineering and fishpass technology would be given to BWDB design engineers and DOF fishery biologists through study visits and on-the-job instruction.

FPP would yield the following tangible and intangible outputs:

- Pilot fishpass. One functioning vertical slot fishpass at Manu River FCDI Project;

- Expertise. A body of expertise residing with civil engineering staff at BWDB and fishery biology staff at DOF (as well as individual professional consulting personnel contracted by NERP) on planning, designing, constructing, operating, maintaining and monitoring vertical slot fishpasses for application in FCDI projects, and

- Technical Manual on Fishpasses.

During the lifetime of FPP it was expected that a measurable increase in fish production would be realised at MRIP.

FPP design and construction phases were subject to a demanding time schedule. The order of activities was sequential, and determined by unpredictable and narrow windows of opportunity controlled by the pre-monsoon/monsoon annual fish migration patterns, the fishing calendar and the dry season construction calendar. Failure to execute a task in the prescribed time period could have meant a one year delay in execution of downstream dependant activities. The project team was largely successful in ensuring that the several design and construction steps were executed on time and within the tolerance levels of quality and safety specified. Thus, the construction of the fishpass was completed in entirety during one dry season (January to May 1995). Failure to complete the structure before the onset of the monsoon could have endangered both the structure and the MRIP embankment.

The Fishpass Pilot Project was originally conceived as a project whose main component was a structural intervention aimed at restoring fish production in Kawadighi Haor. Intuitive weigh was also given to non-structural interventions, though these were not necessarily unique to the MRIP/Kawadighi Haor location, or even to FCDI projects. It become increasingly clear as the project progressed that there is a complex interaction between the technical requirements of FPP and the social responsibilities associated with operating a fishpass. Implementing an apparent solution to one particular problem often led to other problems coming to the forefront - a process that is not always predictable. FPP maintained a flexibility and responsiveness to the changing situation in Kawadighi Haor. This stemmed from the perception that a fully refined and effective model for a fishpass project that would be applicable throughout Bangladesh must be based on an integrated activity program. It must simultaneously address fishery resource management, environmental quality, social equity, economic efficiency criteria, and must be able to effectively move the target zone into an enhanced positive normative state. Thus, in its final stages, the FPP program was highly diversified, and the structural interventions laid the groundwork for non-structural improvements.

1.7 Project Implementation Groups

NERP technical staff were divided into several groups that were responsible for implementation of FPP (as well as working in other NERP activities). The core staff of each group was as follows:

- Fisheries Group: consisting of the Project Coordinator, one international fisheries adviser, the field office manager (seconded from DOF), and two fisheries field biologists;

- Engineering and Hydrology Group: consisting of one international design engineer and one hydrologist;

- Agriculture Group: consisting of one agronomist, and

- Sociology Group: consisting of one senior sociologist, one international sociology adviser, and two community organisers.

Other staff were contracted on short-term basis as required (i.e.: economist).

2. DESCRIPTION OF PROJECT AREA

2.1 Environments

2.1.1 Rivers

The Kushiyara River comprises the principal link between the Barak and the Meghna Rivers. In addition to carrying two-thirds of the flow of the Barak, the Kushiyara collects all outflows from Tripura (6,845 km^2 catchment) and the Surma-Kushiyara floodplain (520 km^2 in Bangladesh). The Tripura Hills consist a series of seven long, narrow, north-south oriented, northwards plunging, anticlinal ridges separated by six wide, low-lying, flat bottomed synclinal valleys opening to the north. The ridges are about 15 km apart, and they penetrate up to 30 km into Bangladesh where they are known as the Sylhet Hills. The lower reaches of the valleys, particularly within Bangladesh, contain large *beel* complexes. Notable among these are Son *beel* in Assam, and Hakaluki *haor* and Hail *haor* in Bangladesh. The Kushiyara has eight significant tributaries all originating in Tripura and entering it from the south. These tributaries are Sonai-Bardal, Juri, Manu, Dhalai, Langla, Karangi, Khowai, and Sutang. At MRIP, the width of the river varies from 150 m to 200 m. The maximum depth of the river at MRIP during the monsoon is 22 m in bends and 12 m in straight reaches. Return periods of flood discharges in the Kushiyara are presented in Table 2.1.

Table 2.1: Return Periods of Flood Discharges along the Kushiyara River
Discharges in m^3/sec.

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Sheola	2,162	2,492	2,652	2,773	2,806	2,894	2,963
Sherpur	2,575	2,771	2,852	2,905	2,919	2,952	2,975

The Manu River can be subdivided into three reaches:

- Upper Manu River in Tripura State;
- Middle reach, from Bangladesh border to Dhalai river confluence, and
- Lower Manu River from Dhalai river confluences to its junction with Kushiyara River.

The upper Manu River occupies a narrow valley between two prominent north-south trending anticlinal ridges. The lower portions of these ridges consist of poorly consolidated, often highly weathered Pleistocene and Pliocene-age sediments (dihing and dupi tila formation) that are dissected and gullied by a network of headwaters channels that form a dendritic drainage pattern. The upper Manu River flows in a confined, irregularly meandering channel. Downstream of the border, the Manu River flows in a north-westerly direction, across the strike of the anticlines and breaks through a gap between the ridges below Hashimpur. The channel turns westwards and is confined by the Bhattera Hills on its right bank and bordered by Dakdhala *haor* on its left. The Dhalai River flows into the Manu River about 6.4 km upstream of the Manu Barrage. The Manu and the Dhalai have catchment areas of 2,226 km^2 and 572 km^2, respectively, of which 59.5 km^2 and 292.5 km^2, respectively, are in Bangladesh. The Manu River is confined by embankments along most of its length in Bangladesh. This confinement, together with further confinement and increasing deforestation in India, is resulting in steady increases in peak discharges and water levels. Return periods of flood discharge are presented in Table 2.2.

Table 2.2: Return Periods of Flood Discharges in the Manu and Dhalai Rivers
Discharges in m^3/sec.

Station	Return Period (Years)						
	2	5	10	20	25	50	100
Manu R B	607	699	737	763	769	785	796
Dhalai	228	273	302	329	337	362	386

Note: Manu R B (# 201) is located above the confluence with Dhalai River.

2.1.2 Kawadighi Haor

This is a large wetland of outstanding national and international importance situated 6 km to the east of the confluence of the Kushiyara and Manu Rivers (24°32'N to 24°38'N; 91°44/E to 91°51'E). The *haor* has an area of 11,295 ha, and consists of large permanent *beel*s (the largest is Patasingra *beel* at 234 ha), temporary *beels*, numerous kahls crisscrossing floodlands and some relict wetland forest stands (Appendix A, Table A.1.1, for a list of *beels*). Most of the *haor* area is currently used for rice cultivation. Since construction of MRIP the *haor* has become entirely contained within the boundaries of the flood control embankments.

2.1.3 Manu River Irrigation Project (MRIP)

This FCDI project features full flood control, pumped drainage and irrigation (Appendix A for a full technical description of MRIP). It encompasses a gross area of 22,580 ha. Flood control is intended to benefit agriculture over an area of 10,480 ha. The project also provides for drainage of 4,250 ha and irrigation of 12,090 ha. Infrastructure consists of:

- A large barrage across the Manu River to divert water into the project area for gravity irrigation;
- An internal irrigation distribution network and drainage system that includes 145 km of canals and 42 regulators and sluices;
- 59 km of full flood embankments along the Kushiyara and Manu Rivers with 27 pipe inlets for irrigation;
- One six-vent and one three-vent regulator (the latter not part of the original project design but added later), and
- A 34 m^3/s capacity electric pumping station on the left bank of the Kushiyara River which is designed to partially remove local rainfall runoff.

The project objective is to increase crop production by providing full flood protection, passive and pumped drainage and dry season and supplemental monsoon surface water irrigation. The irrigation component was intended to increase the area cultivated with *boro*, and the drainage and flood control facilities to increase the area cultivated with transplanted *aman*.

2.2 Climate

Maximum temperatures in the project area vary from about 28°C to 36°C with the highest temperatures experienced during the period March to June. There is a significant diurnal fluctuation with minimum temperatures ranging from about 6°C to 23°C.

The mean annual rainfall over the project area, based on the results of three local rainfall stations, is about 2,865 mm (Table A.1). The rainfall exhibits a seasonal pattern with up to 65% of the annual total experienced during the monsoon period June to September. The period from December to March is significantly dry with less than 5.5% of the annual total.

The relative humidity is high throughout the year, with average humidity ranging from 72% to 88%. The humidity is highest during the monsoon period June to September.

The average wind speed varies from about 3.5 to 5.4 m/s with the highest speeds occurring in between March and July.

Potential evapotranspiration rates reflect seasonal patterns with the highest rates of up to 4.9 mm/day during the pre-monsoon month in May. The lowest rate (2.6 mm/day) occurs during the winter months of December and January.

2.3 Hydrology

Water sources at the MRIP are from rainfall, inflow from Manu barrage and inflow through chhoras from Bhattera Hills. Main inflow during the dry season is from irrigation canals. During the pre-monsoon, monsoon and post-monsoon, inflow sources are from rainfall and upstream flows. Before the construction of the embankment, peak flows of the Manu River by-passed the Manumukh outfall by overland flow towards:

- Hakaluki Haor via the Phenai River;
- Kawadighi Haor to the Kushiyara River via the Koradair River, and
- Hail Haor to the Kushiyara River via the Gopla River and the Gunjiajuri river and the Ratna River.

Manu River water level fluctuates tremendously during the pre-monsoon and monsoon. Sharp rises and drops in water level of up to 5 m occur. This sharp rise in water level often causes threats to the embankment and Molvibazar town. During the pre-monsoon, the Kushiyara water level varies approximately 2 to 4 m, while during the monsoon it varies up to 2 m with a few flood surges. During the monsoon, the *haor* is inundated (equal to 60% - 75% of the MRIP area) depending on the rainfall and inflow from the Bhattera Hills. The rainfall in the Northeast region is comparatively higher than the other regions in Bangladesh. The pre-monsoon water level is kept at a constant level by withdrawing water from the *haor* with pumps as long as the water added by heavy rainfalls does not exceed the pumping capacity. During the monsoon there is steady increase in water level in the *haor* even though the pumps remain in operation. If a high flood level occurs in the river, the *haor* water level also becomes higher. Maximum flooding of the *haor* occurs in the month of August-September. Peak water level also occurs in the river during August-September.

Depending on the seasonal distribution of rainfall and water levels in the river, the following hydrological cycle is approximately followed:

Pre-monsoon:	March-May.
Monsoon:	June-August.
Post-monsoon:	September-October.
Dry season:	November-February.

A number of nomenclature conventions were adopted in order to differentiate between the various hydrological conditions and phenomenon related to fishpass operation:

- <u>Dominant Water Mass (DWM)</u>: The DWM is responsible for water flow through the fishpass, and could be either the river water mass or the *haor* water mass, depending on which level is higher. DWM is river water during the pre-monsoon and early monsoon seasons, and *haor* water during the late monsoon and post-monsoon seasons. DWM alternated during the mid-monsoon, resulting in flow reversal inside the fishpass.

- <u>Potential Operation Period (POP)</u>: A POP is defined as any period of time when the DWM level was above the river side (R/S) invert level of the structure. POPs occurring during the pre-monsoon and early monsoon seasons were due to flood surges in the river. The POP was continuous during the monsoon due to high river water levels. The *haor* water mass derived from rainfall and *haor* catchment sustained the POP during the late monsoon and post monsoon seasons, as well as after the river level fell below the R/S invert level. *Haor* drainage during the post-monsoon led to the eventual termination of the POP. This happened when the *haor* water level fell below the R/S invert level. During any POP, the direction of water flow inside the structure was determined by whichever of the two water masses was the DWM.

- <u>Non-Operation Period (NOP):</u> A NOP is defined as any period of time when the level of the DWM was less than the R/S invert level, resulting in zero water flow through the structure.

- <u>Actual Operation Period (AOP):</u> The AOP is defined as any part of a POP during which the gates of the structure were open (opening the gates during a NOP is irrelevant to fish migration).

- <u>Pre-monsoon Flood (PMF):</u> A PMF is a rapid surge in river level which does not result in sustained river flooding and bank overspill. PMFs produce characteristic sharp spikes in R/S water levels when plotted on hydrographs (see for example Figure 28). The number of PMFs varies from year to year, and are numbered consecutively (PMF1, PMF2, and so on). A PMF can be subdivided into a flood surge phase (the left side, positive slope of the flood spike) and a receding water phase (the right side, negative slope of the flood spike). The magnitude of the flood surge can vary. In general, the final recession level of a particular PMF is higher than its initial flood surge level, resulting in progressive ratcheting upwards of river water level over three or four PMFs.

- Monsoon Flood (MF): The difference between a MF and a PMF is that a MF results in a sustained flood level in the river and bank overspill. The sustained monsoon flood level in the river (and eventually in the *haor*) is punctuated by occasional flood surges, each of which is also termed a MF. Numbering conventions applied to MFs are the same as applied to PMFs.

The last MF in a particular year is followed by a gradual recession of both R/S and country side (C/S) water levels over a period of several months. A large portion of the monsoon flood recession period is usually a NOP.

2.4 Fish Biodiversity

The ichthyofauna of the project area is moderately diverse. A total of 116 fish species (including 3 non-indigenous) occur in the Kushiyara River (Tables A.2 and A.34), while 80 species (including 3 non-indigenous) occurred in Kawadighi Haor prior to the construction of the Kashimpur fishpass. In comparison a total 145 species (including 8 non-indigenous) are known from the Northeast Region. It is not known how many species occurred in Kawadighi Haor prior to the construction of MRIP as no survey was done. However, it may safely be assumed that the number was higher than after MRIP construction.

Cyprinids and catfishes are the two most important groups of fishes in the area. Large carps include *rui*, *mrigel* and *kalibaush*, while large catfish include *boal, bagair* and *air*. Knifefish (*chitol*) and *ilish* are other important large species. Small species of ambassids (*chanda*), cyprinids (*puti*, *chela*, *mola*), catfish (*batashi*, *bacha, garua, tengra*) and sardines (*chapila*) are abundant. Crustaceans include the valuable giant river prawn (*golda chingri*) and a number of extremely abundant small species (*icha*).

2.5 Wildlife

An outstanding flagship species occurring in the Kushiyara River is the Gangetic dolphin (*sishu*). Larger wildlife populations inside Kawadighi Haor are severely depleted compared to pre-MRIP years and include only fishing cat, jackal, small Indian mongoose, large Indian civet, small Indian civet, common otter, and Indian pangolin. Small mammals include five bats, a shrew, and five rodents. Amphibians include six frogs and the common toad. Reptiles include two species of *Varanus*, 5 smaller lizards, and nine snakes (including the banded krait and monocellate cobra).

The most biodiversity-rich group of vertebrates occurring in Kawadighi Haor are birds. Some 166 species have been recorded. The *haor* is of international importance as an overwintering ground for migratory waterfowl. Birds arrive as early as August and leave at the end of April. Populations peak in December and January. The birds congregate mostly on Patasingra, Majherbandha and Haowa *beels*. The main migratory species are *friya* (Garganey) and *lenjha* (Northern Pintail). *Shorali* (Whistling duck) is a common resident species. Nesting of whiskered tern in the *haor* is the only known occurrence in Bangladesh. Pallas fish-eagle, Grey-headed fish-eagle, Crested serpent-eagle and Steppe eagle have been recorded from the *haor*.

2.6 Plantlife

The indigenous aquatic and marginal plants communities are biodiversity-rich and abundant. They include submerged species (Hydrilla, Naja, Ceratophyllum, Sagittaria, Aponogeton), rooted-floating species (Hygrorhyza, Echinochloa, Nymphea), free floating species (Azolla, Wolffia, Utricularia), and sedges and meadow grasses (Cyperus, Fimbristylis, Ipomoea, Ludwigia, Polygonum). A non-indigenous pest floating plant (Water hyacinth) is also present and forms large dense mats during the monsoon.

The *haor* has been severely deforested. Relic wetland tree species occur in small patches and as lone individuals, including *hijal, koroch, barun, mandail. Nolkhagra* and *chailla* also occur and are used for homestead protection. Many species of trees and plants have apparently become extinct in the *haor* due to rice cultivation and construction of MRIP, including *pukol*.

2.7 Beneficiary Communities

2.7.1 Data Sources and Methodology

Primary data on the beneficiary communities has been collected by a team of Community Organisers (COs), who conducted field surveys and focus group discussions, using Participatory Rural Appraisal (PRA) methods. Secondary data has been used from the Bangladesh Bureau of Statistics (BBS).

A preliminary census was conducted in September-November 1994 to sample the demographic composition of the area and to identify the villages to be selected for the reconnaissance survey.

A reconnaissance survey of 26 selected villages in 22 mouzas was conducted in November-December 1995. The selected villages all had a sizeable fishermen population and were located around Kawadighi Haor. Data on household occupation, water and sanitation facilities, ethnic characteristics and women's involvement in NGO activities was collected.

A fishermen survey was conducted in 7 fishing villages, which were selected from the 26 villages covered under the reconnaissance survey. The sample group consisted of 202 fishermen, composed of 67 full-time fishermen, who were mainly concerned with dry season fishing in Patasingra Beel and 135 seasonal fishermen. The fishermen survey was conducted twice a year, for two years, related to the monsoon and dry season fishing periods. The study was intended to monitor the social impact of the fishpass on fishermen. Data was collected on livelihood sources, land ownership, involvement in *beel* and *haor* fishing, use of fishing gear and fish catch, consumption and income from sale.

The first fishermen survey was carried out in February-March 1996 to collect data for dry season fishing in 1995-1996, as well as data on monsoon fishing for 1995. The second survey was done in September-October 1996 to collect data on 1996 monsoon fishing. The third survey was conducted in February-March 1997 for 1996-1997 dry season fishing. The fourth and last fishermen survey was carried out in September-October 1997 for 1997 monsoon fishing.

An impact review of the 3 Vent Regulator on Kawadighi Haor fishing was conducted in April 1996. An assessment of NGO activity in the project affected area was carried out in May 1996.

An infrastructure survey on postal, telephone, transportation and medical facilities was conducted in September 1997.

2.7.2 Project Boundary and Demographics

Project Affected Boundary
The area affected by the fishpass falls within the MRIP but the people affected are not limited to those living within its geographical boundary. The social catchment of the FPP includes various groups, including as leaseholders, fishermen, farmers, fish traders and fish consumers. Figure 3 shows the social catchment boundary.

Project Affected Area and Population
The project is located in Moulvibazar district, covering most of Rajnagar *thana* and a small portion of Moulvibazar Sadar *thana*. There are 277 villages in the social catchment of the FPP. According to the 1991 population census (Table A.3), these villages cover an area of 26,311 ha and have a population of 158,735. Population statistics are pro-rated from union-level statistics.

The project area accounts for 1.09% of the NERP area and 0.93% of the NERP population. NERP population and area have been quoted from the NERP study, entitled "Population Characteristics and State of Human Development". Of the total project area, 76% is in Rajnagar *thana* and 24% is in Moulvibazar Sadar *thana*. Of the total project population, 73% comes from Rajnagar *thana*, while the remainder comes from Moulvibazar Sadar *thana*.

Household Size and Sex Ratio
According to the 1991 population census, there is an average of 6.2 persons per household. This is more than the average size household size in Bangladesh, which is 5.6 persons per household.

The sex ratio is 104 (sex ratio is defined as the ratio of males to 100 females). This figure is very close to that of rural Bangladesh, which is 103. A sex ratio higher than 100 is typically perceived to indicate the disadvantaged position of women.

Demographic Trends
According to the 1991 population census, there are 603 persons per km^2. This is less than the national density, which is 755 persons per km^2. The absence of settlements throughout the vast Kawadighi Haor accounts for this lower population density. However, the population of villages which are clustered on high land surrounding the hoar is relatively dense.

Overall, the population has increased more than six times since the beginning of the century (Figure 4). The population has also almost doubled during the last three decades (1961-1991). The long term population growth rate in the project area has been higher than that of the country. During the 90 year period from 1901 to 1991, the population in the project area increased at an average annual rate of 2.07%. In Bangladesh, the population increase was only 1.51%. This means that the area may have been experiencing a net in-migration for quite a long time. However, the annual growth rate during the 1980's was low, at 1.10% per year, compared to a growth rate of 2.17% for all of Bangladesh in the corresponding period (Table A.4). A reduction of the annual growth rate in the area may be correlated with deterioration of the natural resource base of the region.

87

The medium-term growth rate of the population during the inter-census period between 1974 and 1991 was 1.75% per year. Based on projections, the 1995 population is estimated at 169,930. The estimate of the 1995 population is based on the World Bank projection of growth rate for the country at a future point (year 2025) and an assumption of a linear decline in growth rate between 1991 and the future point.

2.7.3 Fishing Communities

Fishing Villages and Households
According to the 1991 Bangladesh population census, there are 25,709 households in the total project area. The reconnaissance survey determined that there were 4,112 households in the 26 villages. These households represent 16% of households in the total project area (Tables A.3 and A.5).

Household Ethnicity
Results of the reconnaissance survey indicate that 81% of households are Muslims and 19% are Hindus. (Table A.6). The society is fragmented among different *jaats* or castes. The common characteristics among members of a *jaat* is a certain occupation, a set of social norms and specific cultural practices. Inter-caste social mobility is quite restricted.

The Muslim community is primarily composed of three *jaats*. *Maimol* is the largest *jaat* (48%) in terms of population, followed by *bangal* (26%) and *abadi (7%)*. Fishing is the predominant occupation of the *maimol* people. The *bangals* are local farmers, while the *abadi* people are farmers, who have migrated into the region and settled. They are mainly immigrants from the greater Mymensingh district.

The Hindu community is fragmented into several *jaats*. Amongst them, *das* (9%) is the largest *jaat*, followed by *namasudra* (6%). *Namasudra* is the major fishermen caste among the Hindus. The main occupation of the *das* community is farming (Table A.6).

Occupational Characteristics
Leaseholders have the highest socio-economic status in the project area, and act as investors and resource controllers/exploiters in the fisheries sector. There are about seven leaseholders, all from the MRIP area, who control all the *beels* in Kawadighi Haor. Fishermen are from different villages of the MRIP area. Fishing households are concentrated in the villages around Kawadighi Haor. Farmers, however, are the largest occupational group. There are farmers in every village. Most of the fishermen are also farmers. For these households, agriculture is either the principal or secondary source of livelihood. Fish traders come from different villages in the MRIP area. Some fish traders also come from outside the MRIP area, from such locations as Balaganj, Fenchuganj, Sherpur and Moulvibazar. The catchment area of fish-consumers is very wide. It includes MRIP villages, as well as the urban population of Moulvibazar and Srimangal.

Livelihood Sources
In the project area, particularly in the villages around Kawadighi Haor, almost all households are active in fishing, farming or a combination of both. Some households are dependant on year-round fishing, while others earn from fishing only in the monsoon period. Farming or fishing is either a principal or secondary income, depending on the amount of land owned or leased, and on the traditional occupation of particular ethnic groups (Table A.7).

There is an average of two economically active male members per household. The rate of male employment is 88% for full-time fishing households and 83% for seasonal fishing households. For full time fishermen, 2% are engaged in agricultural wage labor, while for seasonal fishermen, 14% are engaged in agriculture wage labor. Trading provides an alternative livelihood for 15% of full-time fishermen and 11% for seasonal fishermen (Table A.8). The female population is overwhelmingly involved in home-based activities, including the cleaning and repair of fish nets and in fish processing for domestic consumption and sale.

Land Ownership and Landlessness
The extent of landlessness differs between full time and seasonal fishermen. Based on the BBS classification, landless households are those owning less than 0.05 acres. Findings of the fishermen study show that 60% of full-time fishermen are landless, while 44% of seasonal fishermen own less that 0.02 ha. The extent of landlessness is averaged at 49% for full-time and seasonal fishermen in the 7 sampled fishermen villages of the project area (Table A.7). The 1991 Population Census indicates that 43% of households in the corresponding project area do not own cultivable land, while the landless figure for all of rural Bangladesh is 41%.

Thirty six percent of full-time fishermen and 39% of seasonal fishermen are also small farmers, owning up to 1.0 ha of cultivable land. Three percent of full time fishermen and 13% of seasonal fishermen are considered to be medium farmers, owing 1.0 to 3.0 ha of cultivable land. One percent of full-time fishermen and 4% of seasonal fishermen are also large farmers, owning over 3.0 ha of cultivable land (Table A.7 and Figure 5). Small, medium and large landowners in the *beel* areas are involved in fishing and farming. Those households owning more land tend to be more involved in farming than fishing. In addition, these farmers are more active in monsoon fishing, rather than in dry season (*beel*) fishing.

Those who do not own cultivable land are engaged in fishing, agricultural wage labor and small fish trading in the dry season (Table A.8). During the monsoon, landless households tend to be involved full-time in fishing. In the backdrop of the relative scarcity of land, fish is a critical resource in the region.

Fishing Gear
Various types of fishing gear is used in the area. Fishing gear consists of nets cast by hand, nets on bamboo frames, bamboo traps, hooks attached to lines and boats. The type of gear used is specific to species and differs from *haor* to river fishing. The type of gear used is also related to the season, the particular location, the boat requirements for specific nets, the fishing method and timing, the ownership of gear and the number of persons needed to operate particular nets.

In *haor* fishing, the most commonly used gear are:

- *phelon*, *monipuri* and *beshal* (moveable nets suspended from a bamboo frame);
- *fanda* (also known as current nets);
- *tanaber, hator* (also known as *footpine* nets);
- *pai*, *kapri* (mosquito nets);
- *chai* (bamboo trap);
- *ural*, *rek* (hand-cast nets);
- *boro* (stationary net, fixed to a bamboo frame);
- *choto, afa* (nets used from a boat);
- *ghori* (nets attached to bamboo fencing), and
- *borshi* (hooks on line).

86

A fishing household often possesses more than one type of gear. All fishermen possess different types of fishing gear, either individually or jointly. A *bori or bangshi* (types of hooks) is the most widely possessed gear. Among full-time fishermen, 73% individually own fishing gear and 27% own gear on a joint basis. Among the seasonal fishermen, 72% individually own gear and 28% own gear jointly. Among the full-time fishermen, 39% individually own a boat, while among seasonal fishermen, 51% individually own a boat (Tables A.9 and A.10).

Some types of nets are set and lifted after a short time period (*monipuri, kapri, tanaber, footpine, ural, rek, choto, afa*). With the exception of the *monipuri and ural* nets, this gear always requires the use of a boat because the nets are moved on a daily basis from one place to another within the *haor*.

Other types of nets (*fanda, pai, chai, bori*) are set in the *haor* and lifted after an 8 hour period. These nets only require a boat for setting and lifting. *Beshal* and *boro* nets and their accompanying boats are used in the same water location for several weeks. These nets are set in flowing water and are lifted frequently throughout the day.

The types of gear commonly used in river fishing include *ural*, *tanaber, laya, rek and beshal* (nets) and *hongu* (large bamboo trap), depending on the season, the variety of fish and the fishing method.

Fisheries Organisations

Conventional fishery organisations are known as *Matsyajibi Samabaya Samity* (Fishermen Cooperative Society). Although such cooperatives have registration with the government, they are traditionally not an effective organisation to represent the interests of poor fishermen. In most cases, such cooperatives exist only on paper. Poor fishermen are often unaware that their names have been included as cooperative members.

Fishermen cooperatives are usually monopolised by wealthy and influential people, who are not actively engaged in fishing. In most cases, such elite persons use the government registration of the fishing cooperative to provide documentary evidence that they are traditional fishermen. On this basis, wealthy people are able to lease large *beels* as lucrative fishing grounds (*jalmohals)* for the dry season fishing period. In Kawadighi Haor, all lease-holders are leaders of such cooperatives. Findings show that only 21% of the full-time fishermen, who are involved in *beel* fishing are members of fishing cooperatives (Table A.11).

Leaseholders control fishing cooperative members in a number of ways. They may engage some cooperative members on their dry season (*beel*) fishing teams. When leaseholders are also large landowners, they may provide poor fishermen with opportunities to be engaged as agricultural labor or to lease small portions of cultivable land at the edge of the *beels*. During *beel* fishing, lease-holders may allow poor fishermen the opportunity to take fish on credit to trade in the market and re-pay the leaseholder at a later date.

Women's Perspective

In the project area, women are not actively engaged in catching fish, with the exception of 6 poor fisherwomen who fish with rod and hook at the 6 Vent Regulator. Most women in fishing households are engaged in making fishing nets and bamboo fishing traps. Women are involved in processing fish to make *shutki* (dried fish) and *shidal* (fermented fish). Women also work with their husbands to clean and repair fishing nets. In the fishing villages studied, women from 24%

of households are involved in NGO sponsored groups in the area. Such groups are active in income-generating activities which are not particularly related to fishing (Tables A.11 and A.12).

NGO Involvement
An assessment of NGO activity conducted in 1996 indicates that 4 NGOs are involved in 16 of the 26 villages surveyed in the project affected area. The main NGOs involved are Grameen Bank (9 villages) and Bangladesh Rural Advancement Committee (BRAC) (7 villages). The Association for Social Advancement (ASA) and Unnayan Sahayak Sangstha are each working in one of the villages where the larger NGOs are located. The NGOs have extended their group programs in micro-credit and income-generating activities to 668 women in the surveyed villages (Table A.12).

2.8 Economic Activities

2.8.1 Fishing

Monsoon Season
When people fish in the *haor* during the monsoon season, they often shift from one location to another. Fishermen survey data collected for the 1995 monsoon season indicates that 73% of fishermen changed fishing locations three or more times (Table A.13). Seventeen percent of fishermen changed location at least two times. Ten percent fished in only one location. Changes of location in monsoon *haor* fishing is related to changes in the depth of water in particular *haor* areas during different phases of the monsoon period, and to possession of suitable gear required for the different water velocities of *haor* fishing.

Fishing is a regular activity for most people throughout the monsoon season. Based on data from the fishermen survey, the average period of *haor* fishing in 1995 was 115 days for full-time fishermen and 122 days for seasonal fishermen. However in 1997, due to the delayed arrival of the monsoon, the average period of *haor* fishing was reduced to 93 days for full-time fishermen and 106 days for seasonal fishermen. A comparison of monsoon fishing days is presented in Table A.14.

Fishing during the monsoon season is a common method of subsistence. The volume of catch and the income (or wage earned) largely depends on the gear used. Some gear can only be used by a team of fishermen, in which case the catch is shared by all members of the team. The boat-owner gets an extra share for rent of the boat.

Even though fishermen have traditionally had unlimited access to the *haor* for monsoon fishing, fishermen are now required to pay *tole* (an unofficial tax or fishing permit fee) to lease-holders for permission to fish during the monsoon period. Collection of *tole* has been enforced since the construction of Manu River embankment. The main lease-holder of Kawadighi Haor claims that the embankment has prevented fish from entering the *haor* from the river. Therefore, the leaseholder claims that fish from the *beels*, which he has leased as *jalmohals* for the dry season are the only fish available throughout the *haor* during the monsoon. On this rationale, the main lease-holder claims ownership of all fish in the *haor*. He feels that he is justified in extracting *tole* from fishermen for monsoon fishing. Those who do not pay *tole* are prohibited from fishing in the area. Often their gear is seized. Monitoring of the area is carried out by the *paharadars* (guards) of the leaseholder.

89

Dry Season
Beel fishing usually starts in November and ends in February. Out of 67 full-time fishermen interviewed in the fishermen survey of February-March 1996, 51 fishermen were involved in *beel* fishing in Kawadighi Haor during the 1995-1996 dry season. The average period of employment was two months per fishermen. The majority of fishermen (63%) were engaged for 31 to 60 days (Table A.15).

In the 1996-1997 dry season, 62 fishermen were involved in *beel* fishing in Kawadighi Haor. Thirty two percent of fishermen were engaged in *beel* fishing for 1 to 30 days, 34% of fishermen were engaged 31 to 60 days, and 34% were engaged for 61-90 days.

For dry season fishing, fishermen are engaged by the lease-holder on the basis of catch sharing. However the percentage of catch shared with the fishermen is based on the market price of fish in any particular year. In most years, fishermen are provided with an average of 10 to 12 percent of the catch.

Fishermen owning the necessary gear for fishing in different phases of the dry season are contracted by the lease-holder well ahead of the fishing season. In the beginning of the season, the catch is high and the market price is low, while fishing labor is in abundance. Therefore, the proportion of the catch accruing to the fishermen is kept low. As time passes, the area and depth of water decreases and the volume of fish becomes scarce. At this time, only very specialised fishing gear can be used. This gear is usually possessed by fishermen who are dependant on fishing for their year-round income. In addition, the end of the dry season fishing period is also the beginning of the main cropping season. At this time, fishing labor becomes scarce because those fishermen owning land begin their cultivation activities. Therefore, during the latter part of the dry season, there is an increase in the relative share of catch and income accruing to fishermen.

Full-time fishermen tend to maximise their period of employment by shifting to *beels* where work is still available due to late drainage. Findings show that the majority of fishermen (67%) worked in two *beels* in the same dry season (Table A.16).

On an average basis, there has been an increase in fishing income between the dry seasons of 1994-1995 and 1996. During the dry season of 1994-1995, the average seasonal wage was Tk 3,807 and the average daily wage was Tk 61. During the 1996 dry season, the average seasonal wage was Tk 3,934 and the average daily wage was Tk 98 (Table A.17).

2.8.2 Farming

The material on farming and crop cultivation is based on data for all of the MRIP area. Data sources included the Directorate of Land and Water Use, BWDB, Moulvibazar and the Thana Agriculture Officer, Rajnagar.

Rice Crops
Of the total area cropped in MRIP, 99% of land is used for rice cultivation. Of the total cropped area in 1997, 68% was cultivated with HYV rice and 31% was cultivated with local variety rice (Table A.18). MRIP was intended to increase cropping intensity. By increasing the number of crops grown during the year, the cropping intensity was targeted at 175%. In 1997 the cropping intensity in the MRIP area was 157%. The lower achievement in cropping intensity is likely

related to the high incidence of absentee farmers, who own large tracts of land within the MRIP area. They have migrated abroad and are therefore unable to manage intensive agriculture practices on their land. In addition, local farmers are reluctant to use irrigation water from the Manu River because they believe that this water, coming from a rocky source, does not contain adequate silt and nutrients for irrigating crops.

Other Crops
Of the total area cropped in the MRIP, only 1% of land is used for other crops (Table A.18). Other cultivated crops include wheat, potato, pulses, mustard, jute, sugarcane, sweet potato and vegetables.

2.8.3 Other Economic Activities

The reconnaissance survey conducted in 1995 on 4,112 households living in 26 villages, indicates that fishing, fish trading and farm production are the main economic activities in the area (Table A.19). However, a portion of the population have other occupations as their main source of income:

- Sixteen percent of households are engaged as farm labor;
- Four percent of households are dependant on the remittance of earnings from family members living abroad;
- Two percent of households earn from navigation and construction labor, and
- Earning from salaried employment, small trading and *jalmohol* leasing activities, each accounts for 1% of household occupations.

2.9 Infrastructure

2.9.1 Power Supply

Moulvibazar, Rajnagar, Kazirhat, Ekatuna, Mansurnagar and Balaganj towns and union *parishads* within and adjacent to the project are supplied with electricity by the Power Development and Rural Electrification Boards. In the project area as a whole, including its vast rural area, only 4% of dwellings have electric supply. People in the villages usually use kerosene lamps to light their houses. In Moulvibazar District with its large municipal area, 11% of households use electricity. In all of Bangladesh, electricity is supplied to 15% of dwellings.

2.9.2 Fuel Supply

No piped gas supply is available for domestic use but gas cylinders are available in Moulvibazar, although the supply of cylinders is short. In the villages, the common form of fuel for domestic use in poor households is made from cow-dung and crop residues, whereas wealthy households use firewood.

89

2.9.3 Telecommunication Services

Telephone and telegraph services are supplied in the project area through both public and private facilities (Table A.20). People in the project area have to travel to municipal and *thana* centers to avail of these services. In Moulvibazar, Rajnagar, Balaganj and Kashimpur, the Bangladesh Telephone and Telegraph (BT&T) have offices with micro-wave linkages for national and international telephone connections. With the exception of Kashimpur, telephone card facilities are available in these offices. A private telephone company Bangladesh Rural Telecommunication Authority (BRTA) rents out telephone lines to commercial shops, from which private users pay to use the telephone on a per-call basis. BRTA provides such facilities in Moulvibazar, Rajnagar, Balaganj and Kazibazar.

2.9.4 Postal Services

The Government of Bangladesh provides postal services throughout the project affected area. People in the 26 villages surveyed have access to 9 post and sub-post offices at *thana*, *union* and village levels (Table A.21).

2.9.5 Transportation Facilities

Of the 26 villages surveyed, 11 villages are situated in the north-west of the project area, near the fishpass at Kashimpur, Sherpur and Manumukh. Most of their required administrative and trading facilities are at considerable distance, in Rajnagar to the south-east, in Moulvibazar to the south-west and in Fenchuganj to the north-east. The means of transport used and the linkage points for transportation varies in the monsoon and the dry seasons (Tables A.22 and A.23).

During the monsoon season, engine boats are commonly used to carry both goods and passengers between Kashimpur to Kazibazar via the Kushiyara and Manu Rivers. In the dry season, people travel this route by rickshaw or on foot via the BWDB embankment. From Kazibazar, year-round road transportation is available on the Dhaka-Sylhet highway to all centers including Sylhet, Moulvibazar, Rajnagar (via Moulvibazar), Srimongal and Dhaka. Traders dealing in fertiliser travel to Fenchuganj by launch on the Kushiyara River. During the monsoon season, the connecting point for the fertiliser trade is Kazibazar but during the dry season, when the Manu River has limited draught, the connecting point is at Sherpur on the Kushiyara River.

The remaining 15 survey villages are located on the south-east and eastern sides of Kawadighi Haor. These people have very few problems related to transportation because they have year-round, road access to administrative and trading centers.

For all villages in the project affected area, transportation routes for fish trading are important. During the monsoon season, fishermen transport their fish from Kawadighi Haor by engine boat to small markets at Moquambazar, Munshibazar, Kamalpurbazar, Jagatpur, Kazibazar and Balaganj. Fish traders purchase from these local markets and then transport fish by road via the Dhaka-Sylhet highway to wholesale markets at Sherpur and Srimongal. During the dry season, fish traders travel by engine boat to the main fishing *beels* in Kawadighi Haor and directly purchase fish for the wholesale markets.

8H

2.10 Social Services

2.10.1 Education Facilities

There are primary schools in most of the villages in the project affected area. According to the 1991 census, the literacy rate in Rajnagar Thana, for children 7 years and above was 32% and 23%, for males and females respectively. The school attendance rate (5-24 years) has increased annually by 5.6% for male children and 8.6% for female children during the period 1981-1991.

2.10.2 Water Supply

According to the reconnaissance survey of 26 villages, (NERP, 1995) only 19% of households use tubewell water for drinking (Table A.24). The 1991 Bangladesh Population Census indicates that the national standard for tubewell water use is 76%. The majority of households (55%) in the project affected area use pond water for drinking. Access to tubewell water for drinking is very low in the region; only 29% in Rajnagar Thana and 37% in Moulvibazar district.

2.10.3 Sanitation Facilities

The state of sanitation in the project affected area is also less than the national standard. Only 8% of households covered by the reconnaissance survey had sanitary latrines of acceptable standard (water seal and concrete pit latrines) (Table A.25). Seventy one percent of surveyed households had unacceptable sanitation facilities (earthen pit and hanging latrines), compared to a national standard of 53% for unacceptable sanitation. One fifth (21%) of the households surveyed had no sanitation facility and commonly use open areas for defecation, compared to a national standard of 34% of households lacking any sanitation facility.

2.10.4 Health and Medical Services

Both health and family planning services are available to villages in the project area (Table A.26). Each *thana* in the project area has a health complex, run by a team of professionals and para-professionals and equipped with in and out patient facilities. There are also union health centers in 3 unions of the project area for the provision of primary health care. In addition, there is also one Family Welfare Centre (FWC) in six of the seven unions, where limited Maternal and Child Health (MCH) services are available. The FWC is operated by a Family Welfare Visitor (FWV) who is responsible for maintaining and updating a list of eligible couples, to whom she supplies contraceptives. For the treatment of serious health conditions, patients travel to hospitals in Sylhet, Moulvibazar and Balaganj.

2.11 Environmental Problems Associated with Kawadighi Haor and Fishpass

2.11.1 Environmental Status of Kawadighi Haor

The current status of Kawadighi Haor is poor compared to conditions which probably prevailed 50 or 100 years ago. Clearing of wetland forest (almost complete deforestation due to cutting of *koroch*, *hizal* and other wetland trees and bushes) and conversion of land to rice paddy - a process that was accelerated by the construction of MRIP in the early 1980s - are the two most severe disruptions of the primordial *haor* ecosystem. Annual inundation of the *haor* with water from the Kushiyara and Manu Rivers is also restricted by the flood control embankments, and nutrients derived from river silt no longer replenish soil fertility in the *haor*. Haor inundation from the Bhattera Hills continues unabated during the monsoon (and is only marginally reduced by the underdesigned pumping capacity of MRIP) and this appears to provides sufficient water to meet critical minimum inundation levels necessary to maintain the aquatic ecology and ecosystem integrity of Kawadighi Haor. This fortunate error in engineering design is however severely eroded during the dry season by the excessive drainage of the beels by the 3-vent regulator.

The maintenance of adequate flooding during the monsoon allows a significant floodplain production of fish and other aquatic biota to take place. Selective harvesting of plants, amphibians, over-wintering aquatic birds, and wildlife however has severely depressed *haor* biodiversity.

Moreover, loading of the environment with agrochemicals (mineral fertilisers, pesticides) from HYV rice cultivation and from tea garden run-off from the Bhattera Hills results in deterioration of water quality, excessive growth of nuisance aquatic macrophytes, outbreaks of disastrous fish disease epidemics and sublethal and lethal toxicity to aquatic organisms.

2.11.2 Water Hyacinth Infestation

A major problem during the middle and end of the monsoon season during Years 2 and 3 was the infestation of the fish sanctuary (Koradair Khal) with water hyacinth, a noxious macrophyte introduced to Bangladesh from South America. The coverage was close to 100%. It is unlikely that the environmental conditions in the *khal* during the infestation would have been conducive to fish migration. Fish would have had to swim for a distance of 4 km in water with inadequate oxygen content. Movement of fish inside the *khal* was not monitored, so the real impact of the infestation was not documented. The use of the *khal* by certain species (such as *carpio*) as spawning grounds would have been negatively affected.

Some hyacinth clearing work was carried out in the vicinity of the fishpass, but this could not keep up with the rate of plant growth and infestation. Moreover, *haor* drainage during the late monsoon resulted in a strong water flow inside Koradair Khal. This swept massive quantities of hyacinth into the fishpass forecourt from the *haor*. Eventually water velocity was sufficient to evacuate most of the hyacinth out of the *khal* through the 6 vent regulator and into the Kushiyara River.

The water hyacinth infestation problem will likely become an annual event - and possibly increase progressively in severity. A comprehensive hyacinth control program needs to be formulated and implemented for the entire MRIP/Kawadighi Haor area.

2.11.3 Water Quality Deterioration

Kawadighi Haor suffers from water quality deterioration due to human activities. Chemical fertilisers are used to cultivate HYV rice in higher lands of the MRIP area and for tea production in the hilly areas adjacent to the MRIP area. Fertilisers are not usually applied to the crops which are cultivated in lowlands. The use of insecticides in crop production is not widespread in the project area. Herbicides are used in tea production in hilly areas.

Heavy rainfall or irrigation following the application of fertilisers, herbicides, and insecticides may cause accumulation of chemical residues from higher fields and upstream hills in the soils and water of adjoining depressions in the project area.

Chemical analysis of *haor* water was compared to river water during Years 1 to 3 (Appendix G, Tables G.12 to G.14). Dissolved oxygen levels in the *haor* were generally lower than in the river during the dry season. Some acidification of *haor* water is also apparent.

2.11.4 Dry Season *Beel* Dewatering

Water Management Issues in Beels During Dry Season
MRIP was designed to store water levels at 4.1 m PWD during dry season. This water level would maintain 1,964 ha submerged, of which 869 ha is *jalmohal* (lease area). In 1988, a formal request was proposed to BWDB both from leaseholders and farmers to construct a second regulator to reduce water area during the dry season. BWDB accordingly constructed a 3-vent regulator with the invert level set at 1.4 m PWD. If water level were to be maintained at 1.4 m PWD, the submerged *beel* area would only be 14 ha.

After construction of the 3-vent regulator, a minimum water level was observed at 3 m PWD. With water level at 3 m PWD, the submerged *beel* area is 612 ha. Due to construction of the 3-vent regulator, the submerged area is reduced by 1,352 ha. This reduction in water area severely depresses fish abundance during the dry season. This has a direct negative impact on fish production.

The 3-vent regulator is opened when project water level falls below 4.1 m PWD. The water level inside the project area gradually falls, and farmers start cultivation of local *boro* in low lands. *Beel* fishing also starts during this period. The leaseholders want the minimum possible water level in the *beels* to get the maximum fish harvest. The leaseholders also offer seasonal tenancy to farmers for cropping the dried up areas. The leaseholders take lease of *beels* for three years from the MOL. During the third year, the leaseholders try to dry the *beels* completely to catch all the fishes from *beels*, because of the uncertainty of getting a new lease for the next three year period. Some of the *beels* are dried up using LLPs.

Farmers crop low lands on a high risk basis. If no rainfall occurs during March-April, and no inflow comes from upper catchment, farmers can harvest without crop damage. Rainfall and inflow from upper catchments during the period of February to April causes partial or complete damage to low lying area crops. During rainfall or any inflow from the upper catchment, river water levels also increases. Hence, stored water in the low lying areas cannot be drained by gravity flow. There is a pumped drainage facility at the MRIP. Due to slow drainage, pumps cannot be operated immediately to reduce water level to mitigate crop damage. Pumps can be operated only with sufficient head of water, and the number of pumps in operation depends on adequate volume of water. Also, cropping of lowlying areas interrupts the opening of the fishpass during the pre-monsoon.

Impacts of MRIP on Hydrology of Kawadighi Haor
The hydrological environment of Kawadighi Haor has suffered several damaging effects from the MRIP due to:

- Overdraining of *beels* during the dry season by the 3-vent regulator.

- Cessation of dry season flushing of *beel*s by runoff from the Bhattera Hills due to stream closure.
- Lowering of *beel* water quality through eutrophication with fertiliser runoff and contamination with pesticides.

Beel overdraining by to the 3-vent regulator is particularly devastating for overwintering broodstock, both through overcrowding by habitat constriction and enabling of overfishing. The original MRIP design *beel* area (based on the 6-vent regulator invert elevation) of 1964 ha can be reduced by up to 99% by the 3-vent regulator, as shown in Table 2.3.

Table 2.3: Dewatering Effect of 3-vent Regulator on *Beels*

Regulator	Invert Elevation m PWD	Corresponding (ha)	% of Total Project
6-vent	4.1	1,964	8.08%
3-vent	1.4	14	0.06%
Beel area lost due to		1,950	99% of *beel* area

The multiple and synergistic effects of these factors result in severe stress to fish stocks during the dry season and high mortality due to overfishing and ulcerative disease outbreak.

Study of the 3-Vent Regulator

FPP was particularly concerned to prevent dry season dewatering of the *beel*s. A study was undertaken to examine the consequences of closing the 3-vent regulator and increasing dry season *beel* flushing flows through the irrigation system.

A fish conservation strategy is imperative for successful rehabilitation of Kawadighi Haor. It is argued that some water should remain in the *beels* in order to facilitate fish conservation. Lease-holders are very enthusiastic to completely drain the *beel*s and catch all the fish. It has also been observed that as the water level starts falling, farmers plant *boro* crops in low-lying areas. Some of these areas are listed as *jalmohals*, and are not intended for crop production. Some lease-holders, however, exploit *jalmohal* land by sharecropping it with poor tenant farmers. The 3-vent regulator facilitates this process. It quickens post-monsoon drainage, drains water from the bottom of the *beels*, and allows farmers to expand their crop area at the expense of reduced fish conservation area. Whether it is at all necessary to allow the usage of the 3-vent regulator is a critical question. The pertinent issues that need to be addressed are: 1) how large a catchment does it affect, 2) how much crop benefits are generated as a result of its operation, and 3) who are the beneficiaries?

Kawadighi Haor contains many *beels*. Most of these are used as *jalmohal*s, and are auctioned to private parties for fishing. Farmers grow *boro* crops along the shallow edges of the *beel*s, and fishermen catch fish in the dry season. In the monsoon season, the entire area becomes submerged. As the water starts receding in the post-monsoon season, *beel* fishing activities begin, and farmers start preparing land for *boro* crops. As fishing continues, water recedes and plantation of *boro* seedlings advances into deeper areas of the *beel*. The actual fishing area in the *beels* has been decreasing every year. This has happened because of siltation on the one hand and increasing demand for crop land on the other. Now, farmers grow different varieties of traditional *boro* crops on the edge of the *jalmohals*. This land had previously been used solely as fishing grounds. According to an estimate based on a reconnaissance survey of 16 *beels* in Kawadighi Haor (April-May 1996), 1,590 ha of land is at a relatively lower elevation. Cropped area in these *beels* is subject to late drainage in the post-monsoon season and early inundation in the pre-monsoon season. The 3-vent regulator installed near the Kashimpur Pump House quickens drainage of water from these areas, and makes *boro* cultivation possible. If there is heavy rain or an onrush of water from the Bhattera Hills through the *chhoras*, *boro* crops in the *beels* submerge and are ruined.

Farmers grow traditional varieties of *boro* rice in the *beels*. Among the varieties grown, *koiyaboro* is the most widely planted. In 1996, farmers grew *koiyaboro* in 14 out of 16 *beels*. Among other dominant varieties are *poshushail* (cultivated in 9 *beels*), *garshishail* (cultivated in 5 *beels*), and *ratashail* (cultivated in 4 *beels*). Although *koiyaboro* is the dominant variety, its yield of 1.42 tonnes/ha is relatively low. The weighted average of yield for all traditional varieties is 1.90 tonnes per hectare. Farmers reported that higher yields were achieved on certain occasions. The highest yield has been 3.47 tonnes. This was when rainfall, drainage, and other natural factors all favoured cropping.

It is difficult to ascertain how much land is actually owned and how much is *khas*. *Jalmohals* are *khas*, and are leased out by the government exclusively for fishing. It was endeavoured to identify the persons who own or control land in the *beels* of Kawadighi Haor. Data on persons controlling more than three hectares of land were collected. In 16 *beels* of the *haor*, 77 large land-owners were identified. Together they own or control 665 ha of land. This amounts to 42% of the total area of those 16 *beels* under *boro* cultivation. Among them, area under individual control ranges from 3 ha to 53 ha. The average is 8.6 ha. Most of these landlords engage tenant farmers under various conditions. There were 515 tenant farmers (in 16 *beels*) in the 1995-96 *boro* season. Each landlord has an average of eight tenants. As much as 93% of the crop area in the *beels* is cultivated by tenant farmers. In five *beels*, about 58 ha of *khas* land was cultivated by 185 small farmers. *Khas* land area accounts for about 10% of the total crop area in those five *beels*. The average farm size of *khas* land farmers is 0.31 ha. The top ten landlords (possessing land in the *beels*) control 222 ha of land in 6 *beels*. Together they control 31% of the crop area in those 6 *beels*. One landlord from Gargaon village controls 67% of the crop area in Ulauly Beel. Another landlord from Dhulijuri village controls 33% of the crop land in Kursha Beel. In Majherbondh Beel, 27% of the crop area is controlled by one landlord from Rokta village, and another 21% in the same *beel* is controlled by another landlord from Gargaon village.

Potential for Dry Season Flushing of Beel with Irrigation Water

A study was undertaken of the irrigation system to assess the potential for using irrigation water to flush the *beel*s during the dry season to flush in order to maintain adequate water quantity and quality for overwintering fish stocks. The detailed results of the study are presented in Appendix A (Section A.4).

At MRIP, a total 105 km of irrigation canal system convey water to the fields from the Manu River. A total of about 6 cumec water is diverted from Manu River to the project area. Some of the canals are directly connected to the drainage channels, and the tail end of some canals are close to the *beel* area. Irrigation water is required for *boro* crops from January. From the first week of December some of the canals can be used to carry Manu River water to flush *beel* areas. This continuous flushing irrigation water can be discharged through the 3-vent regulator. This would result in adequate fresh water storage in *beel* areas. Continuous flushing and discharging through regulator will reduce turbidity of the *beel* water and may reduce fish disease during the dry season.

The proposed *beel* flushing scheme using irrigation water is judged to be feasible, and it is recommended that 2 year trial be conducted to monitor and assess impacts.

2.11.5 Wetland Deforestation

Kawadighi Haor is virtually entirely deforested. Only a few patches and lone trees of flood-tolerant *hizal* and *koroch* are still standing. These are the most valuable species to be grown in *haor* areas, and at present they are generally very scarce in the region. Fishermen in Kawadighi Haor pay Tk 80 per branch of *hizol* and *koroch* in order to build *katha* for *beel* and river fishing. They often travel as far as Sunamganj to purchase such trees. Deforestation has also negatively affected wildlife in the *haor*, and generally disturbed the natural ecological balance.

Selective afforestation of Kawadighi haor could have significant environmental and economic benefits. In order to initiate such an afforestation effort, FPP implemented a small tree planting trial along the bank of the fish sanctuary during Year 3. In March 1997, 30 poor women were targeted for inclusion in the tree plantation program, with the intent of providing them with an income-generating activity. The women were selected on the basis of their living distance from the plantation area (half a kilometre) and on their economic status (widow or woman of a landless household). A half day training was provided to the 30 women by the District Forestry Department. The objectives of the training was to explain the benefits of the program and to provide knowledge on the methods of sapling transplantation, care and watering.

The land used for tree plantation is owned by BWDB, as part of the MRIP embankment. Different varieties of wetland trees and hardwood trees were planted on low land and high land, in two areas (Figure 55). The areas and resulting experiences were as follows:

- Low Land Plantation Area for Wetland Trees: 1.45 decimals of low land north-east of the pumphouse were planted, as well as along approximately 1 km of the left bank of the Koradair Khal. The plantation program began on 7 April 1997. The *hizol* and *koroch* saplings were not available from any nursery, so were obtained from individual owners in the *haor* areas near Antehori and Sonapur. The average cost of each sapling was Tk 10. Between the March to mid-April 1997, the 30 women were engaged in making pits for planting the trees. Between April 15 and 20th, 1,000 *hizal* saplings (200 saplings were 1.6 m high, and the rest were 0.3-1.0 m high) were planted on both sides of the Koradair Khal. Each woman was paid Tk 5 for labor in preparing pits and planting saplings. The trees were planted in April, during the height of the dry season. Eighty percent of the *hizol* and *koroch* transplanted saplings failed to survive because of lack of moisture, related to the incorrect time for transplantation of *haor* trees. The remaining 20% of saplings were destroyed by grazing from goats and cows, and by suffocation from water hyacinth in the canal. The women involved in tree plantation were unable to devote enough time for watering or protecting the saplings, as of necessity they remained engaged in other income-earning activities.

- <u>High Land Plantation Area for Hardwood Trees</u>: 1.84 decimals of high land west of the pumphouse were planted. Five hundred saplings of wood-bearing trees including *Korai*, *Jam*, *Raintree*, *Mehogani*, *Shishu*, *Neem*, *Akashi*, *Pimarong* and *Chamrul* were purchased from various nurseries in Moulvibazar. The average cost per sapling was Tk 10. These saplings were transplanted on higher land outside the embankment June 1 to 15, 1997. Each woman was paid Tk 5 for labor in preparing pits and planting saplings. Out of the 500 wood-bearing saplings, 90% have survived. The trees which were destroyed by grazing animals have been replaced. The high survival rate for high land, wood-bearing trees is a result of the correct time for their lifting and transplantation, in the period immediately preceding the monsoon season. Furthermore, they were not subject to smothering by water hyacinth since they were planted mainly on the R/S of the embankment.

In preparation for handover, the NERP social team have arranged for the follow-up needed for the women tree plantation group, which could not be appropriately provided for under BWDB. BRAC has formally leased 30 km of the MRIP embankment from BWDB, including the land and surviving trees near the Kashimpur Fishpass and Sanctuary. BRAC will assume responsibility for the 30 women of the tree plantation group. Ownership of the trees has been arranged as follows: 60% for the women's group; 20% for BWDB and 20% for BRAC. BRAC expects that hardwood trees can begin to produce a harvest in 10 years time. The women of the group will now be eligible to receive all the services provided under the BRAC Rural Development Program. BRAC will provide the women plantation group with a wage for tree care and maintenance for a 10 month period. From this wage, women will begin to make savings in preparation for micro-credit for short-term income-earning activities.

A number of items should be taken into consideration in future afforestation activities in the *haor*:

- <u>Time of Planting</u>: Transplantation of flood-tolerant trees should be done between November and January to utilise the moisture of low-land *haor* areas, as *hizol* and *koroch* saplings will likely not survive if lifted from the *haor* areas and transplanted in March-April (at the height of the dry season) without adequate watering by hand.

- <u>Support Budget for Poor Women</u>: A budget may have to be provided for sapling care to meet the opportunity costs of poor women (i.e.: poor women may be unable to give time for unpaid sapling care when their families were dependant on their daily labor in other income-earning activities). In other tree plantation programs (such as the NERP PDP, CARE, BRAC and RDRS), a budget for sapling care and maintenance has been found to be essential for sapling survival. Profits from tree plantation can only be realised in the long-term. Flood-tolerant trees can produce a profit after approximately 4 years, while hardwood trees only produce a profit after approximately 10 years. Programs which target poor women in tree plantation need to consider their income-earning requirements in the short-term. Ideally, tree plantation should be considered as one of several components in a comprehensive design for women's programing - which can also include group savings, micro-credit, short term income earning opportunities and long-term investments.

3. DESIGN AND CONSTRUCTION OF KASHIMPUR FISHPASS

3.1 Design

3.1.1 Analysis of Data

The river and *haor* side water levels have been recorded by BWDB at the Kashimpur pump house twice daily since the opening of MRIP in March 1983. The twelve years of hand entered records were scrutinised for accuracy. Any observed entry errors were rectified and the corrected data computerised. Topographic data, engineering designs and operation of the MRIP presented in "Definite Project Report" (1971), and in the BWDB Systems Rehabilitation Project "Feasibility Report of Manu River Project" (1993) were analysed.

The operational status of MRIP engineering, and the status of fisheries, agriculture and socio-economy were studied by NERP over a two-year period from May 1992 to May 1994 and presented in the NERP report "Project Monitoring Program, Manu River FCDI Project (1992-1994)". The work on the analysis of design data was carried out intermittently from August to October 1994.

3.1.2 Preliminary Design of Fishpass

Considering the high range of variation in water levels at the river side (R/S) and country side (C/S), a vertical slot fishpass had been identified as the most suitable type of structure. The available literature on the design of vertical slot fishpasses was reviewed. Literature references from Canada, Japan and Australia (countries where vertical fishpasses have been constructed) were consulted.

The special requirements of a fishpass at an FCDI project differ significantly from conventional applications at dams and weirs (Figure 6). In conventional applications the following conditions pertain:

- The migration barrier (i.e.: dam, weir) is perpendicular to stream flow;
- Fishpass water inflow and outflow is to the same waterbody (i.e.: river);
- Fishpass water flow is unidirectional (i.e.: down-slope);
- Fish migration is countercurrent (i.e.: up-slope), and
- In most cases, access is specified for only one species (i.e.: salmon) of strong swimming ability.

In an FCDI application, the following conditions pertain:

- The migration barrier (i.e.: flood control embankment) is parallel to stream flow;
- Fishpass water inflow and outflow is to different waterbodies (i.e.: river, floodplain or *haor*);
- Fishpass water flow is bidirectional (i.e.: river to *haor*, *haor* to river);
- Fish migration is concurrent and countercurrent (i.e.: depending on direction of migration and relative water elevations in river and *haor* at any point in time), and
- Access is specified for a large number of species with varying (i.e.: strong, moderate and weak) swimming ability.

These differences were taken into account in designing the Kashimpur fishpass.

Work on the preliminary design started in September 1994, and continued through October 1994. At the end of October 1994 a set of drawings (excluding structural and foundation design details) was send to Canada for review by the Fishpass Design Specialist. The dimensioning of the Kashimpur Fishpass was based on a design type developed from hydraulic model studies carried out for the design of salmon fishpasses in Canada. The width of the baffle slot opening (one of the main design parameters of the structure) was established by NERP biologists. A 0.41 m opening would allow free passage of the largest expected fish (i.e.: large catfish species such as *boal*).

Two years of water level data (1993-94) published in the PMP report were used for the hydraulic and hydrologic design of the structure. The site plan and structure lay-out were prepared based on the existing topographic maps.

The preliminary design comprised a vertical slot fishway with 18 baffles and 19 pools, and the adopted parameters were as follows:

- Maximum hydraulic head (H): 2.7 m
- Maximum water velocity (v): 1.3 m/s
- Minimum depth of water (D): 1.0 m
- Slot width (W): 0.41 m
- Size of pool: 2.44 x 3.05 m
- River side invert elevation: 5.00 m
- Haor side invert elevation: 3.00 m

A computer program simulating operation of the fishpass was used to determine the expected flow velocities through baffles, which control the fish movement. Discharge rates and volumes of the water inflows through the structure were determined to assess its potential impact on the protected farmland in the *haor* area. The obtained average flow velocity varied from 0 to 1.26 m/s. The estimated maximum daily water inflow through the fishpass from the Kushiyara into Kawadighi Haor reached about 122,000 m^3 during the pre-monsoon and about 93,000 m^3 during the monsoon season. The expected increase in the *haor* water level (without pumping) at the end of pre-monsoon would be 11 cm, and the flood affected area could reach about 160 ha.

3.1.3 Australia Study Visit

Study of the literature suggested that the most relevant experience with vertical slot fishpasses designed for slow swimming warm-water species was in Australia. A number of pool and weir (i.e.: salmon type) fishpasses had been built in Australia during the first half of the century, but these were found not to function for native species and introduced common carp. Later, design work was carried out on vertical slot design fishpasses and these proved to function successfully in most cases.

It was decided to visit Australia to familiarise the NERP staff with fisheries in Australia, to make contacts with local fisheries specialists and institutions, and to study the designs and operation of Australian vertical slot fishpasses used for carps and other warmwater inland species. A two-member NERP FPP team (Project Coordinator and Fisheries Specialist; Fishpass Design Engineer) participated in the Australia Study Visit from 12 to 20 December 1994. In addition, the Fisheries Specialist Consultant joined the team for the two day field excursion to the Murray River.

The visit was organised by the New South Wales Fisheries Research Institute (NSW FRI) in Cronulla, Australia. Discussions were held with the Director of NSW FRI, the Director of Manly Hydraulic Laboratory in Sydney, Australian biologists, fishpass specialist, designers and engineers involved in design and construction of fishpasses. During the field trips and visits to hydraulic laboratories, the NERP team was guided by the fishpass specialist and biologist of the NSW FRI in Cronulla.

The facilities and places visited were:

- Audley River Fishpass test site: The site is located in the Royal National Park of Sydney. Various fishpass design experiments conducted by the FRI fisheries specialists were discussed at the Audley weir/bridge site.

- FRI Fishpass Workshop: Plywood models of vertical slot fishpasses tested at the Audley River site were inspected.

- Manly Hydraulic Laboratory: The Australian type of vertical slot fishway had been developed at this laboratory in collaboration with NSW FRI. At the time of our visit (December 13, 1994) a model of a vertical slot fishpass, made of transparent acrylic, was being tested using live fish.

- Fish Lock at Yarrawonga Weir and Lake Mulwala Hydro-Electric Power Station: The Yarrawonga Weir is constructed on the Murray River flowing between New South Wales and Victoria provinces of Australia. The weir which was constructed about 50 years ago cut off the migration route of common carp, Murray cod, trout cod, catfish and other fish species. The Power Station was constructed in 1993 and includes a quite advanced semi automated fish lock arrangement. Operation of the lock was observed during the fish migration period.

- Vertical Slot Fishpass at Torrumbarry Weir: The Torrumbarry Weir & Lock is located in Victoria province on the Murray River about 350 km downstream of the Yarrawonga Weir. The weir was constructed in 1924, without fishpass. A two-stage, 26 pool and 11 pool, vertical slot fishpass was added to the weir in 1991. About 100 kg of common carp was observed in the fishpass sampling cage which had migrated upstream in the river. Reconstruction of the weir was in progress, and a new fishpass is incorporated in the new design.

- Vertical Slot Fishway on Nepean River near Sydney: This fishpass is located on a tidal river, next to an old low-head ungated weir. Steel and synthetic materials were used for the fishpass baffles and pilasters.

On December 19, 1994 a working session was held with the FRI biologist and fishpass specialist. The preliminary design of the Kashimpur fishpass was reviewed and changes were recommended. The vital recommendation was the arrangement for adjustment of the baffle slot width.

3.1.4 Final Design

Work on finalization of the fishpass design started at the end of October 1994. According to the recommendation made by the Canadian Fishpass Design Specialist, received in November, the number of baffles was reduced by two from 18 to 16. Revised designs of the 16-baffle fishpass were completed in November 1994. Initially the structural and foundation design details were based on average soil conditions, as the results of sub-soil tests were not available yet. These drawings were used for the cost estimate and preparation of tender documents.

The sub-soil boring was carried out at Site 1, located 93 m east from the 6-vent drainage regulator, on November 20, 1995. As the foundation soil was found not suitable new soil boring was carried out at Site 2, located 60 m east from the 6-vent regulator.

The set of drawings prepared in November 1994 was taken to Australia for review by the Australian Fishpass Specialist. Based on the observations made during the inspection of Australian fishpasses and discussions with the Australian fisheries specialists, the Kashimpur Fishpass design was finalised in December 1994. The final design and construction drawings were completed and approved by the BWDB Design Directorate NE Zone on 5 January 1995 (Appendix B, Drawings B.3 to B.9).

Salient data of the Kashimpur fishpass are as follows:

- Type: Single-jet vertical-slot
- Length (concrete section): 61.85 m
- Length (including protective works) 83.85 m
- Maximum Height: 6.54 m
- Maximum Width: 5.00 m
- Invert Elevation at C/S: 3.16 m PWD
- Invert Elevation at R/S: 5.46 m PWD
- Deck Elevation at C/S: 8.16 m PWD
- Deck Elevation at R/S: 11.46 m PWD
- No. of Pools: 17 + 2 observation chambers
- Pool Length: 2.90 m
- Pool Width: 2.50 m
- No. of Baffles: 16
- Baffle Height: 4.50 m
- Slot Width: 410 mm

The design of the fishpass limits the water velocity through baffle slots to 1.3 m/s, and inlet water velocity to about 0.5 m/s about 95% of the time. The extreme parameters are predicted from computer simulation of the fishpass using R/S and C/S hydrographs for March, April, and May recorded over a twelve-year period (1983-1994):

- Maximum Average Velocity (through baffle): 1.62 m/s
- Maximum Velocity at Inlet: 0.95 m/s
- Maximum Total Head (R/S wl - C/S wl): 3.78 m
- Maximum Head per Baffle: 0.24 m
- Maximum Total Inflow: 1.96 m^3/s

3.2 Contracting

The Kashimpur fishpass construction contract was carried out under FPP of NERP. Government of Canada Treasury Board regulations pertaining to competitive bidding were followed in the award of the Kashimpur fishpass construction contract.

The contracting process included:

- Pre-qualification of construction firms/contractors;
- Preparation of contract documents, and
- Calling for tenders and contract award.

The relevant contracting and construction documents are presented in Appendix B.

3.2.1 Pre-qualification

The criteria followed in the pre-qualification of contractors were:

- Must be a BWDB registered "A" Class contractor;
- Have a proven record of timely completion of projects;
- Constructed hydraulic structure of value Taka 50.0 lakh or above;
- Have worked in the area (preferably local contractor), and
- Be financially solvent.

Pre-qualification notice was posted with the BWDB Executive Engineer offices in Moulvibazaar and in Habiganj in October 1994.

A list of 17 "A" Class contractors was prepared, 7 contractors from Moulvi Bazar, 9 from Habiganj, and 1 from Dhaka. These contractors were interviewed in person by the NERP Engineer and were requested to submit the relevant documents regarding their work records. Following the review of the received documents, discussions with the BWDB staff and information received from other consultants working in Bangladesh, five contractors were selected who satisfied the above pre-qualification criteria. The five selected contractors were contacted and informed in detail about the time schedule and work involved in the construction of the fishpass. This information process was completed before 15 November 1994, and all the five pre-qualified contractors expressed their interest in participation in the competition.

3.2.2 Preparation of Contract Documents

The current BWDB tender format has been used in preparation of contract documents for the construction of the Kashimpur fishpass structure. General Conditions of the contract were those used on the previous CIDA projects in Bangladesh (CIDA Project 170/00905-B, Small Scale Water Control Structures Program). Preparation of the contract documents, the contract award, and construction supervision and payments have been made by the consultant (NERP) on behalf of the BWDB. Preliminary design drawings prepared by NERP (Dwg No. NERP/FPP-01/1-7 dated November, 1994) have been used in preparation of bill of quantities of works, and the current schedule of rates for the Moulvibazar O&M Circle, BWDB, Moulvibazar, has been used in preparation of the cost estimate.

The fishpass construction Tender Documents were completed on 22 November 1994, and sent to BWDB for review and permission to call for tenders.

3.2.3 Construction Contract Award

The Tender Notice was issued on December 5, 1994, and the 5 pre-qualified contractors were invited by mail to submit bids. On 15 December, two tenders were received and the lower bidding contractor was selected. A draft Work Order was issued to the Contractor on December 20, 1994. As per the BWDB instruction their clearance was required to proceed with the award of contract. The clearance was received on January 5, 1995.

A revised schedule of rates and bill of quantities, based on the final construction drawings approved by BWDB, were prepared and a formal construction contract was signed on January 11, 1995. The detailed Work Order (formal work order) for construction of the Kashimpur fishpass structure was issued to the Contractor on January 11, 1995.

3.3 Construction

The field works on Kashimpur fishpass commenced with the laying of the corner stone and inauguration of the structure by Finance Minister Saifur Rahman on January 7, 1995. The following day the contractor started mobilisation and procurement. The earthworks started on January 12, 1995, and major structural works were completed in the last week of April. Scaffolding from the fishway was removed and the diversion channel cofferdams opened on May 1, 1995. The fishpass became operational for passage of fish on May 24, 1995. However, work on the mechanical components needed for monitoring of fish movement continued till June 9, 1995. The date-wise Kashimpur fishpass construction activities are presented in Table 3.1.

Table 3.1: Record of Construction Activities at Fishpass

ACTIVITY	START	COMPLETION
Year 1: 1995		
Mobilisation & Procurement	January 12, 1995	January 31, 1995
Delivery of Materials	January 15, 1995	March 10, 1995
Excavation Works	January 15, 1995	February 20, 1995
Construction of Coffer Dams	January 15, 1995	March 5, 1995
Foundation Treatment	February 10, 1995	February 20, 1995
Sheet Piling	February 5, 1995	February 12, 1995
MS Reinforcement Work	January 25, 1995	March 31, 1995
Concrete Works	February 11, 1995	April 26, 1995
Channel Protection Works	February 10, 1995	March 31, 1995
Metal Works: Installation of Gates, Hinges, Protective Railing,	April 1, 1995	May 31, 1995
Earthwork in Back-filling, removal of Cofferdams	February 20, 1995	May 25, 1995
Testing & Corrective Works to Metal and Mechanical Parts	June 1, 1995	June 9, 1995
Works Completed		June 10, 1995
Year 2: 1996		
Erection of guard shed and rain shelter	October 1995	November 1995
Installation of electricity line and lights	November 1995	December 1995
Fabrication of sampling cages	November 1995	March 1996
Construction of concrete walkway	January 1996	February 1996
Installation of sampling cages	March 1996	March 1996
Year 3: 1997		
Walkway along fishpass (C/S)	March 1997	April 1997
Fishpass R/S channel protective works	March 1997	April 1997
Metalled cage trap at sampling cage	March 1997	April 1997
HBB bricksoiling over the embankment	March 1997	April 1997
Bamboo fence at pumping channel	March 1997	April 1997
Maintenance and Miscellaneous works	March 1997	April 1997

Construction carried out during Year 2 was limited to building the sampling cages and their facilities, installing electricity, improving the walkway, and erecting a guard shed.

Since there was no electricity at the structure, the lack of light made it difficult to work at night during the first year. An electricity line was installed at the fishpass structure, and some lights were provided.

No guard shed or rain shelter was provided at the site in the first year. There was nowhere to take shelter at night and during rainy or sunny periods. In order to improve the situation, a temporary guard shed on the R/S slope of the embankment and two rain shelters on the observation chambers were built. A concrete walkway from the embankment to the C/S end of the structure was constructed. This facilitated access to the C/S observation chamber during the pre-monsoon and early monsoon seasons.

During Year 3, the following constructions were carried out:

- A walkway with railing along the fishpass on the country side from embankment to C/S deck was constructed for safe movement of visitors and FPP staffs. During the early monsoon it was cumbersome to reach the C/S observation chamber due to the increase in *haor* water level;

- During Years 1 and 2 of operation of fishpass, the fall in river water level during the post-monsoon drainage period caused erosion of the river side channel for 30 m. To protect against further erosion of the channel, protection measures were taken with placing stone boulders, gunny bags, and earth filling at the confluence of channel and *duar* in front of the 6-vent regulator;

- Sampling cages constructed during Year 2 had two square openings (250 mm width x 250 mm height) set at different elevations for funnel traps. These opening were modified into a full height slot opening (250 mm width x 2,000 mm height) to take elongate slot funnel traps to improve sampling efficiency;

- During rainy days, the top of the embankment becomes muddy which makes it difficult for monitoring fishpass sampling and sanctuary management. An HBB road was constructed over the embankment from the fishpass guest house to the fishpass structure for a length of 350 m, and

- It was observed that when pumps were in operation, fishes of different sizes were attracted by the water flow into the pumping channel. To reduce movement towards the pumping channel, and to increase movement of fish into the fishpass channel, a bamboo fence with G.I. wire mesh (5 cm) was installed across the pumping channel at its confluence with the fishpass channel.

3.4 Supervision

The Canadian Planning/Civil Engineer was responsible for design and construction monitoring of the Kashimpur fishpass. Structural design, mechanical design, and construction supervision was carried out by NERP engineers. Design and drawings of fishpass were verified and approved by BWDB Design Circle-6. NERP did not have deputed BWDB Engineer, although there was a provision for two BWDB Engineers in the FPP on-the-job training program during the construction phase.

The Consultant's field supervision of the fishpass construction had been carried out by the locally hired Construction Supervisory Engineer (former Chief Engineer, BWDB) posted at the site for the duration of construction. The Planning/Civil Engineer monitored the construction progress during field inspections two or three times a month. He also worked with the Contractor on design and manufacturing of sheet metal form work for the fishpass baffles and pilasters.

The construction was inspected one time by the Superintending Engineer, BWDB, Moulvi Bazar, and one time by Executive Engineer, Planning Schemes - I, BWDB, Dhaka.

From the Contractor's side two engineers and two foremen were posted at the site permanently for supervision of earthwork and concrete works. One engineer (supplied by the manufacturer) was present during the installation of gates.

As the time allotted for the construction was short, the work scheduling was crucial. Since the waterways leading to Kashimpur are not passable during winter, all the materials for construction of the fishpass had to be carried by trucks over the MRIP embankment. BWDB cut this embankment in May, 1995, but by that time all the materials had been transported to the site.

The quality of structural works is satisfactory, the concrete strength is as per specification or above. The principal departure from the design specification is the elevation of the base slab, resulting in R/S and C/S invert levels that are 0.46 m higher than specified (i.e.: 5.46 m PWD and 3.16 m PWD, respectively). The effect of this on fish migration opportunity during the premonsoon and early monsoon flood surges was probably minimal during Year 1, but was likely significant during Year 2 and 3. Deck elevations are also 0.46 m above specification, therefore 11.46 m PWD at R/S and 8.16 m PWD at C/S. Some problems have been encountered in installation of the metal parts of the structure, mainly the fish trapping and lifting components. This could be traced to lack of experience of the supervisory staff with mechanical works, and the experimental nature of the designs.

3.5 Sampling Cages

During the first year of operation of the fishpass, three different sampling devices were deployed:

- Temporary make-shift bamboo trap;
- Rigid metal basket, and
- Collapsible metal basket (Appendix B, Drawing B.10).

None of the devices performed efficiently. They were only able to trap a small fraction of the fish migrating through the structure.

With a view to reduce the severe sampling underestimation by the inefficient devices, two new metal sampling cages fitted with internal one-way funnel traps were fabricated and installed in both observation chambers of the structure in Year 2 (Appendix B, Drawing B.11). Each cage was 1 m wide and 2 m high. It had two openings at 0.5 m height and at 1.5 m height for square funnel traps. The dimension of openings were 300 mm x 300 mm. Each opening was fitted with a funnel trap that tapered from 1000 mm to 300 mm, and was bent. Purpose of bending the funnel trap was to make it less likely for fish to escape. This cage trap would become partially ineffective at under 2 m height of water level. A new elongate trap (i.e.: slot trap) was fitted in Year 3 to make it more functional (Appendix B, Drawing B.12). The opening of the slot trap is at full height (2,000 mm). It is tapered from 1,000 mm to 250 mm and is bent towards the left. With this new trap it was possible to trap fishes at any height of water level.

3.6 Repair and Maintenance

The structure did not require repair or maintenance during Years 1 and 2.

During Year 3, the following repair and maintenance works were done:

- Cleaning of fishpass structure and sampling cages;
- Replacement of G. I. wire meshes at screen gates and at sampling cages;
- Repainting of sampling cages, M.S. grill at the top of the fishpass, guard shed, and trusses;
- Repair of I beam at truss which was bent due to water thrust, and
- Placing of bamboo fence at R/S channel and at C/S channel of fishpass to protect against debris and water hyacinth.

Major maintenance work had to be done due to erosion of the R/S channel. The bed of the river side channel was eroded up to 2 m depth and for a length of 30 m during the post-monsoon when water was draining through fishpass. The channel was repaired with a slopping channel bed, and by placing boulders, gunny bags, and earth fill.

4. FISHPASS OPERATION

4.1 History of Operation of Fishpass

4.1.1 General Aspects

The operational history of the fishpass during Years 1 to 3 is summarised in Table A.27. Annual Potential Operation Period (POP) was between 42.7% and 63.4% of total elapsed time during the study years. To maximise fisheries benefits, the ideal situation would be for Actual Operation Period (AOP) to equal POP. Protests and construction during Years 1 and 2 resulted in AOP being 75.4% and 78.9% of POP, respectively. The percentage increased markedly during Year 3 to 97.4%.

4.1.2 Year 1: 1995

This year may be generally described as a high flood intensity year (Figure 11). The inundation index for MRIP was 1,748 mcm-months (11.9% above the long term normal mean) and the maximum flood level reached was 9.08 m PWD on 25 August 1995 (Table A.28). There were three premonsoon flood surges and three monsoon flood surges in the Kushiyara River.

Construction was completed and the fishpass began operation on 24 May 1995. This coincided with a large premonsoon flood surge in the Kushiyara. This was the third and last premonsoon flood of 1995 (it had been preceded by very small premonsoon surges in mid April and early May). River level began rising sharply from 4.96 m on the evening of 18 May, peaked at 7.54 m on 23 May, and then declined to a low of 5.95 m on 3 June. The first operation of the fishpass thus coincided with the declining water level phase of the first premonsoon flood surge. When the riverside gate was opened for the first time at 10:00 on May 24, 1995, water level in the river was at 7.37 m (i.e.: 1.91 m above the riverside invert elevation of 5.46 m).

On 26 May a number of people from Kashimpur village asked the BWDB to close the gate of the fishpass. They felt that the water passing through the fishpass represented a threat to their *aman* rice crop. The structure was closed for one day and then reopened.

The first monsoon flood, which initiated sustained flooding of the river and *haor*, began on 9 June. On 17 June some people again asked for the fishpass to be closed. However, water level continued to rise and people felt less threatened by the discharge from the fishpass. The structure was re-opened.

The first monsoon flood surge peaked at 9.17 m PWD on 21 June and declined to a minimum of 8.73 m PWD by early July. Sampling suggested increased fish movement took place from river to *haor* in the fishpass during the rising limb of the flood surge. However, given the inadequacies of the sampling gear used during Year 1, traffic rates through the fishpass cannot be considered reliable and will generally not be discussed in this report. The declining water level in the *haor* during the last week of June caused some local crop cultivators to again ask for the fishpass to be closed. However, water levels stayed high due to rainfall, and it became clear that there was no possibility to save the inundated crops. Another group of crop cultivators came with a demand to close the fishpass with an apprehension that if it was kept open their seed bed may be inundated due to inflow of additional water. The fishpass was again closed and the matter was investigated by the FPP team. After investigation it was found that the seed beds were in higher elevation lands beyond the reach of flood waters. The gate of the fishpass was re-opened on 25 June.

A second monsoon flood surge in the river followed almost immediately, peaking at 9.09 m PWD on 7 July. Some people again demanded closing of gate on 18 July as they felt that their *aman* seed bed might get submerged. Despite their demand, the gate was kept open as the C/S water level at that time was declining and dropped from 8.21 m PWD on 16 July 8.17 m PWD on 18 July. The complainants were so informed and no one expressed adverse opinion. However, on 19 July the BWDB issued a letter to NERP requesting closure of the gate. But at that time (07:00 in the morning) the R/S and C/S water levels were 8.76 m and 8.22 m PWD (C/S started rising again), respectively, giving a head difference of 0.54 m. The *Katari* rice (local transplanted *aman*) was under water. Saving this crop would have required drainage of about 1.5 m of water, and the pumping capacity to achieve this was inadequate. The fishpass gate was re-opened on 1 August.

River level declined after the second monsoon flood to a lower level than the *haor*. This resulted in a flow reversal inside the fishpass (*haor* to river flow) under a maximum head difference of -0.29 m on 12 August. On 13 August heavy rain fell and the water had risen to its highest level on the *haor*. People of the locality were concerned that the additional water passing through the fishpass might result in some crop loss. They demanded that the gate be closed. After analysing the whole situation, and also to show respect for the fears of local people, the fishpass was closed. Flow reversal was short lived, and the third and last monsoon flood surge in the river peaked at 9.36 m PWD on 20 August. River level then declined to below *haor* level by 5 September. This induced a second flow reversal in the fishpass which persisted throughout the late monsoon drainage phase during which the *haor* level was consistently higher than the river level. The fishpass was reopened on 6 September after the perception of danger had passed and no complaints were received after that date. The outflow through the 6-vent regulator started from the first week of September.

The fishpass was closed on 20 November when the water level in the riverside came down to 5.76 m PWD and no significant movement of fish through the fishpass was observed. Moreover, large quantities of water hyacinth and other aquatic weeds were being carried into the fishpass by the *haor* water flow and it was judged preferable to close the gate.

Both river and *haor* water levels continuously declined during January and most of February 1996.

4.1.3 Year 2: 1996

This year may be generally described as an average flood intensity year (Figure 11). The flood intensity index for MRIP was 1,549 mcm-months (-0.8% below the long term normal mean), and the maximum flood level reached was 8.52 m PWD on 22 August (Table A.28). There were four premonsoon flood surges and four monsoon flood surges in the Kushiyara River.

The first pre-monsoon flood began on 26 February, but was of small magnitude. The second pre-monsoon flood began on 15 March, and surpassed the fishpass R/S invert level for the next six days. The fishpass gate was closed during this flood surge in order to install the sampling cages.

The magnitude of the third pre-monsoon flood was large. It began on 28 March and lasted until 18 April. Installation of the sampling cages was completed on 3 April, and the R/S gate was opened briefly to test the cages. The gates were again opened for a number of hours on 5 and 6 April, but protests from farmers concerned about the safety of their *boro* rice crops forced their closure. One sample taken during this pre-monsoon flood surge indicated that a large number of fish were migrating from river-to-*haor*.

The fourth pre-monsoon flood began on 23 April but was of small magnitude. On 26 April the river level surpassed the R/S invert for the third time in 1996, and remained above it until the end of the monsoon.

The first monsoon flood, which initiated sustained flooding in the river, began on 10 May. The *boro* crop had already been harvested by then, and on 11 May the R/S gate was opened and normal full time operation and sampling of the fishpass began. Sampling revealed that a heavy migration of fish from river-to-*haor* took place during the first monsoon flood.

The second monsoon flood surge began on 28 May. This flood produced only a small surge in river-to-*haor* fish traffic through the fishpass.

The third monsoon flood began on 2 July. This was the strongest flood surge of the year, and the river level peaked at 9.03 m PWD on 7 July to its highest level in 1996. Sampling showed a large migration of fish from river-to-*haor*, as well as a significant migration in the opposite direction.

The fourth and last monsoon flood began on 12 August, and was accompanied by weak fish migration traffic. *Haor* water reached its highest level (8.52 m PWD) on 22 August.

The river level began declining after the fourth monsoon flood, but there were small flood surges on 22 September, 6 October, and 30 October. The outflow through the 6-vent regulator started from the first week of September. Some minor increase in fish migration was recorded for the first two surges, but none for the last.

4.1.4 Year 3: 1997

This year may be generally described as a moderate flood intensity year (Figure 11). The estimated annualised inundation index for MRIP was 1,611 mcm-months (3.1% above the long term normal mean; extrapolated for the period 21 Oct 1997 to 30 April 1998), and the maximum flood level reached was 8.96 m PWD on 1 October (Table A.28). There was one premonsoon flood surge and five monsoon flood surges in the Kushiyara River.

The one and only premonsoon flood surge of the year began on 19 March. It surpassed the R/S invert of the fishpass on 23 March, peaked at 5.65 m PWD on 25 March and receded to below sill level by 27 March. Farmers would not allow the fishpass to be opened during the premonsoon flood surge due to fear of possible damage to *boro* crops.

The first monsoon flood began on 5 May. The river level surpassed the R/S invert on 20 May and remained above the invert to the end of the monsoon. All *boro* crops had been harvested inside the *haor* and there was no further opposition to opening the fishpass during the rest of the year. The R/S gate of the fishpass was opened on 21 May and remained open until the end of the study period. Routine fishpass sampling began on 22 May. The first monsoon flood surge peaked at 6.87 m PWD on 26 May, and then declined. Heavy fish traffic was recorded moving from river to *haor* in the fishpass during the rising phase of the flood surge.

The second monsoon flood in the river began on 2 June and peaked at 7.86 m PWD on 8 June. Heavy traffic through the fishpass was also recorded during this flood surge.

Subsequent monsoon floods number three, four and five in the river peaked at 8.4 m PWD (27 June), 9.22 m PWD (17 July) and 9.30 m PWD (28 July), respectively. Fish migration continued to be stimulated by these later monsoon flood peaks, but the pattern of traffic was more erratic and de-synchronised with flood surges. More peaks of lesser magnitude occurred both during the flood surge rising phases and also during flood decline phases.

The outflow through the regulator started from the third week of August. As is normally the case, the peak in *haor* flood level lagged behind the river peak, reaching 8.96 m PWD on 1 October.

After monsoon flood surge number five, the river level generally declined but was punctuated by a number of additional flood surges. FPP field monitoring for hydrology and fisheries terminated by mid-September 1997 (although the socioeconomic fish consumption and fishing income survey continued into mid-October). Heavy rainfall in September caused the *haor* level to rise to its annual maximum, and additional flood surges to occur in the river.

4.2 Hydraulic Performance of Fishpass

4.2.1 Hydraulic Measurement and Data Collection Procedure

The objective of the hydraulic and hydrology studies was to understand the factors governing the behavior and movement of fish in the flow system, verify the hydrological and hydraulic design of the fishpass structure, adjust the structural design, develop design principles for fishpass structures, determine the impact of sediment at the fishpass structure, determine the impact of flow from the fishpass structure within the project area, and establish operating rules for the fishpass. Other objectives include flushing irrigation water into *beel* areas, demarcating dry season *beel* area, determining the flooding extent at MRIP, and developing a water balance model representing quantitative inflow/outflow for the project area.

Hydrological monitoring was carried out at the fishpass structure, MRIP, 3-vent regulator, 6-vent regulator, irrigation and drainage system, incoming *chhoras* from the upper catchment, and the Kushiyara River. This included data collection of water levels, evaporation and rainfall, water velocity and discharge measurement at the fishpass structure, drainage regulators, inlet channels, outlet channels, upstream *chhoras*, irrigation canals, drainage channels, and the Kushiyara River. Dry season *beel* areas and depth of *beels* were also measured. Detailed topographical surveys of MRIP were also carried out for hydrological analysis.

Project water level and Kushiyara River water level at Kashimpur data was available from 1983 to September 1997 (Figures 7 to 11), collected from Kashimpur pumping station, BWDB. NERP installed two water level gauges, one at river side and another at country side for precision record of data. Measurements of water level were taken at twelve hour intervals, while the BWDB pumping station keeps records of hourly readings. There are small deviation of water levels between NERP and BWDB data because water level fluctuates when the pumps are in operation or drainage regulators are open or fishpass is in operation. The method of L-moments is used for statistical analysis of river water levels. Two parts of this method are computation of sample L-moments and General Extreme Value Distribution computations.

There is no rainfall station within the project area, but there are four adjacent stations. These are located at Moulvibazar (R-122), Chandbagh (R-104), Manumukh (R-119), and Langla (R-117). The NERP rainfall station at Manumukh (R-119) was abandoned in 1993. For computational purposes, the other three rainfall stations were considered. Data was available from 1961 to October 1996.

Data regarding the number of pumps and operating hours were collected from the Kashimpur pumping station. These data allow to estimate the volume of water bailed out from the project area.

Daily evaporation data from January to October 1996 was collected from the Srimangal station.

During Year 1, velocity and discharge measurements were started from 07 July 1995 and discontinued at the end of October 1995, since depth of water became less than 1 m above the invert level of the fishpass structure. Measurements were taken weekly or every alternate week. A total of ten sets of measurements were taken which include velocity measurements at vertical slots of the fishpass structure, discharge measurements at inlet and outlet channels of the regulators and pumping station.

During Year 2, velocity and discharge measurement at the fishpass started from 17 May 1996 and were discontinued at the end of October. This was when the water level fell to less than one metre above the invert level of the fishpass structure. Measurements were taken weekly or as necessary. A total of 30 sets of measurements were taken at the fishpass for a variety of water levels and flow conditions. Other discharge measurements were:

- 3-vent and 6-vent regulator discharges;
- Pumping station discharge;
- Kushiyara River discharge;
- Discharge of incoming *chhora*s from the upper catchment;
- Irrigation inflow, and
- Dry season outflow.

During Year 3, discharge measurement was taken in the Kushiyara River. A topographic survey was carried out at outlet channel of pump house, at the three vent channel, and at Machuakhali channel.

4.2.2 Water Levels in River and *Haor*

General Aspects
Hydrographs indicate that water level starts rising from March and recession begins in September (Figures 7 to 10). The nominal pre-monsoon period can be generally considered as April-May, the nominal monsoon period as June-August, and the nominal post-monsoon as September-October. Due to flash floods from upstream, rise of water level at the river may occur already

in March - which extends the pre-monsoon period. The occurrence of flash floods which cause maximum water level difference between *haor* and river (about 2 to 3.5 m) is usually from the middle of April onward.

Water level data analysis was based on available data (Appendix G). During the pre-FPP period (1983 to 1994), annual maximum river water level varied from 10.38 to 8.83 m PWD (Table A.28). The highest maximum water level occurred in 1993 at 10.38 m PWD and the lowest maximum river water level occurred in 1992 at 8.83 m PWD. Annual maximum MRIP water level varied from 10.00 to 8.36 m PWD. The highest maximum project water level occurred in 1993 and the lowest maximum water level occurred in 1987. Table A.28 shows the maximum water levels at recorded years. Water level hydrograph for available years (1983 to 1997) are shown in Figures 7 to 11.

From the period of record, the maximum head difference across the structure was found to be 3.78 m during flow from R/S to C/S in 1985. For flow from C/S to R/S, the maximum head difference was 1.62 m in 1987. Tables A.29 and A.30 show the maximum head differences for different years during flow from R/S to C/S and C/S to R/S, respectively. Maximum head difference for R/S to C/S flow occurs in the pre-monsoon, while maximum head difference for R/S to C/S flow occurs at the end of post-monsoon.

The Kushiyara River water level (Kashimpur Pumphouse) at various return periods is presented in Table 4.1, and shown in Figure 12.

Table 4.1: Statistical Analysis of the Kushiyara River Water Level

Return Period	Water Level (m PWD)
2	9.30
5	9.71
10	10.00
20	10.29
25	10.38
50	10.68
100	10.99
200	11.31

Rainfall
Average total rainfall during the period January-September 1995 was 2,876 mm. It was 2,692 mm during the same period in 1996. Rainfall totals in 1995 (from January to September) were 2,150, 2,509, and 3,969 mm respectively at Moulvibazar, Langla, and Chandbugh. Rainfall totals (for the same period) in 1996 were 2,188, 2,734, and 3,155 mm respectively. Submergence of the project area is governed by rainfall at Chandbugh. This rainfall data indicates that a substantial volume of water enters the project area from the upper catchment. The hydrograph from 1992 to 1996 are shown in Figures 13 and 14. Monthly rainfall data from 1961 to 1993 are shown in Appendix G (Tables G.1 to G.3). The monthly and annual mean rainfall of the three stations are shown in Table 4.2.

Table 4.2: Monthly and Annual Mean Rainfall in Project Area for the Period of 1961 to 1993

Station Name & Number	May (mm)	June (mm)	July (mm)	August (mm)	Sept. (mm)	Oct. (mm)	Annual Mean (mm)
Moulvibazar (R-122)	446	528	437	396	295	152	2714
Chandbagh (R-104)	529	635	528	434	362	181	3172
Langla (R-117)	485	552	420	410	304	176	2826
Average	**487**	**572**	**462**	**413**	**320**	**170**	**2904**

Pumping Hours
In 1995, project water level increased abruptly in mid-June, and pumps began operating. They stopped at the end of October. The average number of pumps operating during this period was 6.

In 1996, the pumps began operating in mid-March, after the first pre-monsoon flood. They continued until the second week of September. On average, 3 pumps were in operation from March to May, and 6 pumps from June to September. The rise in water level in the project area was gradual.

In 1997 pump operation began from 23 May. At the beginning of monsoon on average 4 pumps were in operation. At the middle of monsoon on average 6 pumps were in operation. At post-monsoon, though there was outflow from the *haor* to river through 6-vent regulator, due to heavy rainfall project water level increased abruptly. On average 6 pumps were in operation from end of September to middle of October.

4.2.3 Water Velocity inside Fishpass

Methodology
During Year 1, 10 set of measurements were taken under various conditions of river water level and project water level. During measurements observation no. 1, 2, 4, and 5 had flow direction from R/S to C/S and observation no. 3, 6, 7, 8, 9, and 10 had flow direction from C/S to R/S. During Year 2, 30 sets of water velocity measurements were taken. Fifteen measurements were taken when the water was flowing from R/S to C/S, and 15 measurements when it was flowing in the opposite direction. Data was collected at various conditions of river and project water levels.

The width of the vertical slot of the fishpass structure is 0.41 m. Measurements were taken at the surface, 0.2, 0.4, 0.6, and 0.8 unit depths of the vertical slots. At each depth, it was possible to measure only the maximum velocity. The average maximum velocity was calculated at each slot. In 1995 and 1996, many C/S baffles were submerged during the monsoon and early post-monsoon. The C/S observation chamber was under water during the monsoon season and part of the post-monsoon season. Due to submergence of the baffles at C/S, the water level profile remained level. A schematic diagram of the flow is shown in Figure 15.

In 1995, velocities were measured at a maximum head difference of 0.90 m across the structure. Computations of velocity, discharge, and turbulence were based on extrapolated data. In 1996, velocities were measured at a maximum head difference of 3.12 m across the structure (during flow from R/S to C/S). Computations in 1996 are from observed data. The measured velocities were analysed, and computed velocities for water flow in both directions for Year 1 and Year 2 are shown in Appendix G (Tables G.4 and G.5).

Based on the empirical data, equations were derived to determine the maximum water velocity at critical slots. The equations are presented below, and the water velocities are shown in Figure 16. These analyses are based on 1996 data.

Flow from R/S to C/S :
$$V = 1.308H^{0.60} \text{ (m/sec)}$$
$$V = 6.220h^{0.58} \text{ (m/sec)}$$

Flow from C/S to R/S :
$$V = 2.340H^{0.72} \text{ (m/sec)}$$
$$V = 5.320h^{0.446} \text{ (m/sec)}$$

Where : V = Velocity (m/sec)
h = Head loss at vertical slot (m)
H = Total head loss across structure (m)

The above equations were developed considering pool dimensions of 2.9 m x 2.5 m, 16 slots, and a gradient of 4.63%. The expressions will change with the change of any hydraulic parameter.

In 1996 a complete annual set of measurements was taken at various water levels and at various head difference. Hence, in 1997 no velocity was measured at the fishpass structure. Equations derived for velocity measurement in 1996 were also used in 1997. Appendix G, Tables G.6 to G.8, represent 1995, 1996 and 1997 maximum velocity data. These are shown graphically in Figures 17 to 19.

Effect of Water Surface Profile
The invert level of the fishpass is 5.46 m PWD at R/S, and 3.16 m PWD at C/S. The elevation difference is 2.3 m. The inclined length of the bed is 49.64 m. Slope of the bed surface profile is 4.63%. When water is flowing from R/S to C/S, the relation of the water surface profile to the bed surface profile is one of the following:

- Situation 1: water surface profile is parallel to bed surface profile ($S_w = S_b$);
- Situation 2: water surface profile is steeper than bed surface profile ($S_w > S_b$), and
- Situation 3: water surface profile is milder than bed surface profile ($S_w < S_b$).

If the head difference across the structure is 2.3 m there is equal drop in head at each vertical slot, and the depth of water remains constant along the length of the structure (Situation 1). This results in equal velocities at vertical slots and equal turbulence in pools. This is the most desirable state, but it was not observed. It is usually transitional between Situations 2 and 3.

If the water surface profile is steeper than the bed surface profile (Situation 2), the depth of flow reduces downstream (D/S). This results in higher velocities at D/S slots and higher turbulence in D/S pools. In this case, the critical vertical slot is no. 16 (Figure 15). This situation was observed during PMF2, PMF3, and MF1 events in 1996.

If the water surface profile is milder than the bed surface profile (Situation 3), the depth of flow increases D/S. This results in increased velocities at upstream (U/S) slots and increased turbulence in U/S pools. In this case, the critical vertical slot is no. 1 (Figure 15). In 1996, this situation was observed for a longer period.

During flow from C/S to R/S, the slope of the water surface profile is reversed. The water deepens towards C/S. This results in increased velocities at D/S slots, and increased turbulence in D/S pools. For this flow system, the critical vertical slot and critical pool is no. 1 (Figure 15).

Maximum Water Velocity for R/S to C/S Flow
Water velocity along the structure can either increase (Situation 2) or decrease (Situation 3) when it is flowing from R/S to C/S. Measured velocities during Situation 2 at a head difference of 3.12 m were 1.97 m/sec at slot 1 and 2.36 m/sec at slot 16 (Figure 16). Measured velocities during Situation 3 at a head difference of 2.19 m were 2.08 m/sec at slot 1 and 1.77 m/sec at slot 16. The maximum head difference was 3.17 m (when water was flowing from R/S to C/S), for which the computed velocity at slot 16 was 2.40 m/sec.

Maximum Water Velocity for C/S to R/S Flow
When water is flowing from C/S to R/S, water depth decreases D/S. This results in increased velocities at D/S slots. For a head difference of 1.27 m, water velocity at slot 1 was 2.67 m/s and at slot 16 was 0.66 m/s (Figure 16).

Water Velocity Distribution
During Year 1, the fishpass structure was in operation from May 24 to November 20, 1995. Water levels were recorded every twelve hours. Velocity was calculated for each set of records. Frequency of occurrence of velocities at slot 1 with different ranges are shown in Table A.31. The design velocity of the fishpass structure is 1.50 m/sec. But distribution shows that 41% velocity of occurrence remains above 1.50 m/sec when flow is from R/S to C/S and 11% velocity of occurrence remains above 1.50 m/sec when flow is from C/S to R/S.

During Year 2, the potential operating period (POP) of the fishpass structure was from mid-March until mid-November, except for a few days in March and April. Water velocities at slot no.1 and slot no. 16 were calculated for each set of records. The frequency of occurrence of water velocities at critical slots is shown in Table A.31. The distribution shows that velocity was above 1.50 m/s about 36% of the total operating period. The proportion of time that water velocity exceeded the design velocity was the same for water flowing from R/S to C/S as for water flowing from C/S to R/S. Velocity distribution from measurements taken in 1996 is shown graphically in Figure 20.

During Year 3, the fishpass was in operation from May 23 to October 20, 1997. The frequency of occurrence of water velocities at critical slots is shown in Table A.31. The distribution shows that velocity remained above 1.50 m/sec for 27% of the time when water was flowing from R/S to C/S, and 17% of the time when water was flowing from C/S to R/S.

Variation of Velocities
During Situation 2 and Situation 3 head drop at slots varies along the structure. Also, velocity is a nonlinear function of head drop. Hence, velocities at slots vary non-linearly. Variation of velocities at different head differences across the structure is shown in Figure 21.

9 a

4.2.4 Water Discharge through Fishpass

A total of 10 sets of discharge measurements was taken at the R/S gate of fishpass structure during Year 1. Four sets of measurements were taken during flow from R/S to C/S and 6 sets during flow from C/S to R/S.

During Year 2, a total of 29 sets of discharge measurements were taken at the river side gate of the fishpass. Then, 15 sets of measurements were taken during flow from R/S to C/S, and 14 sets when flow was from C/S to R/S. Discharge measurements are shown in Table A.32.

The water discharges for Years 1 to 3 are shown in Appendix G (Tables G.9 to G.11).

The discharge computation when water is flowing from R/S to C/S is as follows :

$$Q = C_d A (2gh)^{1/2}$$

Where Q = Discharge in m^3/sec
h = Head loss at vertical slot (m)
g = Acceleration due to gravity (m/s^2)
C_d = Coefficient of discharge
A = Area in m^2

The coefficient of discharge is calculated from measured discharges using the above equation. The value of the coefficient of discharge (C_d) was calculated as 0.62.

The above equation does not apply to water flowing from C/S to R/S. From measured data, it was found that the weir formula fits better for discharge computation.

The equation can be written as:

$$Q = CLH^{1.5}$$

Where C = Coefficient of discharge
L = Width of slot (m)
H = Upstream depth of water (m)

The coefficient of discharge C varies with the froud number (Fr). The value of C is computed from the following formula :

$$C = 0.275\ (\exp)^{2.23H}$$

Where H = Total head (m), (maximum 1.30 m)

During flow from C/S to R/S, flow through the fishpass can be in the state of subcritical or supercritical flow. The coefficient of discharge C changes with the change of the froud number Fr. Relation between C and Fr can be written as :

$$C = 0.96\ Fr^{1.24}$$

The above equations are valid for this specific structure. Relations will be changed with the change of any dimension of the structure.

4.2.5 Water Head Loss at Vertical Slots

During hydraulic measurement, some of the C/S baffles were submerged. Head losses were only measured at vertical slots which were not submerged. Since the bed level of the structure declines towards C/S by 2.3 m, the water area at vertical slots increases gradually from slot 1 to slot 16. This increase in water area reduces velocities across the slots. This reduction in velocity causes head losses to decrease till total head is less than 2.3 m. The situation reverses when total head is greater than 2.3 m. When water was flowing from R/S to C/S, the changes in head loss were nearly linear. When it was flowing in the other direction, the change in head loss was linear at U/S slots and sharply increased at D/S slots. Head drop at each slot at high head difference is shown in Figure 22.

When water was flowing from C/S to R/S with a total head difference of 1.27 m, the cumulative head loss at baffles did not account for the total head loss. Some head losses were observed at the R/S inner gate and R/S outer gate.

Head losses in a flowing fluid are due to:

- Friction on the sides of the structure;
- Change of direction;
- Change of section (enlargement and contraction), and
- Obstruction in passage.

The derived equation for head loss at critical slots is expressed below (Figure 21):

Flow direction R/S to C/S: $h=0.079H^{0.80}$

Flow direction C/S to R/S: $h=.006(\exp)^{3H}$

Where h = Head loss at slot 1 (m)
H = Total head loss across structure (m)

4.2.6 Water Turbulence within Fishpass

Turbulence within a fishway is determined by the discharge and velocity of the water entering the fishway pool, and the pool volume that is available to dissipate the energy of the water.

This is expressed in general terms by the following equation:

$$P = Qht/V$$

where P = Power (watts/m^{3})
Q = Discharge (m^3/s)
h = Head loss (m)
t = Weight density of water (newtons/m^3)
V = Pool volume in m^3

The Kashimpur fishpass structure has pool dimensions of 2.9 m x 2.5 m. The invert level of the structure at R/S is 5.46 m PWD and at C/S the invert level is 3.16 m PWD. The elevation difference between R/S invert level and C/S invert level is 2.3 m. Slope of the bed level is 4.63%.

For turbulence computation from R/S to C/S, the following parameters have been considered :

- Head difference at slots;
- Water surface profile;
- Bed slope;
- Baffle submergence, and
- Pool volume.

If $S_w = S_b$, the turbulence in each pool is equal. If $S_w > S_b$, the turbulence in downstream pools is higher. If $S_w < S_b$, the turbulence in upstream pools is higher. The number of active pools also affects turbulence.

If the head difference across the structure is 2.3 m, then water surface profile is parallel to bed profile, and the depth and flow conditions are constant across the structure. In this case head losses at vertical slots will be equal and turbulence will be equal in each pool.

If the head difference across the structure is greater than 2.3 m, then water surface profile is steeper than bed profile and the depth of flow will vary. The water volume at D/S vertical slots decreases causing increase in velocities and head losses at D/S vertical slots. Hence, turbulence affects at D/S pools are higher than U/S pools.

If the head difference across the structure is lower than 2.3 m, then water surface profile is milder than bed profile for which depth of flow varies. The water volume at D/S vertical slots increases causing decrease in velocities, the head loss, and turbulence level.

Since the return walls at the C/S are reduced from 11.46 m PWD to 7.46 m PWD, during monsoon and at the beginning of post-monsoon some baffles were submerged at C/S. This reduces the effective length of the structure. Hence head drops at vertical slots were governed by the unsubmerged portion of the structure. At higher pool volume, the turbulence effect is reduced. Turbulence level can be minimised by changing the dimensions of the pool and also by lowering the invert level.

The following maximum turbulence values for P were used as design guidelines:

• Salmon	200 W/m^3
• Non-salmon temperate species	150 W/m^3
• Large migrating fish (Australia)	125 W/m^3
• Small species and juveniles (Australia)	100 W/m^3

During Year 1, the computed turbulence during the pre-monsoon was 101 W/m^3 at a head difference of 2.34 m when flow was from R/S to C/S. For flow from C/S to R/S, the computed turbulence was 237 W/m^3 at a head difference of 1.01 m. The pre-monsoon and monsoon turbulence levels were within the limit of about 100 W/m^3. The post-monsoon turbulence level exceeded by 10% the limit of 100 W/m^3.

During Year 2, the computed turbulence during the pre-monsoon was 135 W/m^3 at a head difference of 3.17 m when flow was from R/S to C/S. For flow from C/S to R/S at the end of October, the turbulence level was very high due to the low river water level and high head difference. The pre-monsoon turbulence level exceeded by 11% the limit of 100 W/m^3, while the post-monsoon turbulence exceeded it by 27%.

During Year 3, the computed turbulence during the pre-monsoon and monsoon was within the limit of 100 W/m^3. During the post-monsoon, the turbulence level exceeded by 7% the limit of 100 W/m^3. The turbulence level sharply increased with low pool volume of water and at high head difference. During the pre-monsoon and late post-monsoon, turbulence levels were high for the above reasons. During the monsoon, turbulence is low because of high pool volume of water and low head difference across the structure.

Turbulence levels for Years 1, 2, and 3 are shown graphically in Figures 23 to 25, and the data is presented in Table 4.3.

Table 4.3: Cumulative Percent of Turbulence inside Fishpass

Turbulence (watts/m^3)	Cumulative Percent					
	Year 1		Year 2		Year 3	
	R/S to C/S	C/S to R/S	R/S to C/S	C/S to R/S	R/S to C/S	C/S to R/S
25	57	63	42	23	31	67
50	84	84	64	67	84	86
75	93	89	76	71	100	93
100	99	90	89	73		93
125	100	92	96	77		95
150		95	100	83		95
175		97		85		96
200		98		85		100
225		99		85		
250		100		85		
> 250				100		

4.3 Fish Movement through Fishpass

4.3.1 Sampling Gear and Procedure

Information on the traffic of fish through the fishpass was acquired primarily by sampling in the observation chambers, and secondarily from visual observations of the water surface of the pools. Sampling was done in a systematic manner, while visual observation was cursory and by chance.

During Year 1, three different sampling gears were used to sample fish migrating through the fishpass (Table A.33):

- Bamboo trap;
- Rigid metal basket, and
- Collapsible metal basket (Appendix B, Drawing B.10).

The design of these devices was mainly governed by cost considerations.

The procedure for sampling fish in the observation chambers consists of lowering the sampling gear to the bottom of the chamber, lowering the outside wall screens (to prevent fish from exiting the chamber to the outside), and raising the sampling gear after a certain length of time (i.e.: several hours). The procedure of lowering the outside screen of the observation chamber prevented fish from migrating into the chamber from outside, and ensured that all fish trapped in the sample had to have entered the observation chamber by passing into the structure from the other end. All sampled fish therefore were assumed to have successfully traversed the entire length of the structure, either upstream or downstream, depending on which observation chamber was being sampled and the direction of water flow. Samples taken in the R/S chamber were interpreted as fish migrating from *haor* to river. Samples taken from the C/S chamber were interpreted as fish migrating from river to *haor*.

Fish caught in samples were quickly counted and measured, and then released back into the river or *haor*. Sampled fish suffered some handling mortality, and efforts were made to keep this to a minimum, as high sampling mortality might further reduce actual impact of the fishpass on *haor* fish production. In many of the samples, large numbers of certain small species (i.e.: *chanda*, *chela*, *icha*, *kechki*, *mola*) were trapped. Counting the number of individuals and at the same time avoiding high mortality proved difficult. During Year 1, the enumerators adopted the expediency of recording the presence of a 'school' in such cases. For purpose of data analysis, the number of individuals in a school was taken as 100. This is regarded as an underestimate of the true number. During Years 2 and 3, total counts were made of all fish taken in samples.

None of these three sampling devices used during Year 1 performed efficiently, and were able to trap only a small fraction of the fish migrating through the fishpass during a sampling period (resulting in a large underestimation of the number of fish migrating through the structure). The most serious inefficiency was due to the absence of one-way traps to prevent fish from leaving the observation chamber once they had entered it. Gaps between the chamber walls and the metal baskets (10 cm for rigid basket and 5 cm for collapsible basket) allowed fish to escape while the basket was being raised, and this was aggravated by the slow speed at which the hand-operated winch raised the basket. Virtually all of the fish caught were of small body length. Large fish were observed jumping inside the structure (Appendix D, Table D.1) but were rarely trapped with the three sampling devices used.

Problems were also encountered when longer sampling times were used with clogging of the screens with plant debris and small fish of less than 2 cm length (which were killed by being forced against the screen by high water pressure). This resulted in water overflowing through the top of the observation chamber, and fish escaping. The water pressure also bent the clogged screens out of shape, so that they could not be lifted out of their locating slots once sampling was completed.

It became clear that a more substantial (and much more costly) sampling cage fitted with internal one-way traps was required to reduce the severe sampling underestimation. Proven designs for efficient sampling cages were examined during the Australia study visit. Two large metal cages were constructed and used exclusively for sampling during Years 2 and 3. The dimensions of each sampling cage were: width 2400 mm, length 2400 mm, and height 2000 mm. The metal frame was covered by wire mesh of size 0.75 cm. In addition, at the top of each sampling cage another metal frame rectangular basket was placed (width 2.4 m, length 2.4 m, and height 0.4

m). The top of this basket was uncovered. The purpose of this additional, open cage was to trap any fish present above the top of the primary sampling cage (when water level is high) as the trap is raised. Each sampling cage had two openings at R/S, and two openings at C/S. Each opening was fitted with a tapered funnel (reducing from 1 m to 0.3 m), and bent downwards. Bending the funnel made it less likely for fish to escape the cage. The materials used to construct the cages are angles of different sizes (from 25 mm x 25 mm x 5 mm to 50 mm x 50 mm x 6 mm), and 25 to 40 mm flat bars. The total weight of each sampling cage was 860 kg.

Each cage was suspended from a truss constructed of I-beams and angles. The base of each cage is three metres above the deck level of the structure. The lifting mechanism is manual, by 2 chain block pulleys, each capable of lifting 2 tonnes.

The sampling procedures using the metal cages were the same as those used during Year 1, with two exceptions:

- During the periods when the C/S platform was inundated, special sampling in the R/S cage was used to simulate C/S sampling. This involved opening the outside funnel traps of the R/S cage and closing the inside traps. These samples are identified by the sample code number adjuncts 's' and 'ss' (Appendix D, Table D.2), and are categorised as 'Direction of Migration: River to Haor'.

- During the latter part of the monsoon flood recession, water level in the R/S observation chamber fell below the level of the lower funnel trap. Special sampling in the C/S cage was used to simulate R/S sampling. This involved opening the outside funnel traps of the C/S cage and closing the inside traps. These samples are identified by the sample code number adjuncts 's' and 'ss', and are categorised as 'Direction of Migration: Haor to River'.

During Year 3, modified funnel traps in the shape of elongate slots were installed in the sampling cages. The reason for this was the apparent inefficiency of the cages to trap large fish observed jumping inside the pools of the fishpass. This was attributed to the square design and location of the traps (i.e.: they did not extend far enough along the vertical axis of the fishpass pools).

4.3.2 Sampling Schedules

Summary data on fishpass sampling schedules is presented in Table 4.4.

Table 4.4: Summary of Fishpass Sampling Schedules

Item	Year 1: 1995	Year 2: 1996	Year 3: 1997
Total no. of samples	104	240	172
River to *haor* movement	50	127	91
Haor to river movement	54	113	81
AOP (hrs)	3,744	4,399	3,648
No. of sampling hrs	403.75	904.67	458.5
Sampling hrs as % of AOP	10.8%	20.1%	12.6%
No. of daytime samples	96	109	92
No. of nighttime samples	8	131	80
Ratio daytime/nighttime samples	12.0:1	0.8:1	1.2:1

The largest number of samples was taken during Year 2 (240), constituting 20.1% of AOP. Sampling during Year 3 was terminated early due to project completion. Sampling during year 1 was largely exploratory in nature due to the inefficient sampling gear available during that year.

4.3.3 Sampling Bias and Error

During Year 1, the sampling of fish migrating through the fishpass was very inefficient and resulted in a severe underestimate of numbers of fish. Underestimation was due in part to the inefficiencies of the sampling gears noted above. Other sources of bias were the design of the structure itself, and unevenness in the sampling schedule:

- The relatively low design elevation of the structure on the C/S resulted in the C/S observation chamber and the lowermost pools (numbers 13 to 17) becoming submerged below the *haor* water level during part of the mid and late monsoon. This made normal operation of the sampling gear in the C/S chamber difficult, and hampered study of fish migration from river to *haor* during this period, and

- Prior to installation of the collapsible basket on September 25, 1995, only a single gear was in use. Difficulty was experienced in physically moving the rigid basket between the R/S and C/S observation chambers. This resulted in sampling of only one chamber for lengthy periods, rather than the statistically correct procedure of frequent and regular switching of sampling between R/S and C/S chambers. Chamber sampling switching was carried out for only two periods: June 20, to July 1, 1995, and October 18 to 26, 1995).

These factors in combination introduced some large gaps and irregularities in the sampling schedule during Year 1.

The sampling was much more efficient during Years 2 and 3 due to the installation of the metal cages. There is greater confidence in the validity of the sampling results. There was an improvement in the sampling of large fish. Specimens of *boal* up to 56.2 cm and *kalibaush* up to 51.0 cm were trapped in the cages. However, disparities between visual observation of large fish inside the structure (Appendix D, Table D.1) and fish taken in the sampling cages, suggest that undersampling of large specimens may still have occurred.

The mortality of sampled fish was sometimes high, especially when there were a large number of specimens. Every effort was made to reduce mortality and return specimens live to the water. Fishermen expressed their concern that FPP sampling should cause as little mortality as possible to the migrating fish, as they perceive this to decrease their catch and income.

A certain number of fish escaped from the cages. In one instance, three live *ilish* were present in the cage when lifted. The cage was resubmerged, and then lifted a second time, only to reveal that one *ilish* had escaped (and one had died). It is possible that some fish escaped through the funnel traps.

During post-monsoon *haor* drainage, a large quantity of plant debris was swept through the fishpass. This rapidly clogged the mesh of the cages. Sampling duration was shortened to minimise the problem.

The interpretation that fish taken in the R/S and in the C/S cages were migrating through the fishpass from *haor* to river and from river to *haor*, respectively, may not be correct in all cases. Because it was not practical to totally evacuate the structure of water or fish prior to the beginning of a sampling period, there is a possibility that some or all of the samples were 'contaminated' with fish which had not negotiated the structure in the direction indicated by the observation chamber sampled. It is entirely possible that some fish may be attracted to enter the structure, 'loiter' in the first few pools for some time, and then turn around and leave. Fish may also actively attempt to negotiate the structure, but tire part way, and turn around and swim back out. As fish traffic through the structure was continuous and in both directions, the structure would contain fish in many or all pools migrating in both directions at the time of commencement of a sampling period. A portion of these fish may reverse swimming direction due to fatigue or other reasons, and contaminate the sample.

4.3.4 Estimation of Fish Traffic through Fishpass

General Results

The general results were in agreement during all three years of sampling:

- All 516 samples taken during three years contained fish. The 100% success rate suggests that there is a continuous traffic of fish through the fishpass during the AOP. In contrast, conventional fishpass applications elsewhere usually cater for seasonally migrating species, and water flow in the structure typically carries fish traffic for only part of the operational year;

- Fish traffic moved simultaneously bidirectionally in the fishpass. Conventional fishpass applications usually cater for fish traffic moving unidirectionally;

- Fish traffic moved both countercurrent and concurrent. Conventional fishpass applications are usually designed only for countercurrent fish traffic, and

- Fish traffic remained high even when the water current changed direction within the structure. Conventional fishpasses usually operate under conditions of unidirectional water flow.

Some of the results have never been previously reported anywhere, and are a world first. At the planning stage, there was in fact great uncertainty about the fish using the structure, and CIDA took a significant risk in embarking on the fishpass experiment.

The presence of fish in the concurrent samples might possibly be interpreted wholly or in part as passive drift into the structure, especially small fish. However, the consistent presence of fish of all sizes classes in the countercurrent samples is more likely explainable as active entry and migration through the structure. There is probably some contamination of samples by fish which reverse swimming direction or are non-migrating loiterers inside the structure, but the consistency in the sampling results suggest that a large portion of the fish sampled are intentional migrants.

Quantity of Fish

Three different methods were used to generate estimates of the number of fish which had moved through the fishpass.

Because of the differences in sampling gear and schedules between Year 1 and Years 2 and 3, slight differences in the computation methods were used:

- Pooled Mean Method: For Year 1, mean hourly migration rates were calculated separately for pooled data for individual fish and for schools of fish (Appendix D, Table D.3). The migration rates were multiplied by the total number of hours elapsed, and the sum of the products was multiplied by 2 to correct for simultaneous migration in both directions. For Years 2 and 3, the overall mean rates of migration for all samples (unweighted and uncorrected for direction of migration) were multiplied by the AOP hours, and doubled for bi-directional migration.

- Direction-Dependent Method: For Year 1, the mean hourly migration rate was calculated for each sample (Appendix D, Table D.2). The samples were separated into groups, based on direction of migration (*haor* to river; river to *haor*) and type of swimming (concurrent; countercurrent). As there were four different periods of water flow through the structure during the study (due to three flow reversals), the sorting procedure produced eight groups. The mean migration rate was calculated for each group, and then multiplied by the number of hours elapsed during each water flow period. The sum of the products gave the number of fish migrating in both directions. For Years 2 and 3, the samples were separated into two groups on the basis of direction of migration. Mean rates of migration (unweighted) were determined for each group, and multiplied by the AOP hours. The sum of the products gave the total traffic in both directions.

- Time Series Method: For Year 1, the samples were separated into two groups, based on direction of migration (*haor* to river; river to *haor*). Gaps in the chronological sequence of daily values for migration rates calculated from sampling results were filled by carrying over the migration rate from the previous day. This resulted in a complete time series of 156 days for both groups. The hourly migration rates for each day were multiplied by 24 to estimate the total number of fish for the day. The grand total of the sums of the daily totals of the two groups gave the number of fish migrating in both directions. For Years 2 and 3, the samples were separated into two groups on the basis of direction of migration. The total traffic for each day was calculated by multiplying the migration rate by 24. In some cases, means for two or more samples were used. When data were missing, interpolation was done by carrying over the traffic value from the previous day(s). This resulted in complete annual estimates of traffic through the fishpass for both groups. The total of the sums of daily traffic for each group gave the number of fish migrating in both directions (Figures 26 and 27).

Nominal traffic generated by the three methods of estimation for the three years of sampling is presented in Table 4.5.

Table 4.5: Estimated Fish Traffic in Fishpass

Estimation Method	Year 1: 1995	Year 2:1996	Year 3: 1997 *
Fish			
Pooled-Mean	n/a	755,072	1,310,157
Direction-Dependent	n/a	727,286	1,245,853
Time Series	n/a	579,394	1,087,245
Icha			
Pooled-Mean	n/a	541,217	488,090
Direction-Dependent	n/a	516,282	464,056
Time Series	n/a	n/a	n/a
Total			
Pooled-Mean	412,892	1,296,289	1,798,247
Direction-Dependent	541,736	1,243,568	1,709,909
Time Series	343,440	n/a	n/a

* Up to 1 Sept. 1997 (incomplete year)

The low estimates for Year 1 are due to the severe underestimation caused by sampling gear inefficiencies and extended gate closure time. Estimated traffic during Year 3 exceeded Year 2. Since sampling was terminated early in Year 3, the traffic estimate for the entire year would have been higher still.

An estimate of the weight of traffic during Year 2 in either direction was generated from the mean migration rate, the median length, and the median weight of each species (Appendix D. Table D.4). The estimate is that 10.69 tonnes of fish and *icha* migrated from river-to-*haor* during the AOP, and 3.03 tonnes migrated in the opposite direction.

Though traffic estimates for Years 2 and 3 are more reliable than for Year 1, they are still to be regarded as significant underestimates of the true traffic numbers. This is due to two reasons:

- Hatchling and larval fish are small enough to pass through the wire mesh of the sampling cages, and therefore did not appear in samples. The number of hatchlings and larval fish is likely to be very large during the pre-monsoon and early monsoon, and
- Large carp and catfish are probably underestimated despite the installation of the improved metal sampling cages.

Number of Fish Species

Species composition of fishpass traffic is shown in Table A.34. During Year 1, a total of 45 species were recorded from sampling inside the fishpass. During Years 2 and 3, the number of species recorded increased to 63 and 88, respectively. This is the greatest number of species recorded anywhere in the world to date successfully using a fishway.

Comparison of Fish Traffic with Hydrology

The patterns of fish traffic are compared to river level fluctuation during Year 2 (Figure 28) and Year 3 (Figure 29). During both years, most of the traffic was in the river to *haor* direction.

Moreover, traffic was heaviest during the pre-monsoon and early monsoon flood surges. Overall traffic during Year 3 was significantly heavier than during Year 2.

Detailed examination of fish traffic during individual flood surges shows a strong correlation between the two. During Year 2, the river-to-*haor* migration during MF1 and MF3 had some similarities (Figure 30 and 31). In both cases, the migration rate increased as the flood surge progressed. It peaked at about the same time as the flood reached its maximum level. The flood level was maintained for a number of days, but the migration rate fell off rapidly in both cases. A second peak in migration rate occurred during MF3, but may not have been directly flood-induced. The pattern of *haor*-to-river migration was somewhat different. Little migration was recorded during MF1. A relatively high migration rate was observed during the MF3 surge, but this fell off well before maximum flood level was reached. A second migration peak took place during the sustained flood period, but this was before the second peak observed for river-to-*haor* migration.

Early monsoon traffic and flood patterns during Year 3 were similar to those of Year 2. River to *haor* migration increased rapidly as the monsoon flood surge progressed for MF1 (Figure 32) and MF2 (Figure 33), with both peaking at roughly the same time, and fish traffic falling off afterwards. Patterns during later monsoon flood surges were more erratic, and fish traffic and flood peaks were de-synchronised for MF3, MF4 and MF5 (Figures 34 to 36). However, MF6 (Figure 37) showed virtually the same pattern as the early monsoon floods MF1 and MF2.

Species Composition of Fish Traffic

Overall species composition in number terms of fishpass samples for Years 2 and 3 are shown in Figures 38 and 39, and data is presented in Appendix D (Table D.5). Traffic is dominated by small prawns (*icha*) and glassfish (*chanda*). Other frequently occurring species were small cyprinids (*mola*, *puti*, *chela*), small catfish (*batashi*, *bacha*, *tengra*), the sardine *chapila*, and the giant river prawn (*golda chingri*). The most common large fish species were *air*, *baim*, *bamosh* and *kalibaush*.

The species composition of fish traffic during individual flood surges is generally similar to the overall annual traffic, with minor differences (Figures 40 to 43; Appendix D, Tables D.8 and D.9).

Percentage species composition in number terms differs from weight terms (Appendix D, Table D.4) with large species (*boal*, *mrigel*, *kalibaush*, *air*, *gonia*) making up a larger proportion of the total in the latter case.

Detailed accounts of the migration records of individual species is presented in Appendix E.

Fish Tagging Program

A fish tagging program was carried out from May 22, 1995 to August 11, 1995 in order to gain additional information about the movement of broodstock and recruits of larger species between river and *haor*. A total of 145 fish were tagged with plastic tipped dart tags and T-bar tags (supplied by Hallprint) as shown in Table 4.6.

Table 4.6: Summary of Numbers of Fish Tagged

Species	No tagged
Rui	36
Gonia	22
Rita	18
Catla	14
Ilish	12
Bacha	10
Air	9
Boal	8
Foli	5
Chitol	4
Baim	3
Garua	3
Kalibaush	1
Total	**145**

Most tagged fish were from the Kushiyara River, within 7 km downstream of the fishpass. Fish were either purchased from fishermen or were donated. A reward of TK 500 was offered for the return of tags. However, no tags were returned during the project lifespan.

4.3.5 Selected Factors Affecting Fish Migration through Fishpass

Diurnal Cycle

To examine the possible role of diurnal period in stimulating migration, continuous sampling over 24 hour periods was carried out during Year 2 (from June 20 to 22, 1996, river-to-*haor* direction only) and Year 3 (from July 10 to 12, 1997, both river-to-*haor* and *haor*-to-river directions). Results are presented in Appendix D, Table D.10, and shown in Figures 44 to 46. There is a significant and large variation in migration rates over the 24 hour diurnal period. During Year 2 sampling, the highest migration rates were observed during the first half of the night (approximately 18:00 to 24:00 hrs), and minimum rates during daylight hours (approximately 08:00 to 18:00 hrs). Fish and *icha* showed similar patterns. Year 3 sampling results differed somewhat. The highest migration rates for fish were observed during the second half of the day for both directions of movement. *Icha* showed the highest rate during the second half of the night, for both directions.

In a separate analysis, 49 appropriate pairs of samples from Year 2 and 14 from Year 3 were compared to determine the difference in daytime and nighttime migration rates (Appendix D, Tables D.11 and D.12). The couplets were from adjacent diurnal periods. The difference between daytime and nighttime migration rates for fish (Figures 47 and 49) and *icha* (Figures 48 and 50) are plotted separately. The nighttime migration rate was generally higher for both groups in both year, but especially for *icha*. Fish tended to have a high proportion of couplets with migration unaffected by diurnality.

It may be concluded that both fish and *icha* show a general preference for migration during the night, but fish are more flexible and also migrate during the day.

Attraction Flows

The situation regarding attraction flows for the Kashimpur fishpass is extremely complex, and cannot be compared to conventional fishpasses. Not only is the fishpass relatively remote from the principal migration stream (i.e.: the Kushiyara River), but there are complex bifurcations of access/feed channels on both sides of the BWDB campus to service the BWDB hydraulic structures (pumphouse, 6-vent regulator, 3-vent regulator) as well as the fishpass (Figure 51). Undoubtedly, this causes some problems for migrating fish for locating the fishpass entrances. At the same time however, the various water flows generated by the BWDB hydraulic structures serve to increase the overall volume of water outflow at the point of confluence between the Karadair Khal and the Kushiyara River, and this likely serves to attract more fish into the *khal*, and ultimately into the fishpass.

The BWDB hydraulic structures are normally operated to evacuate water from the *haor*side of the embankment during the premonsoon and monsoon season. This delivers a flow of generally clear *haor* water into the *khal* on its R/S, and creates an artificial attraction stream at the point of confluence with the Kushiyara. Flow velocities in the *khal* and along the river margin were of the same order of magnitude (i.e.: 0.25 to 0.33 m/s, respectively) in July 1995, but the difference in turbidity was marked. The *haor* water produces a plume of clear 'black' water in the turbid silty river water, and it is possible that the primary factor which attracts fish migrating in the Kushiyara into the *khal* is the quality (clarity and chemical characteristics) of the *haor* water, rather than any minor difference in flow velocities. Additionally, some of the migrating fish navigating upstream along the left bank of the river might also be 'led' into the *khal* by confluence bathymetry.

Once in the *khal*, migrating fish are faced with a choice among three channels. The pumphouse channel conducts virtually the same flow as at the river confluence, and a significant number of fish may be attracted towards the pumps. Witnesses commonly report large fish jumping out of the water in the forecourt of R/S pumphouse channel while pumps are running. After the end of the monsoon of Year 2, a bamboo screen was installed across the R/S entrance to the pumphouse channel at its confluence with the common channel leading to the six-vent regulator and the fishpass. This evidently served to successfully block out large fish as the number of visual observations of large fish jumping in the pumping channel during pump operation during Year 3 was greatly reduced.

The R/S channel to the 6-vent regulator conducts no flow during the first part of the monsoon as the regulator is closed to prevent river water from entering the *haor*. Some migrating fish may be attracted to the stagnant water to rest, but are not likely to remain long in the dead-end channel. The fishpass channel has a weak flow (0.039 m/sec in July, 1995) in the opposite direction (i.e.: towards the *haor*), which differs from the stronger pumphouse flow towards the river. The evident traffic of migrating fish passing from river to *haor* suggests that migrating fish are able to detect the weak flow in the fishpass channel, and are attracted to enter the channel. An alternate explanation is that fish enter the fishpass channel due to a combination of chance and/or after trial-and-error exploration of the three available channel options.

Fish migrating from *haor* to river swim concurrently along the Karadair Khal (flow velocity of 0.21 m/s in July, 1995) and encounter first the 3-vent regulator channel. Normally the regulator is closed during the first part of the monsoon, and the channel should be stagnant. However, this regulator has a sealing problem and leaks a significant flow of river water into the *haor*, which probably attracts some of migrating fish into the channel. The next bifurcation of the *khal* is with the fishpass channel, which conducts the weak discharge flow from the fishpass. The sampling results suggest that fish migrating along the *khal* are able to detect the weak flow in the fishpass channel, and are attracted to enter the channel. The next bifurcation is with the stagnant 6-vent regulator channel. The active *khal* flow continues to the pumphouse and is then discharged through the pumps under the embankment. Migration in this channel is evidently quite hazardous during the monsoon as dead and dying fish are caught in the pumphouse channel on the R/S. These have probably been damaged when passing through the pumps after entering them from the *haor*side. A portion of the pumphouse flow returns to the R/S entrance of the fishpass (Figure 52).

The situation changes during the second part of the monsoon when the *haor* water level exceeds the river level. The two regulators are opened and there is generally a large evacuation flow to the river. The pumps may or may not be operated, depending on various factors such as cost and degree of *haor* flooding. The flow velocity in the fishpass channel is at least an order of magnitude less than the other channels. Nonetheless, the sampling results indicate that there is fish traffic in both directions through the fishpass during the late monsoon, and the fish are evidently attracted into the fishpass channel and then into the structure itself.

Since the fishpass channel narrows and terminates at the openings of the fishpass at either end, the attraction flows from the fishpass would appear to be adequate to allow fish to locate the entrances of the structure once they have entered the fishpass channel.

Swimming Behavior and Water Velocities inside Fishpass
The migration behavior of fish manifests itself as three very general conditions:

- Swimming direction;
- Swimming mode, and
- Swimming performance and endurance.

Swimming direction is either from river-to-*haor* or from *haor*-to-river. The other two conditions have a major influence on the efficiency of the fishpass for conducting fish traffic. Because the application of the Kashimpur fishpass is different and more complex from conventional applications, it is necessary to examine the theoretical and practical aspects of various contributing factors.

Swimming mode refers to the direction of movement of the fish in relation to the direction of movement of the water stream that the fish is in at any particular location and time. Two generalised situations are possible

- Concurrent swimming (fish swimming in the same direction as water flow),or
- Countercurrent swimming (fish swimming in the opposite direction to water flow).

Over the course of a migration episode, an individual fish may encounter water currents moving in various directions and adopt appropriate concurrent or countercurrent swimming modes in order to reach its ultimate destination.

Four combinations of swimming direction and mode are possible for fish negotiating the fishpass:

Time Period	Swimming Direction	Swimming Mode
Premonsoon, early monsoon	River-to-*haor*	Concurrent
Premonsoon, early monsoon	Haor-to-river	Countercurrent
Late monsoon	River-to-*haor*	Countercurrent
Late monsoon	Haor-to-river	Concurrent

Countercurrent swimming requires significantly greater expenditure of energy compared to concurrent swimming. Therefore, not all four combinations can be considered to be of equal challenge or difficulty. It may be assumed that the strength of the migration imperative is balanced against energy cost in countercurrent swimming mode, while concurrent swimming would be less likely to act as a check on migration.

Swimming performance and endurance refers to the characteristics of a fish's ability to make headway over time. It refers both to long distance movement, such as during a spawning migration, and to short distance movement, such as against a strong current during countercurrent swimming.

Two general types of water velocity parameters occur inside the fishpass:

- *Water velocity at the slots*. This is relatively high, and was measured directly on several occasions and extrapolated for the full operational period of the fishpass, and

- *Average water velocity in the pools*. This is relatively lower, and was calculated from discharge estimates (based on pool cross section area and velocity measurements) and is about 30% of slot velocity. Given non-uniform, non-laminar flow inside the pools, actual instantaneous velocities inside pools will range widely from almost nil in areas of stagnant water to the high velocities in turbulent areas.

In the discussion below, slot velocity was used as a proxy for both types of velocity in analytical comparisons with fish traffic parameters. In some (or even all) cases, the actual limiting velocity may have been pool velocity, but separation between slot velocity and pool velocity effects was not possible with the sampling regimes used.

Slot velocity in the fishpass does not appear to be a serious problem for fish traffic moving in concurrent swimming mode. Forty-one species were recorded migrating when the water velocity ranged between 2.25 to 2.50 m/sec during Year 2, and 39 species were recorded at 1.75 to 1.99 m/s during Year 3 (Appendix D, Table D.7; Figures 53 and 54).

In contrast, the number of taxa occurring in traffic migrating in countercurrent mode appears to be affected by slot velocity. During Year 2, 36 species were recorded when water velocity was less than 1.5 m/sec, but at higher velocities the number of species decreased. At greater than 2.25 m/sec, only nine species were recorded. At the highest observed velocity (2.49 m/sec), only *chanda*, *gutum*, and *puti* were recorded. During Year 3, slot velocities observed during sampling were less than in the previous year and the tendency for the number of species to decline as slot velocity increased was less apparent.

A particularly strong correlation between body length and slot velocity for countercurrent migration samples was not apparent. Even the smallest of fish made use of the fishpass. Body lengths of less than 3 cm were frequently recorded, even against relatively high slot velocities (i.e.: 1.91 m/s) (Appendix D, Table D.6. See also individual species records in Appendix E). Improved sampling gear during Years 2 and 3, as well as visual sightings in the pools, indicate that large individuals of *kalibaush* (40 to 45 cm), *gonia* (30 to 40 cm), *boal* (45 to 90 cm) and *rita* (30 cm) migrated through the fishpass. Thus, for most species, both juveniles and sexually mature adults make use of the fishpass. Even such species as the ungainly *potka* pufferfish and the fragile diminutive *kechki* sardine are able to negotiate the fishpass in countercurrent swimming mode.

The original design of the fishpass aimed at maintaining the slot velocity at 1.5 m/s or less in order to provide a hydraulic environment which would not inhibit the countercurrent movement of small or weak swimming fish species, and well as larvae and juveniles of larger species. Actual operational results indicate that this design velocity threshold was exceeded for substantial periods each year. At the same time, the actual swimming ability of many fish species that were thought to be vulnerable hydraulically appears to have been underestimated.

Two types of swimming velocities exhibited by fish are especially important for negotiating a fishpass:

- *Burst velocity*. This is a single high speed swimming velocity which is not sustainable for more than a few seconds, such as to evade the sudden lunge of a predator or to dart through the slot of a fishpass. Nominal burst speed is estimated as 2 times cruising speed.

- *Cruising velocity*. This is a swimming velocity that a fish could maintain for an extended period of time (several hours) without undue duress, such as during a spawning migration or movement along the pools of a fishpass. Nominal cruising speed is estimated as 3.5 time body length per sec for pelagic species, and 0.75 times body length per sec for benthic species.

Nominal burst and cruising velocities were estimated for selected species in Table A.35 for two size intervals: 1) length at first maturity, and 2) maximum length. The table predicts that many species would not be able to overcome the design slot velocity of 1.5 m/s. Small cyprinds, small catfish (except for the largest *pabda*, *bacha* and *garua*) and other small species (except for *foli*, and the largest *kaikka*) would not be expected to be able to negotiate the fishpass in countercurrent swimming mode. Most carp are strong swimmers and would not be inconvenienced, but the table predicts that *lachu* and *sarputi* of first maturity length would be excluded. All large catfish would encounter difficulty at first maturity length, and only the largest *boal* and *bagair* would be capable of passage. *Chitol* and *illish* would be successful, but neither *baim* nor *golda chingri* would be capable of passage.

Actual results indicate that despite the higher slot velocities existing in the fishpass compared to the design velocity, many more species were able to negotiate the fishpass in countercurrent swimming mode at velocities greater than 1.5 m/s than had been predicted. These included:

- <u>Small cyprinids</u>: *chela*, *darkhina*, *dhela*, *mola*, *puti*.
- <u>Small catfish</u>: *batashi*, *jainzza*, *kazoli*, *shing*, *tengra*.

- Other small species: *bailla, boicha, chanda, chapila, chirka baim, gutum, ketchki, potka, rani, taki, tara baim.*
- Carp: *lachu.*
- Other large species: *baim.*

Other prediction were generally correct. In particular, large catfish and *golda chingri* appear to be sensitive to high velocities in countercurrent swimming mode.

It may be concluded that the high slot velocities recorded during the premonsoon and monsoon flood surges could present a problem to some fish migrating *haor*-to-river, and that high velocities recorded during late monsoon drainage could affect some traffic moving river-to-*haor*. Traffic migrating in the opposite directions during the respective time periods (i.e.: concurrently) would not appear to be especially inconvenienced by slot velocity. Whether it is actually slot velocity or pool velocity (or a combination - perhaps synergistic - of both) which affects countercurrent swimming is not clear. If pool velocity is too high, it may exceed the cruising velocity of a species and result in failure to negotiate the fishpass. This may occur even if the burst velocity of the fish is sufficient to overcome the slot velocity, because fish will generally expend more time (and possibly energy) in swimming through pools than darting through slots. In the absence of actual measurements of fish swimming ability (cruising and burst velocities by species and body length), it is not possible to reach any firm conclusions about the possibly differing importance of slot velocity and pool velocity for fish traffic in countercurrent swimming mode.

Turbulence inside Fishpass

Disturbed non-laminar water turbulence in the confined space of fishpass pools can be expected to have some effect on fish migrating in either concurrent or countercurrent mode. The impact of turbulence might therefore differ from water velocity in that the latter appears to only affect fish moving in countercurrent mode. The amount of calculated turbulence in the fishpass increases with increasing velocity. Pool no 1 was considered to be the one most likely to exhibit potentially problematic levels of turbulence, as slot no 1 consistently showed the highest velocities in the structure in either flow direction. High head differences across the fishpass during the premonsoon/monsoon season and the late monsoon season resulted in high water velocities and high turbulence. Mid monsoon head differences were small, yielding low velocities and turbulence.

Estimated maximum seasonal turbulence levels in pool no 1 for the three operational years are presented in Table 4.7.

Table 4.7: Maximum Seasonal Turbulence Values Calculated for Fishpass
units of measurement: W/m^3

	Year 1	Year 2	Year 3
Premonsoon	101	135	59
Monsoon	74	88	69
Late monsoon	140	692	n/a

There is no available information which allows the setting of critical turbulence levels for fish species of the project area. The following maximum turbulence values gleaned from the literature were used as guidelines:

- Salmon 200 W/m^3.
- Non-salmon temperate species 150 W/m^3.
- Large migrating fish (Australia) 125 W/m^3.
- Small species and juveniles (Australia) 100 W/m^3.

Turbulence impacts vary with species and body size. Turbulence values of 100 or greater would likely cause problems for some species and size groups in the Kashimpur fishpass. The turbulence data suggests that values of 100+ can be expected during the premonsoon flood surges in some years. Monsoon flood surge turbulence appears to be below the critical level. However, nominal late monsoon turbulence is above 100 and in some years may be excessively high due to large head loss across the structure (caused by a rapid fall in river level). Reverse water flow in the fishpass during the late monsoon drainage produces a different flow pattern from conventional flow (i.e.: a strong jet which passes directly from one slot to the next, causing minimum eddying in the main water mass in the pool). Thus, the actual turbulence may be less than the values calculated by the power equation. During the mid monsoon small head differences between river and *haor* resulted in calculated turbulence values below 60 W/m3. This should pose no problems for fish migration.

The results suggest that turbulence is not a problem to fish negotiating the fishpass during most of the operational period. The expected evidence of a negative turbulence effect would be physical damage to fish, as well as dead and dying fish. No such evidence was observed during sampling. Apart from high turbulence values for short periods during the premonsoon (and apparent excessive turbulence during late monsoon drainage), the design of the structure appears to be adequately fish friendly.

4.4 Design Adjustment of Fishpass

The hydraulic design of the Kashimpur fishpass is based on previous model studies carried out for structures constructed in Canada for passage of salmon, and as modified for warm-water fish species in Australia. To accommodate carp and catfish, two important groups of migratory fishes in Bangladesh, sufficient number of baffles were provided to obtain the required design flow velocity of about 1.5 m/s.

Only unidirectional flow has been considered in the hydraulic model studies conducted to date in other countries, as fishpasses are typically used to aid fish migrating in the upstream direction only. In Bangladesh, however, fish migrate in both directions, with and against the current, depending on species and the migration season.

As there is no rational approach to the problem of energy dissipation in a vertical slot fishpass (the previous structures built have been copied from original designs made with the aid of hydraulic model studies), no attempt was made to design a two-way fishpass.

The Kashimpur fishpass has been designed for flow in one direction (i.e.: R/S to C/S) and sufficient provision has been made to prevent channel erosion on the *haor* side.

There is necessity to allow water flow through the structure in the opposite direction (i.e.: C/S to R/S). But as the flow velocities and the hydraulic behavior of the structure could not be determined at the time of preparing the designs, an engineering judgment was used in the design of the channel protective works on the river side. Flow measurements are being carried out. If the protective works are found not adequate, improvements will be made based on hydraulic tests *in situ*.

Provision has been made for fixing flow adjusting plates to the baffles and pillars (3/4 inch nuts embedded on the river side faces of baffles and pillars). If need be, the baffle slot width can be reduced and/or the direction of the flow jet changed. These operations would reduce the inflow rate and the turbulence level. The baffle flow velocity, however, would not be affected.

The fishpass design has shown itself to be fully capable of providing concurrent passage to fish migrating from river-to-*haor* during the pre-monsoon and early monsoon seasons. High velocities at the slots, however, may impede some countercurrent movement from *haor*-to-river during the same period. It may be desirable to alter the design to mitigate this problem.

Conversely, concurrent *haor*-to-river migration in the late monsoon appears to be unimpeded (after flow reversal occurs inside the structure). Movement from river-to-*haor*, however, is partly impeded by the high slot velocities (in excess of those encountered during the pre-monsoon and early monsoon). Correcting the design may also be warranted.

It is not presently clear if the design should be altered. It may be argued that migration of fish from *haor*-to-river during the pre-monsoon and early monsoon seasons (in effect, a loss of fish from the *haor*) is undesirable, given that the objective of the project is to rehabilitate the Kawadighi Haor fishery. The recharge of river fish stocks is mainly from the other four mother fisheries in the region and the upper river basin in India and Burma. The contribution from Kawadighi Haor is negligible. The reduction of water velocity at the slots during the pre-monsoon and early monsoon seasons would therefore not be necessary.

Movement of fish into the *haor* during the late monsoon would certainly be desirable. The 6-vent regulator is open at this time to drain the *haor*, but water velocities are too high for many fish species to swim against the current and enter the *haor*. There is also a change in the flow state across the regulator, from subcritical to supercritical, due to the Venturi effect of the regulator opening. Water velocity instantaneously changes from 0.5 m/sec to about 2.0 to 2.5 m/sec - a transition which most fish are unlikely to tolerate. It is observed, however, that fish are trying to move from river-to-*haor* during this period. Consideration could given to possible design changes to reduce water velocity inside the fishpass during the late monsoon period.

A second possible design problem concerns the complex layout of the R/S access channels. It could be redesigned to make it more likely for fish to locate the entrance to the fishpass. It was observed that during the pre-monsoon and monsoon seasons numerous fish are attracted to the pumping channel by the outflowing *haor* water, though they are of course unable to enter the pipework. It may be proposed to cut an access channel between the pumping channel, the 6-vent regulator, and the fishpass. This would allow fish to migrate laterally from the pumphouse to the fishpass, and then migrate into the *haor*.

5. IMPACTS OF FISHPASS

5.1 Impacts on Fisheries

5.1.1 Methodologies for Fisheries Studies

Catch assessment surveys (CAS) were used to obtain information on fish production in Kawadighi Haor, and also in the Kushiyara River. Routine weekly visits were made to survey sites (Patasingra beel, Salkatua Majerban beel, Rukka beel, Melagor beel, Akhali canal) and data was collected from fishermen on fish catch and effort that was used to compute production.

As the estimates of production generated by the CAS are subject to sampling bias and error (in part, due to the modest resources that were available for this activity), a simple monthly 'index of abundance' for individual species was developed as an alternative indicator estimate of production, biodiversity and standing crop. The index ranks the abundance of individual species each month in *haor* and river as high (3 points), medium (2), low (1) and not recorded (0). Ranking is based on discussion and interview information received from fishermen about their catches, and regular surveys of fish market supplies. The index is useful as a broad indicator statistic, and is comparable to the fishermen's own conceptual stock assessment ranking system (i.e.: a species is either very abundant, moderately abundant, in low abundance or absent).

5.1.2 Changes in Fish Production and Biodiversity

Yields to the Openwater Capture Fishery
NERP and later FPP carried out regular catch assessment surveys in Kawadighi Haor during the monsoon floodplain fishing season and *beel* fishing (dry) season since May, 1992. Relevant pre-FPP and with FPP average production data is presented in Table 5.1, and shown in Figure 56.

Table 5.1: Change in Average Fish Production in Kawadighi Haor after Construction of Fishpass

	pre-FPP (1992 & 1994)	with FPP (1995 & 1996)	% Increment
Monsoon floodplain (tonnes)	412	553	34.2%
Dry season *beels* (tonnes)	58	175	201.7%
Total catch (tonnes)	470	728	54.9%
Flood intensity * (mcm-months)	1,475	1,649	11.8 %

* Calculated as the area under the annual flood volume curves in Figure 70 and 71, from 1 May to 30 April. See also Table 5.9 and Figure 72.

Production data for individual year is presented in Table 5.2.

Table 5.2: Annual Fish Production and Flood Intensity for Kawadighi Haor

	pre-FPP			with FPP		
	1992	1993*	1994	1995	1996	1997**
Monsoon floodplain (tonnes)	314	572	509	539	567	296
Dry season *beels* (tonnes)	23	229	92	149	200	n/a
Haor total (tonnes)	337	801	601	688	767	n/a
Flood intensity (mcm-months)	1,526	2,433	1,423	1,748	1,549	1,611

* Production data for 1993 is unusable as it represents an abnormal year due to the massive breaching of the MRIP embankments (resulting in a large influx of fish from the river, and therefore mimicking the behavior of the fishpass).

** Data for 1997 (Year 3) is incomplete as field work was terminated at the end of September 1997.

The overall *haor* production increased by 54.9% after fishpass construction. Mean monsoon floodplain production increased by 34.2%, while *beel* production increased by 201.7%.

Monthly monsoon catch data by different gears in presented in Appendix F (Table F.7) and summarised in Table 5.3.

Table 5.3: Total Monsoon Season Catches for Various Fishing Gears in Kawadighi Haor

Total Catch (tonnes)	1994	1995 Year 1	1996 Year 2	1997 * Year 3
Konajal/berjal	105.5	150.5	125.2	16.2
Gillnet	119.2	148.2	134.3	120.5
Thelajal	174.3	118.1	140.2	58.0
Hook & line	87.1	122.1	83.2	72.0
Utherjal	5.8	5.6	5.0	1.0
Vashaljal	13.1	15.7	12.1	21.2
Chai	4.4	6.9	6.3	6.7
TOTAL	509.4	567.1	506.3	295.6

* Incomplete year (up to Sept 1997).

Seine nets (*konajal, berjal*), gillnets (current *jal*) and push nets (*thela jal*) account for the largest portion of production in most years. The seine net output in 1997 was much reduced due to enforcement of a ban by the leaseholder (the reason given was to protect stocked carp fingerlings). *Beel* production data by fishing gear is presented in Appendix F (Tables F.8 and F.9).

The species composition of annual fish catches from the *haor*, for 1992 to 1997, is presented in Appendix F (Tables F.1 to F.6). Average pre-FPP and with FPP production levels for the main species groups are shown in Figure 57. Substantial increases have been recorded for all groups.

Floodplain fisheries production theory is based on the highly significant effect of flood intensity on production. Accordingly, any observed year to year differences in fish production of Kawadighi Haor may in part be due to annual variations in flood intensity. Moreover, the positive impact on fish production of a high flood intensity year can be carried over into one or more succeeding years due to the lag effect of growth of longer lived large species, which might only be recruited to the fishery at 2 or more years of age. This is less likely for large species in Kawadighi Haor given the current practice of dewatering and complete *beel* harvesting (stocks of small species probably suffer slightly less damage from dewatering than large species).

The relationship between flood intensity (Table 5.9) and annual *haor* fish production is shown in Figure 58. There is a positive but weak correlation between the two parameters. This suggests that part of the increase in average *haor* fish production since fishpass construction may be due to the greater average flood intensity of 1995 and 1996. However, the difference in average pre-FPP and with FPP flood intensity for the years monitored is only 11.8% (Table 5.1), and cannot by itself account for the observed increase in average fish production of 54.9%. The relationship in Figure 58 suggests that an 11.8% increase in flood intensity would only increase fish production by about 8 to 9%. A small portion of the residual production increment can be attributed to carp stocking (see below), but the greatest part is likely due to the impact of the fishpass.

Changes in Fish Biodiversity

Comparison of the number of species occurring in the MRIP before and after the construction of the fishpass indicates that the project has had a positive impact on fish biodiversity in Kawadighi Haor as shown in Table 5.4.

Table 5.4: Summary of Species Numbers in Project Area

Location	Species Numbers		
	Indigenous	*Non-Indigenous*	*Total*
Kawadighi Haor w/o fishpass (1992)	77	3	80
Kawadighi Haor w fishpass (1996-97)	92	3	95
Kushiyara River	113	3	116
Northeast Region	145	8	153

A total of 116 species have been recorded from the Kushiyara River, but only 80 from Kawadighi Haor prior to FPP. Since construction of the fishpass, the net number of species in the *haor* has increased by 18.8% to 95.

Comprehensive data on species numbers and occurrence is presented in Table A.34. The database suggests that species can be categorized into several groups:

- 74 species occur in the river and in the *haor* (both pre-FPP and with FPP). 68 of these species were recorded in the fishpass during at least one of the operational years;

- 3 other species occurring in the river were recorded in the *haor* prior to FPP, but have not been recorded in the *haor* since FPP. Two of these are very rare carps (*angrot* and *nandina*). The third is a large catfish (*rita*) which was recorded in the fishpass during Year 1, but does not appear to have established itself in the *haor* as of yet;

- 19 other species occur in the river, were not recorded in the *haor* prior to FPP, but have been recorded in the *haor* since FPP. All these species have also been recorded in fishpass samples. It would seems likely that the fishpass is directly responsible for the re-establishment of these 19 species in the *haor*;

- 20 other species occur in the river, but have never been found in the *haor* (either pre-FPP or with FPP). These species have also never been recorded in fishpass samples. It seems likely that these species are entirely riverine in habits and do not enter floodplains during any part of their life cycles, and

- 3 other species have not been recorded from the river, but are known only from the *haor*. Two species occur in the *haor* both pre-FPP and with FPP, and were also recorded in fishpass samples. A third species is known only from the *haor* pre-FPP.

The grouping of some of these species may change in the future. The fish biodiversity of the *haor* may be regarded as still in a transitional state due to the impact of the fishpass.

Index of Abundance

Monthly data for index of abundance in Kawadighi Haor and the Kushiyara River for the period May 1992 to September 1997 is presented in Appendix F (Table F.11). Trends in abundance for selected species are shown in Figures 59 to 66. The abundance indices for the Kushiyara River are generally in agreement with production data derived from CAS (Appendix F, Table F.10). Most species show higher abundance in the river than in the *haor*.

There are two general abundance trend patterns for species that appear to have been benefited from the fishpass:

- Species such as *bacha*, *bagair*, *gonia* and probably also *lachu* appear to have been excluded from the *haor* prior to FPP (except for a brief appearance in 1993 due to the embankment breach), but have become regular components of the *haor* ichthyofauna since FPP, and

- Species such as *air*, *golda chingri*, *kalibaush* and *mola* were regular components of the *haor* ichthyofauna prior to FPP, but have become more abundant year round since FPP.

More complete re-establishment of *haor* fish biodiversity and abundance will likely take several more years. This process would be enhanced, accelerated and consolidated by the termination of *beel* dewatering and total harvesting, and by improvement of environmental quality of the *haor*. Conversely the process will be undermined and weakened in the absence of such desirable ancillary initiatives.

Floodplain Stocking of Carp Fingerlings and Pond Escapade

The level of catches and standing crop of major carp in the *haor* were not entirely due to natural reproduction, as both floodplain stocking programmes and escapade from ponds contributed to production. Floodplain stocking programmes were carried out in Kawadighi Haor in 1993 and 1995 by the DOF under the 2nd Aquaculture Project (Asian Development Bank-financed). In 1997, some fingerling of carp were stocked by the main leaseholder of the *haor*. The record of carp species and quantities of fingerlings stocked in presented in Table 5.5.

Table 5.5: Record of Stocking of Kawadighi Haor

Period	Location	Quantity		Size (cm)	Species
		Wt (kg)	Approx. no.		
Stocking by DOF (2nd Aquaculture Project)					
Aug. 3, 93	Patasingra	1,200	120,000	7.5-10	*Rui, Catla, Mrigel*
Jun 27-28 95	Patasingra	4,236	423,600	7.5-10	*Rui* 730 kg
Stocking by leaseholder					
March 3 97	Salkatua &		40,000	7-8	Carpio
May 1 97	Salkatua &		60,000	7-8	*kalibaush, Catla*

The actual impact of stocking on *haor* catches in not clear. During the monsoon, many fishermen (who pay *tole* to the leaseholder) caught carp fingerlings, despite instructions not to catch them. The fingerlings were sold to pond owners. According to one pond owner from Pailanpur, pond owners usually ask the fishermen to supply *haor* fingerlings as these are better value than seed from nurseries. Haor fingerlings are larger in size, healthier, cheaper (Tk 125 per 100) and no transportation cost is involved. Fingerlings removed for pond stocking would therefore not contribute to *haor* catches.

On the other hand, flooding of ponds occurs during years of heavy flooding (i.e.: 1993). This allows fingerlings (as well as larger carp) to escape to the *haor*, where they would contribute to *haor* catches.

5.2 Impacts on Hydrology

5.2.1 Water Balance Model

A mathematical model was developed to investigate the water levels in the MRIP (Appendix H). Total inflow into the project area and total outflow from the project were used to predict the impact of the flow system on the project water levels. The model estimates quantitatively any inflow or any outflow. The impact of fishpass inflow is analysed, and the effect is described quantitatively in the model.

The databases used in the model are water levels, rainfall, evaporation, pump drainage, irrigation inflow, fishpass inflow/outflow, sluice outflow, and topography of the project area. Both observed measurements and theoretical measurements were used to study the water balance. This model represents a quantitative comparative statement of different flow system.

A detailed description of the model and its application at MRIP in 1996 is presented in Appendix H.

5.2.2 Impact of Fishpass on Haor Hydrology

The MRIP is bounded by the Kushiyara River to the north, the Manu River to the south and east, and the Bhattera Hills to the east. Some 11 channels and many culverts carry runoff from the Bhattera Hills catchment into MRIP. The upper catchment slope is very steep compared to the flat floodplain and *haor* slopes. Any flood or rainfall in the upper catchment usually results in immediate inundation of the *haor*. The MRIP water level is therefore not only governed by rainfall within the project area and river levels, but is also highly influenced by the hydrological conditions in the upper catchment.

During the pre-monsoon and monsoon seasons, sources of inflow are direct rainfall, upper catchment runoff, and the fishpass. Outflow can occur through the 6-vent regulator, 3-vent regulator, pumping station, and fishpass. The design capacity of the pumping station, which has eight pumps, is 34 m^3/s. The maximum water loss through evaporation is 7.6 mm/day. Percolation loss is about 2 mm/day. During the pre-monsoon and the first half of the monsoon seasons, the fishpass acts as an inlet structure. During the latter part of the monsoon, and at post-monsoon it acts as a drainage structure.

Nominal *haor* water area and volume at various water levels is presented in Table 5.6.

Table 5.6: Nominal *Haor* Water Area and Volume at Various Water Elevations

Project Water Level (m PWD)	Area Submerged (ha)	Project Volume (ha-m)	Maximum Flooding Depth (m)
5.0	3,667	4,016	4.0
5.5	4,745	6,120	4.5
6.0	5,645	8,715	5.0
6.5	6,716	11,808	5.5
7.0	8,279	15,524	6.0
7.5	10,377	20,169	6.5
8.0	12,807	25,941	7.0
8.5	15,301	32,954	7.5
9.0	18,266	41,340	8.0

The project area consists of 24,300 ha. The elevation-area-storage curve (Figure 67) indicates that maximum inundated area of the project in Year 1, Year 2, and Year 3 were 18,266 ha, 15,418 ha, and 18,025 ha, respectively.

The effect of inflow through the fishpass on the MRIP water budget was estimated using measured discharges from the fishpass and the MRIP elevation-storage-area curve. The average flow across the fishpass during the pre-monsoon and monsoon seasons is 0.5 m^3/s and 0.8 m^3/s respectively. No losses such as evaporation, percolation, and pump outflow are considered for affected area computation. The comparative inflow and outflow system is presented in Appendix H.

Table 5.7 shows the cumulative area affected at various months due to inflows through the fishpass under the existing conditions (with pump). The additional inflows were computed based on the measured differences between the project and the river water levels. These inflows were then added to the project storage volumes. The additional depth of flooding due to fishpass and corresponding area affected were analyzed from the area-elevation and storage volume data. This analysis has been carried out for Years 1 to 3 and is presented in Appendix G (Tables G.15 through G.17).

Table 5.7 also shows the cumulative area affected under the normal conditions (without pump). The normal condition represents a simple FCD project without any unusual inflows from upstream *chhoras,* irrigation water supplies, and leakage through the hydraulic structures. These inflows do not exist in most of the FCD projects of Bangladesh.

Hydrological and flood routing analysis were carried out for MRIP in order to estimate the impacts of fishpass under the normal conditions (without pump). The following data of Year 2 were used for the hydrological analysis:

- river water level;
- rainfall;
- infiltration;
- evapotranspiration;
- iinflow / outflow through fishpass, and
- outflow through the regulator.

The analysis shows that additional area inundated (without pump) during the pre-monsoon season (April-May) is about 60 ha and during the monsoon season (July-September) ranges between 109-126 ha (Table 5.7). The analysis also shows that the impacted area during the pre-monsoon and monsoon seasons are not significant particularly for the MRIP. This analysis gives an impression of impact on agriculture at other FCD projects of Bangladesh with similar size and topography (Table G.18, Appendix G). However, the impact could be increased significantly with the decrease of project area and under the changed topographical configuration. This suggests that the project size and topographical configuration (area-elevation and storage volume) will be a critical factor in selecting the location of fishpass.

In Year 1, the maximum project water level was 9.1 m PWD. The maximum storage in the project area was 41,340 ha-m. In Year 2 maximum project water level was 8.5 m PWD and corresponding storage was 32,954 ha-m. In Year 3 maximum project water level was 9.0 m PWD and corresponding storage was 40,640 ha-m. Pre-monsoon and monsoon season flood depth intensity maps (Year 2) are shown in Figures 68 and 69, respectively. Annual flood volume curves from the years 1992 to 1997 are shown in Figures 70 to 71. Monthly average project area submerged and corresponding storage for Year 1, Year 2 and Year 3 are summarised in Table 5.8.

202

Table 5.7: Effect of Fishpass Inflow on Inundated Area inside MRIP

Month	Av. Fishpass Inflow (m^3/sec)		Cum.Area Affected (ha)		Cum. Additional Flooding Depth (cm)		Cumulative Pumping Hour	
	With	Without	With	Without	With	Without	With	Without
Year 1:1995								
May 15	0		0		0		0	
May	0.63		25		2		45	
June	0.68		107		2		161	
July	0.89		171		3		314	
August	0.65		188		4		394	
September 06	0.43		188		4		406	
Year 2: 1996								
March	0.26	0.29	14	21	1	1	13	15
April	0.55	0.60	74	134	6	7	85	92
May 15	0.25	0.28	91	150	6	8	106	116
May	0.69	0.77	133	223	6	11	206	227
June	0.88	1.06	253	329	7	10	354	408
July	0.96	1.26	284	393	6	9	522	629
August	0.59	0.88	342	468	7	9	622	784
September 12	0.46	0.63	352	468	7	9	644	826
Year 3: 1997								
March	0.04		0.70		0		0.63	
April	0		0.70		0		0.63	
May 15	0		0.70		0		0.63	
May	0.45		21		1		29	
June	0.80		112		3		164	
July	1.05		189		4		374	
August 23	0.78		245		5		448	

Note: "with" refers to MRIP at existing situation (with pump).
"without" refers to MRIP without pumping and without upstream flows (normal condition).

Table 5.8: Summary Data of Areas Submerged and Storage Volumes

	March	April	May	June	July	August	September
Project Area Submerged (ha)							
Year 1	1,150	1,831	2,354	5,387	13,904	17,363	17,182
Year 2	3,338	2,405	3,797	7,340	13,570	14,312	14,520
Year 3	412	2,269	3,104	7,695	13,189	14,884	
Project Storage (ha-m)							
Year 1	730	1,393	1,984	7,957	29,023	38,713	38,187
Year 2	3,543	2,058	4,252	13,498	28,085	30,170	30,756
Year 3	150	1,861	3,206	14,272	27,012	31,782	

Flood intensities have been calculated for the years 1983 to 1997 (Table 5.9). Average flood intensity of MRIP is 1,562 mcm-month for normal years without embankment breaches. In Year 1 flood intensity was 1,748 mcm-month which is 11.9% above the normal average. In Year 2 and Year 3 flood intensities were 1,549 and 1,611 mcm-months, respectively, which were near average (-0.8%) and above average (3.1%), respectively. Flood intensities are shown graphically in Figure 72.

Table 5.9: Flood Intensity Index for MRIP

Period	Year	Flood Intensity Index (mcm-months)	% deviation from normal year mean
NORMAL FLOOD YEARS (no embankment breaches)			
Pre-FPP	1983-84	1,775	13.6%
"	1986-87	1,220	-21.9%
"	1987-88	1,418	-9.2%
"	1989-90	1,644	5.2%
"	1990-91	1,707	9.3%
"	1992-93	1,526	-2.3%
"	1994-95	1,423	-8.9%
Year 1 w-FPP	1995-96	1,748	11.9%
Year 2 w-FPP	1996-97	1,549	-0.8%
Year 3 w-FPP	1997-98	1,611	3.1%
	Normal mean =	1,562	
ABNORMAL FLOOD YEARS (with embankment breaches)			
Pre-FPP	1984-85	2,070	32.5%
"	1985-86	no data	
"	1988-89	2,238	43.3%
"	1991-92	no data	
"	1993-94	2,433	55.8%
	Abnormal mean =	2,247	43.8%

5.3 Impacts on Agriculture

5.3.1 Land Use inside MRIP

The net cultivated area of MRIP covers more than 75% of the gross project area. Land type varies from non-flooded to deeply flooded land including *beels* and *haors*. Under present conditions, 45% of the cultivated area can be considered to be free from flooding and 10% shallowly flooded. More than two-fifths of the cultivated area floods to a depth of more than 90 cm and is mostly used for single cropping. Therefore, this land is subject to major cropping constraints due to the flooding in pre-monsoon and monsoon, and late drainage in the post-monsoon. The main crops grown in this area include deepwater *aman*, local transplanted *aman* and local *boro*. The deepwater *aman* and transplanted *aman* are planted in the premonsoon season and early monsoon season, respectively. They are harvested in the beginning of the dry season. The growth period of the local *boro* extends from mid winter to the premonsoon season.

5.3.2 Possible Inundation Risks to Rice Crops

The fishpass represents an environmental mitigation measure for some of the negative effects suffered by the fisheries sector from construction of MRIP, whose primary intended beneficiary is the agriculture sector. The inflow of water through the fishpass during the premonsoon and early monsoon flood surges of the Kushiyara River might have a certain potential for diminishing the incremental gain to agriculture afforded by MRIP in low lying areas. Any significant changes in the water regime and inundation of low elevation land during the premonsoon season caused by the fishpass could result in the submergence of deepwater *aman* rice at an early vegetative growth stage and *boro* rice at the ripening stage. Moreover, the *aus* crop could also be inundated and transplantation of *aman* seedlings could be delayed in medium highlands. Late transplantation will reduce the yield level as the plants would not get sufficient time for their vegetative growth.

5.3.3 Impacts on Rice Crop During Year 1

There was considerable apprehension within the agricultural community concerning the possible damage that the fishpass might inflict on rice crops. While there was reason to believe that this apprehension was largely a psychological problem (i.e.: fear of the unknown) rather than an actual hydrological threat, FPP nonetheless followed a strategy of being at all times highly responsive to the perceptions, sentiments and concerns of the local population. The record of complaints received against the fishpass gate and follow-up investigation of actual impacts is given below.

The fishpass began operating on May 24, 1995. This corresponded to declining water level phase of the Kushiyara's main premonsoon flood surge. On May 26, 1995 a number of people from Kashimpur village asked the BWDB to close the gate of the fishpass. They felt that the water passing through the fishpass represented a threat to their *aman* rice crop. The structure was closed for one day and then reopened. The premonsoon flood surge was shortlived and the water level quickly dropped again in the river and the *haor*, and the fishpass stayed open without any protest.

Two weeks later, water level began rising quickly in the *haor*, and on June 17, 1995 some people again asked for the fishpass to be closed. At that time the *haor* had started flooding due to heavy rainfall, and the BWDB had started pumping water out of the *haor*. The fishpass was closed, but despite both the pumping and the closure of the fishpass, water level within the *haor* continued to rise. It became apparent to the people that the amount of water being discharged by the fishpass into the *haor* had little effect one way or another on the flood level in the *haor*, and that most of the flooding was due to rainfall. Water level continued to rise and people felt less threatened by the discharge from the fishpass. The structure was re-opened.

One week later, water level began to drop in the *haor*. On June 20, 1995, the local crop cultivators again asked for the fishpass to be closed. Those people who had *aman* rice under water wanted to see if the waters would recede enough to save their crop. They were therefore opposed to letting any additional water in through the fishpass, as they felt this would keep water levels high. However, water levels continued to rise due to rainfall, and there was no public opposition to keep the fishpass open.

On June 23, 1995, some crop cultivators again came with a demand for closing of the fishpass with an apprehension that if it is kept open their seed bed may be inundated due to discharge of additional water. The fishpass was again closed and the matter was investigated by the fishpass team. After investigation it was found that the seed beds are in the highlands and beyond reach of flood waters. The gate of the fishpass was re-opened on June 25, 1995.

Some people again demanded closing of gate on July 18, 1995 as they felt that their *aman* seed bed might get submerged. Despite their demand, the gate was kept open as the C/S water level at that time was in declining and dropped from 8.21 m PWD on July 16, 1995 to 8.17 m PWD on July 18, 1995. The complainants were so informed and no one was found with adverse opinion. On July 19, 1995, BWDB issued a letter to the NERP requesting closure of the gate. But at that time (07:00 in the morning) the R/S and C/S water levels were 8.76 m and 8.22 m PWD (C/S started rising again), respectively, giving a head difference of 0.54 m. The *Katari* rice (local transplanted *aman*) was under water. Saving this crop would have required drainage of about 1.5 m of water, and the pumping capacity to achieve this was inadequate. Due to drought, transplantation of *katari* rice was late this year and the stems of the rice plants were not long enough to withstand the monsoon water. But the reason that led the people to request closure of the gate was something other than the state of *katari* crop. Some people who have a pond inside the *haor* area at Islampur village where they culture fish took an initiative for closing the gate. The bank of the pond is not high enough and was vulnerable to inundation by flood, and they were afraid of losing the fish stock. They collected signatures from other people and handed a petition to the local BWDB staff, arguing that crop land was in danger. On getting petition the fishpass was closed. Some other people of the adjacent villages came to the fishpass team and reported that there was no crops in the field which were susceptible to damage and fishpass could be kept open. Leaders and some members of the fishermen community met with local district administration and local DOF officials with a demand for its opening. In that situation, the Project Coordinator met and discussed the matter with local people and arranged a meeting with local BWDB officials, Superintending Engineer, Moulvibazar and Director (Planning Scheme 1), Dhaka, and reached a consensus. Finally, the fishpass gate was re-opened on August 1, 1995.

On August 13, 1995, heavy rain fell and the water had risen to its highest level on the countryside. People of the locality perceived that the additional water passing through the structure might result in some crop loss. They demanded that the gate be closed. After analysing the whole situation, and also to show respect to the people's fears, the fishpass was closed. It was reopened on September 6, 1995 after the perception of danger had passed. After that date, the *haor* level was consistently higher than the river level, resulting in reverse flow through the fishpass (i.e.: fishpass began acting as a *haor* drainage structure). No complaints have been received since.

FPP staff at the time of their field visits to the villages during the second week of November, 19 95 found two crop cultivators groups in a state of conflict over the operation of the 6-vent regulator. One group wanted the regulator to be kept open for rapid *haor* drainage, and quick drying of their lands at lower elevations. The other group owns land it higher elevation and wants the regulator closed in order to retain water for dry season irrigation. Both groups have come to the local BWDB officials with their own demands. To 'resolve' the problem, 3 gates out of 6 are now kept closed, thus slowing *haor* draining.

5.3.4 Impacts on Rice Crop During Year 2

During the first pre-monsoon flood on 3 March, when the water crossed the fishpass R/S invert level, the gate was opened for the first time in Year 2. At that time, farmers asked for the fishpass to be closed. They were apprehensive that the water would be an additional threat to the ripened crops. The crops in low-lying areas were already highly exposed to inundation due to rainfall and water discharged by hilly streams. Immediately after the protest, the fishpass was closed. The water levels subsequently dropped below the R/S invert level. To adopt a strategy for operation of the fishpass and proper management of the sanctuary, and also to address the protests which may occur in the future, a meeting was organised on 24 April. Representatives of local people, farmers, and fishermen, as well as officials from BWDB and DOF participated. In the meeting, the objectives and impacts of the fishpass, the process of inflow of water through fishpass, and areas affected in the previous year were reviewed. When it was realised that the fishpass would not have a significant impact on the water level in the *haor*, a consensus was reached to form a committee to handle the matters required for smooth operation of the fishpass. Immediately after formation of the committee, some decisions were taken to operate the fishpass without interruption. Several meetings were held subsequently to follow up on the decisions of the first meeting. The minutes of the meetings are included in Appendix K. The committee cooperated fully with the FPP team, and the team did not face any objection or protest to the operation of the fishpass.

During Year 2, the crops grown kn the MRIP area during the AOP of the fishpass were deepwater rice (broadcast *aman*) and *aus*. The transplantation of *aman* crops started in late August. Local *boro* was reported to be completely harvested about ten days before the opening of the structure. The HYV *boro* crops were at a mature stage, and on relatively higher land.

The plantation of broadcast *aman* rice started in lower parts of the medium lowlands in late April. It continued in the relatively higher parts until late May. The crop grown in the lowlands was at the vegetative growth stage when the fishpass structure opened. No farmer complained that the additional flow through fishpass structure had inundated or damaged broadcast *aman* crops. This suggests that the plants had sufficient time to elongate with the gradual rise of flood water.

In the northeast area of the *haor*, transplanted *aman* could not be cultivated because the seed beds were covered by water hyacinth.

During Year 2, the impact of pre-monsoon runoff from the Bhattera Hills on crops was negligible. The volume of pre-monsoon and monsoon floods was not large. Seasonal rainfall was low. It appeared that additional inflow of water into the *haor* through the fishpass structure did not create any problem for cropping.

5.3.5 Impacts on Rice Crop During Year 3

The Operation Committee met on April 7, 1997 to discuss their plans for the fishpass opening in the critical pre-monsoon season and their role in managing the fish sanctuary.

The first pre-monsoon flood occurred suddenly on March 15, 1997. The fishpass was open as part of the regular dry season schedule but it was immediately closed when the water dropped below the fishpass R/S invert level. The flood lasted for only one day. No damage was reported to the rice crop in the distant *haor* because the minimal volume of flood water was mostly absorbed by dry land near the fishpass.

There was minor river surging in April but the water did not rise above the fishpass R/S invert level. The first monsoon flood occurred on May 22, 1997, at which time the fishpass was officially opened for the season.

The crops grown during the AOP of the fishpass included broadcast *aman* (a deep water crop), *aus* (broadcast local, transplanted local and transplanted high yielding varieties) and transplanted *aman*.

Boro rice crops (local variety and HYV) were not damaged by water entering the *haor* through the fishpass. The local *boro* crop was harvested 20 days before opening the fishpass. Although the HYV *boro* crop had reached a mature stage during the AOP, its location on high land prevented this crop from being damaged as a result of water passing through the fishpass structure.

The broadcast *aman* was grown on medium low and low land between late April and late May. Farmers reported no damage to broadcast *aman* because it had reached the height of the vegetative growth stage when the fishpass was opened. All types of *aus* crops were grown in May and June and harvested in August, with no reports of damage because the fishpass did not influence the level of water in the *haor* during the monsoon period.

The transplantation of T. *aman* was completed by early September, when the *haor* water level had begun to recede. This crop is never damaged by water from the fishpass. In Year 3 however, approximately 400 ha of T. *aman* was submerged by one week of heavy rainfall, which began on September 19th. During this sudden rain in the latter part of the monsoon period, water was drained from the *haor* to the river as per routine schedule, through the 6 Vent and 3 Vent Regulators and the fishpass. The BWDB pumphouse was normally closed in this period. Although the pumphouse was opened to drain the extra rain water congested on the *hoar*, it could not adequately pump the volume of water which resulted from this unusual rainfall. As a result, 50 hectares of T. *aman* were fully damaged and 150 hectares were partially damaged.

In Year 3, no farmers reported damage of rice crops as a result of water on to the *hoar* through the fishpass during its AOP.

5.3.6 Year-wise Comparative Impact of Fishpass on Agriculture

The fishpass has not produced any negative impact on rice cultivation and production in the MRIP. Data from BWDB (Moulvibazar) and the Thana Agriculture office (Rajnagar) on total cultivated area, total rice production and yield per hectare (Tables A.36 to A.38) substantiates FPP field observations.

Within the total MRIP, 1994 has been considered as the base-line year for comparison of cultivated area, rice production and yield per hectare following the opening of the fishpass in May 1995.

- Area Cultivated: Table 36 presents a comparison of the total area under rice cultivation in the MRIP between 1994 and 1997. In 1994 the cultivated area for rice was 17,515 ha, whereas by 1997, the total area for rice cultivation was 29,910 ha. Since the base-line year of 1994, there has been a 71% increase of cultivated rice area. As farmers were willing to increase the area under rice cultivation following the opening of the fishpass, they obviously neither anticipated, nor experienced crop damage as a result of water passing onto the *haor* from the fishpass.

- Rice Production: Table 37 presents a comparison of the total rice production in the MRIP between 1994 and 1997, although a portion of rice production is not calculated for 1997 because the harvest had not been completed at the time of data collection for the final report. Based on the total rice production up to 1996 (where the data is complete), the rice production from all varieties, in all seasons was 58,437 tonnes in 1994. By 1996, farmers had produced 90,386 tonnes of rice for a production increase of 55% over the base year in 1994.

- Rice Yield: Table 38 presents a comparison of the yield per ha of rice cultivated in the MRIP between 1994 and 1997, although a portion of rice production is not calculated for 1997 because the harvest had not been completed. Based on the 1996 completed data, there has been an increase of per hectare production for all varieties of rice, grown in the MRIP area, in different seasons, among the years 1995, 1996 and 1997. The increase of per hectare production varies from 1% to 10%.

Contrary to local apprehension among farmers at the time the fishpass was built, there has been no negative effect of the fishpass on rice production. As was expected, the fishpass has not impacted rice production. The increase in rice production in the MRIP since 1994 is most probably a result of changed cropping patterns, from local varieties to high-yielding varieties. This pattern is consistent with changing cropping patterns experienced in other parts of Bangladesh. As well, there have been favourable weather conditions over the past three years, with no exceptionally high floods in the Kawadighi Haor. Agricultural inputs, such as fertiliser were readily available in 1996 and 1997.

The FPP has always been careful to consider the opinions of farmers during operation of the fishpass and in particular, to include the farmers views in setting the dates for opening the fishpass in the pre-monsoon season. In addition, FPP staff have been effective in strengthening the local Operations Committee to settle any disputes which have arisen about fishpass operation. FPP staff have also conducted information campaigns to alleviate any fears which farmers may have had about the impact of the FPP on their crops (Appendix K).

207

5.4 Socioeconomic Impacts

5.4.1 Impacts on Various Beneficiary Groups

Following construction and fishpass operation in May, 1995, the majority of fishermen in the area were informed about the purpose of the fishpass. According to a survey conducted (Table A.39), most seasonal fishermen (62%) received information from other fishermen, while the majority of full-time fishermen (41%) received their information from discussion with other local people. Information provided by FPP contributed to fishpass knowledge for 10% of full-time fishermen and 18% of seasonal fishermen. Because the fishpass is located at a considerable distance from most fishing villages, only 14% of full-time fishermen and 3% of seasonal fishermen had ever travelled to Kashimpur to see the fishpass.

5.4.2 Changes in Income from Fishing

Data on fishing income was collected during a series of fishermen surveys on 67 full time fishermen and 135 seasonal fishermen. Dry season fishing data was first collected in December, 1995, and January, February, and March, 1996. A second round of dry season fishing data collection was in March 1997. Data on monsoon season fishing (May to October) was collected for the 1996 and 1997 seasons.

For the purposes of comparison of fishermen income in the Kawadighi Haor, data has been gathered by the Sociology Group on the following basis (although this differs from the normal fish production estimation procedure used throughout this report):

- Year 1: Dry season 1994-1995, monsoon season 1995;
- Year 2: Dry season 1995-1996 and monsoon season 1996, and
- Year 3: Dry season 1996-1997 and monsoon season 1997.

The average daily income of fishermen shows a significant increase from Year 1 to Year 3. The average daily fishing income per fishermen during the dry season was Tk 61 in Year 1; Tk 82 in Year 2 and Tk 98 in Year 3. The average daily fishing income per fishermen during the monsoon season was Tk 96 in Year 1, Tk 130 in Year 2, and Tk 127 in Year 3 (Table A.40).

Increased fishermen income is related to many factors, including an increase in catch, an increase in high value fish species, higher market prices for fish and an increase in the number of local fish markets. The income data does not include the value of fish consumed per household.

The drop in monsoon fishing income between Years 2 and 3 is related to the late onset of the 1997 monsoon, resulting in reduced fishing days. In addition, in 1997 the major leaseholder of Kawadighi Haor prohibited the use of *kapri* and *pai* nets, which resulted in reduced monsoon catch. The leaseholder monitored his stated prohibition of gear through the use of his *paharadars* who routinely patrolled fishing areas in the *haor*. As the leaseholder does not earn his main income from the monsoon catch, it is most probable that by limiting monsoon fishing, he expected to benefit from an increased catch during the 1997-1998 dry season fishing period.

5.4.3 Changes in Fish Consumption

Methodology: Data on household fish consumption was collected by the Sociology Group for comparison in Years 1, 2 and 3 in a series of fishermen surveys, using a sample group composed of 67 full-time fishermen and 135 seasonal fishermen. Data was first collected in 1996 on fish catch, sale and consumption for the monsoon season fishing. Data on household fish consumption was collected over a 7 day period. Per capita fish consumption was calculated on the basis of actual household size. Depending on the land-holding category, the data on consumption is based on fish catch only, during the monsoon season and on the combination of fish catch and purchase during the monsoon and dry seasons. Data on the types of fish species consumed was collected for the dry season of 1995-1996 and 1996-1997 and for the monsoon of 1996 and 1997.

The data collected on fish consumption provided a limited base for making a socio-economic analysis of fish consumption. Moreover, the data was only for two years. Under the best of circumstances, consumption studies are difficult. In the case of the FPP, no baseline consumption data was collected prior to the opening of the fishpass. The fishermen surveys were introduced at a late stage of the impact monitoring. Moreover, the survey design did not adequately account for error in reducing the data to a measurement of 'grams per capita'. Fishermen reckoning of consumption at household level in different years and in different catch seasons is too unreliable for such a precise measurement. The analysis of catch, purchase, sale and consumption is limited because the surveys were an incomplete investigative tool. A complete assessment of catch, purchase, sale and consumption should have included data on a wide range of variables. At a household level, material was required on surplus rice production, labor opportunities, purchasing power, the types of gear possessed, production relationships with the leaseholder during *beel* fishing and access to *hoar* fishing locations during monsoon fishing.

Consumption from Only Catch during the Monsoon Season: This data is based on consumption from catch only. Since the opening of the fishpass there has been an upward trend in fish catch, which is positively correlated to increased fish consumption from catch in all categories of households during the monsoon period. In the 1997 monsoon period, the daily consumption of fish per capita is as follows: middle farmer households - 110 g; landless households - 75 g; large farmer households - 74 g and small farmer households - 68 g. (Table A.41).

Consumption from Catch and Purchase during the Dry and Monsoon Seasons: This data is based on consumption from catch and purchase. Although there is an upward trend of per capita fish consumption from catch and purchase for medium farmers between the dry seasons of 1994-1995 and 1996-1997, consumption for small farmers has no significant increase and consumption for landless households has dropped in this period (Table A.42).

In the dry season of 1995, the daily fish consumption of medium farmer households increased from 42 g to 62 g in 1997. In the same period the daily consumption for small farmer households increased by only one gram from 35 to 36 g. The daily consumption of landless households dropped from 59 g to 49 g. The large farmer category has not been considered in this comparison because the one large farmer surveyed, sold his land and became a medium farmer in the dry season of 1996-1997 (Table A.42).

Comparing the monsoon seasons of 1996 and 1997, the daily per capita consumption for large farmer households increased from 106 g to 131 g. Medium farmer households showed an increase from 89 g to 109 g, while small farmer households increased from 81 g to 92 g. For landless farmer households, the daily consumption dropped from 99 g to 82 g (Table A.42).

The decrease in fish consumption for landless farmers is related to their main occupation as agricultural labor and their consequent lack of purchasing power. Large, medium and small farmers have purchasing power, relative to the sale of surplus rice. These households usually purchase fish from the market to supplement their catch. Without sufficient labor opportunities, landless households lack the purchasing power needed to supplement their fish consumption from catch.

Consumption Based on Changes in Fish Species: The fishermen survey included a sampling of fish catch, purchase and consumption by species in the 1995-1996 and 1996-1997 dry seasons and the 1996 and 1997 monsoon seasons (Table A.43). Twenty seven species of fish were caught, consumed and purchased to a greater or lesser extent during these periods.

Overall, there has been an increase in the availability of fish species since the opening of the fishpass. Between the 1995-1996 and 1996-1997 dry seasons, there has been an increase of 16 species. Between the 1996 and 1997 monsoon seasons, there has been an increase of 14 species. *puti* is the most commonly consumed fish, followed by *taki*, *mola* and *icha*.

However, aside from the existence of the fishpass itself, there are other significant variables influencing the availability of species. For example, reduction in the availability of *puti*, *taki*, *mola* and *icha* between the 1996 and 1997 monsoon fishing years is related to the prohibited use of some nets, (*kapri* and *footpine*), which was imposed by the leaseholder in the 1997 monsoon period.

There is an increased consumption of such species as *bheda*, *koi*, *tengra*, *foli*, *gojar*, *magur* and *baim* in the dry season of 1996-1997, compared to the dry season of 1995-1996. This is related to an unusual rain in the last week of February, 1996. The normal fishing method for these species is based on de-watering the *beels* in this period. As a result of the rain, the *beels* could not be de-watered on time and the catch of these species was reduced in the 1995-1996 dry season.

There is significant variation in the availability of the *rui* species between the 1995-1996 and 1996-1997 dry seasons, when *rui* consumption decreased from 13% of households to 1.2% of households. This reduced consumption of dry season *rui* is in contrast to the catch assessment survey. This may be explained by the fact that poor fishermen households tend to sell, rather than consume large species such as *rui*.

Rui fish consumption increased from 0.3% to 2.3% between the 1996 and 1997 monsoon seasons, despite the fact that the *rui* catch in the 1997 *haor* fishing period was limited due to the prohibited use of some nets during the 1997 monsoon period. The consumption increase of the *rui* species is in contrast to the catch assessment survey which shows a decrease between the 1996 and 1997 monsoon seasons. Fishermen report that the increase of *rui* consumption is related to their availability in household ponds, rather than their increased availability on the *haor*.

227

5.5 Economic Evaluation

5.5.1 Analytical Methodology

The objective of economic and financial evaluation is to quantify the costs and benefits resulting from project implementation in order to evaluate the impact of the project on beneficiary income, government expenditure and the overall economy.

Economic evaluation or *cost-benefit analysis* (CBA) provides a key element at the project appraisal stage. It may, however, not be the most appropriate tool for on-going evaluation purposes. An *impact analysis*, whether it focuses on economic impact or environmental impact or both, attempts to quantify the consequences of various project actions. In terms of the FPP, changes in productivity to MRIP *haor* fisheries are measured and valued for the subsequent economic analysis.

The economic impact analysis used a number of parameters to test the potential *incremental production* resulting from FPP to Kawadighi Haor fisheries. Financial (and economic) prices were assigned for the subsequent sensitivity analyses. In this case, the sensitivity analysis was conducted by varying changes in incremental production while keeping the other variables constant, including O&M cost, variable cost comprised of direct cash costs, family labor, interest on operating capital and other costs as applicable. Both the net present value (NPV) and internal rate of return (IRR) was determined which provided an indication of returns to both the initial FPP investment as well as the potential income distributional effects to the MRIP area fulltime and part time/seasonal fishermen.

The effects of the incremental increase in production resulting from the FPP installation were analysed. A number of assumptions have been made to illustrate the economic impacts measured by the NPV and IRR. Using sensitivity analyses to vary the incremental production resulting from the improved fish recruitment (and by way of definition - catches), it can be shown that substantial economic benefits accrue from FPP if the incremental production exceeds 14%. It is evident that the incremental production must be at least 13% in order to have a positive NPV as well as equate the economic discount rate.

The FPCO Guidelines for Project Assessment (May, 1992) indicate that the economic analysis should use a discount rate of 12% to determine the net present value (NPV) of the benefit-cost stream. A project with a positive NPV using a 12% discount rate can be considered as a viable project.

The FPCO Guidelines indicate that planners should use a 30-year project cycle for the discounting period. Unlike the FPCO Guidelines, the FPP economists have stipulated Year 1 as the implementation year rather than Year 0. In general, the process used in discounted cash flow analysis implicitly assumes that every transaction falls at the end of the accounting period. This is accomplished by considering the initial investment to take place at the end of Year 1 of the project, regardless of whether it will actually take a full year or only a few months. The FPCO Guidelines indicate that the investment is to fall in Year 0, but this gives rise to problems when cash flows are aggregated.

Economic evaluation has been performed on the project as a whole to determine its wider benefit to the economy of Bangladesh. This analysis involves repricing of inputs and outputs at prices that reflect their real or 'economic' value. The general approach follows the FAP guidelines for economic appraisal although some prices and conversion factors have been up-dated. Calculation of economic prices involves the following adjustments to financial prices :

- All local costs have been adjusted by a Standard Conversion Factor (SCF) of 0.87.
- All taxes and import duties and lease money have been removed.
- Wages for unskilled labor has been adjusted by a shadow wage factor of 0.71 to reflect under-employment and a surplus of labor in the rural economy.
- Wages for fishermen have been adjusted by a SCF of 0.87
- Conversion factors for construction costs have been derived from MPO/BWDB guidelines based on a basket of different local and imported goods and services. They are generally less than the SCF because there is a considerable element of both unskilled labor and import duties on transport and equipment.
- Shadow foreign exchange rate has been adjusted by a conversion factor of 1.1.

5.5.2 Costs of Design, Construction, Maintenance, Repair and Impact Monitoring

Tables A.44 to A.46 show details of capital, O&M and replacement gear cost. The initial fishpass structure project cost was Tk 7.69 million. The additional development capital cost (replacement of sampling basket, construction of walkway, etc.) in Year 2 was Tk 0.40 million and engineering and administration cost Tk 1.15 million. Thus the total capital cost was Tk 9.24 million. The capital and development costs of the project have been incurred in the first and second year of the project respectively. The total O & M cost in each year is 2% of the structure cost plus engineering and administration cost of Tk 0.5 million (LS). Thus total O&M cost is Tk 0.65 million. The pumping cost is included in O&M (local costs) in Table A.44.

5.5.3 Value of Incremental Fish Production

Economic benefit generated by the incremental fish production is obtained by comparing pre-project fish production to the with-project production. Catch Assessment Surveys conducted by NERP and FPP in Kawadighi Haor and its adjacent floodplain for the years 1992-93, 1993-94, 1994-95, 1995-96, and 1996-97 are the basis for the estimation of the incremental fish production. The years 1992-93, 1993-94, and 1994-95 are the pre-project years, and the years 1995-96 and 1996-97 are the with-project years; the project being in operation since May 1995. The year 1993-94, however, has been excluded from the analysis. The flood water in that year overtopped the embankment, allowing fish to migrate into the *haor*.

The average production during the years 1992-93 to 1994-95 is calculated to find the pre-project production level, and the production of 1995-96 and 1996-97 represents the with-project production level. The incremental production was calculated as 298 tonnes, an increase of around 64% (Tables A.47 and A.48).

The Fish Market Price Survey conducted by FPP collected market prices of the fish species available in the project area. It was done monthly since the beginning of the study. The available species of fish have been grouped into carp species, catfish and other large species, *golda chingri*, and small fishes. The average price has been calculated, with weight given to the catch composition of fishes in a particular year. All prices have been brought to the 1995-96 constant price level using the fisheries sector deflator determined by the Bangladesh Bureau of Statistics.

FPCO Guidelines suggest to using the standard conversion factor to arrive at the economic price of fish from its market price.

The harvest cost per tonne of fish has been calculated taking into account the partial cost of gears and boats, other material costs such as bamboo and rope (where applicable), and costs for lease money, guarding, maintenance, and labor.

The financial/economic margin of fish production in a year is obtained from the total financial/economic value (production multiplied by price) after deducting the total harvest cost. Benefit generated by the project is the differential between the with-project and pre-project margins. It has been assumed that the benefit generated by the project in Year 2 of its operation will be maintained throughout the life of the project. Incremental fish production due to the project is 298 tonnes each year. This represents a benefit of Tk 6.37 million per year.

5.5.4 Net Present Value, Internal Rate of Return and Benefit/Cost Ratio

The Net Present Value (NPV), Internal Rate of Return (IRR) and Benefit/Cost Ratio (BCR) were determined. This provides an indication of the return of FPP investments. The project generates a positive NPV of Tk 27.39 million over a 30 year period, and an IRR to investment of 48% (Table A.49). The BCR is 3.41:1. The results show that the project is economically feasible. The incremental production and benefit includes loss of potential incremental fish production due to closure of fishpass because of farmer protests in Years 1 and 2.

5.5.5 Internalities

Sensitivity Analysis has been carried out for internalities (such as fishpass closure due to farmer protests, illegal fishing in fish sanctuary, killing of *haor* fish fry by pumping water from *haor* to river) resulting in loss of fish production. Table A.50 shows that at 30% loss of potential incremental fish production for these reasons, IRR becomes 41% showing the project is viable.

5.5.6 Externalities

During the 2 years of operation, the fishpass had no adverse effect on crop production and it is expected that it will not have such adverse effect in future in normal flooding years. Sensitivity analysis show that even under condition of 40% reduction of potential incremental fish production against agricultural production loss/crop damage, IRR becomes 38% showing the project is viable (Table A.51).

Switching value analysis was carried out to measure the strength of the project viability for different uncertainties/risks. It showed that even at 86% reduction of potential incremental fish production, the NPV is positive (Table A.52).

The results for analysis of NPV, IRR and BCR are presented in Table 5.10.

Table 5.10: NPV, IRR and BCR of FPP

Sl. #	Item	IRR (%)	NPV (Million Tk)	BCR
1	Base (under condition of fishpass operation of Years 1 and 2)	48	27.39	3.41 : 1
2	Fishpass closure due to farmer protests resulting in 30% loss of potential incremental fish production	41	17.80	2.57 : 1
3	40% reduction of potential incremental fish production against agricultural production loss	38	14.61	2.29 : 1
4	Incremental production reduced by 86% (switching value)	12	0.00	1 : 1

The basis of the economic evaluation was to estimate the incremental production generated by the project. This has been done with the production data of only 4 years (2 years to evaluate the pre-project situation and 2 years for the post-project situation). Given the complexities associated with the environment of the fisheries sector, data of fish production for a longer period is essential.

It is evident that there is a direct relationship between flooding intensity and fish production (Figure 58). The correlation needs to be estimated more precisely. There is sufficient information to construct the index of flooding intensity in the area since 1983 (Table 5.9), but the corresponding information on fish production is not available.

5.5.7 Impacts on Income and Employment

Analysis of income and employment (Table A.53) shows that due to FPP, there have been increments in days worked (12.1%), catch per fisherman (63.2%) and income per fisherman (107.8%). Increase in income was due to increased catch as well as increase in fish price over the five year project time period.

Disaggregated data for the two main groups of fishermen indicates that subsistence monsoon floodplain fishermen days worked increased by 30,552 days (19.7%) and professional *beel* fishermen days worked increased by 64,710 days (10.3%). The improvement in fish abundance resulted in disproportionately greater increments in catch and income for both groups of fishermen. Catch increased by 37.6% and income by 75.3% for subsistence fishermen, while professional fishermen recorded even greater increases (244.8% and 339.2%, respectively).

5.5.8 Comparison of Fishpass with Development Alternative (Floodplain Stocking)

Comparison of costs and benefits of FPP with the floodplain stocking components of the 2nd Aquaculture Development Project (SADP) and the 3rd Fisheries Project (TFP) are summarised in Table 5.11. The data suggests that FPP is more efficient with respect to cost per kg of fish harvested (compared to SADP and TFP), EIRR (compared to TFP) and B/C Ratio (compared to SADP).

Table 5.11: Comparison of FPP with Floodplain Stocking of SADP and TFP

Items/ Indicators	FPP	SADP	TFP
Project area (ha)	16,800	n/a	44,900
Project cost (million Tk)	9.89	n/a	81.09
Specific input cost (Tk per ha)	58.7	n/a	1,806
Gross fish output (tonnes)	767	6,655	9,609*
Cost per unit of output (Tk per kg of fish produced)	2.36	10.25	12.12
EIRR	48%	n/a	38%
B/C Ratio	3.41 : 1	2 : 1	n/a

Sources:
1. Project Completion Report on the Second Aquaculture Development (Loan No. 821-BAN [SF])
2. Implementation Completion Report, Third Fisheries Project (2146-BD)
3. An Assessment of the Economic Benefits from Stocking Seasonal Floodplains in Bangladesh by Md. Liaquat Ali, Department of Fisheries (DOF) and Md. Zahirul Islam, Third Fisheries Project, (DOF).

Notes:
n/a: Total area of stocking of SADP is not available and the actual cost of stocking could not be separated out from the total costs.
* Estimated on the basis of 214 kg/ ha as quoted in Source 3.

5.5.9 Options for Cost Recovery

The preliminary economic results of the fishpass indicate that it has a very high IRR, and is thus economically feasible. Since the capital cost outlay is large, it must be determined who is going to finance future projects of this kind.

When the government invests in projects that increase the incomes of individual farmers and fishermen, the question arises about how much of the government expenditure should be recovered, if at all, from the project beneficiaries. Only through appropriate cost recovery policies can the government recoup the money expended on a project. A part of the project benefit that individuals receive represents a subsidy paid by others in society who did not benefit from the project.

An alternative option might be for the local people interested in the project to invest. The government can provide easy-access loans to the beneficiaries' association. Since the project is the first of its kind, people are unfamiliar with it. DOF and GOB may encourage people by providing incentives in the form of sharing capital cost and/or providing loans at a subsidised rate. As the people become familiarised, the government can reduce its role as a financier, and private banks and financial institutions could take over.

An acceptable solution for financing the project with less budgetary pressure on the government could promote the construction of more fishpass projects in other areas of Bangladesh.

A detailed financial analysis involving different types of fishermen/beneficiaries has been carried out to build an appropriate model for project financing and cost recovery (Tables A.53 and A.54). Annual recovery targets of capital and O&M costs are Tk 1.16 million and Tk 0.65 million respectively. In terms of production, recovery per tonne of fish catch comes to Tk 1,508 (capital cost) and Tk 847 (O&M cost). Recovery target per tonne of incremental production comes to Tk 3,883 for capital cost, Tk 2,181 for O&M cost (equals Tk 6,064 for total cost).

Besides the monetary aspect of recovering the cost, setting-up a proper institution/arrangement involving the beneficiaries, the government, and other parties involved will be the major challenge in building such a model in future.

The existing leasing system needs to be changed to allow participation of the fishermen through their association. In that case, the *haor* may be controlled by the fishermen association so that the cost recovery may be done through participation of the fishermen through their association.

6. INSTITUTION BUILDING ACTIVITIES

6.1 Participation of DOF in Project

Excellent cooperation was received from the Department of Fisheries (DOF) throughout the whole period of the project. A Scientific Officer was deputed from DOF and worked in the project as Fisheries Biologist and Officer in charge for the FPP field office for the entire project duration. The District Fishery Officer (DFO) and Thana Fishery Officer were very much cooperative and visited the project frequently, which was helpful for fishpass operation and fish sanctuary management. Moreover, the DFO came to the fishpass on the occasion of the visits of various missions, training programs, and meetings of fishermen and farmers organised by FPP. The DFO participated in the training program on cage culture as a trainer. Several visits were paid by high officials of DOF which encouraged FPP team to perform their job efficiently. The Project Coordinator worked in FPP as a NERP team members on leave from DOF, and was otherwise in GOB service as an Assistant Director of the DOF. This facilitated getting cooperation from different GOB agencies.

6.2 Participation of BWDB in Project

6.2.1 Training Activities for BWDB Engineers

Engineering design of the fishpass structure was done by NERP staff. Design and drawings were verified by BWDB Design Circle- 6, and approved by the Chief Engineer, Design Circle. The construction contract was awarded in presence of BWDB DPS-1 members. The contract was awarded to BWDB enlisted A class Contractor. During the construction phase, BWDB Moulvibazar O&M Circle Engineers had several visit to the site.

One Sub-Divisional Engineer of Moulvibazar O&M Circle was involved during monitoring phase. The objective was to train him in fisheries engineering and fish biology. The Sub-Divisional Engineer would regularly visit fishpass. Also, other engineers of BWDB showed keen interest in fisheries engineering. The Superintending Engineer, BWDB, Moulvibazar presented several workshops to BWDB officials about the application of the fishpass at MRIP.

A training program entitled 'Design of Fishpass Structure' was held at Moulvibazar on 19-20 November, 1995. Participants included:

- 4 Superintending Engineers (BWDB);
- 4 Executive Engineers (BWDB);
- 2 Sub-Divisional Engineers (BWDB);
- 2 Assistant Engineers (DOF), and
- District Fisheries Officer, Moulvibazar.

A field visit to the fishpass site was also conducted during the training. Biological concepts, planning, hydrology and design, construction and operation of fishpass structure were the main topics reviewed. Operation, sampling and monitoring procedures were demonstrated to the participants. The participants showed keen interest in acquiring new ideas. Active participation and interaction of the participants with the resource persons were also observed during different sessions of the program.

6.2.2 Handover of Fishpass

Handover Arrangements
The overall arrangements for handover of the fishpass (refer to MOU, Appendix I) was made through discussions with NERP, CIDA and the BWDB in a series of meetings held during the CIDA Mission in September 1997. Detailed arrangements for the operation, maintenance and management of the fishpass were worked out through a series of meetings organised by NERP with the following organisations: BWDB in Dhaka, Moulavibazar and Kashimpur, the Department of Fisheries in Dhaka and Moulvibazar, the Operations Committee at Kashimpur, the Kawadighi Haor Fisheries Association, the Fishermen Cooperative Society, women groups, local elected representatives, local administration and BRAC.

Fishpass Operation, Maintenance and Management
The fishpass is situated on land owned by the BWDB as part of the MRIP and the ownership of the fishpass therefore lies with BWDB. They will be responsible for maintenance, operation and management of the fishpass, with cooperation from the Department of Fisheries and local administrative, elected and beneficiary representatives. There will be a two-tier committee system for maintenance, operation and management of the fishpass. A re-structured Operations Committee at Kashimpur will be responsible for fishpass opening and a newly-formed Management Committee at Moulvibazar will be responsible for overall management and planning.

The Operations Committee
The Operations Committee is situated at Kashimpur. Under the guidance of NERP staff, the Operations Committee had been successfully managing the tasks related to fishpass opening and closing and settlement of disputes for the past 2 years. At the time of the handover, the existing committee was slightly re-structured to consist of 14 members, headed by the BWDB Sub-Divisional Engineer (Kashimpur Pumphouse). As the Kawadighi Haor mainly includes Fatehpur Union, the Chairman of Fatehpur Union Council will serve as Member-Secretary of the Operations Committee. This Operation Committee will continue for a 2 years term.. Upon the expiry of the term of the existing committee, the Management Committee will reform the Operation Committee based on the guidelines given in Appendix I.

The Operations Committee will be mainly responsible for opening and closing the fishpass in the pre-monsoon season, in collaboration with the interests of farmers who have crops on the Kawadighi Haor. It is essential that decisions related to opening the fishpass be made within a matter of hours when water suddenly rises on the river in the pre-monsoon period. They will meet at least twice a year in the pre-monsoon season.

The Management Committee
The Management Committee is situated in Moulvibazar. This committee is responsible for overall management of the fishpass including repair, maintenance, annual plans and budgets, as well as monitoring of the fish sanctuary. This Management Committee headed by the BWDB Executive Engineer (Moulavibazar) will continue until the time of the Upazilla election. After this election, the Management Committee will be headed by the Upazilla Chairman. The Fishery Officer of Rajnajgar *thana* will serve as Member-Secretary of the committee.

The Management Committee members include fishermen, farmers, leaseholders, elected male and female representatives, government officers from BWDB, Department of Fisheries, Department of Agricultural Extension, Administration and the Police Department. Before the Upazilla election, the committee will be composed of 8 government officials, 11 elected or locally selected members and 1 NGO representative. After the Upazilla election, the committee will be composed of 7 government officials, 12 elected or locally selected members and 1 NGO representative (Appendix I, Volume - 2).

The Management Committee will meet twice a year - once in the pre-monsoon to monitor fishpass opening and control illegal fishing in the sanctuary and once in the post-monsoon season to arrange maintenance and budget preparations. At other times, the Management Committee may be required to provide support requested by the Operations Committee.

Women Groups
BRAC has taken a 25 year lease with BWDB for a portion of the MRIP embankment for a tree plantation involving women groups. The thirty women who were organised by NERP for tree plantation near the Kashimpur Pump have been incorporated into the BRAC program through a signed agreement between BRAC and BWDB. It is expected that the income from the hardwood trees can be realised in about 10 years. Of the total tree harvest, the group women will be provided with 60% of their value, while 20% will go to BWDB and 20% to BRAC. The women groups will also receive a monthly stipend of Tk 300 to provide tree care for a 10 month period. In addition, BRAC will provide this group with all services associated with their rural development program, including group formation, savings, training and micro-credit.

The 22 women in three groups who were organised by NERP for fish processing are already associated with BRAC, Unnayan Sahayak Sangstha and the Grameen Bank. These women receive micro-credit and training inputs for their income generating projects such as poultry and livestock rearing, net-making, vegetable cultivation and dry fish trading.

The 16 women at Rashidpur who were organised by NERP for cage culture could not be incorporated into any development program at the time of fishpass handover because there is no NGO working in that area at present. Discussions with BRAC indicate that this group will be taken under their tree plantation program in the future.

Handover Workshops
Before the handover of the fishpass to the BWDB, two one-day meetings were held to share the handover plans with the Operation Committee and the newly formed Management Committee. The procedures for operation, maintenance and management of the fishpass were also discussed. The workshops were organised in late December at Kashimpur and Moulvibazar.

6.2.3 Fishpass Operation and Maintenance Manual

An Operation, Maintenance and Management Manual has been prepared by NERP, in consultation with the BWDB (Moulvibazar and Kashimpur Pumphouse), the Directorate of Fisheries (Dhaka and Moulvibazar), the Operations Committee (Kashimpur) and local farmers and fishermen. The manual provides details on the operation, maintenance and management of the fishpass including the composition of the Operation and Management committees and the anticipated annual budget estimates (Appendix I). Appendix I also includes the Memorandum of Understanding between BWDB and DOF on the O&M of FPP.

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6.3 Fisheries Management Initiatives

6.3.1 Fisheries Management Problems and Issues

Fisheries management (*senso stricto*) problems and issues related to access to resources and control of fishing effort and fishing mortality in Kawadighi Haor originate from GOB policy on leasing *jalmohals*. This is a national policy which is concerned solely with generating revenue for GOB through leasing on water bodies (*beels*, rivers, canals) for fishing to the highest bidder. The high price of the lease fee prevents genuine fishermen (who are mostly poor) from gaining direct tenure and access to the fisheries. Leases are routinely won by wealthy investors who then contract fishermen on a wage or share basis to extract the fish from the *jalmohal* on their behalf (mainly from *beels* during the dry season), or issue fishing permits after payment of *tole* (mainly for the floodplain during the monsoon flood season).

Leases are typically from one to three years in duration. This motivates the leaseholder to maximise short term gains from fishing, and usually results in overfishing and resource exhaustion.

6.3.2 Formation of Kawadighi Haor Fisheries Association

Although FPP was not a fisheries management project, an attempt was made to unite all genuine fishermen working in Kawadighi Haor into a single professional trade organisation. The Kawadighi Haor Fisheries Association (KHFA) was formed under the auspices of FPP on July 11, 1995. The objective would be to strengthen the organisational and executive powers of fishermen so as to take various actions which would be in their own best interests. A possible eventual goal would be to bring all *beel* fishing, and professional *haor* fishing in general, under KHFA ownership and management and thereby wrest control away from the leaseholder. Moreover, the KHFA might have an important role to play in the fishpass O&M and the eventual recovery of cost in the long-term.

A series of meetings of the KHFA were held during Years 1, 2 and 3, which are summarised in Appendix K. Fishing villages showed strong interest in the association, and were especially interested in training programmes.

An application was lodged to legally register the KHFA with the Department of Social Welfare. A second application was lodged to transfer Patasingra Beel to the KHFA under the New Fisheries Management Policy (NFMP). Assuming both applications will be successful, there will be an immediate need to strengthen the organisation of the KHFA. The KHFA committee has collected the names of all the principal fishermen in the *haor* for inclusion in its membership roster. The names of fish processors were also be collected for their memberships.

6.3.3 Establishment of Fish Sanctuary

An initiative was taken by FPP to establish a fish sanctuary on both sides of the fishpass in order to protect migrating fish stocks in the Koradair Khal and adjacent part of the Kushiyara River. This area consisted of 4 registered *jalmohals* (Table 6.1).

Table 6.1: Dimensions of Fish Sanctuary in Karadair Khal

Jalmohal	Location	Area or distance
Koradair *khal*	C/S	13.65 ha
Koradair *khal* 1	C/S	4.21 ha
Koradair *khal* 2	C/S	8.40 ha
Junction of Kushiyara 16 and Kushiyara 17 (including pumphouse outlet channel)	R/S	500 m

A proposal was submitted to the DOF to establish a sanctuary in the above area. Accordingly, DOF sent a letter to the Ministry of Fisheries and Livestock (MFL) with their recommendation. MFL agreed with the proposal and sent it to the Ministry of Land to declare the area as a fish sanctuary. The Ministry of Land examined the proposal and obtained necessary comments from the local administration. Finally the area was declared as fish sanctuary in May, 1995 for a period of 5 years.

After declaration of the fish sanctuary, efforts were made to win the participation of local fishermen for proper management of the sanctuary. A positive response were received from the fishermen community. They engaged 3 persons, 2 act as rotating guards, and extended their full cooperation to FPP by preventing anyone from catching fish from the sanctuary area.

Local administration and DOF were instructed by the Ministry of Land to take steps to ensure effective implementation of the fish sanctuary. A magistrate was assigned by the Deputy Commissioner, Moulvibazar to implement the relevant sections of the Protection and Conservation of Fish Act, 1950, with regard to surveillance of the fish sanctuary area. District Fisheries Officer (DFO), Moulvibazar, paid several visits to the fishpass site and rendered full support for better management of the sanctuary. Signboards indicating the fish sanctuary area were put up by the district office of the DOF, and local DOF officers attended some meetings with the fishermen organised by FPP in connection with management of the fish sanctuary and operation of the fishpass.

Experience with the fish sanctuary has generally been satisfactory (apart from the water hyacinth infestation experienced during the late monsoon, and some instances of poaching). It is becoming increasingly clear that the *khal* can act as more than a simple transit route between the river/fishpass and the floodplain/*beels*. *Carpio* has been observed breeding in the *khal*, and eggs and fingerlings have been found. During the dry season the *khal* becomes a relatively secure refuge area for fish stocks inside the *haor*. This is especially important since the *beels* are intensively fished by the leaseholders. The *khal* should be regarded as an important component of the *haor* aquatic ecosystem, and options should be explored for enhancing its functions as spawning and refuge habitats (which are additional to its transitway function).

The *duar* in front of the six vent regulator is contained within the fish sanctuary, and appears to be a breeding site for some species. From the *duar* fingerlings can easily enter through the fishpass.

6.3.4 Control of Destructive Fishing Methods

The use of illegal small-mesh monofilament gillnets (*current jal*) is likely the most damaging fishing method affecting fish stocks during the monsoon season. On 30 August, 1995 a mobile court at Kawadighi Haor was conducted by the local administration and hundreds of current *jal* were seized which were burnt at the Rajnagar Police Station premises in presence of local people.

During the dry season, the most damaging fishing method is *beel* dewatering followed by complete harvest using various traps and nets. Efforts by the project to curtail *beel* dewatering and total harvest have not been successful.

6.3.5 Training in Fisheries Management

The construction of the pilot fishpass structure through the Manu embankment between Kawadighi Haor and the Kushiyara River created a lot of interest amongst the local fishing community. To make them aware of the community's responsibility towards this pilot project, and to seek cooperation for smooth operation of the fishpass structure, a training program was organised on 27 May 1996 at the pilot project site. The training session also initiated discussions on resource management, fisheries regulation, post-harvest handling, fish processing, and other activities necessary for the development of fisheries. About 25 members of the local fishermen community attended this training program.

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7. COMPLEMENTARY FISHERIES DEVELOPMENT ACTIVITIES

7.1 Introduction

Although not specified in the pilot project TOR, two other fisheries development activities were pursued on a trial basis in conformity with the NERP prefeasibility study 'FISHERIES MANAGEMENT PROGRAMME'. The experience of the fishpass (i.e.: a purely structural intervention) indicated that significantly more interventions of a non-structural nature would be required if the fisheries sector of Kawadighi Haor were to be modernised and raised to a level of greater efficiency, socioeconomic equity and environmental and economic quality.

Interventions in two areas were carried out:

- Floating cage culture, and
- Fish processing and marketing.

7.2 Floating Cage Culture Trials

Most high value *boromaach* species (*rui, catla, air, boal, chitol*) breed during the premonsoon and early monsoon. The fingerlings grow as the monsoon progresses, but many are caught long before they reach first maturity. *Boromaach* price structure in Bangladesh is progressive, as consumers are willing to pay a premium for larger individuals of a particular species. Thus, a large *rui* of 4 kg sells for Tk 115 per kg (= value of Tk 460) while a small 0.5 kg *rui* sells for only Tk 23 per kg (= value of Tk 12), based on 1994 BFDC prices. It is in the fishermen's interest therefore to let fish grow to the largest possible size before harvesting. In an open access monsoon floodplain fishery however, this is normally not feasible as undersized fish released back into the *haor* might simply be caught by another less conservationist-minded fishermen. A possible solution to the problem is to transfer living under-sized *boromaach* caught during the monsoon to floating cages for rearing (i.e.: fattening) to market size. This could have the additional advantage of allowing the fishermen to bring fish to market when prices are at a seasonal high (ie in the spring). Cage culture also has potential as a fish production (i.e.: fingerling grow-out) operation for rural households who do not have access to capture fishery resources. Experience at a trial cage culture project operated by CARE near Dhaka (which was visited by the FPP team) has generally been positive.

In order to test the possible applications of cage culture in the FPP project area, two cage culture trials were undertaken:

- Fish Fattening Trial: In order to test the feasibility of using floating cages for fattening fish, FPP installed a floating cage culture unit at Kashimpur near the R/S gate of the fishpass during Year 3. The cage was under the direct supervision of FPP field staff. The cage contained 16 fingerlings of *air* and 2 *kalibaush* which were obtained from fishpass sampling.

- Fingerling Grow-out Trial: Two trial cage culture units were set up in the Kushiyara River at Rashidpur village (5 km upstream from the fishpass) during Year 3 to demonstrate the methods for rearing carp fingerlings in cages. (This village was also selected in part with the intention of providing compensation to fishermen who were displaced from the fish sanctuary area.) Sixteen women of traditional Rashidpur fishing families were selected. They were formed into 2 groups, of 8 women each. Each group was allocated responsibility for maintenance, feeding and night security for one cage. One day training was provided to the women's groups by the District Fisheries Officer, which included an explanation of cage culture and its methodology, cage construction, selection of species, feeding, and cage maintenance and security. The fish fingerlings were purchased from private fish nurseries in Rajnagar and Srimongal. Four varieties of fish, totalling 2,376 fingerlings, were released in stages between 18 July and 30 August, 1997, and included grass carp (240), *tilapia* (408), carpio (1,418) and Thai *pangas* (310).

Each floating cage consisted of a bamboo frame with a small-mesh net hanging inside (Figure 73). The dimensions of a cage were 8 m long by 4 m wide by 2 m high. Each cage contained 4 separate compartments. The cost of construction, installation, stocking and feeding for the fish culture demonstration was Tk 52,300. This included materials and labor (Tk 31,788), fish fry (Tk 14,391), fish feed (Tk 2,200) and transportation (Tk 3,920). The fish were fed twice daily (07:00 and 16:00 hrs). Feed consisted of ricebran (35%), wheatbran (35%) and oil cake (30%), and was supplied at the rate of 8-10 % of body weight. The oil cake was crushed to a fine powder and mixed with the other ingredients and water. The moist feed was placed into a cloth bag that had holes in it, and the bag was suspended inside the cages.

Results for the fattening and grow-out trials are presented in Table 6.2, and Tables A.55 and A.56, and are summarised as follows:

- Fish Fattening Trial: No mortality of *air* and *kalibaush* took place, and growth rates were good. Length increments of 83-122% and weight increments of 312-609% were realised over a 45 day fattening period.

- Fingerling Grow-out Trial: There were significant problems of mortality (especially *tilapia*) and escapade (especially Thai *pangas*). Growth rates were poor for grass carp and carpio. Length increments of 0.4-11% and weight increments of 4.9-30% were realised over 28-60 day grow-out periods.

Table 7.1: Survival, Growth Rates and Causes of Mortality for Floating Cage Culture Trials

	Fry released	Fry surviving at end of trial	% survival	Trial duration (days)	Increment in length (%)	Increment in weight (%)	Cause of mortality or loss
			Fish Fattening Trial				
Air	**16**	**16**	**100%**	**45**	**83%**	**312%**	**n/a**
kalibaush	**2**	**2**	**100%**	**45**	**84+122%**	**326-609%**	**n/a**
			Fingerling Grow-out Trial				
Tilapia	408	0	0%	2	n/a	n/a	High turbidity; suffocation due to compression of net by strong water current and water hyacinth
Grass carp	240	37	15%	60	11%	30%	High turbidity; theft; escape through net opening while feeding
Carpio	1,418	209	15%	60 28	11% 0.4%	23% 4.9%	Suffocation due to compression of net by strong water current and water hyacinth; cutting of net by miscreant; theft; escape through net opening while feeding and through holes cut by crabs
Thai *pangas*	310	0	0%	7	n/a	n/a	Eaten by crabs; cutting of net by miscreant; theft; escape through net opening while feeding and through holes cut by crabs

The poor growth increments of the fingerling grow-out trial can be attributed to the negative effect of high silt load and water velocity conditions existing in the Kushiyara River during the trial period.

Future attempts at similar floating cage trials or dissemination should take into account the following factors:

- Water Quality and Current Considerations: Some technical problems may be encountered when attempting to rear fish in a turbid river such as the Kushiyara - at least during the pre-monsoon and early monsoon when flash floods can carry high turbidity loads and the current is strong. This can cause mortality in some of the more sensitive species. Non-indigenous species (*tilapia*, grass carp, carpio, Thai *pangas*) should probably be grown between October and March, when water turbidity is more moderate. Other species which occur naturally in the river (ie *rui*, *catla*, *kalibaush*) would be less sensitive to turbidity, but fingerlings sourced from hatcheries could still require acclimatisation as hatchery water is of relatively higher quality compared to river water. The negative effect of high current velocity on cage integrity during the monsoon suggests that cages should either be positioned in sheltered river reaches, or cage culture should be practiced only during the dry season when current velocity is moderate. Cage size should also be kept small for river installations.

- Proven Technology Package: Certain problems associated with production should be tested and proven before being disseminated to villagers, in order to avoid disappointed expectations and possible economic losses.

- 24 hour Cage Security: Losses due to theft or malicious acts when cages are unattended can become a major problem, and would have to be solved by cage farmers in the best way possible depending on resources available to them.

- Need for Income Support: No remuneration was provided for participants in the trial as it was expected they would benefit from the harvest of the cultured fish. However, as there is a risk of no income materialising from the trial (as in the present case) provision should be made for meeting opportunity costs in larger projects.

7.3 Fish Processing and Marketing

Training for Women Fish Processors
Women are mainly involved in increasing the market value of the catch through fish processing. In periods of relative abundance, fish processors preserve fish using indigenous techniques including production of dried fish (*shutki*) and fermented fish (*shidal*). Many households are involved in fish processing on a commercial basis. This is an important source of food, as well as income, for many households. Upgrading fish processing skills was expected to improve the economic and nutritional condition of the fishing households in the project area.

Two workshops for fish processing women were conducted to improve their skills in processing technology. Women who were involved in fish processing were surveyed in 18 traditional fishing villages in the project area.

The villages surveyed included Manumukh, Hamidpur, Chandpur, Gaorgoan, Jahedpur, East Berkuri, West Berkuri, Antehori, Rashidpur, Rakta, Amirpur, Betahunja, Paschimbag, Bisonkirti, Noagoan, Mohammadpur, Kashimpur and Khalder.

- In October 1996, 49 women were invited to attend an introductory workshop on fish processing. Of the traditional fish processing women attending the workshop, 69% were Muslim and 31% were Hindu. The workshop was conducted by two trainers, a fish processing specialist from the DOF and a training and communications specialist from the NGO, Communica. The training included material on the nutritional value of fish, modern methods of fish drying, and marketing of hygienically processed fish. Slides and practical demonstrations were provided. Follow-up visits were provided to the women who were trained in the first training workshop to select those who had applied their new knowledge in fish processing. A total of 22 women were identified, including 17 of the original batch and 5 women who had demonstrated their interest in fish processing. These women have received further training and the supply of materials for fish processing. They have been formed into three women's fish processing groups in Chandpur, Gargaon and Manumukh.

- The second training workshop was held on December 23, 1996 for 22 women in the three fish processing groups. The training was conducted by the fish processing specialist from the DOF. The material presented included the construction and use of solar dryers and smoking kilns for fish processing. The material used in this training was used in the preparation of a Fish Processing Manual (Appendix L).

Summaries of various meetings held for women fish processors are presented in Appendix K.

It was intended to provide improved fish processing technology to the women who had been trained. However NERP staff changes during the period resulted in problems in supplying inputs (smoking kilns [not supplied] and solar dryers). Solar dryers (wooden frame, polythene sheets) were to be supplied for fish processing during the dry season. They were eventually supplied in July and August, 1997, but could not be used for fish processing during the monsoon period because there was insufficient sunshine. In addition, the women lacked the capital to buy fish at the high prices existing during the latter part of the monsoon period.

Women involved in fish processing have benefited from improved knowledge in hygienic and modern processing techniques. It is expected that in the dry season of 1997 and 1998, these women will be able to utilise their training and their solar dryers to improve the quality and value of processed fish. However, an assessment of this activity cannot be made at the present time. As part of the handover process, women in the fish processing groups have been introduced to the local BRAC office. Discussions have been held with BRAC to incorporate these women into their Rural Development Program, which will include such activities as group savings, micro-credit and training.

Sherpur Fish Festival

During Year 1, the annual Sherpur *Macher Mela* (fish fair) was organised by local fish traders on 13 and 14 January 1996. Many fishermen in the region attended the fair. It created an opportunity to disseminate the concept of fishpasses to a large gathering of fishermen in the region. FPP had a stall at the fair and displayed pictures, drawings, sample fish, videos on fisheries activities, and distributed a simple Bengali leaflet on fishpass structure. FPP professionals who attended the fair talked to a large number of people and answered their various questions about the fishpass.

During Year 2, FPP did not have a stall in the fish festival which was held from 13th to 14th January 1997. But the FPP fisheries biologist went to observe the situation. The number of people gathering (both sellers and buyers) was less than that of previous years because of month of Ramadan. A lesser quantity of fish was brought to the festival because most of the fish from *haor* were caught before festival, and there was less abundance of fish in the river at that time. Some fish species (*Air, Rui, Catla, Gonia, Mrigel*, Carpio, *Boal, Shole, Gojar*, and especially *bagair*) were less abundant compared to previous years. No large *bagair* were seen. The largest fish was a *boal* which sold for Tk 3,600.

7.4 *Beel* Flushing with Irrigation Water

7.4.1 Water Distribution System

Significant water quality problems occur in the beels of Kawadighi Haor during the dry season when the water inflow and outflow is much reduced. The upstream *chhoras* carry pesticides which pollute the *beels*. Decomposition of aquatic plants also occurs in the dry season, which contributes to eutrophication, deoxygenation, acidification and increased turbidity. The reduced water quality stresses the fish stocks of the haor. From the field study, it is evident that fish disease (especially EUS) starts when the water begins to drop below *beel* banks. About 40-50% of fish are affected by disease.

In order to control water quality deterioration and provide a better dry season refuge environment for fish stocks, the feasibility of an operating scheme to continuously flush Manu River water through the irrigation canals was investigated. Proposed flushing and drainage systems are shown in Figures 74 and 75.

Flushing can be activated through Manumukh main canal and Rajnagar main canal. The status of these canal systems (primary and secondary) are presented in Table 7.2. For efficient flushing and to minimise water loss, the following irrigation canal and drainage channel system can be considered:

Discharge through Manumukh Main Canal. The secondary and tertiary canals which can be used are MR_1, MR_1R_2, MR_2L_2, MR_2L_1, MR_4, and MR_6. This irrigation water will fall into the Lash Channel or lands adjacent to Patasingra Beel. Water will be drained into the Kushiyara River through the Lash/Digora Channel-Patasingra Beel-Mogra Channel-Koradair Channel drainage system.

Discharge through Rajnagar Main Canal. Distributary canals which can be used are RL_2, RL_2L_1, RL_2R_1, RL_4, RL_5 and RL_6L_1. Irrigation canal water will then flow into Digola Channel, Machua channel, and Akali Chhora. This water will be drained into the Kushiyara River through the Digola Channel-Patasingra Beel-Mogra Channel-Koradair Channel drainage system and Machua Channel-Shalkatua Beel-Majherbanda Beel-Akali Chhora-Koradair Channel drainage system.

The inflow of water would be drained through drainage regulators. Total inflow from irrigation canals is 5.70 m^3/sec. One opening of a regulator (1.52 m x 1.83 m) under full flow condition discharges more than 5 m^3/sec during the dry season. This irrigation inflow can be discharged by one vertical gate of a drainage regulator, so the proposed flushing and drainage system will cause no additional storage in the project area.

Table 7.2: Irrigation Canal Status in MRIP

Name	Discharge (m^3/s)	Length (km)	No. of Turn outs	No. of Turnouts	Harvesting Period	Physical Status	Canal end Distance from *beel* or Channe (m)
Manu	2.81	12				Good	
Rajnagar	2.90	18				Good	
MR_2	0.94	5.73	17	B. *aman*, T. *aman*	Nov. 30	T. *aman* at the canal bed	
MR_2L_1	0.20	1.53	4	B. *aman*, T. *aman*	Nov. 30	Weeds and water hyacinth at canal bed	250
MR_2L_2	0.17	1.14	4	B. *aman*	Nov. 10	Good	400
MR_4	0.29	1.45	6	B. *aman*, T. *aman*	Nov. 30	Good	250
RL_2L_1	0.20	1.45	8	B. *aman*	Nov. 10	Canal banks breached	300
Rl_2	0.67	5.57	21				
RL_4	0.95	6.20	27	B. *aman*	Nov. 10		
RL_5	0.48	3.55	10	B. *aman*, T. Aman	Nov. 30	Breached, and public cut,	500
RL_6L_1	0.21	1.06	5	B. *aman*	Nov. 10	Good	
RL_6	0.53	3.94	15	B. *aman*	Nov. 10	Good	500
MR_6				B. *aman* T. *aman*	Nov. 30	Good	300

7.4.2 Flushing Period

It is evident that fish disease starts when individual waterbodies form during the post-monsoon drainage period. Flushing of irrigation water should be started when banks of the *beel*s are submerged by 0.30 m. Some of the irrigation canals are not directly connected with channels or *beel*s. Some overland flow will occur during the flushing period. It has been verified in the field that overland flow will occur on 100 to 500 m of land adjacent to these canals. On these lands, either b. *aman* or t. *aman* is cultivated. Since harvesting of t. *aman* will be completed by the end of November, it is recommended to start flushing Manu River water from the first week of December. Flushing of *beels* with Manu River water may only be possible in the month of December. From January onwards, Manu River water is used for irrigation purposes.

Events during the late monsoon of 1996 and early dry season of 1997 give an indication of the likely benefit that beel flushing might have on fish disease control. Significant rainfall occurred in October 1996 which contributed to reducing turbidity of storage water. Continuous rainfall and drainage through the 6-vent regulator has served the purpose of flushing. In December, no fish disease was observed in beels. Water level at the beginning of December was at 6 m PWD which corresponded to a submerged area of 5,645 ha. The stored volume of water was higher and is likely responsible for the better resistance of fish to disease outbreak. For the above reason flushing activities were not carried out in 1996. Some diseases were observed from the middle of January. At that time, flushing was not possible for irrigation activities, and also the leaseholder refused to allow entry of any additional water into the beels (which interferes with the dewatering of *beels* to catch fish).

Depending on *haor* water level, fish can begin contracting diseases as early as November. *Aman* is still being cultivated at this time, and it is not possible to begin flushing with Manu River water. This problem can be overcome by connecting the end of the canal to the edge of the *beel* using 0.45 to 0.60 m diameter RCC pipe. Approximately 2,500 m of pipe will be required for the total flushing system. If pipes are used, it will be possible to flush river water at any time during the post-monsoon.

7.4.3 Maintenance Works and Necessary Steps

Some irrigation canal banks are damaged by flood water. There are also public cuts that were done because of waterlogging and to hasten drainage. These banks need to be improved. There are some aquatic weeds in the canal bed and earthen dams which also have to be removed.

To avoid overland flow, turnouts in the main canals and secondary canals will have to be closed by wooden or steel plates. Earthen materials can be used to close turnouts that have small diameters. To raise the water level of the Manu River to pool level (12.03 m PWD), Manu barrage gates need to be closed about ten days before flushing begins.

7.4.4 BWDB Assistance

MRIP is operated and monitored by BWDB, and the Manu barrage is also under the control of BWDB. To flush Manu River water into the Kawadighi Haor, the gates of the Manu barrage have to be closed by the middle of November. Gate operation of the Manu barrage and irrigation structures have to be maintained by BWDB. Assistance from the BWDB field staff who control internal irrigation structures is also essential. Several discussions were held between NERP and BWDB O&M Division, Moulvibazar. The objective of the discussions were closing of Manu barrage, and assistance in opening and closing canal structures. BWDB had no special objections to carrying out beel flushing as proposed in the above scheme, and agreed to carry out a trial.

7.4.5 Water Quality Test

Before flushing starts, Manu River water quality should be tested to avoid any adverse effects in the *beel* area. During flushing, the water quality of inflow from *chhoras*, *beel* water, and outgoing water through the regulator should be tested to observe the impact of flushing.

7.4.6 Fisheries and Agricultural Considerations

Beel fishing and *boro* cultivation in the project area begin simultaneously during the dry season. Irrigating the *beel* areas before fishing can cause some fish migration, and can decrease the total catch. This is generally desirable from the perspective of protection of the overwintering brood fish which are required to replenish the *haor* fish stocks during the coming early monsoon breeding season.

Fishing can be marginally more time and labor intensive when the water volume in fishing areas increases. Barrage water supply to *boro* land is delayed in the interest of fishermen and lessees.

Timely, reliable, and regular supply of water are the important factors in HYV *boro* cultivation. Irrigation starting date is fixed in consultation with farmers. Accordingly, farmers prepare seedbeds, raise seedlings, and start transplantation. Delays in irrigation damages seedlings, hampers transplantation, and frustrates farmers.

Timely irrigation is critical to sensitive HYV cultivation practices. HYV *boro* rice is entirely irrigated by water from project canals. According to some farmers, maximising HYV *boro* yields is generally unachievable. Surplus rice growers lose incentive because of low returns. Adoption of improved cultivation and soil management practices, along with timely and adequate irrigation and drainage, are required to improve HYV *boro* yield levels.

In some areas, farmers benefit from the delay in water supply from project canals. According to them, their lands remained waterlogged for a substantial part of the post-monsoon season. Consequently, the soils lose the capacity to bear draft animals, making tillage difficult in winter. The farmers stopped or delayed barrage water supply in their area in order to make the land ready for tillage in *aus* season.

B. *Aman* and T. *Aman* are grown at the end sections of the flushing canals. B. *Aman* is harvested by the 15th of November, while T. *Aman* is harvested by the end of the November. Therefore farmers require 15 days beyond the harvest dates to prepare their fields for the next *boro* crop. From an agricultural perspective, flushing of the canals should best take place between December 1 and January 15th. Farmers need to be informed of the flushing dates one month ahead of time. Farmers request that all unauthorised cuts in the canals and gates at the head of the canals should be closed before flushing. Farmers request that BWDB staff should be deputed to patrol during the flushing period in order to save prevent damage to seedlings and the seed beds.

7.4.7 Social Activities

Villages located along the proposed flushing canals were identified as follows:

Canal Name	Involved Villages
• MR2	Raipur, Ekatona, Uttar Malain and Mallik Sarail.
• MR2L1	Uluail, Mallik Sarail and Uttar Malain.
• MR2L2	Banasri, Raipur, Ekatona and Uttar Malain.
• MR4	Lalpur, Haripur, Badh Uluail and Sampashi.
• MR6	Kandigaon, Durgapur, Parasimul, Sanandapur, Jagatpur and Paguria.
• RL2L1	Borogaon, Bahadurgonj, Banamali-panchesar, Munsurnagar, Panchesar and Malalpur.
RL2	(As above).
• RL4	Rakta, Modhubazar and Gargaon.
• RL5	Sarampur, Uthaia, Baitakhal, Deuail, Bhoradoba, Khemsahasro, Bhabanipur, Nandiura and Chowdhury Bazar.
• RL6L1	Dhulizuri and Keula.
• RL6	(As above).

Discussions were held with fishermen and leaseholders about the water quality and fish disease in the *haor* in relation to flushing of the canals. The beneficiaries presented the following comments and suggestions for flushing:

- Fish disease is related to stagnant water. Fish disease has increased since the construction of the embankments along the Manu River and the consequent obstruction of the natural drainage system. Fish disease has also increased as a result of the use of pesticides and fertiliser in the thirteen tea gardens upstream of the *haor*. Fish disease is mostly observed in January and February. During this time 40% to 50% of fish in the *beels* die from disease.

- Flushing of the *haor* is essential to improve the water quality. Flushing of the *haor* can be done by flushing water through the secondary and tertiary canals of the MRIP. The suggested time period is between December 1 and January 15. This period will not present problems for either farmers or fishermen. Fishermen and leaseholders request that periodic water quality testing be carried out before and after flushing to assure that the flushing has been adequate.

7.4.8 Conclusions and Recommendations

It is concluded from the study that *beel* flushing to improve water quality and quantity during the dry season with the objective of reducing the incidence of fish mortality due to stress and disease is feasible.

It is recommended that a beel flushing trial be conducted over a two year period. The impacts of flushing on fish disease, fish catch, fish abundance, fish biodiversity and agricultural production should be monitored, and the results used to decide whether or not to incorporate dry season flushing of Kawadighi Haor *beels* as a routine component of MRIP operations in the future.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Main Conclusions

The following are the main conclusions of FPP:

- Fishpasses of the vertical slot design are capable of providing an open migration route across full flood control embankments for a great proportion of the freshwater fish species occurring in Bangladesh;

- Although the specific design type tested is not optimised for bidirectional fish traffic or for water flow reversal, it nonetheless proved capable of allowing fish to move in either direction between river and floodplain, and in accommodating water flow both with-gradient and against-gradient;

- At low and moderate head loss across the structure, water velocities and turbulence were within acceptable limits and did not constitute impediments to fish movement in either direction. At high head loss however, velocities and turbulence exceeded design levels and negatively affected countercurrent fish traffic;

- Pre-FPP and with-FPP, monitoring of fish production on the floodplain indicated that a significant increase in fish catch, biodiversity and abundance took place after the fishpass began operation. The greater part of this increment could be attributed to the effect of the fishpass (floodplain stocking with carp fingerlings and marginally greater flooding were likely responsible for the rest of the increment);

- Measurable increases in fishing income and fish consumption took place during the study period which could also be attributed in large part to the impact of the fishpass;

- The volume of water discharged by the fishpass into the FCDI project was minimal and did not result in any measurable damage to rice crops during the three years of fishpass operation;

- Economic evaluation indicates that FPP had a high internal rate of return, and performed well compared to the project alternative of floodplain stocking, and

- The fishpass is a structural measure which was successful in attaining its objective of providing access for fish migration across flood control embankments. More comprehensive development of floodplain fisheries in Bangladesh will however require a host of non-structural measures including environmental improvement (i.e.: wetland afforestation, maintenance of adequate dry season *beel* water volume, water hyacinth control, agrochemical control), effective fisheries management regimes (i.e.: transfer of fishery ownership to genuine fishermen and termination of leaseholding system, establishment of fish sanctuaries to reduce fishing mortality during critical periods in life cycle, assisted rehabilitation of depleted and near-extinct biodiversity), introduction of novel fish production systems (i.e.: floating cage culture) and application of more efficient fisheries technology in processing (i.e.: for dry fish production) and marketing (i.e.: a shift to wholesaling and retailing by women).

8.2 Recommendations

The main conclusions reached from the experience of FPP suggest the following recommendations:

Continuation of Research Program at Kashimpur Fishpass

The Kashimpur fishpass is an excellent research facility for further study of the operation and impact of a vertical slot fishpass across a flood control embankment. It is recommended that a long term research programme be implemented to continue and diversify the work already begun by FPP. Basic research into hydraulics, fish movement and changes in floodplain fish biodiversity and stock abundance should be extended to cover other aspects of *haor* fisheries.

Improvement in Fishpass Design and Functioning

Modifications to the vertical slot design to improve two-way flow and fish movement inside the structure should be modeled and field tested. Other design elements that should be studied are a reduction in pool dimension (and slot width - see above) to reduce cost, and to minimise opposition from farmers to operation of the fishpass during the pre-monsoon and early monsoon flood surges (which are critical periods of fish migration). Reconfiguring of the pool dimensions in order to reduce water velocity and turbulence inside the pool should also be tested. Lowering of the R/S invert level to increase the POP should also be considered.

Construction of More Fishpasses in Bangladesh

The construction of more fishpasses in Bangladesh to mitigate negative FCDI impacts on fisheries appears to be justifiable on technical and economic grounds. All new FCDI projects in the planning stage should be studied for the feasibility of incorporating one or more fishpasses into the design. Fishpass design should be adapted to the particular conditions and features of each individual FCDI project. These vary in size, equipment and environmental conditions, from relatively large full flood control with or without pumped drainage to medium size projects with gravity drainage. There would appear to be little doubt that migrating fish would in most instances make use of appropriately designed fishpasses, and that fish stocks (and fishermen) inside FCDI projects would benefit from re-establishment of an open migration route across embankments. Where water discharge through the fishpass is an issue for agricultural production (i.e.: where there is a high risk of a real threat to crops), a combination of design modification, non-continuous operation, and possibly khal and/or beel re-excavation should be considered to reduce the risk. Given the high IRR of a fishpass project (either as a retro-installation in an existing FCDI project or as an integral component of a new FCDI project), detailed economic analysis should be carried out in order to identify the optimal trade-off between fishpass benefits and risk to agriculture.

26

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FIGURES

Figure 1: Area Map of Fishpass Pilot Project and Manu River Irrigation Project

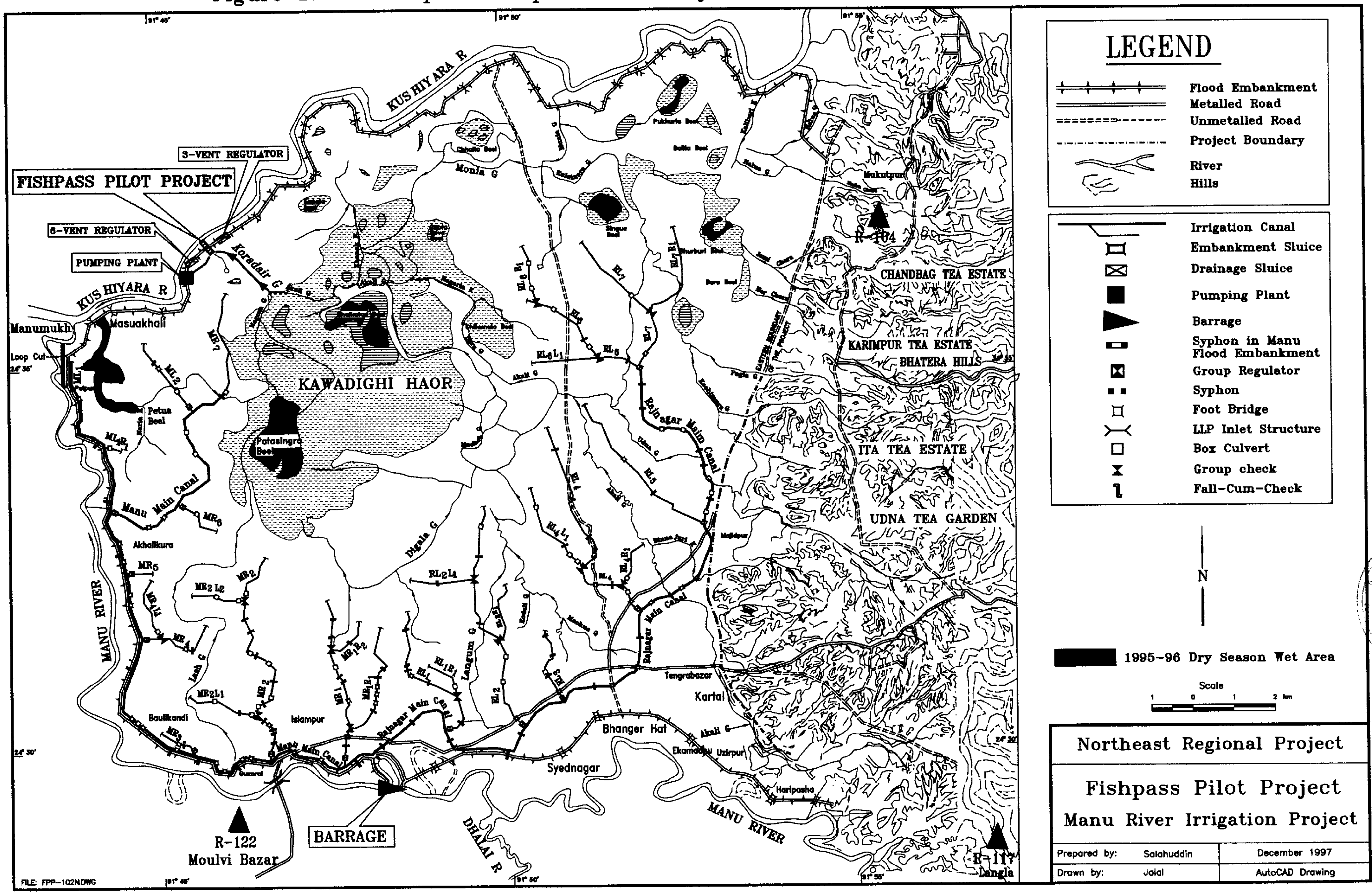


Figure 2: Location Map of FPP

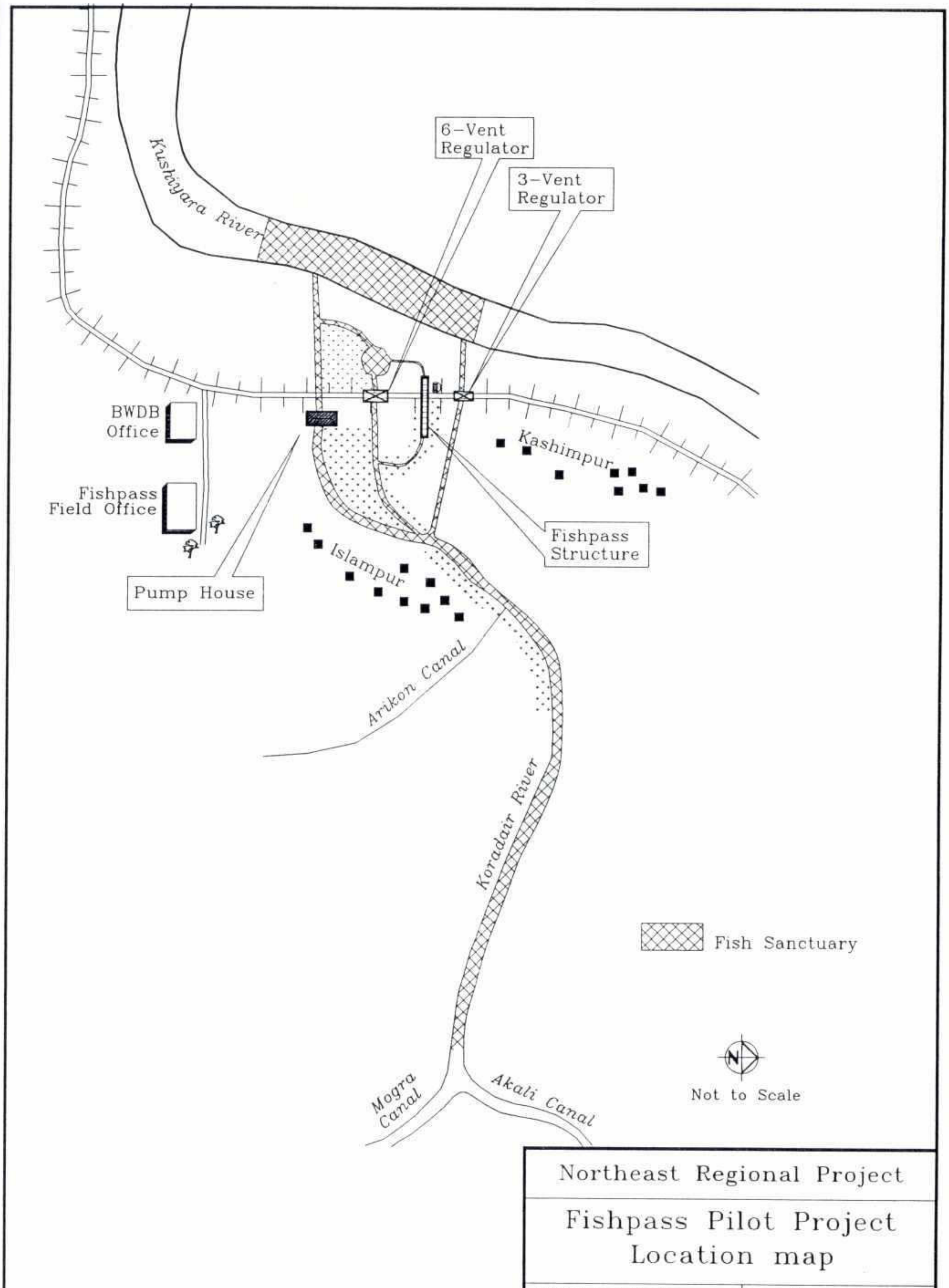


Figure 3 : Social Catchment of Fishpass Pilot Project

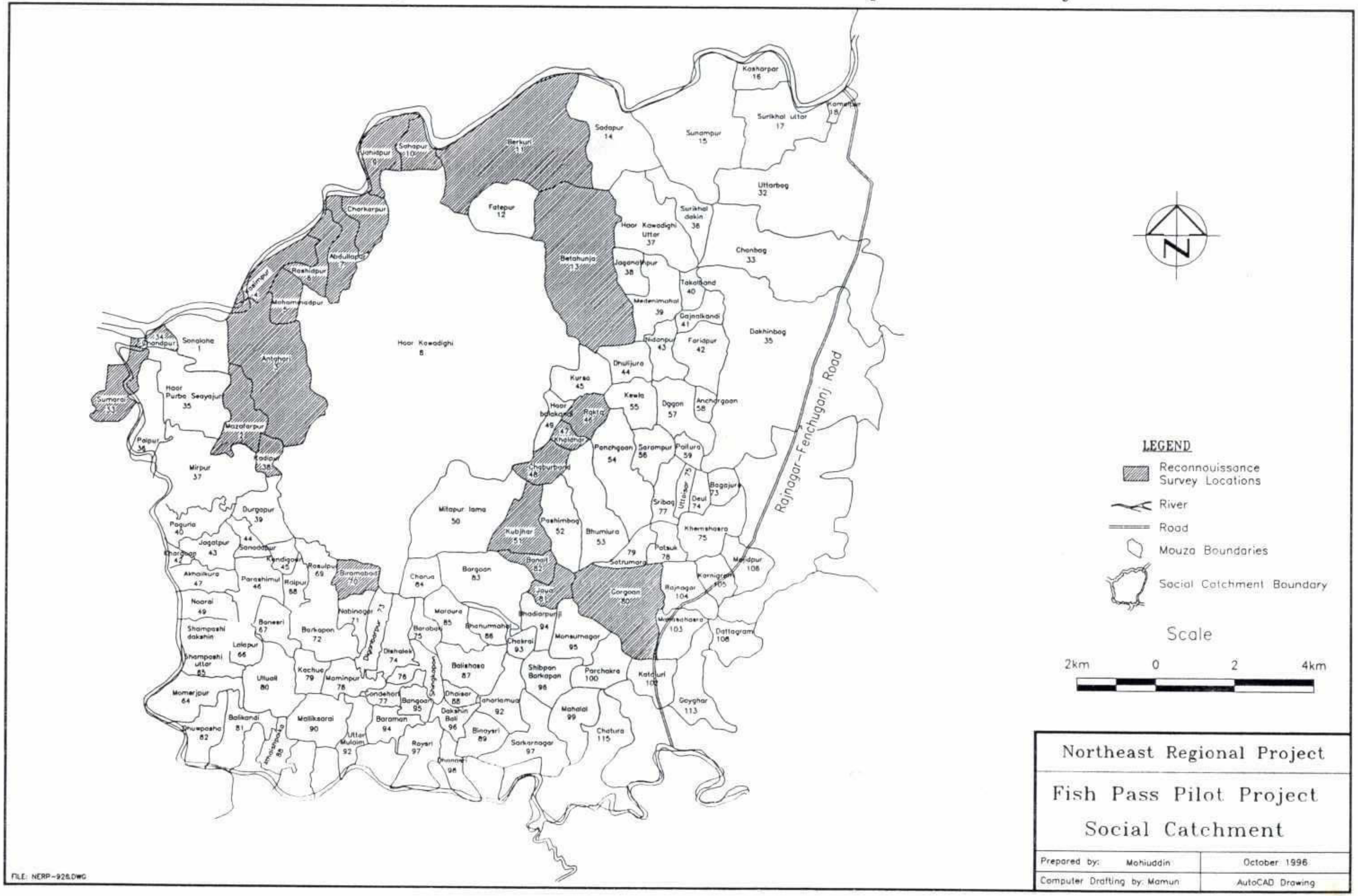


Figure 4: Population Growth in Project Area

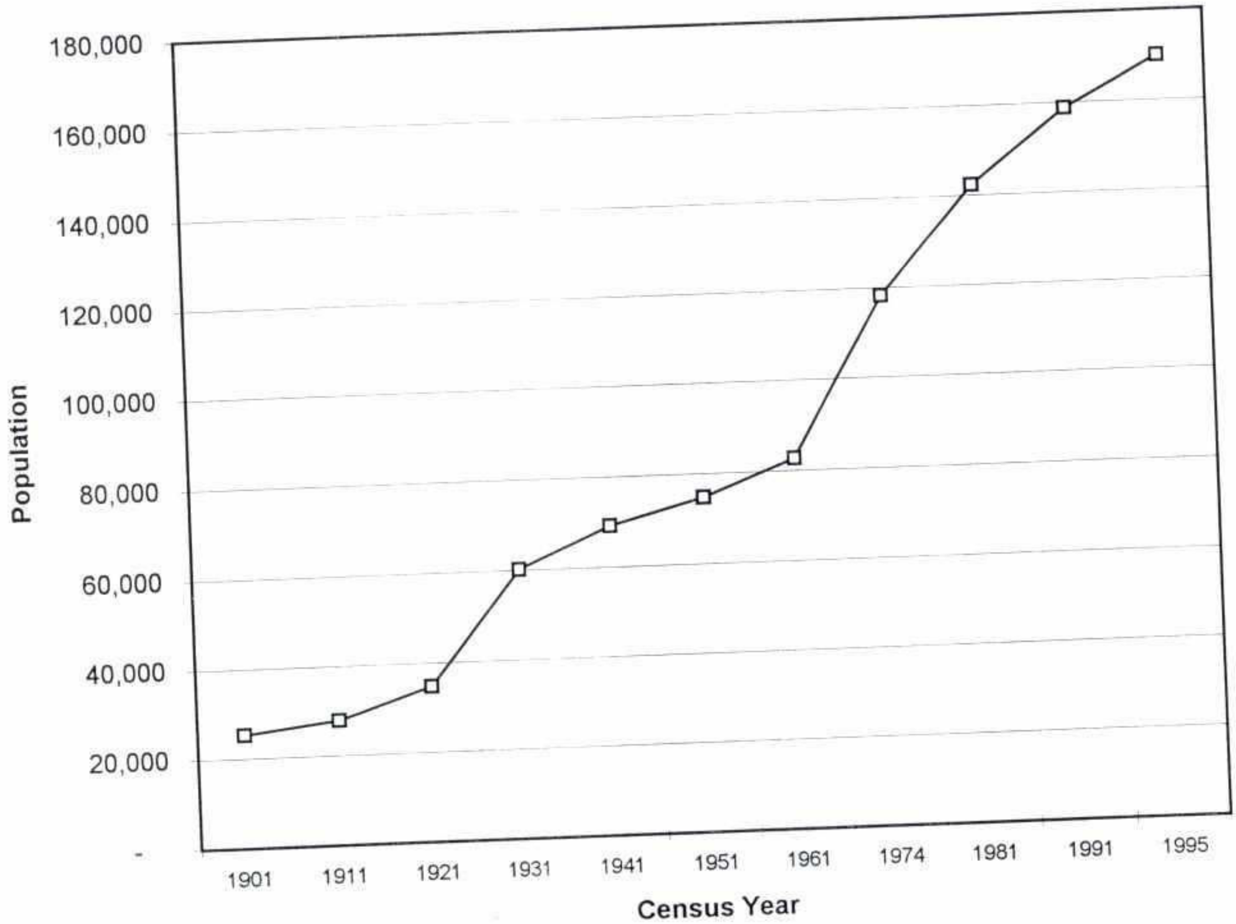


Figure 5: Land Ownership Pattern of Haor Fishermen

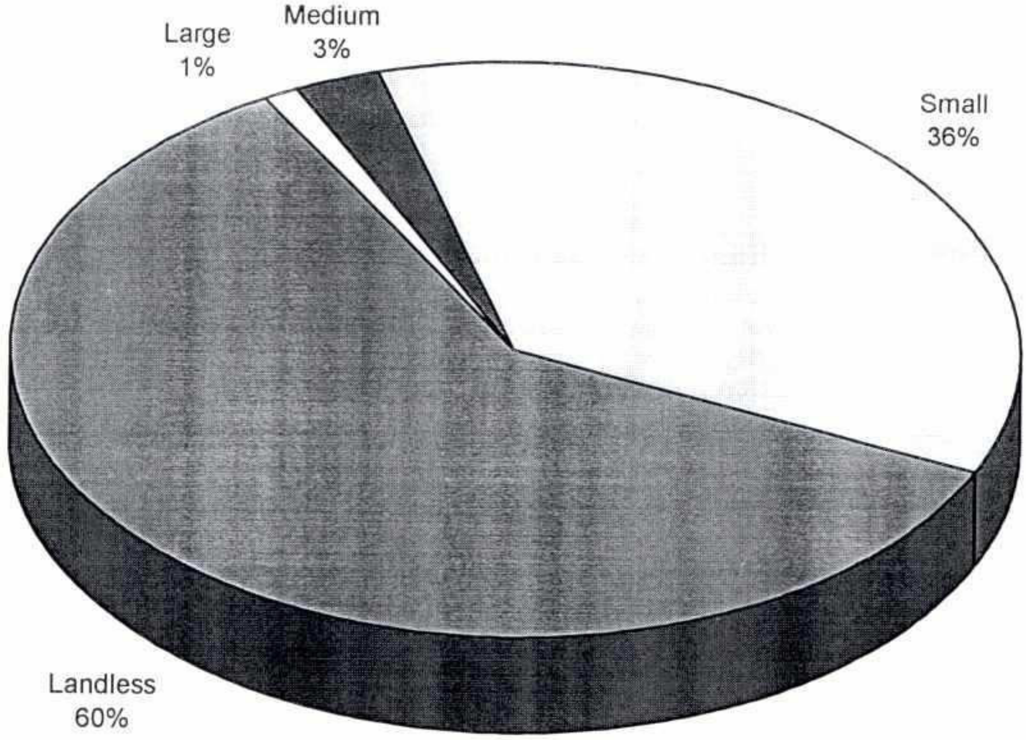
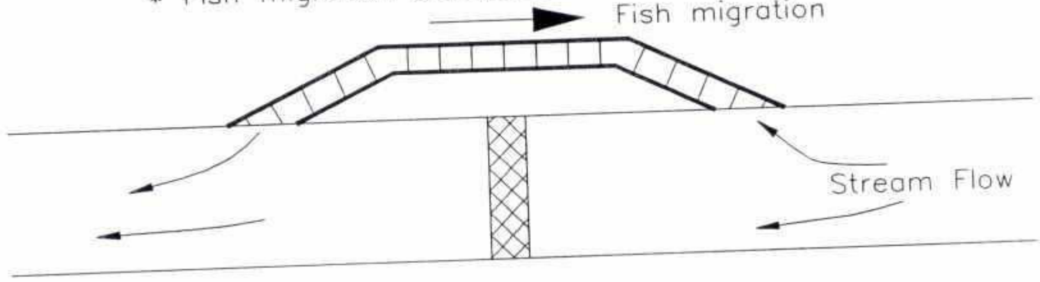


Figure 6: Comparison of Conventional Fishpass and Fishpass Pilot Project Applications

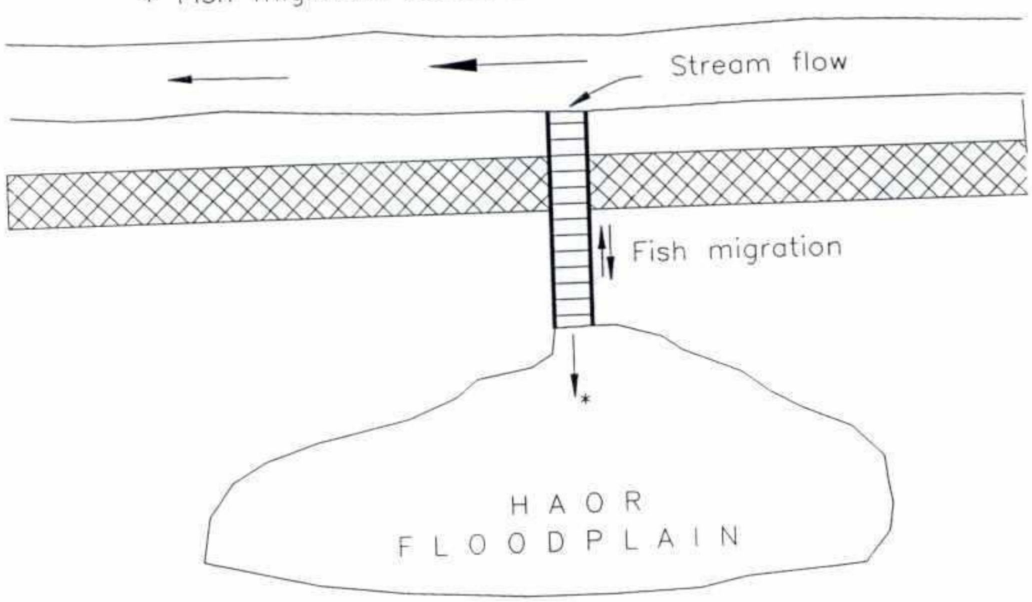
CONVENTIONAL FISHPASS APPLICATION

* Migration barrier perpendicular to stream flow
* Fishpass water inflow and outflow to same waterbodies
* Fishpass water flow unidirectional
* Fish migration Countercurrent



KASHIMPUR/FCDI FISHPASS APPLICATION

* Migration barrier parallel to stream flow
* Fishpass water inflow and outflow to different waterbodies
* Fishpass water flow bidirectional
* Fish migration concurrent and countercurrent

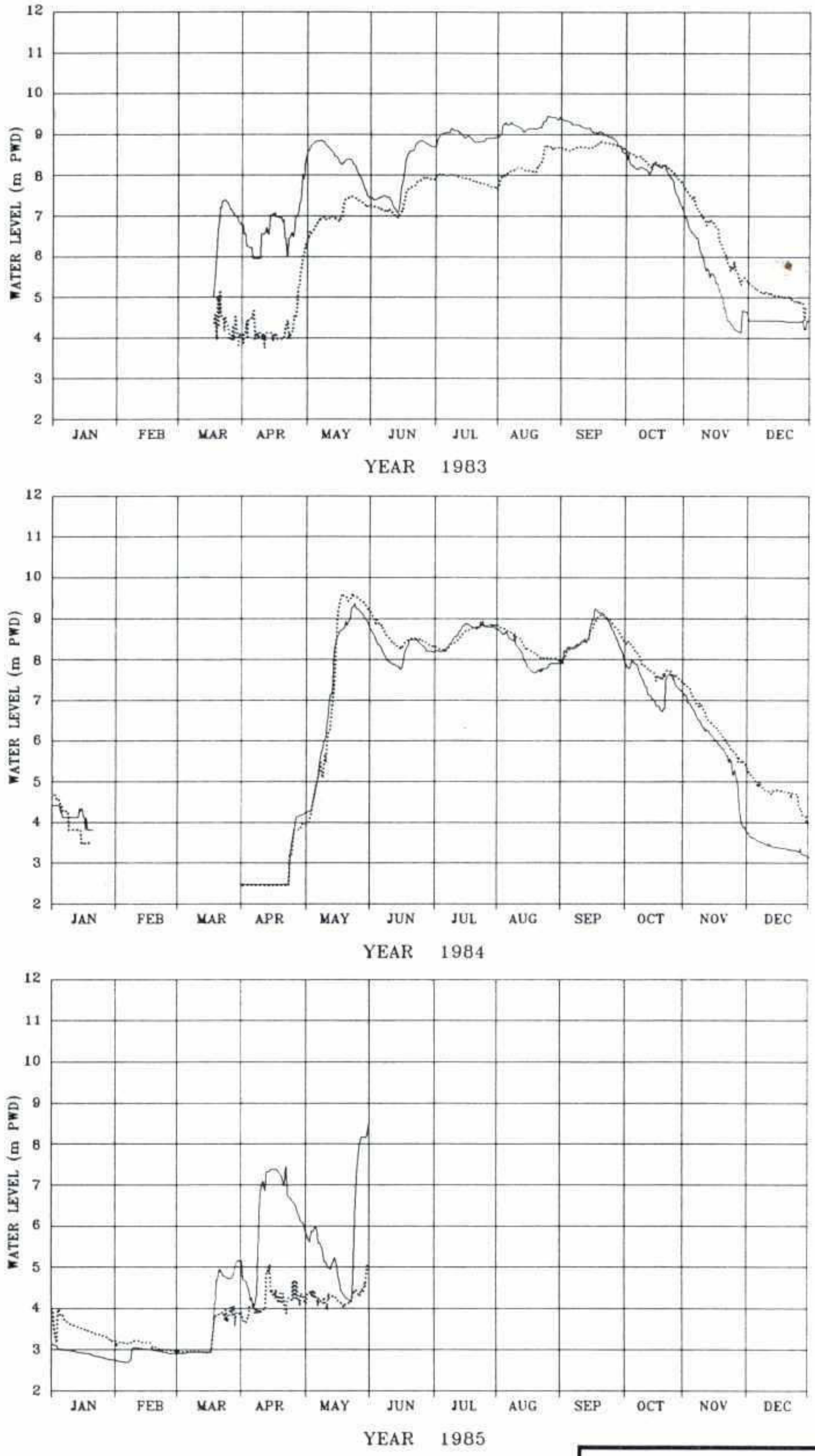


* Water flow through fishpass reverses during late monsoon due to haor drainage

Northeast Regional Project	
Fishpass Pilot Project Fishpass Application	
Prepared by: GB	November 1995
Computer Drafting by: Mamun	AutoCAD Drawing

FILE: FPP-20A.DWG

Figure 7: Water Level Hydrographs (1983-85)



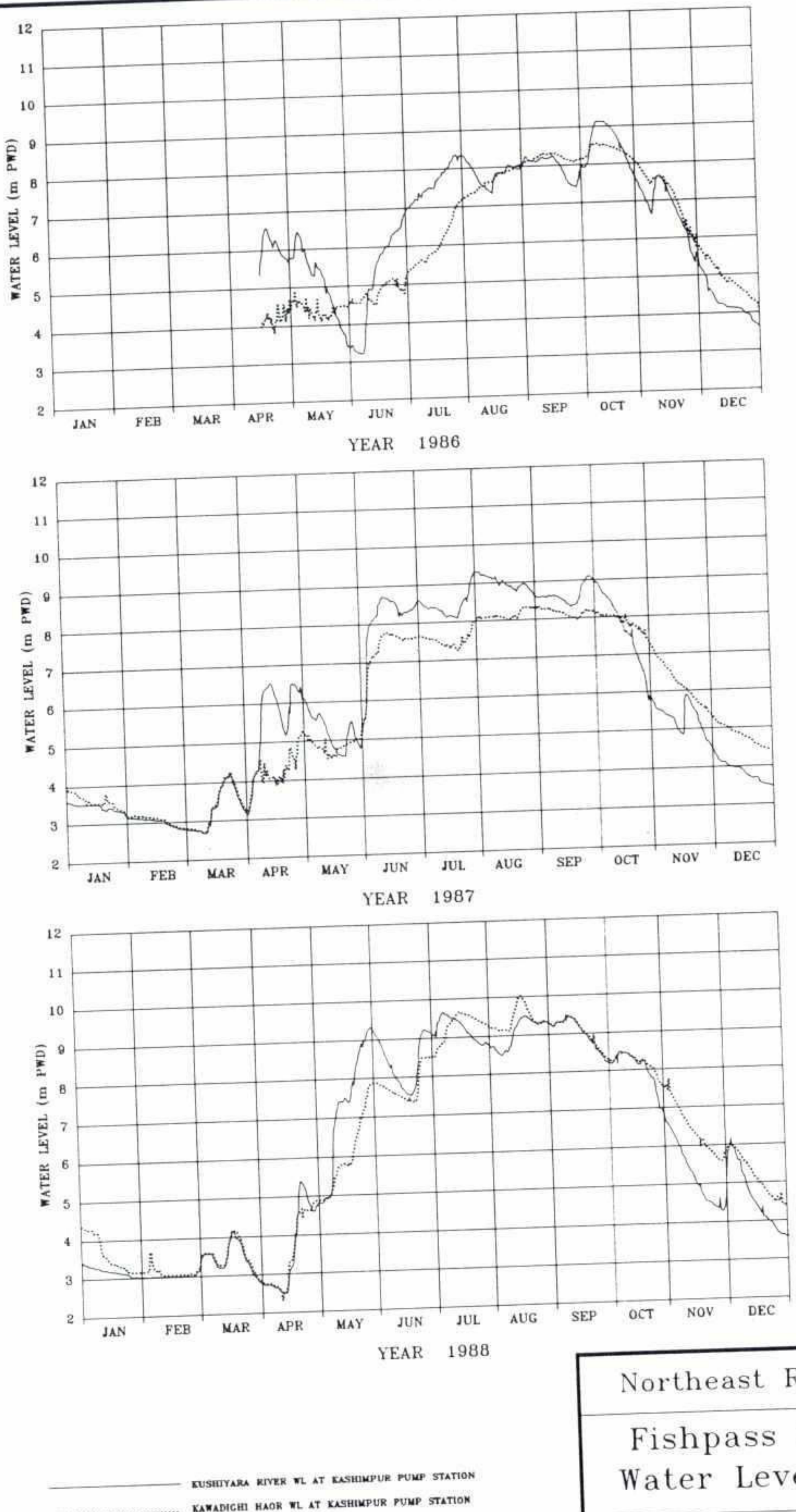
——— KUSHIYARA RIVER WL AT KASHIMPUR PUMP STATION

········ KAWADIGHI HAOR WL AT KASHIMPUR PUMP STATION

FILE: FPP-211DWG

Northeast Regional Project	
Fishpass Pilot Project Water Level Hydrograph	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

Figure 8: Water Level Hydrographs (1986-88)



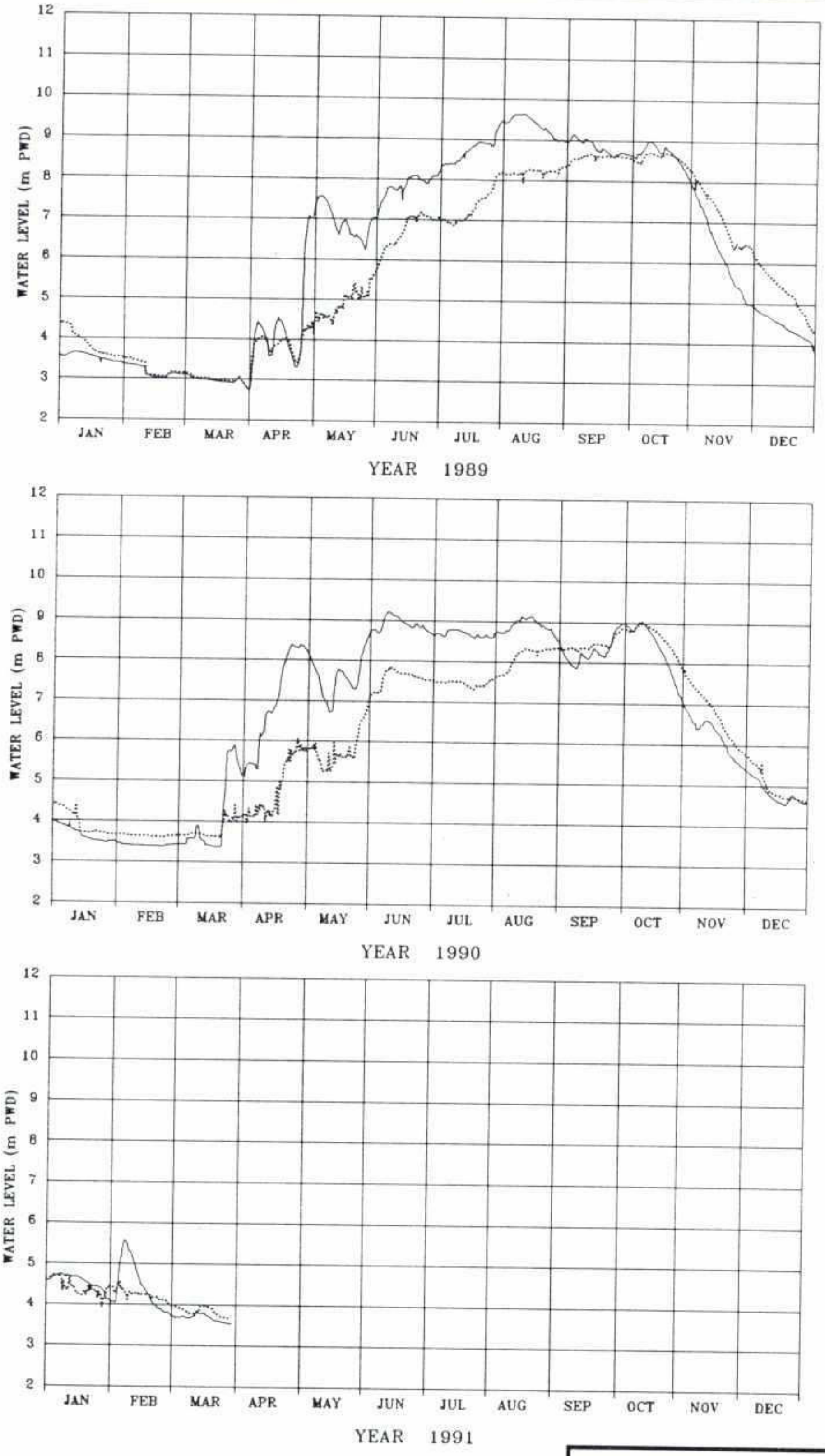
Northeast Regional Project

Fishpass Pilot Project
Water Level Hydrograph

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-212.DWG

Figure 9: Water Level Hydrographs (1989–91)



KUSHIYARA RIVER WL AT KASHIMPUR PUMP STATION

KAWADIGHI HAOR WL AT KASHIMPUR PUMP STATION

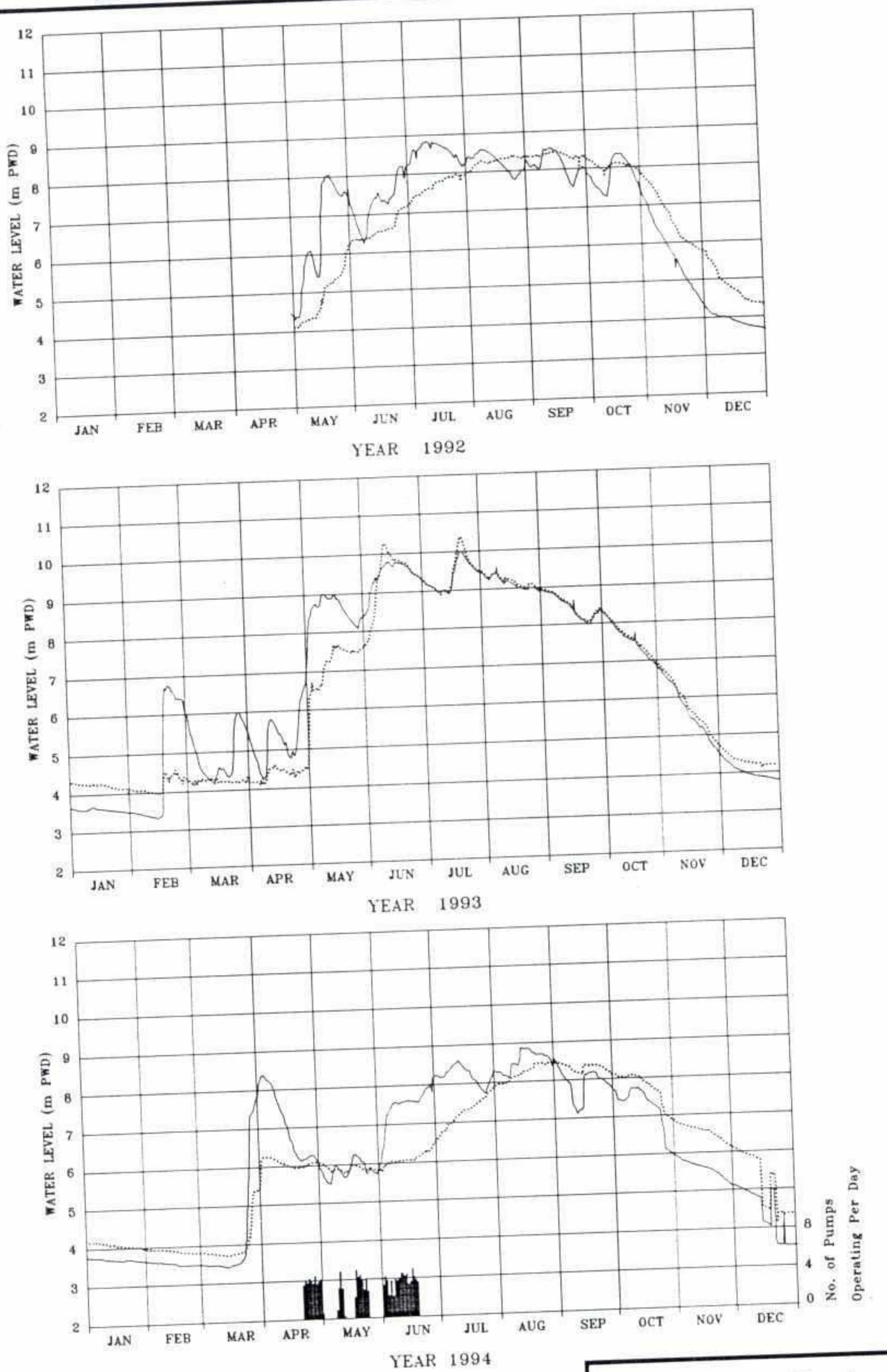
FILE: FPP-213.DWG

Northeast Regional Project

Fishpass Pilot Project
Water Level Hydrograph

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

Figure 10: Water Level Hydrographs (1992–94)



NOTE:
PUMPING HOURS ARE BASED ON THREE YEARS (1994–96) NERP MONITORING RESULTS

———— KUSHIYARA RIVER WL AT KASHIMPUR PUMP STATION

.... KAWADIGHI HAOR WL AT KASHIMPUR PUMP STATION

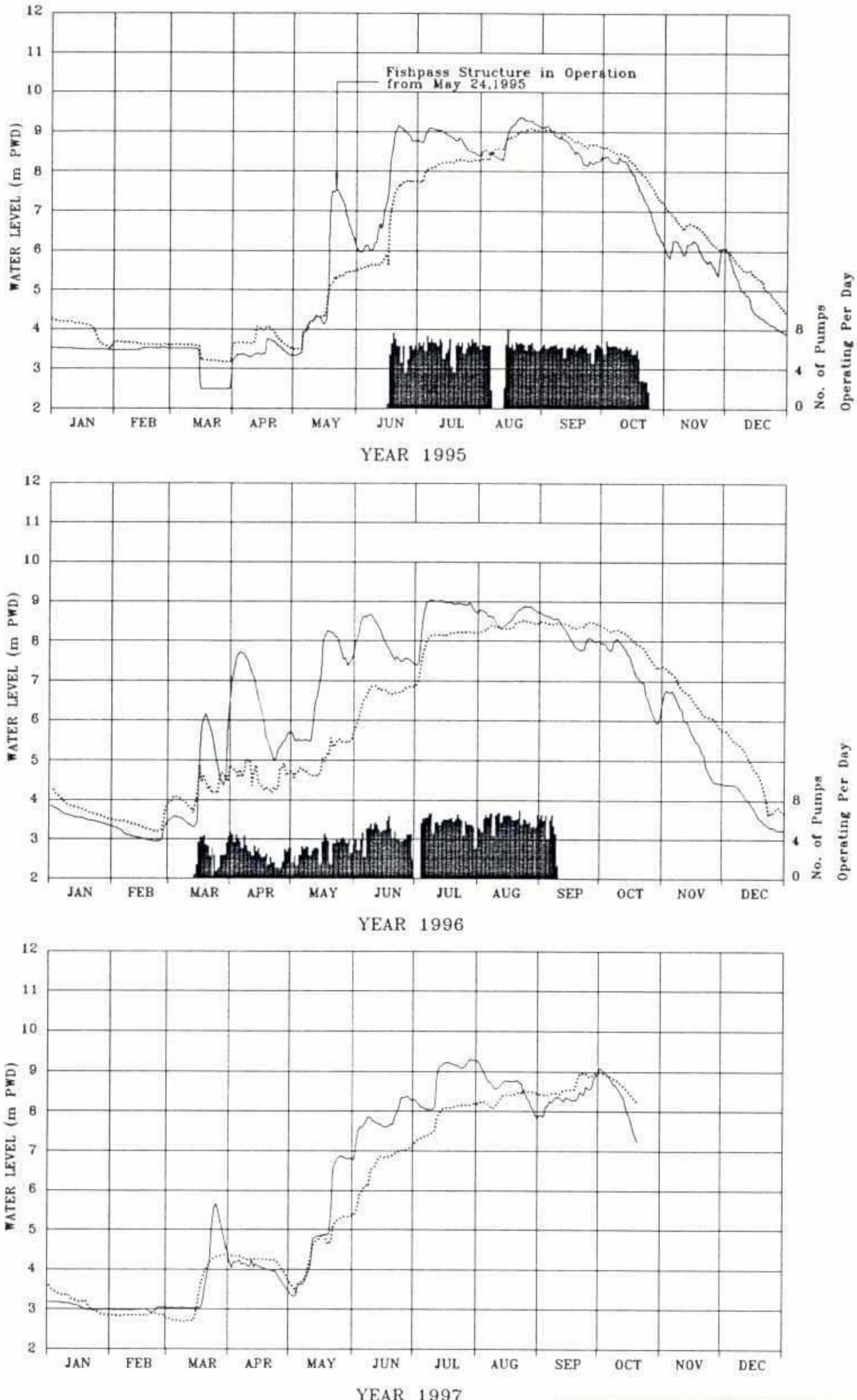
Northeast Regional Project

Fishpass Pilot Project
Water Level Hydrograph

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-214.DWG

Figure 11: Water Level Hydrographs for year 1-3 (1995-97)



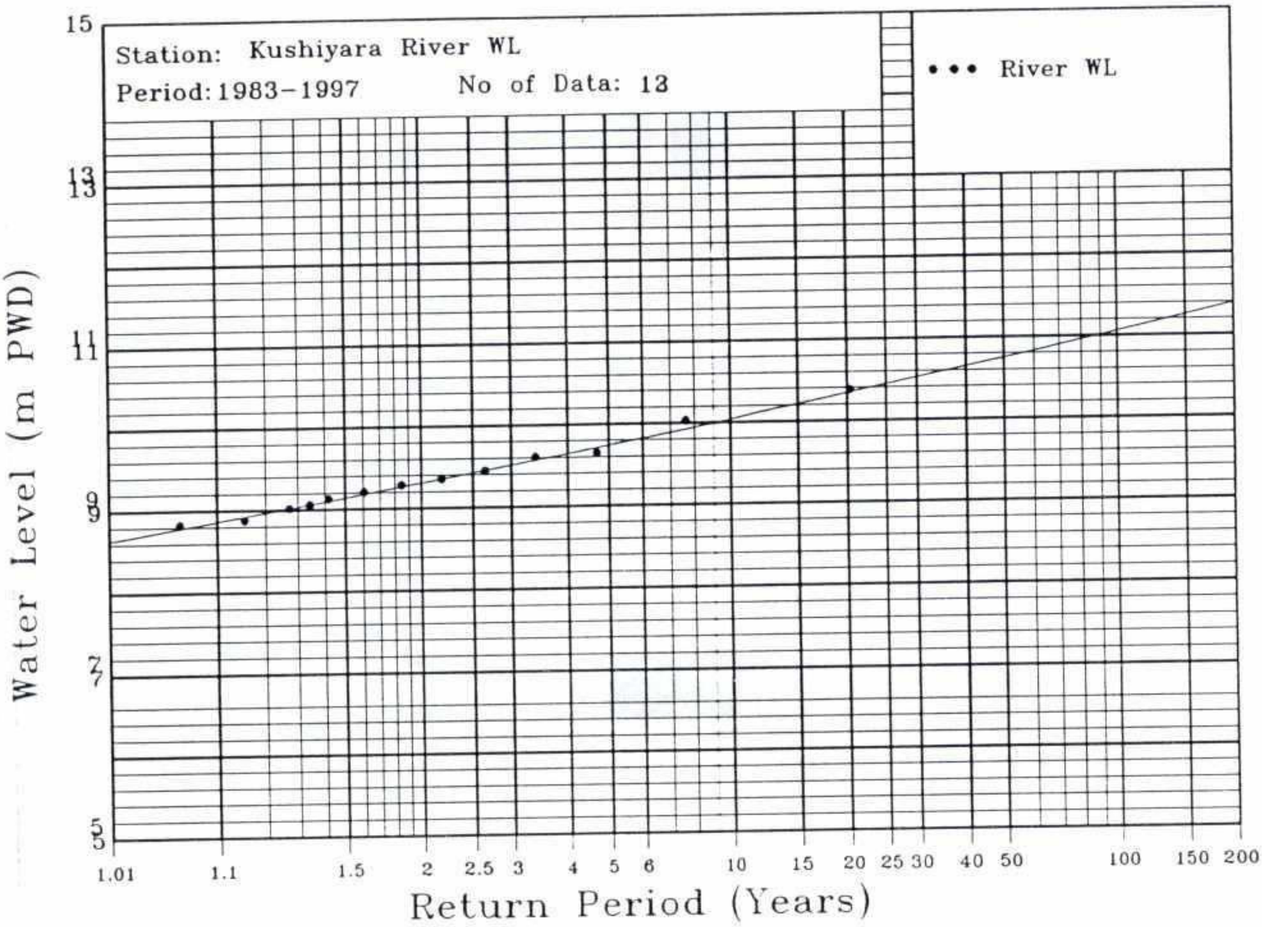
NOTE:
PUMPING HOURS ARE BASED ON THREE YEARS (1994-96) NERP MONITORING RESULTS

——— KUSHIYARA RIVER WL AT KASHIMPUR PUMP STATION
.... KAWADIGHI HAOR WL AT KASHIMPUR PUMP STATION

FILE: FPP-215.DWG

Northeast Regional Project	
Fishpass Pilot Project Water Level Hydrograph	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

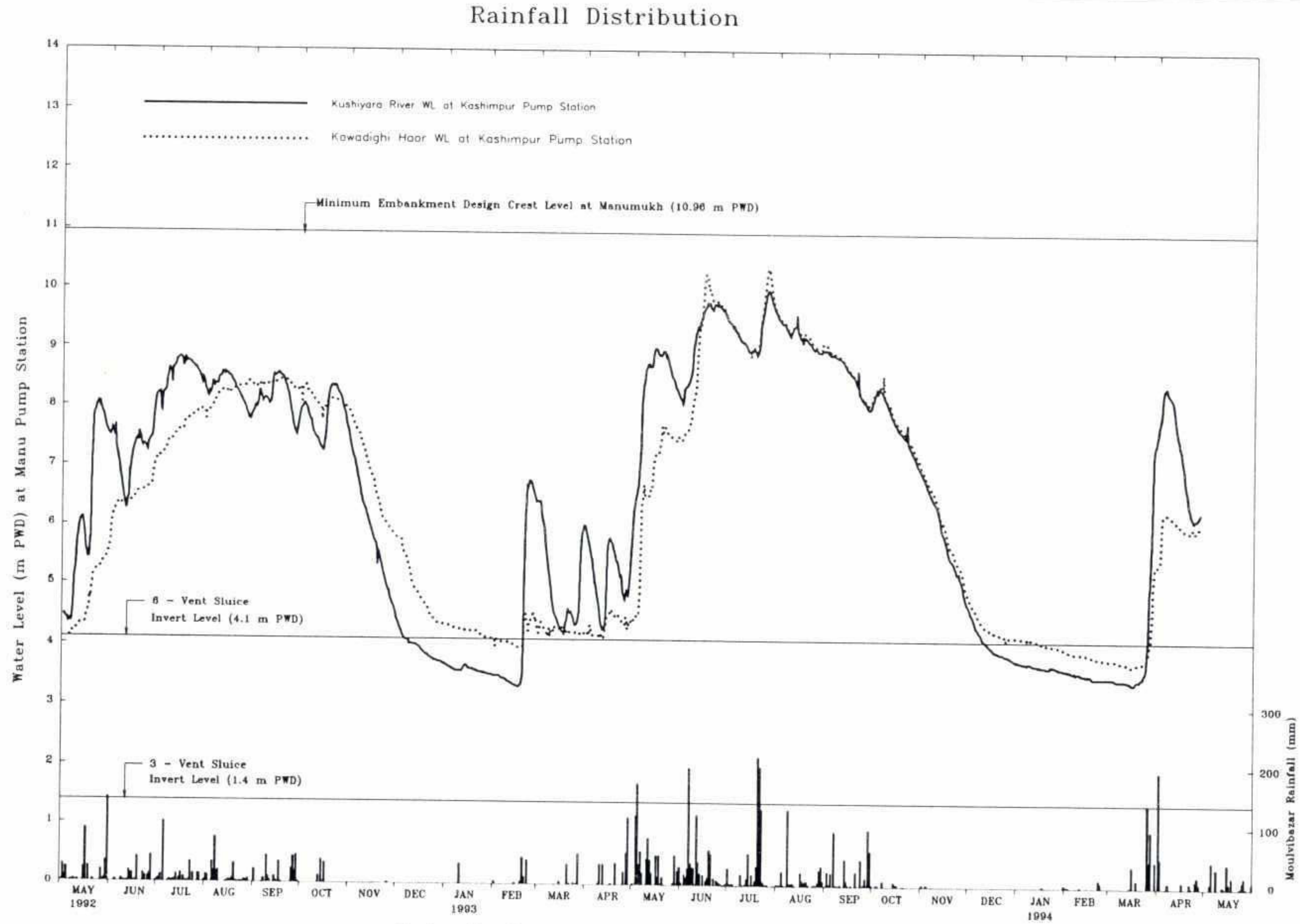
Figure 12: Return Period of Water Level of Kushiyara River



Northeast Regional Project	
Kushiyara River Water Level	
Prepared by: Salahuddin	December 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-247.DWG

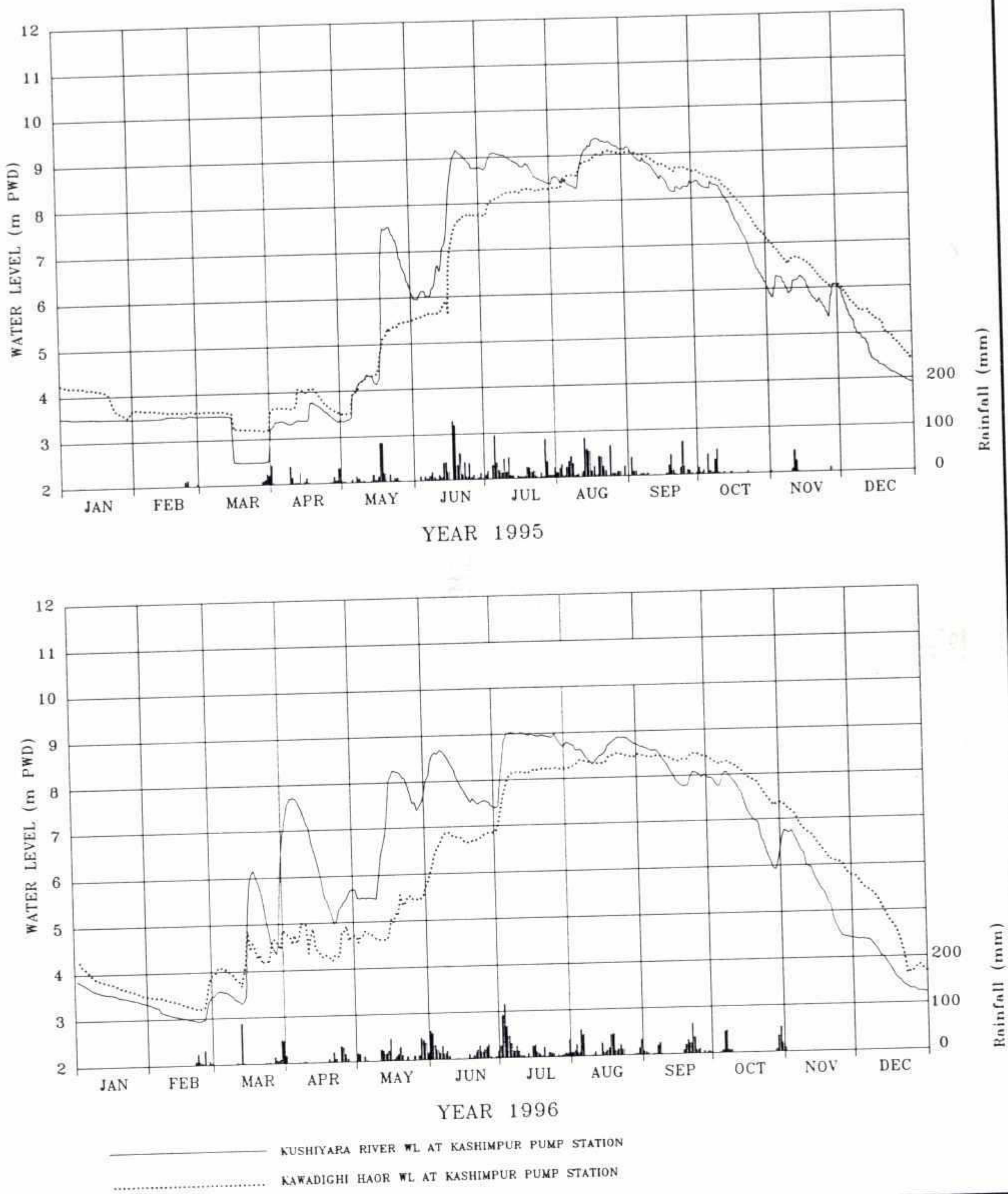
Figure 13: Rainfall Distribution (1992–94)



Hydraulic Operation of Manu Project, 1992–94

FILE : FPP-216.DWG

Figure 14: Rainfall Distribution (1995 and 1996)



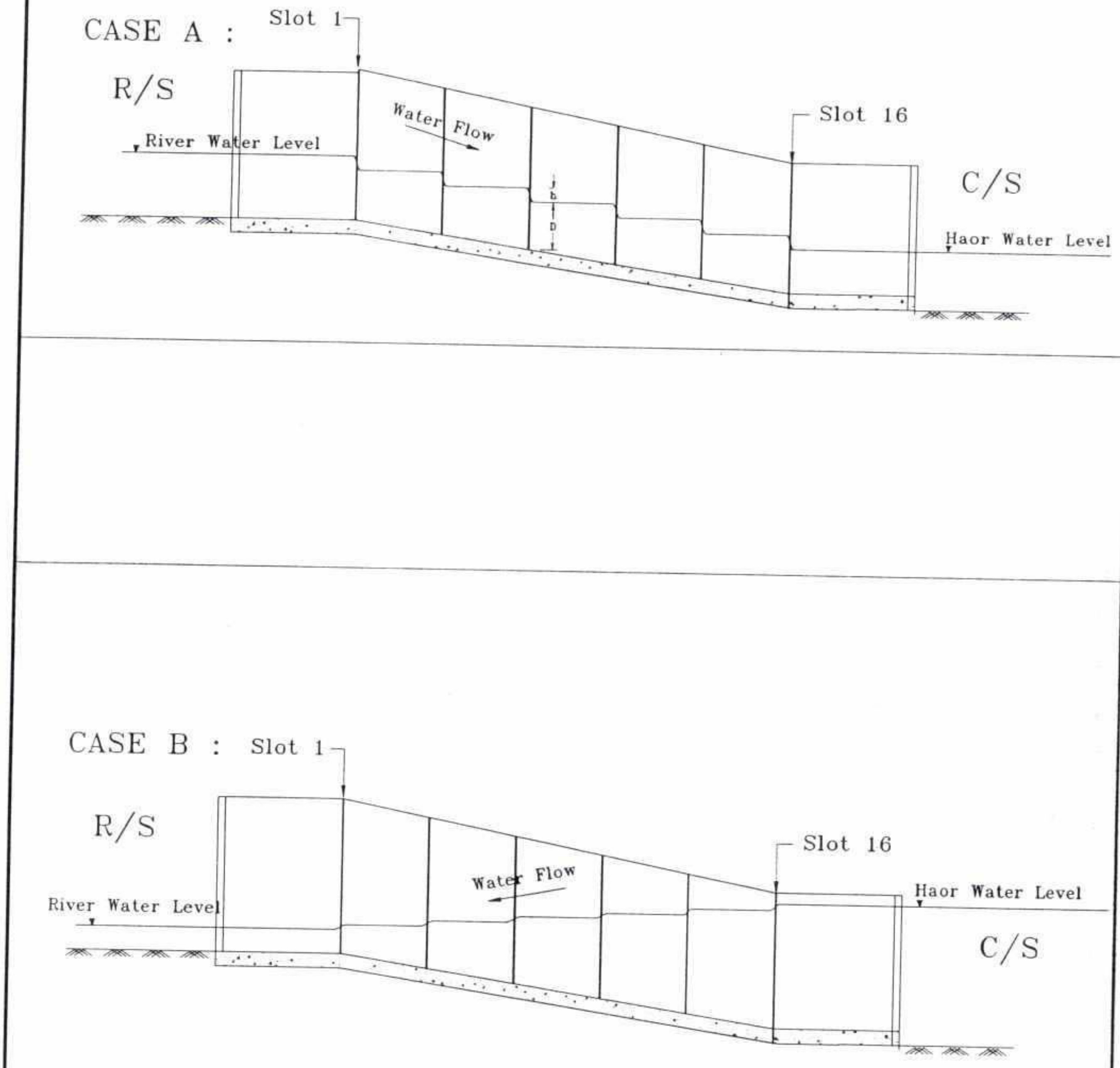
Northeast Regional Project

Fishpass Pilot Project
Rainfall Distribution

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-217.DWG

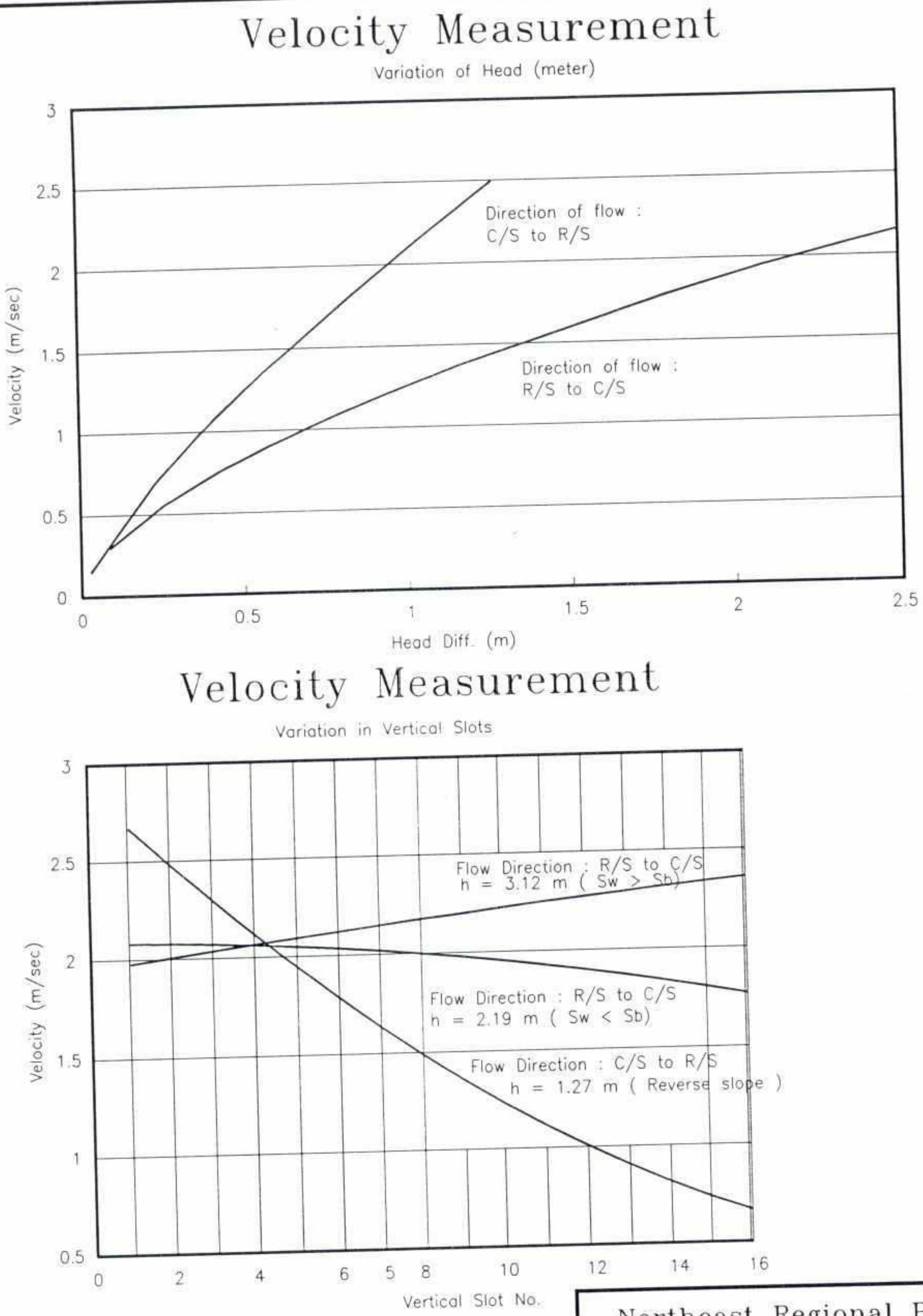
Figure 15: Schematic Flow Diagram of Fishpass



Northeast Regional Project	
Fishpass Pilot Project Schematic Flow Diagram	
Prepared bySalhuddin	November 1997
Computer Drafting byJalal	AutoCAD Drawing

FILE: FPP-218.DWG

Figure 16: Velocity Versus Head Difference



Northeast Regional Project	
Fishpass Pilot Project	
Velocity Vs. Head Diff. & Vertical Slots	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-219.DWG

Figure 17: Water Levels and Velocity During Year 1 (1995)

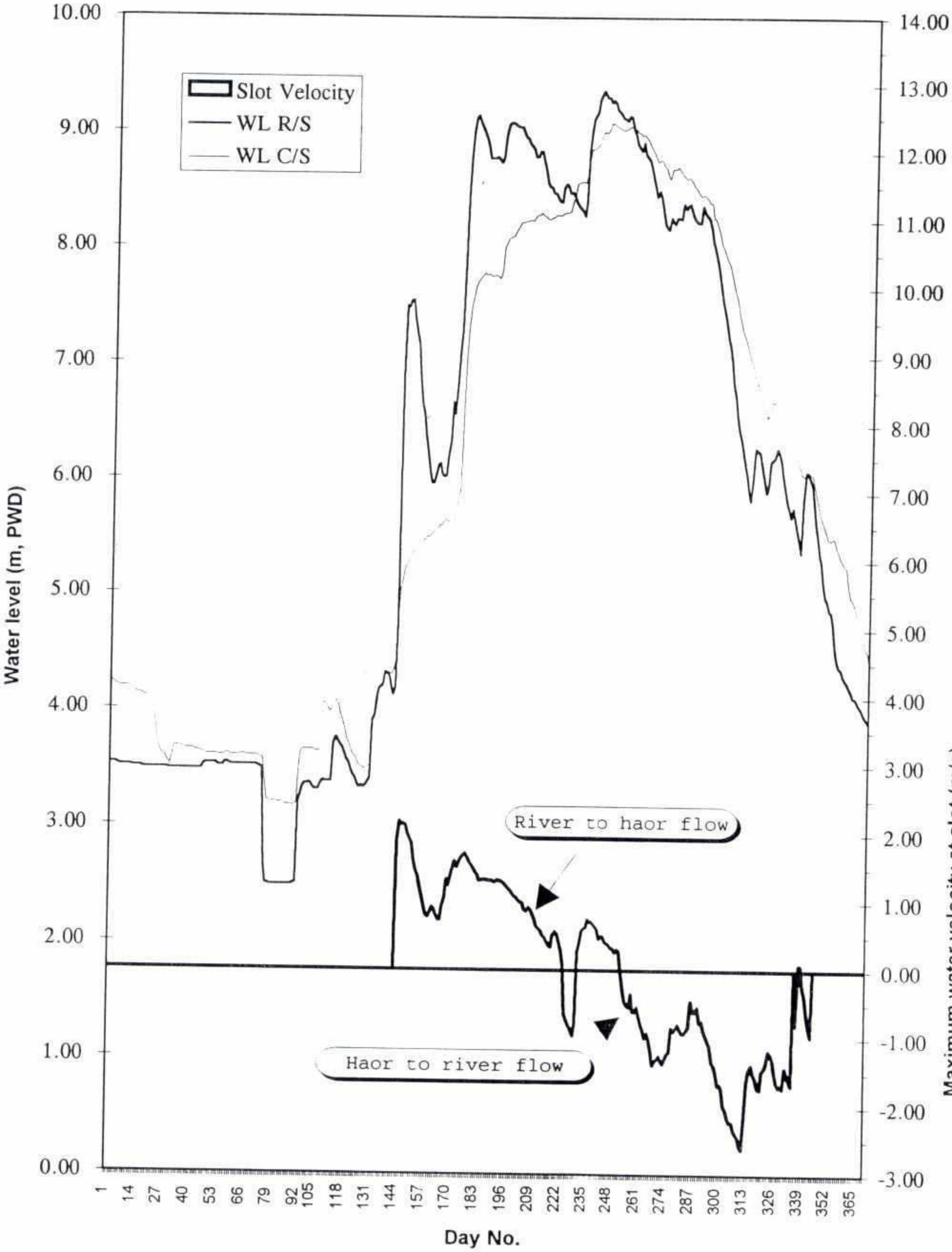


Figure 18: Water Levels and Velocity During Year 2 (1996)

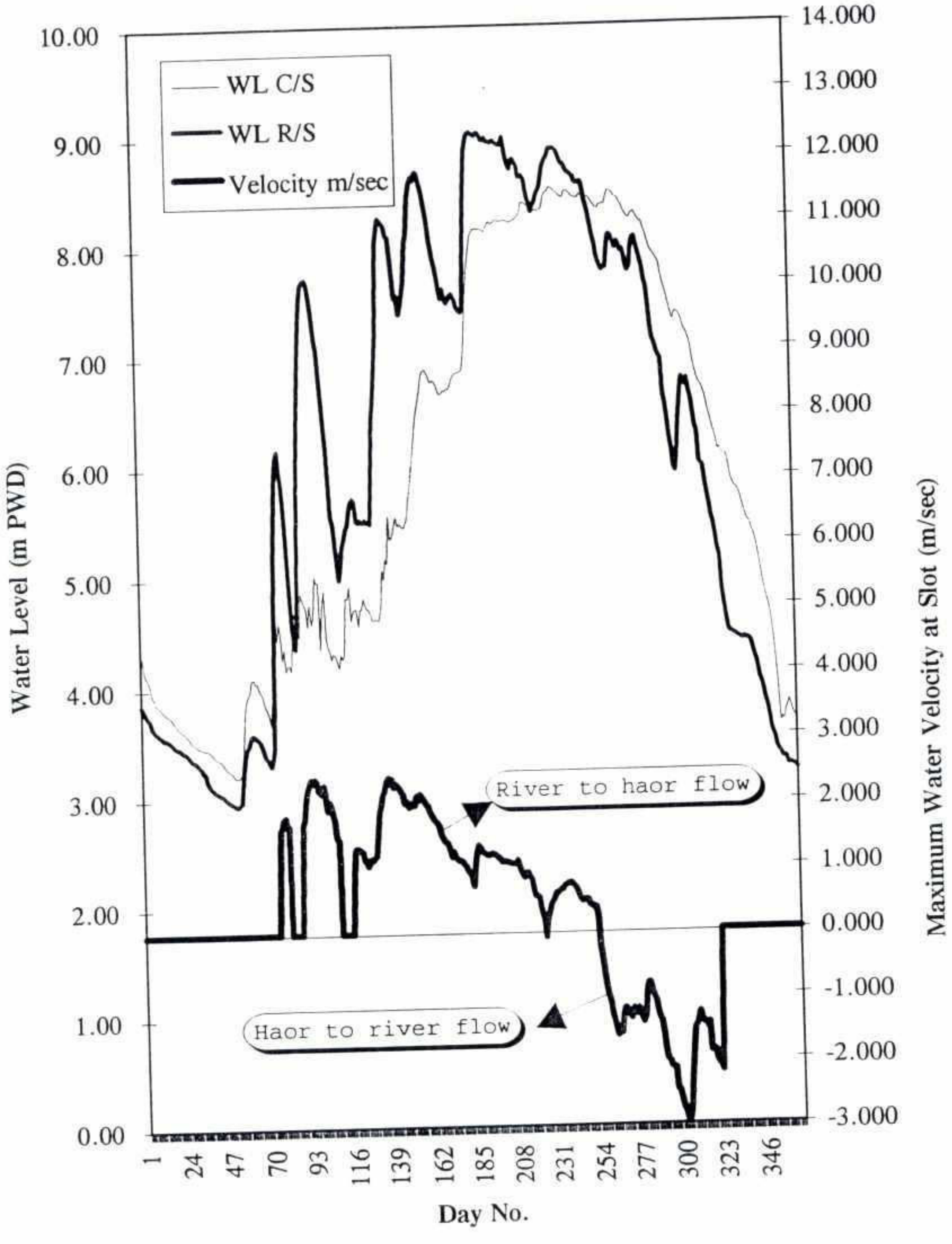


Figure 19: Water Levels and Velocity During Year 3 (1997)

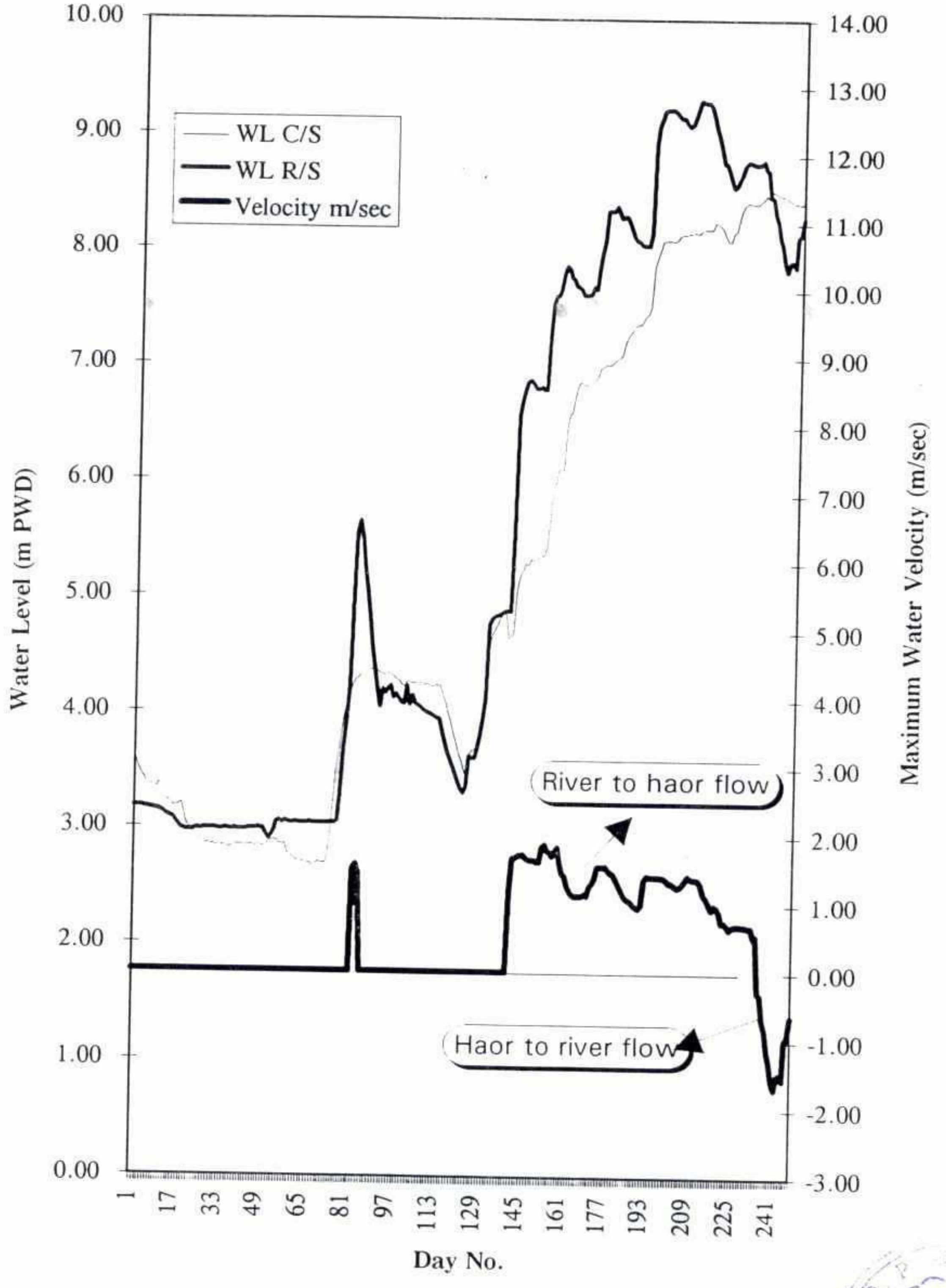
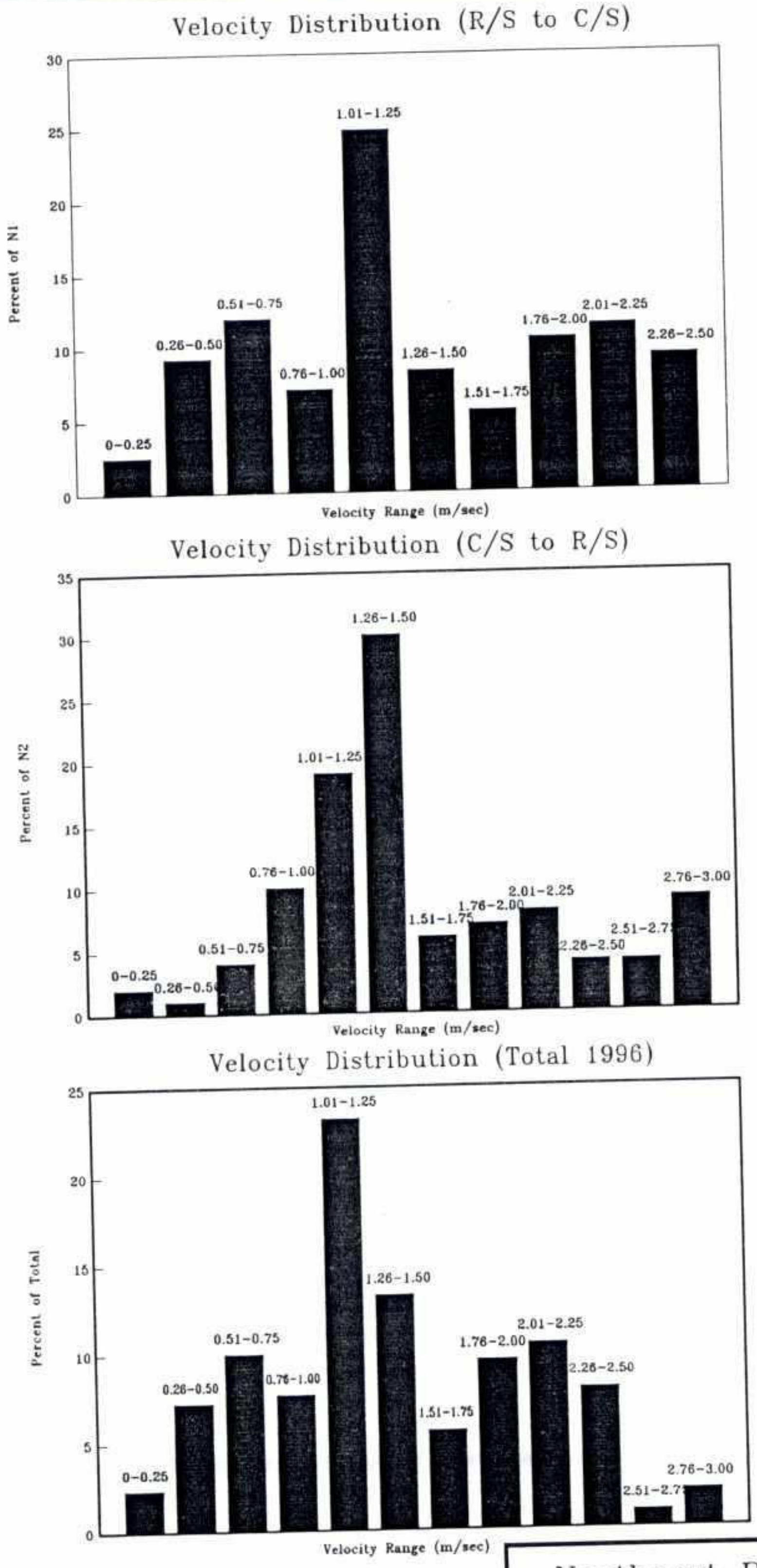


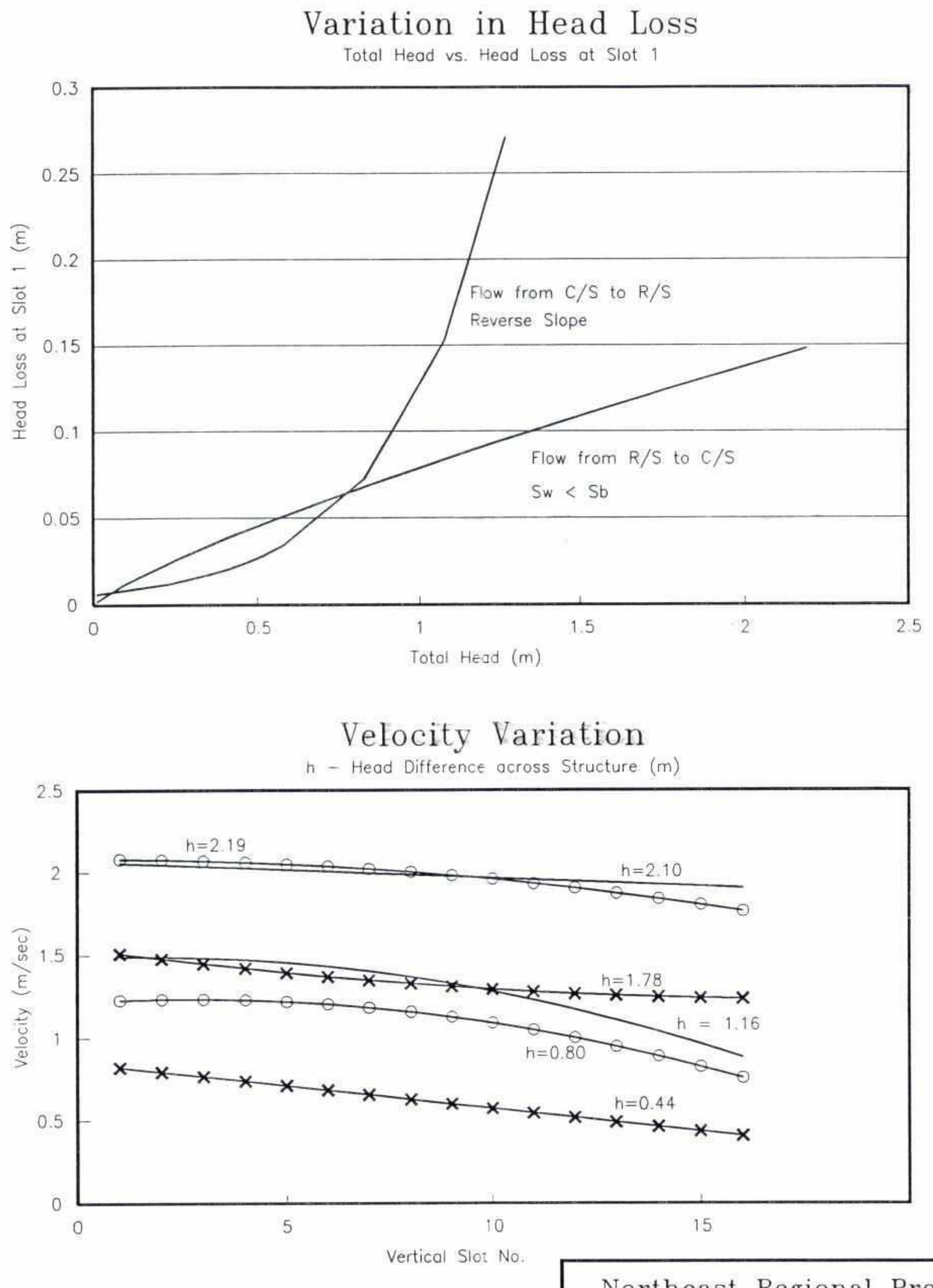
Figure 20: Velocity Distribution During year 2 (1996)



Northeast Regional Project	
Fishpass Pilot Project Velocity Distribution	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-220.DWG

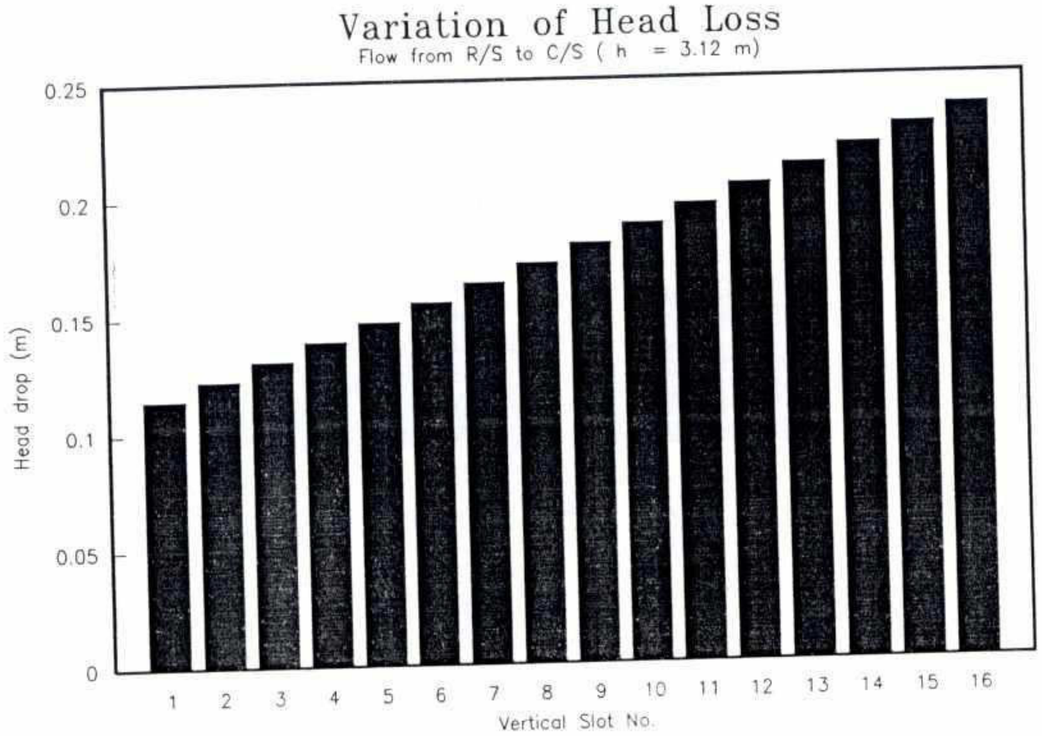
Figure 21: Variation in Head Loss and Velocity

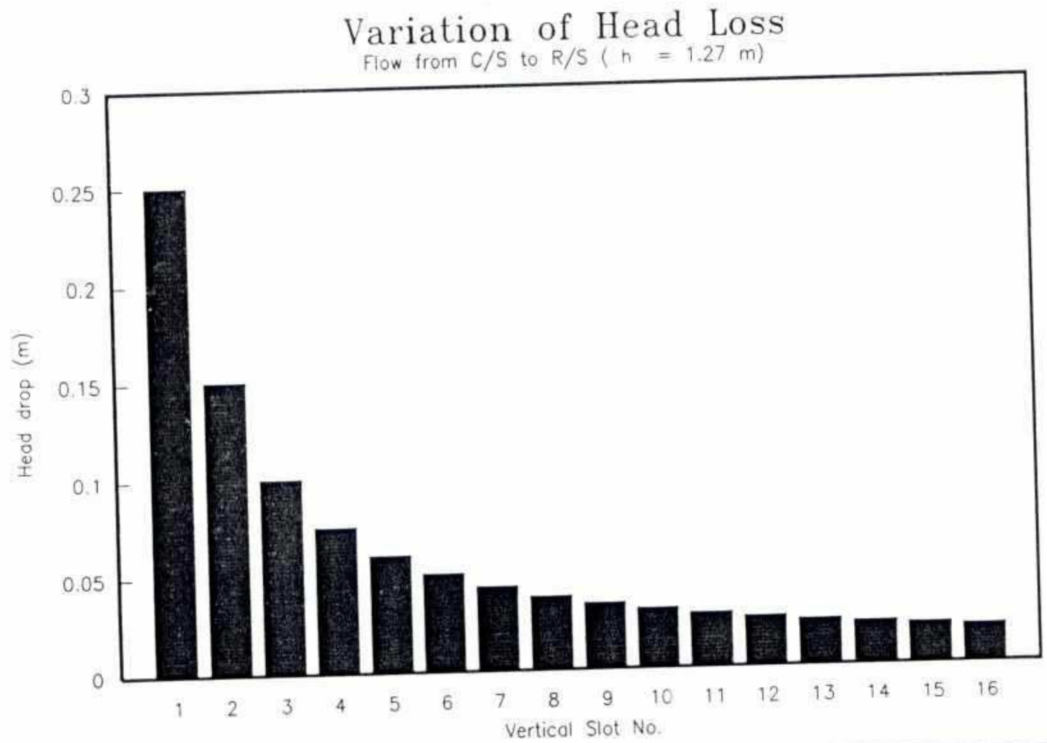


Northeast Regional Project	
Fishpass Pilot Project Variation in Head loss & Velocities	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-222.DWG

Figure 22: Head Drop at Vertical Slots





Northeast Regional Project	
Fishpass Pilot Project Head Drop at Vertical Slots	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-221.DWG

Figure 23: Turbulence in Pools During Year 1 (1995)

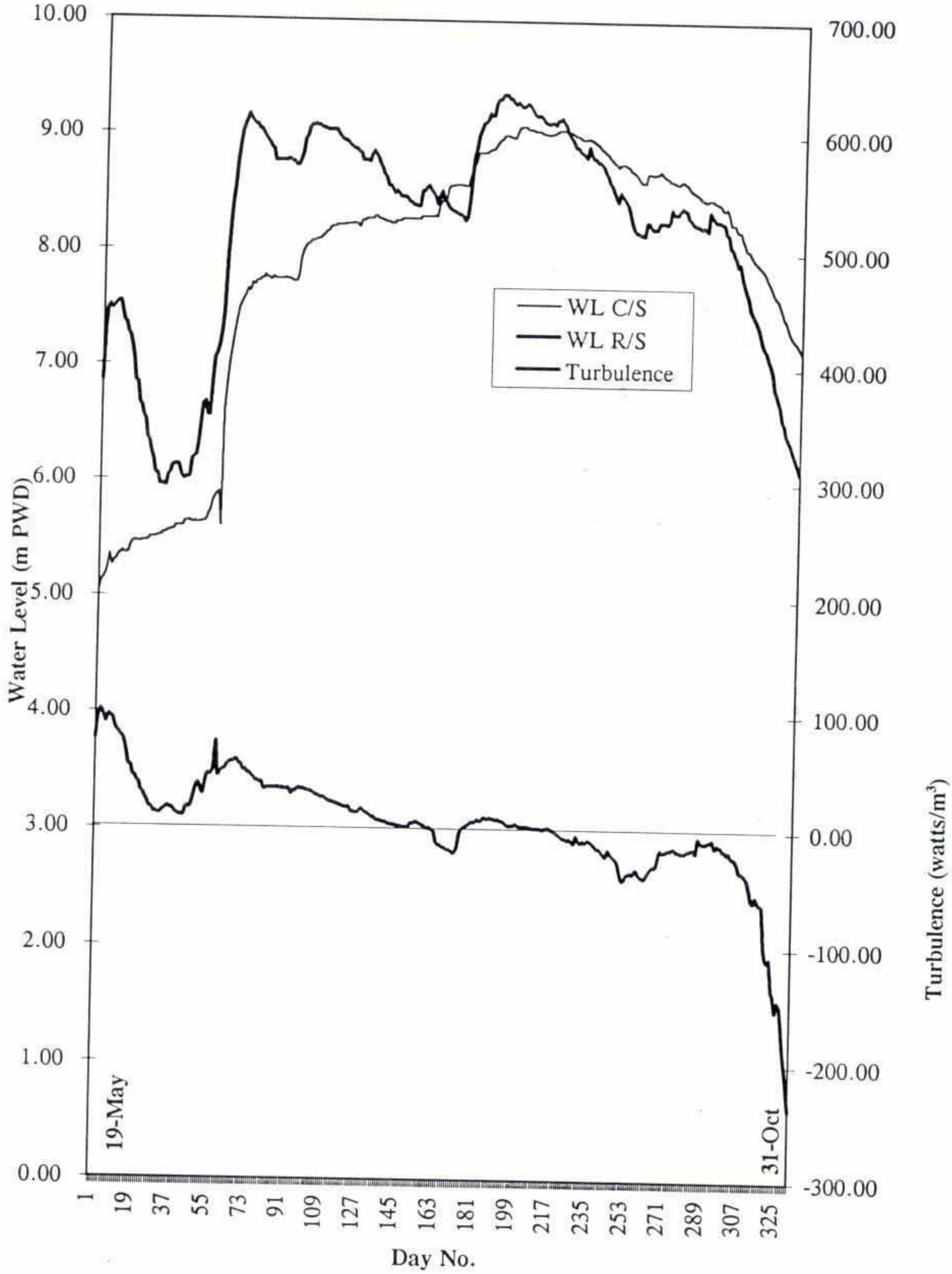


Figure 24: Turbulence in Pools During Year 2 (1996)

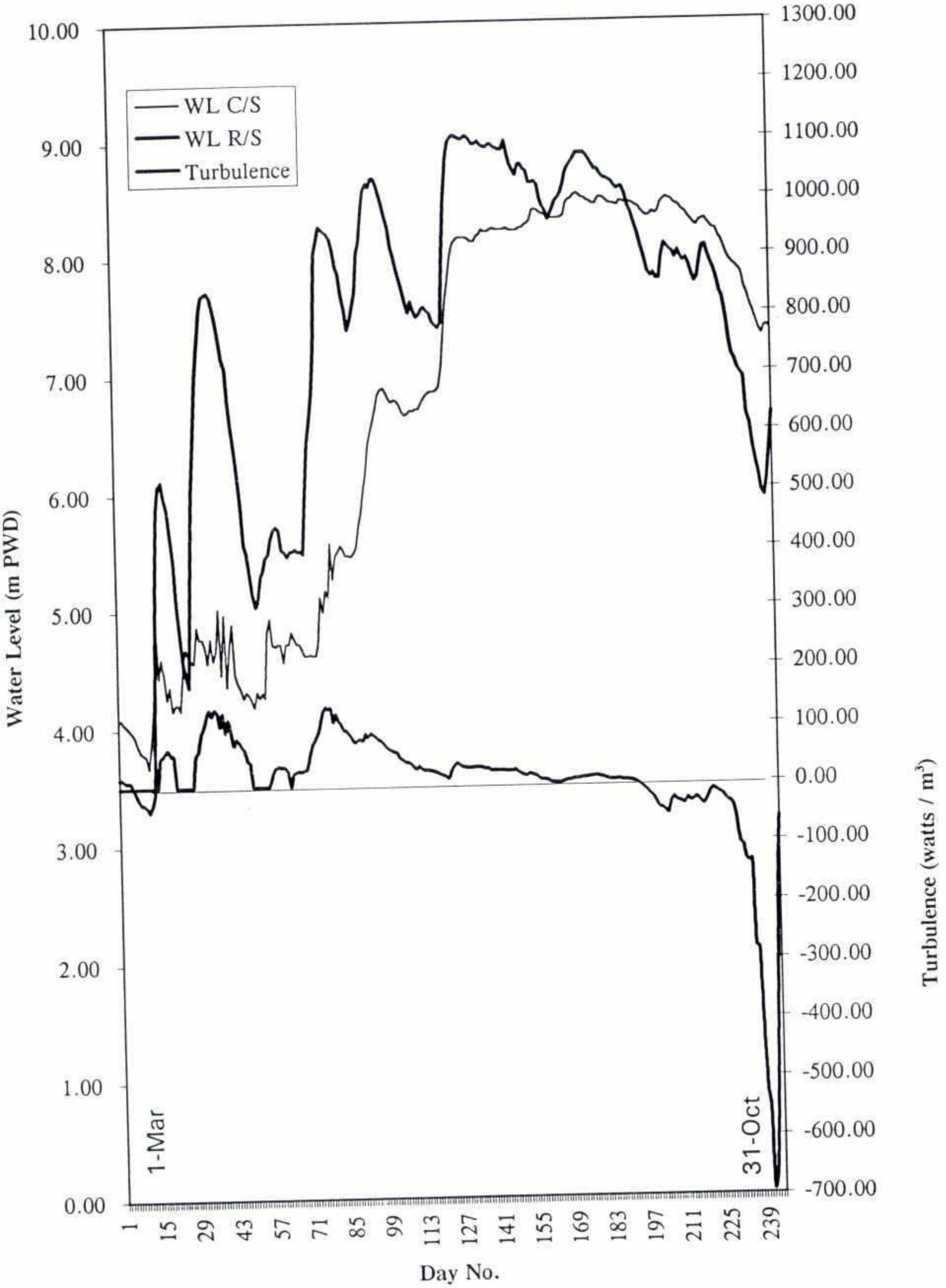


Figure 25: Turbulence in Pools During Year 3 (1997)

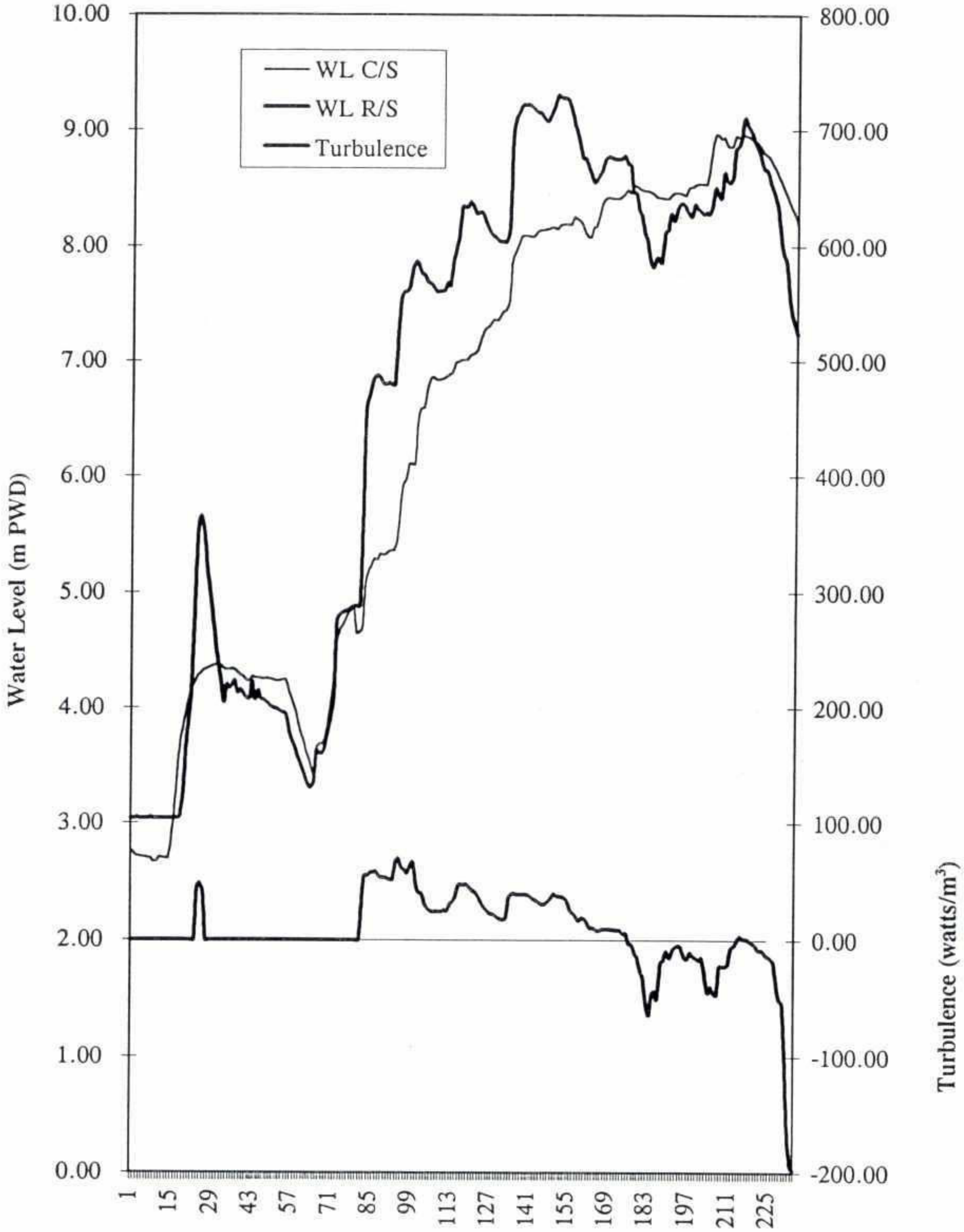


Figure 26: Daily Traffic through Fishpass during Year 2 (1996)

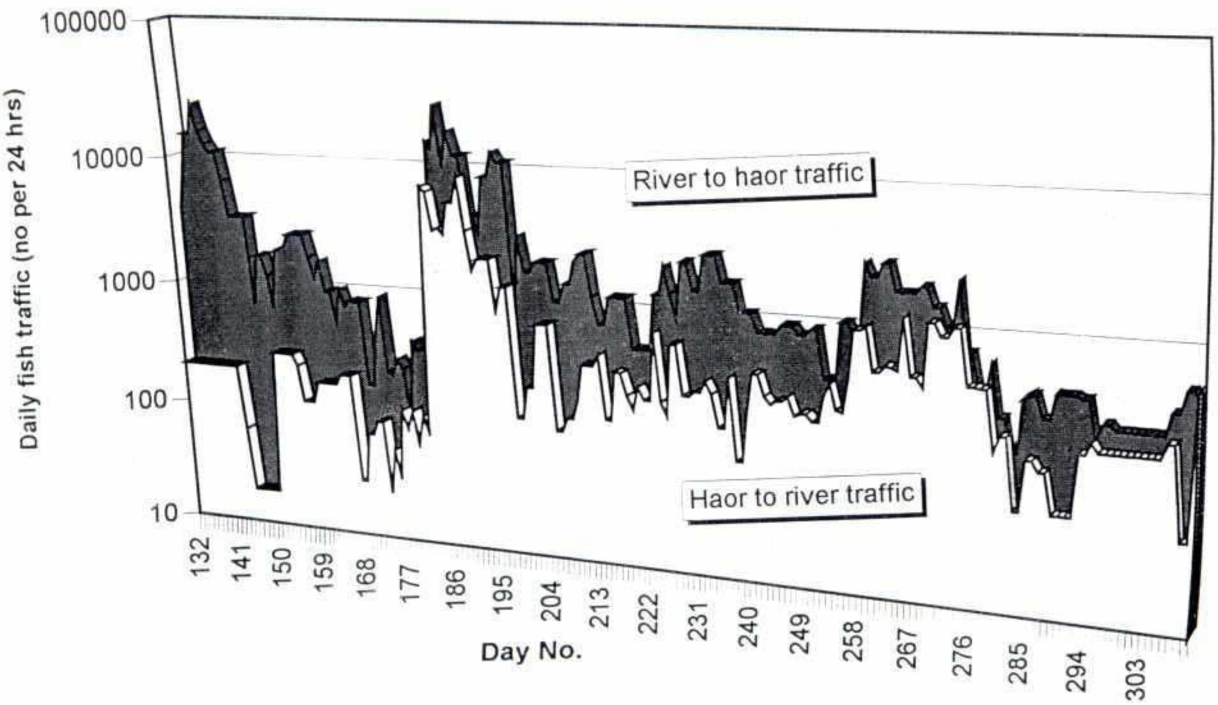


Figure 27: Daily Fish Traffic through Fishpass during Year 3 (1997)

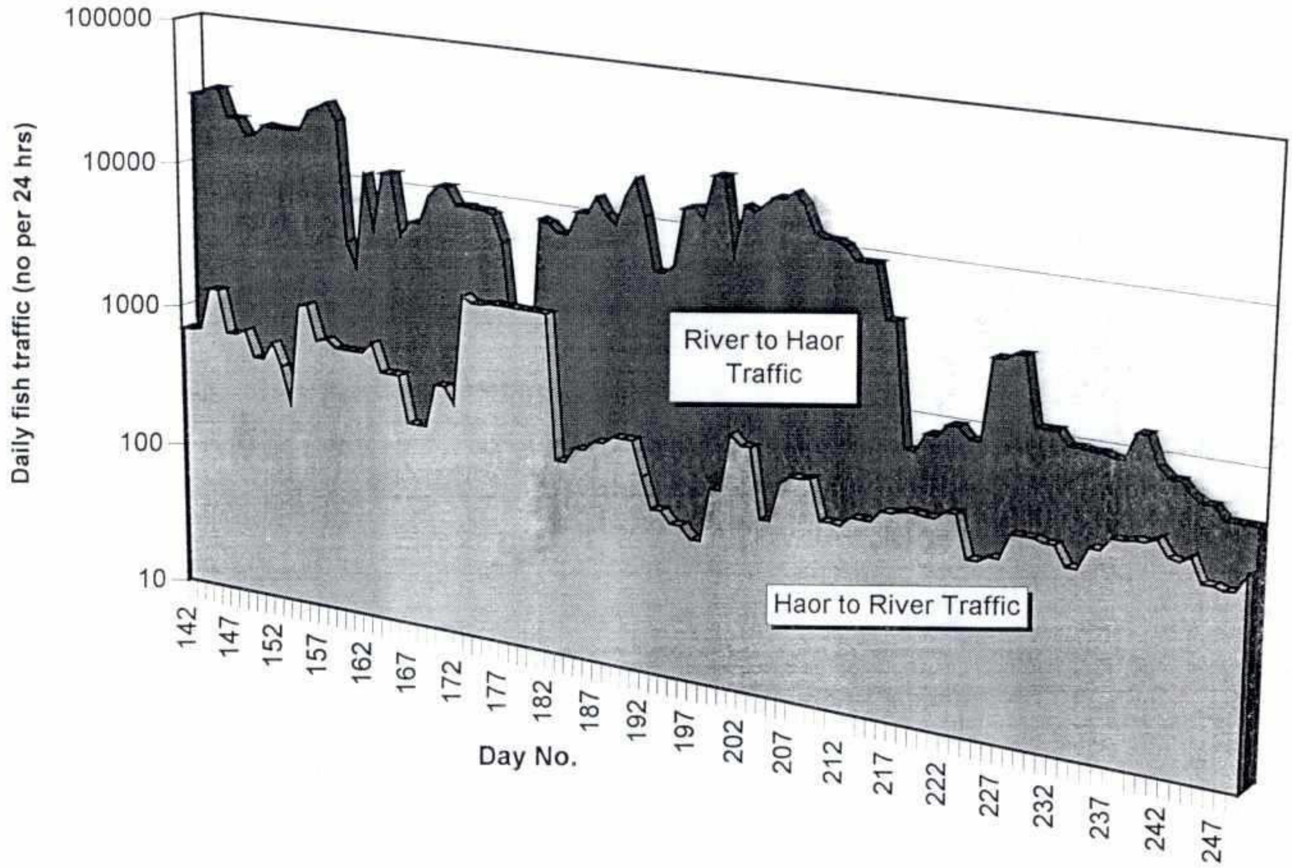


Figure 28: Comparison of Daily Fish Traffic with Riverside Water Level during Year 2 (1996)

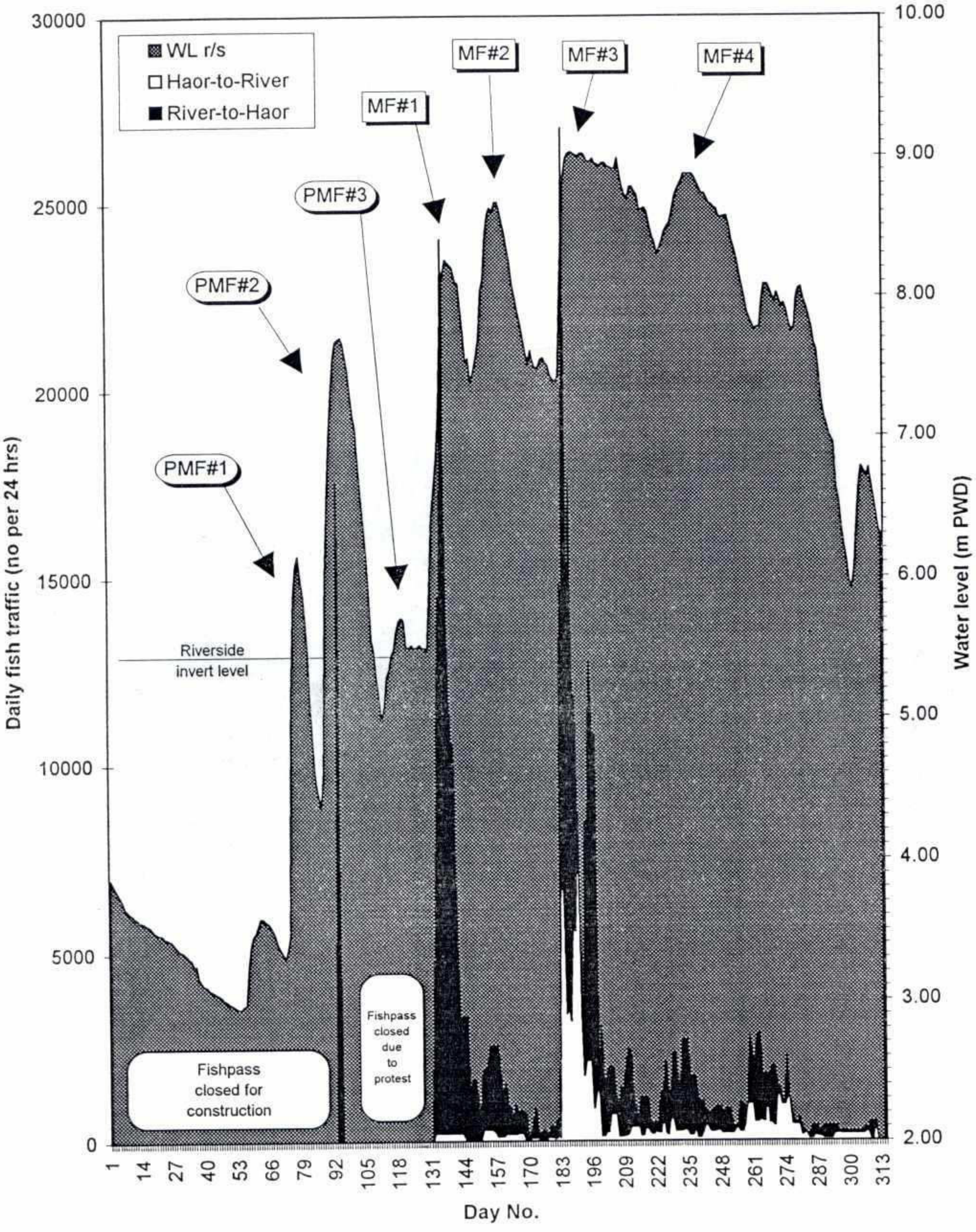


Figure 29: Comparison of Daily Fish Traffic with Riverside Water Level during Year 3 (1997)

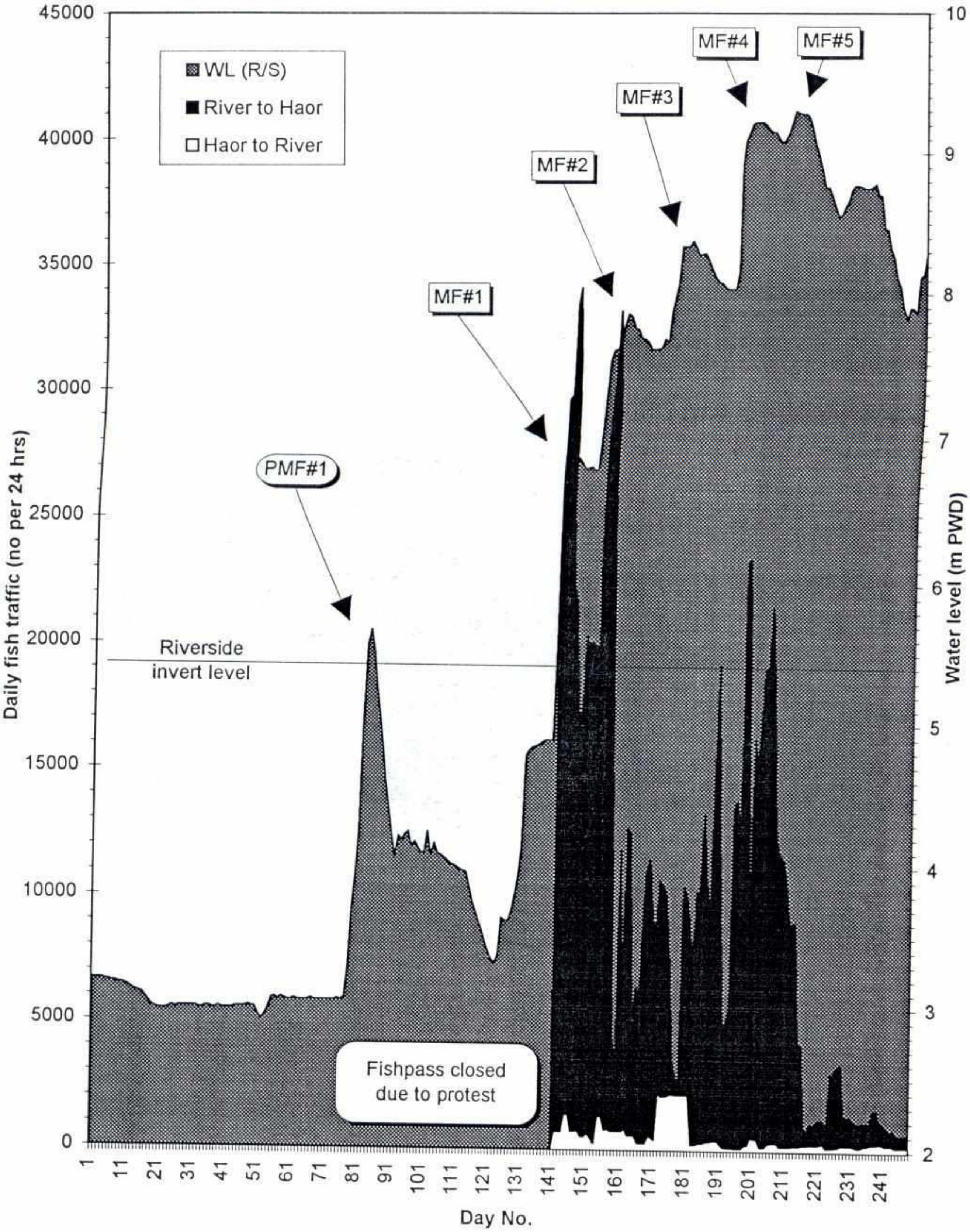


Figure 30: Daily Fish Traffic during Monsoon Flood No 1 (Year 2: 1996)

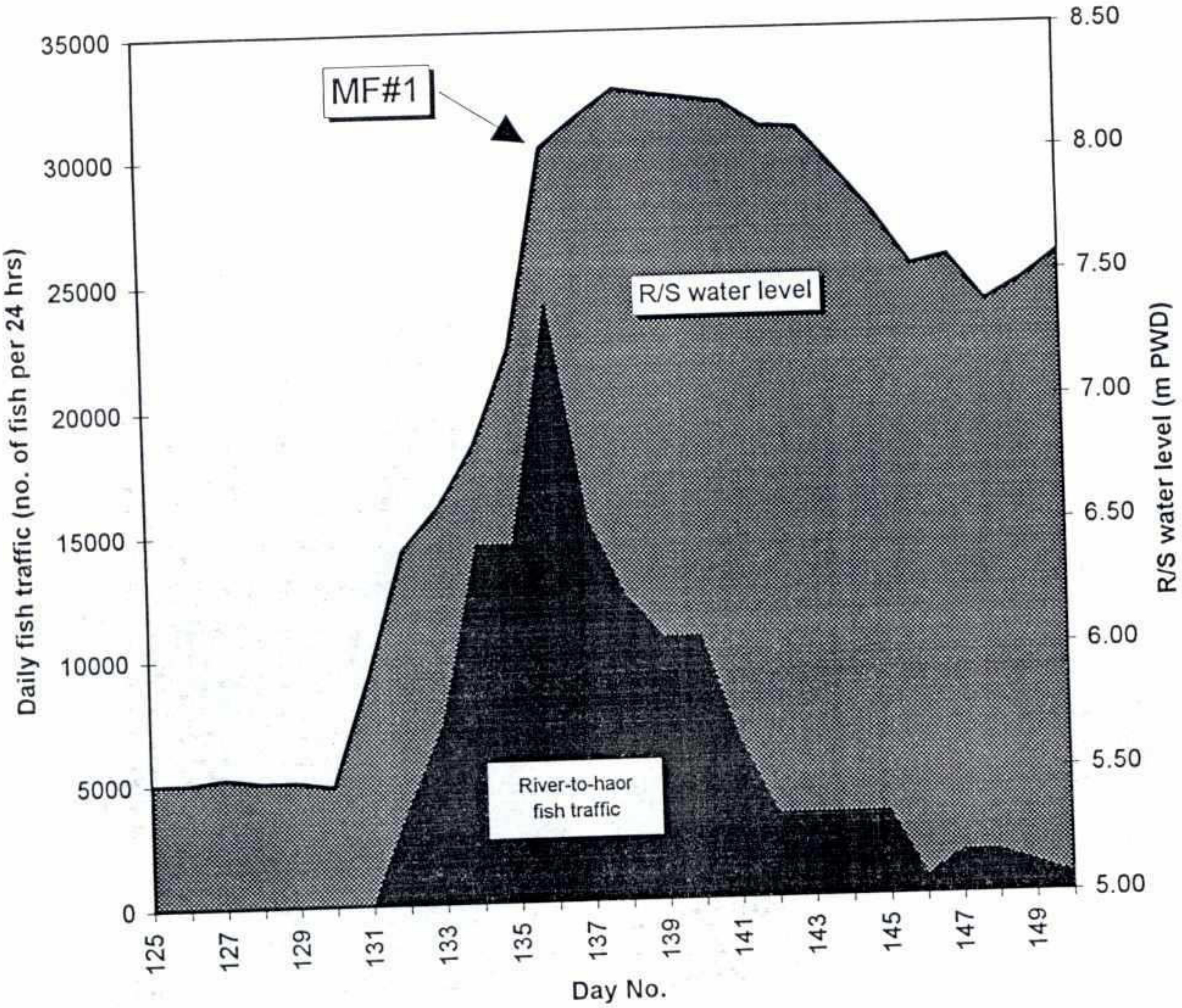


Figure 31: Daily Fish Traffic during Monsoon Flood No 3 (Year 2: 1996)

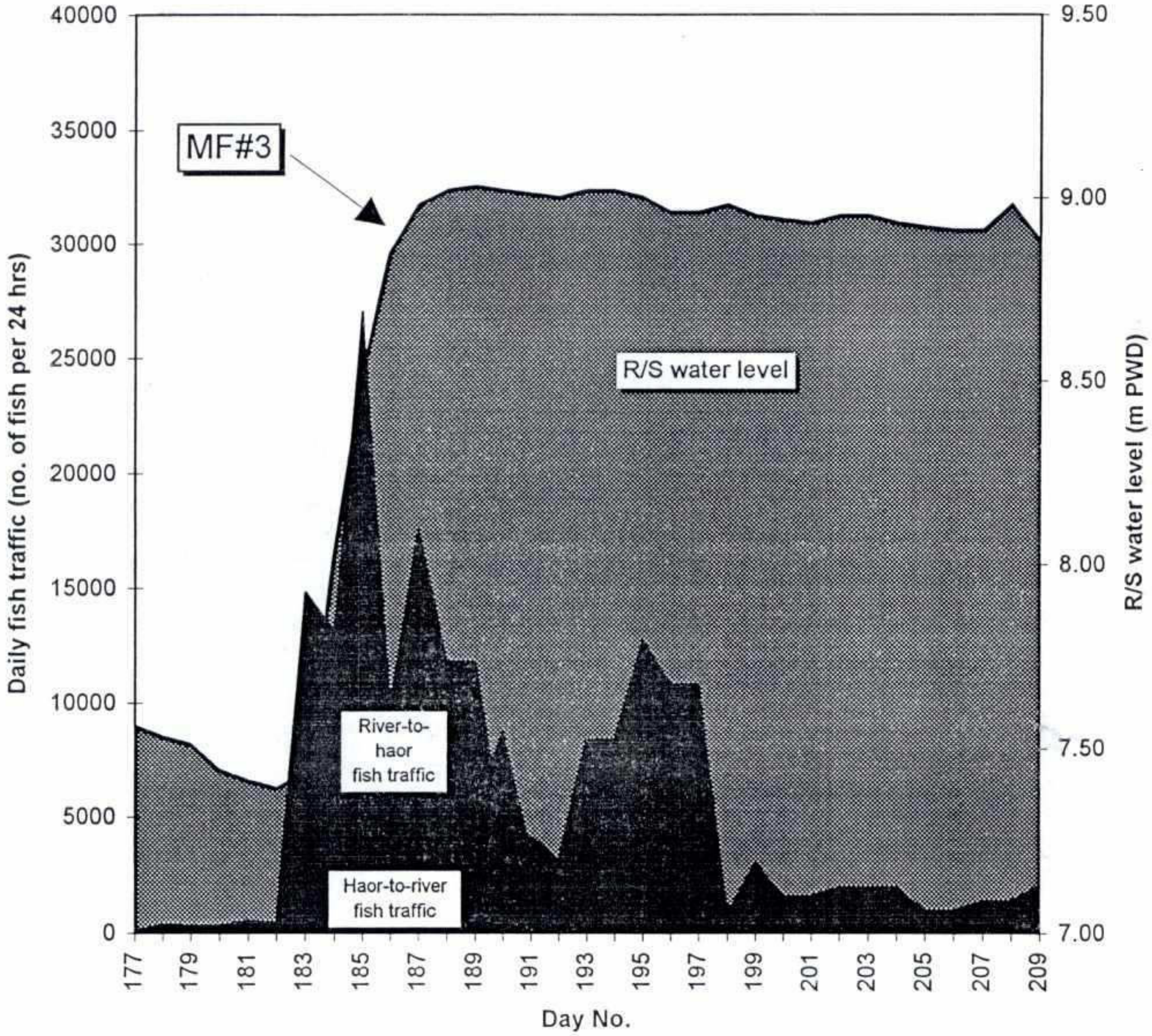


Figure 32: Daily Fish Traffic during Monsoon Flood No 1 (Year 3: 1997)

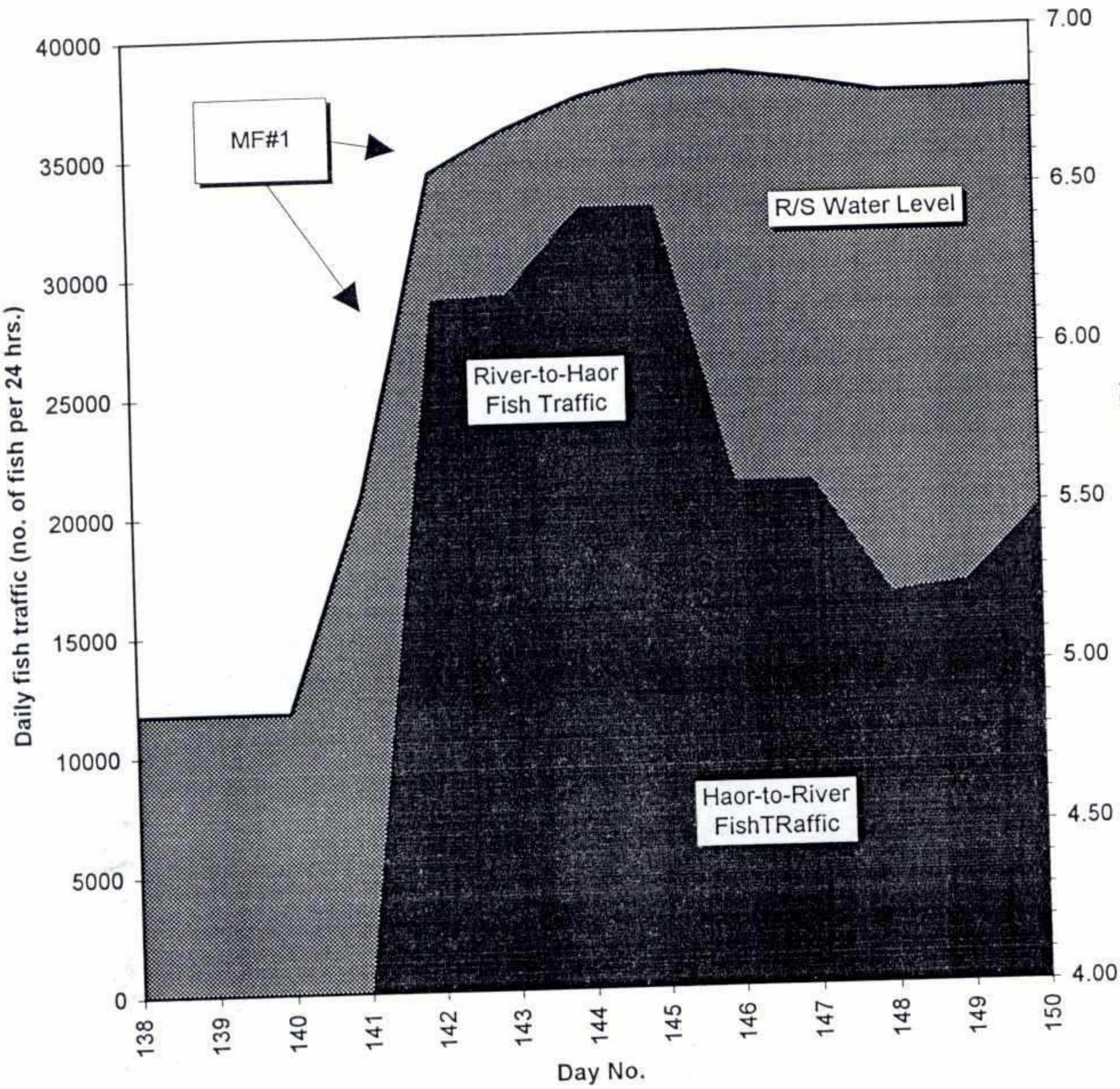
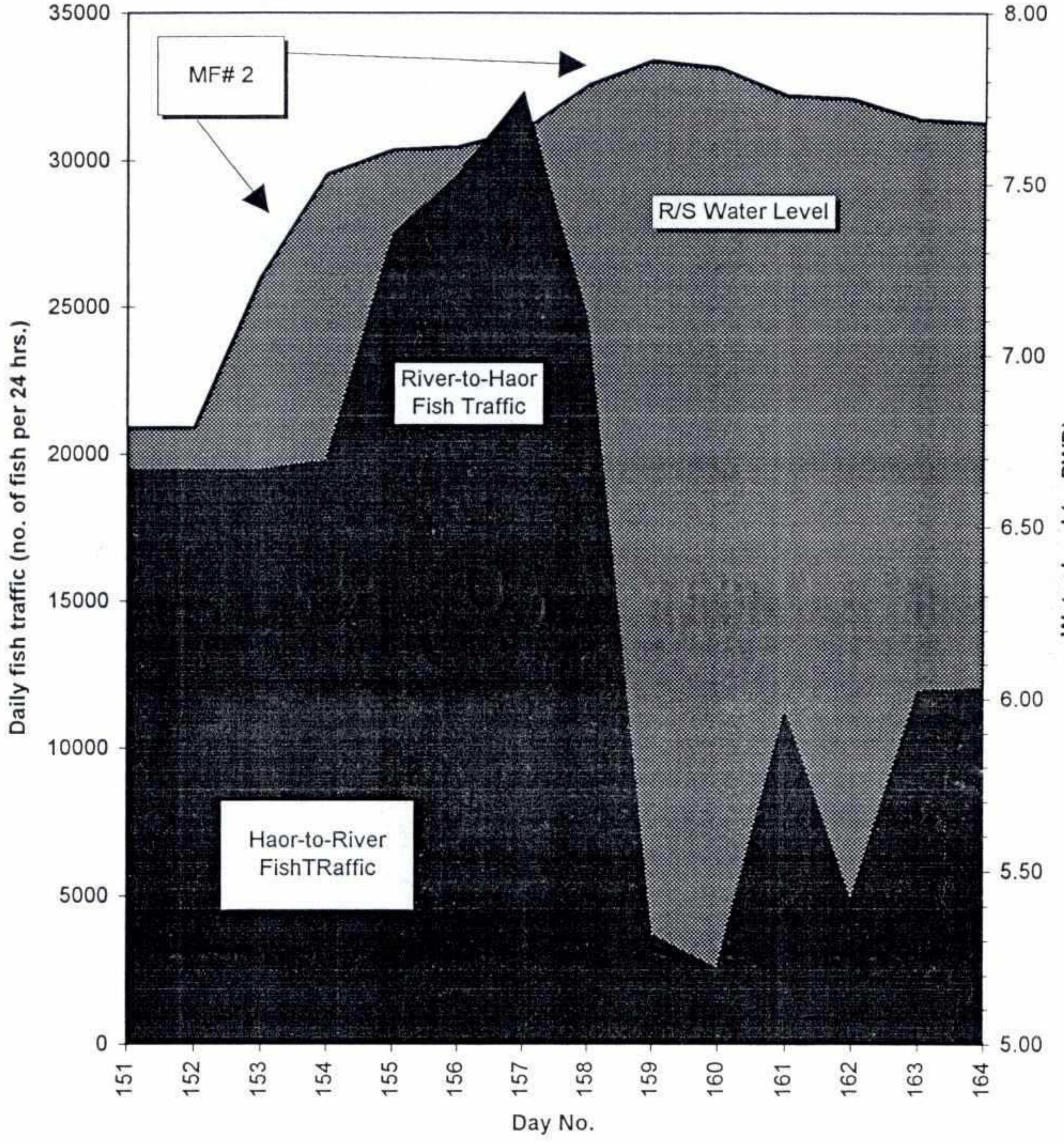


Figure 33: Daily Fish Traffic during Monsoon Flood No 2 (Year 3: 1997)



398

Figure 34: Daily Fish Traffic during Monsoon Flood No 3 (Year 3: 1997)

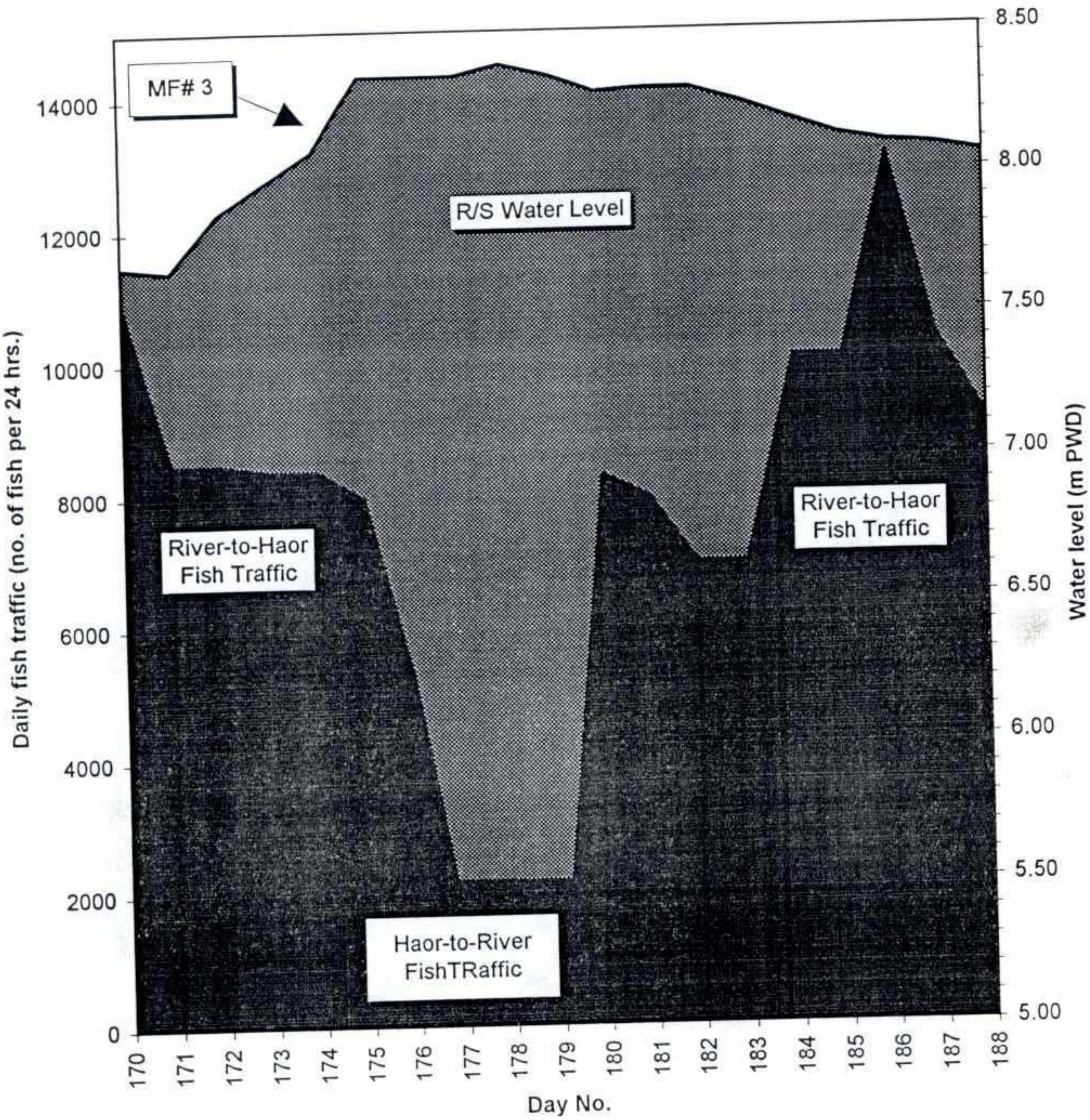


Figure 35: Daily Fish Traffic during Monsoon Flood No 4 (Year 3: 1997)

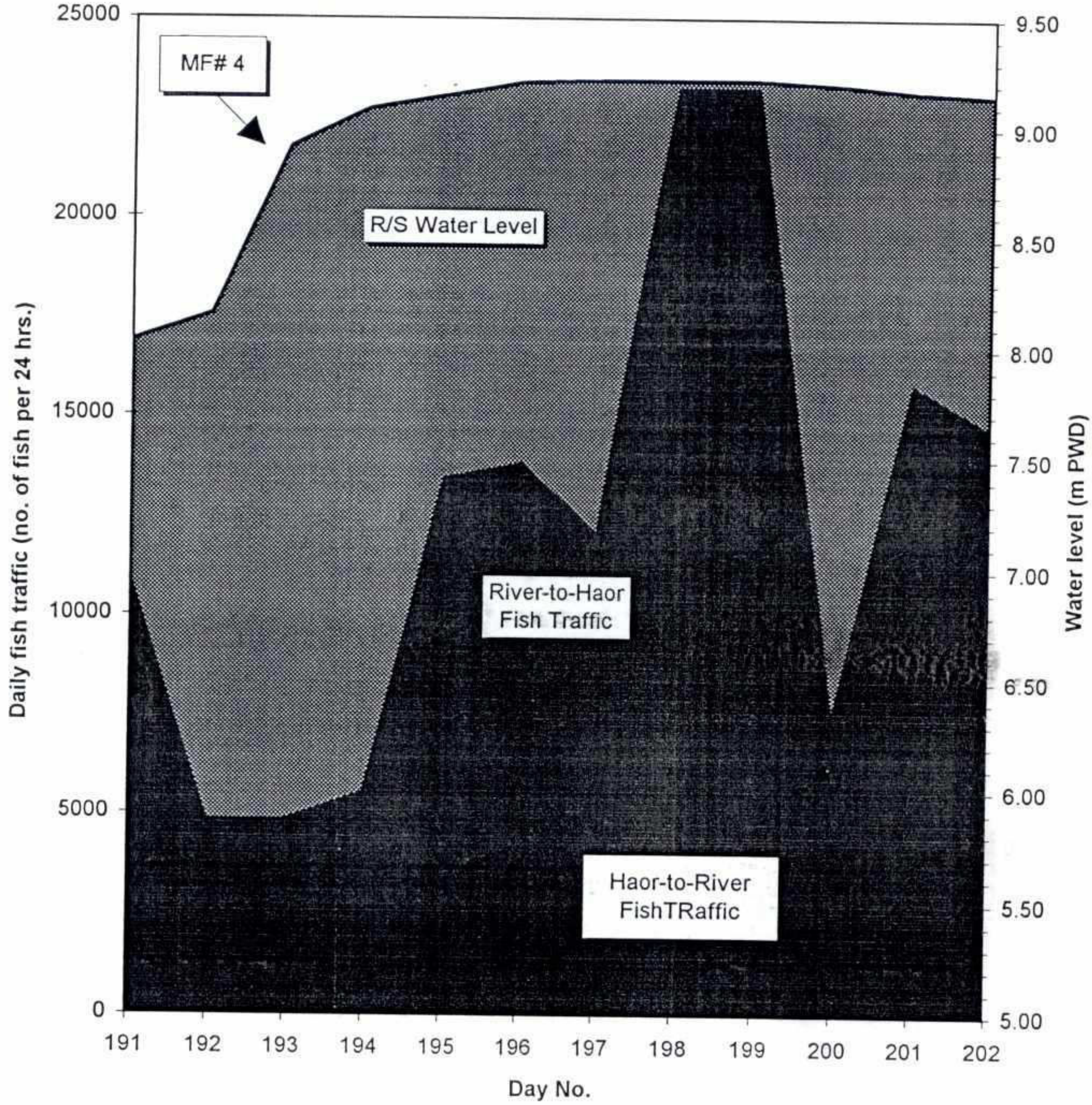


Figure 36: Daily Fish Traffic during Monsoon Flood No 5 (Year 3: 1997)

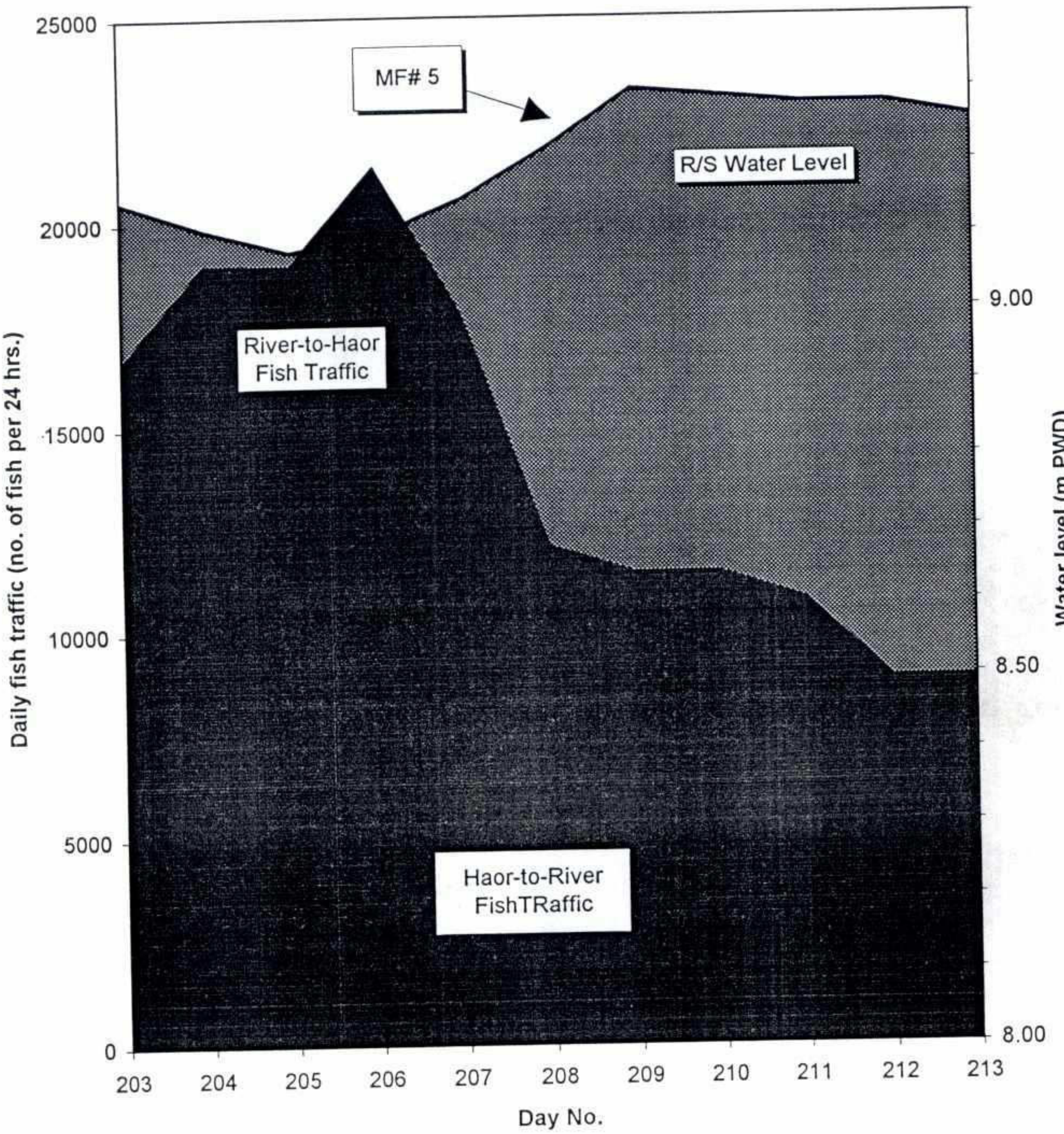
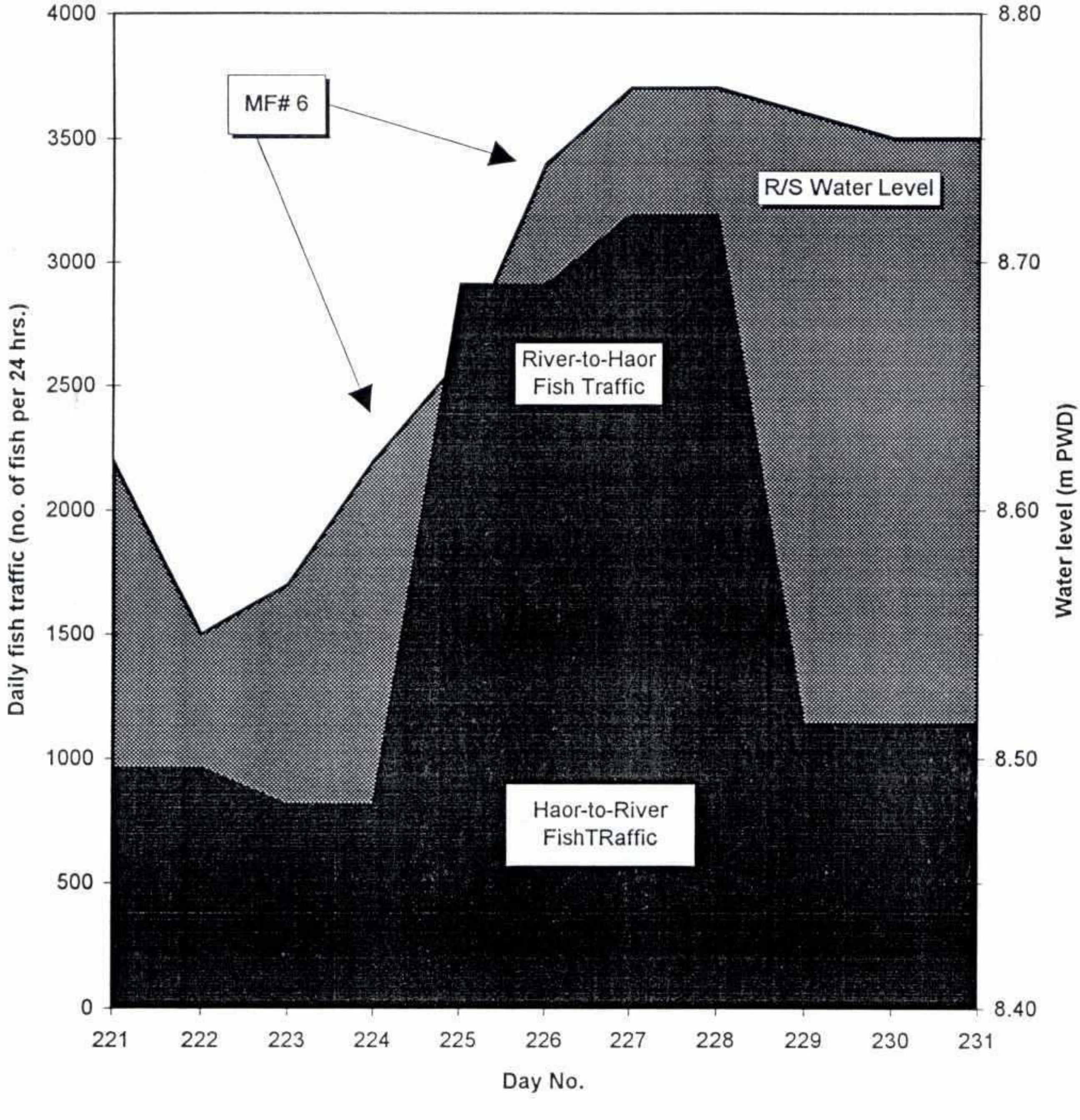


Figure 37: Daily Fish Traffic during Monsoon Flood No 6 (Year 3: 1997)



Figue 38: Species Composition of Fishpass Samples during Year 2 (1996)

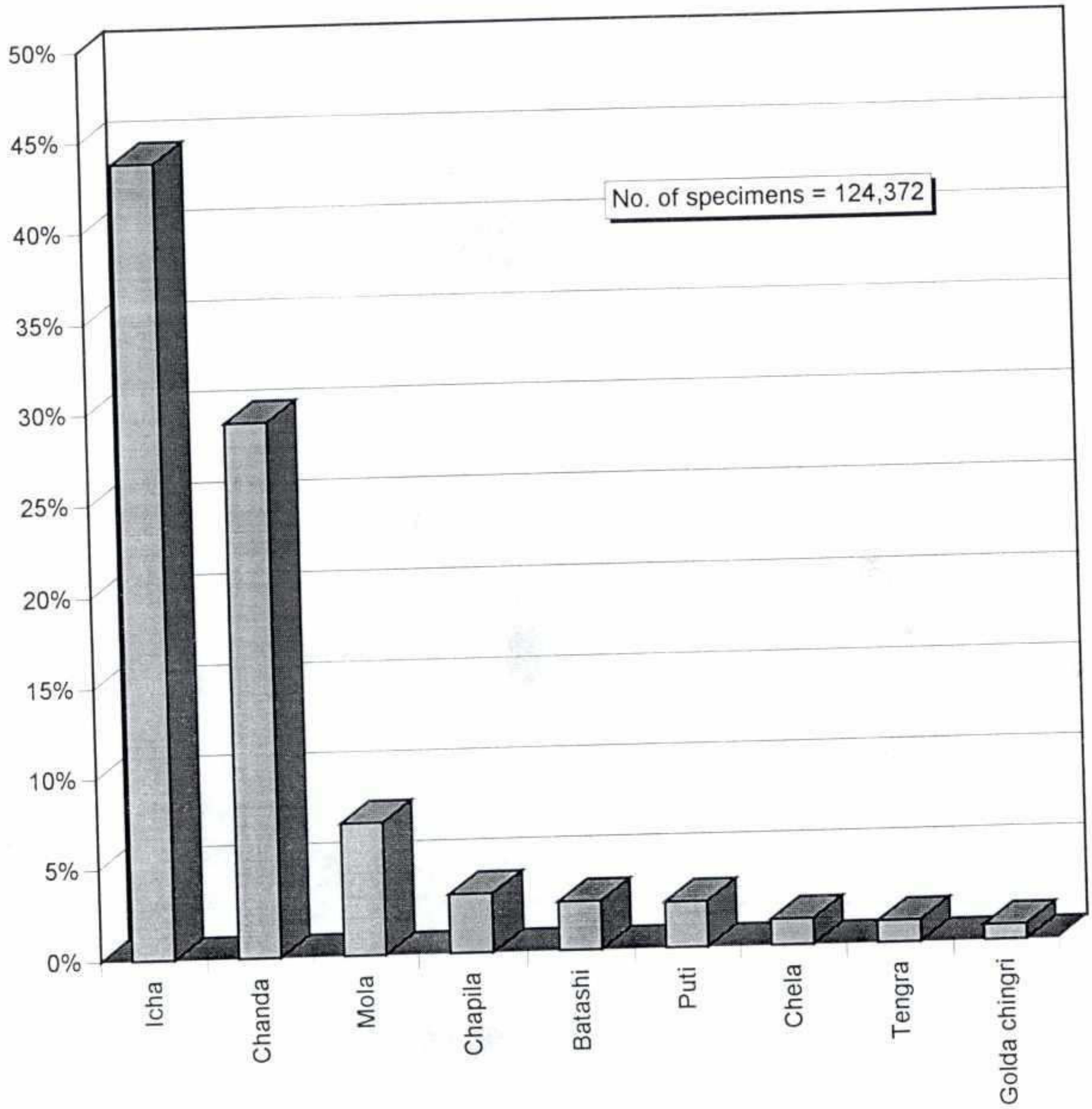


Figure 39: Species Composition of Fishpass Samples during Year 3 (1997)

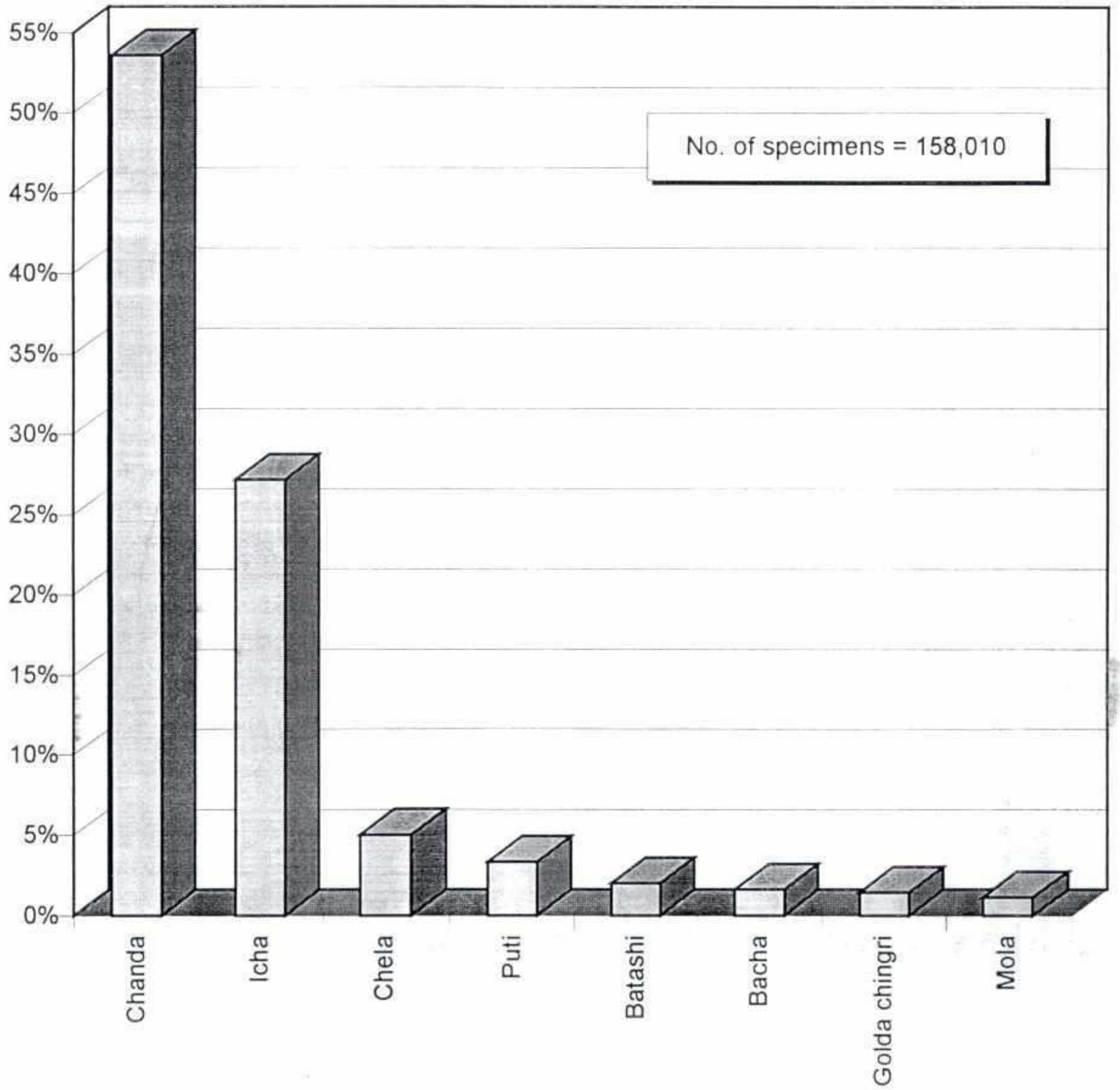


Figure 40: Species Composition of Fish Traffic during Monsoon Flood No 1 (Year2: 1996)

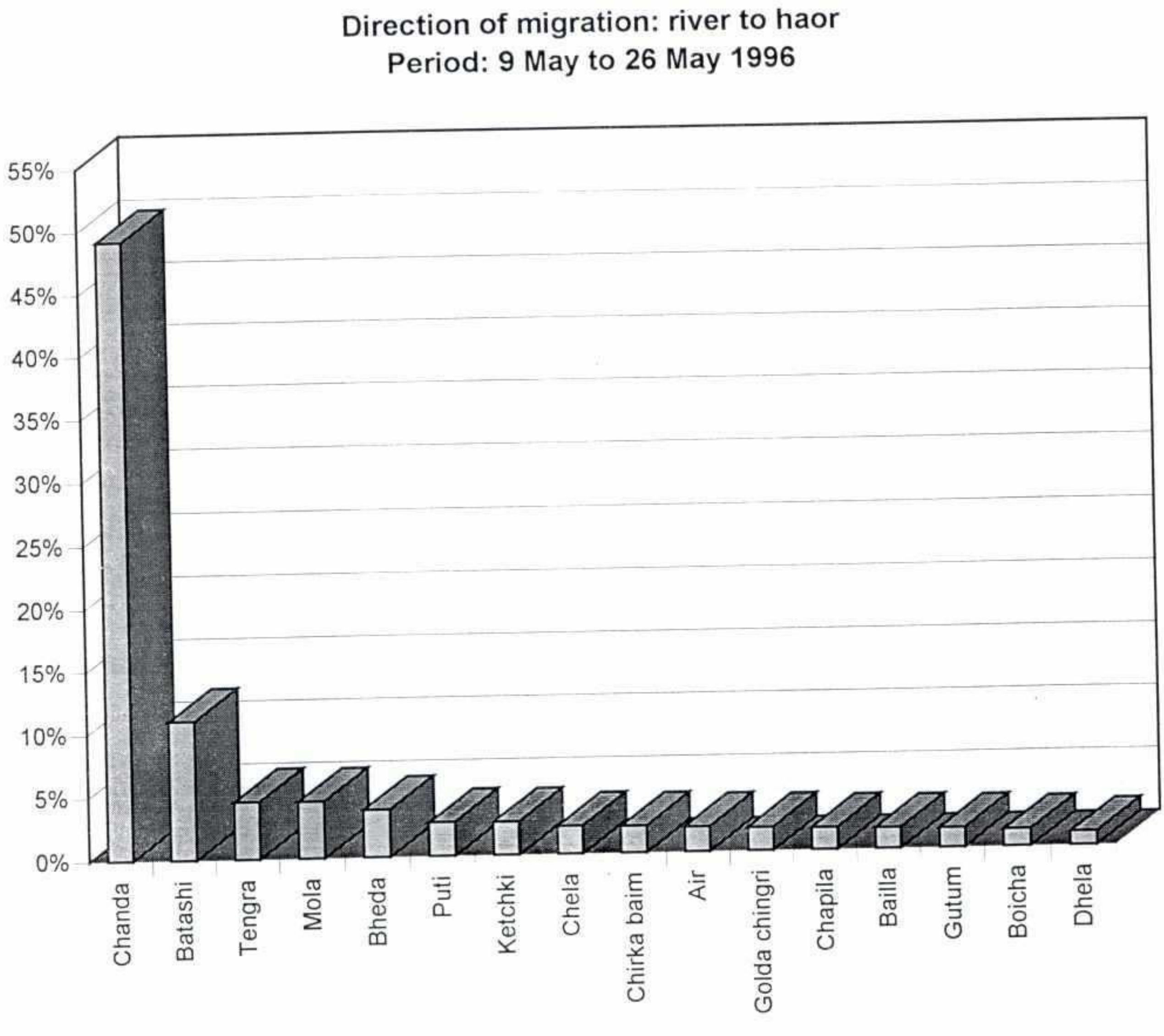


Figure 41: Species Composition of Fish Traffic during Monsoon Flood No 3 (Year 2: 1996)

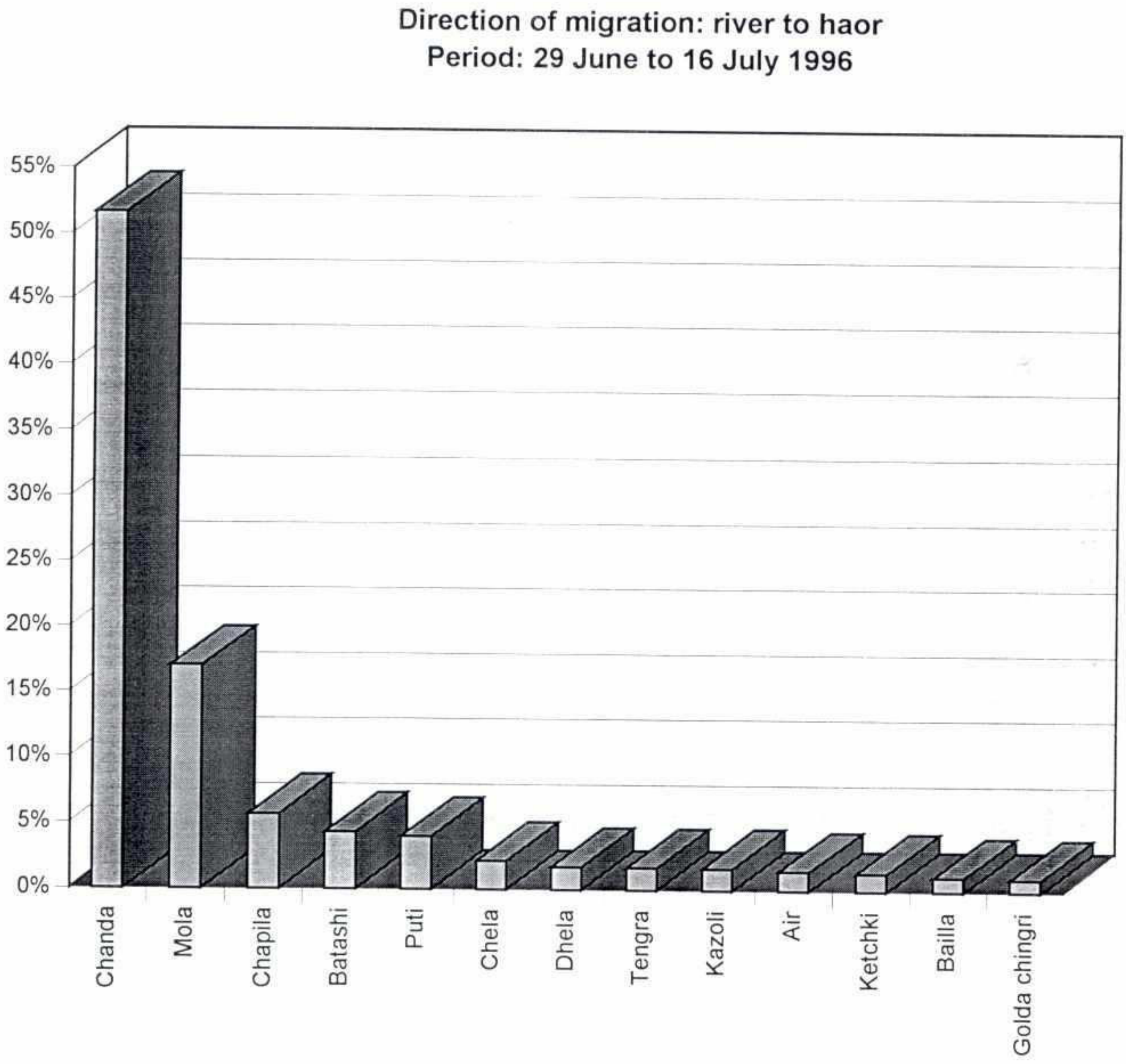


Figure 42: Species Composition of Fish Traffic during Monsoon Flood No 1 (Year 3: 1997)

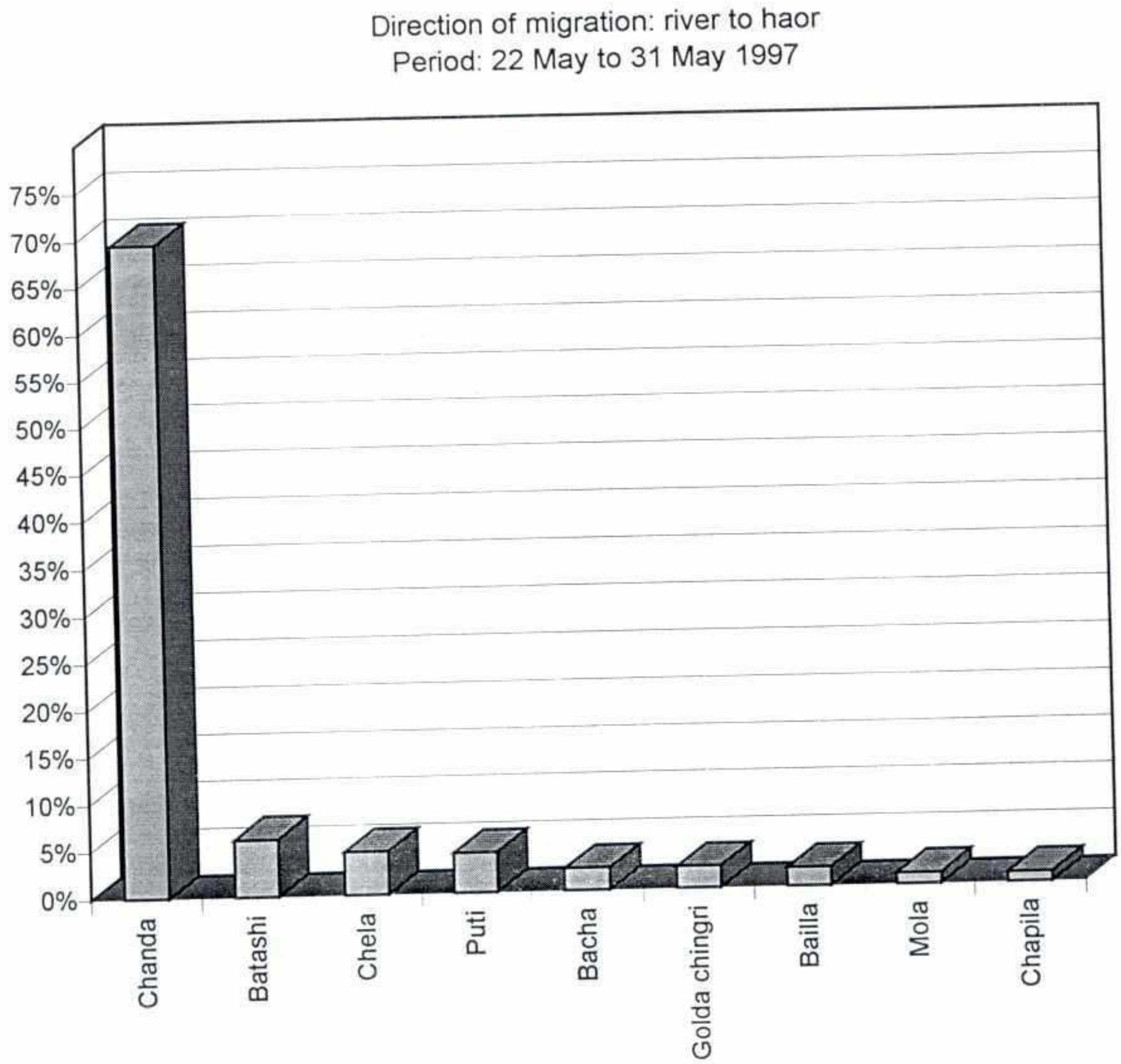


Figure 43: Species Composition of Fish Traffic during Monsoon Flood No 2 (Year 3: 1997)

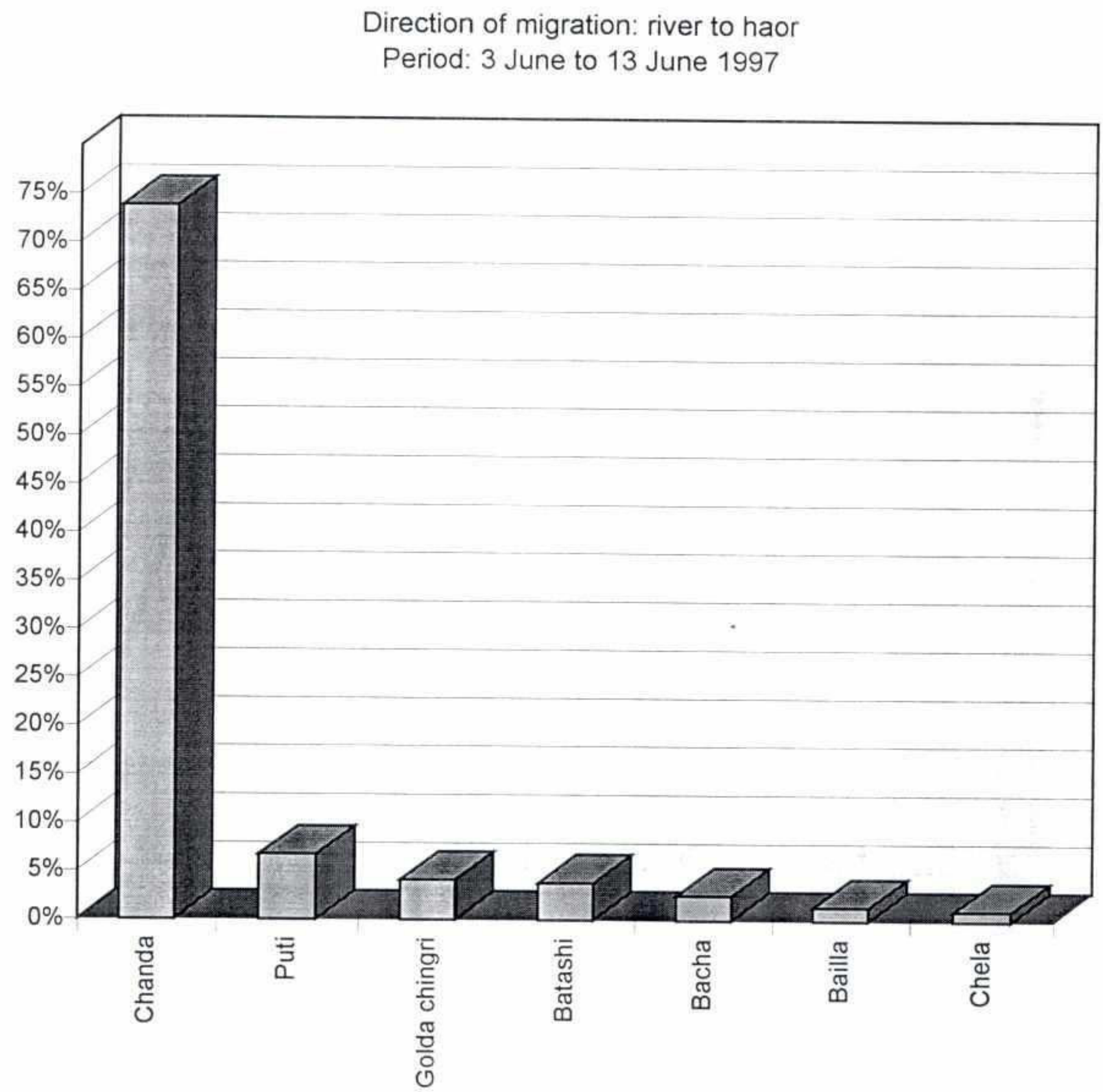


Figure 44: Diurnal Variation in Migration Rate (Year 2: 1996) for River to Haor Movement

218

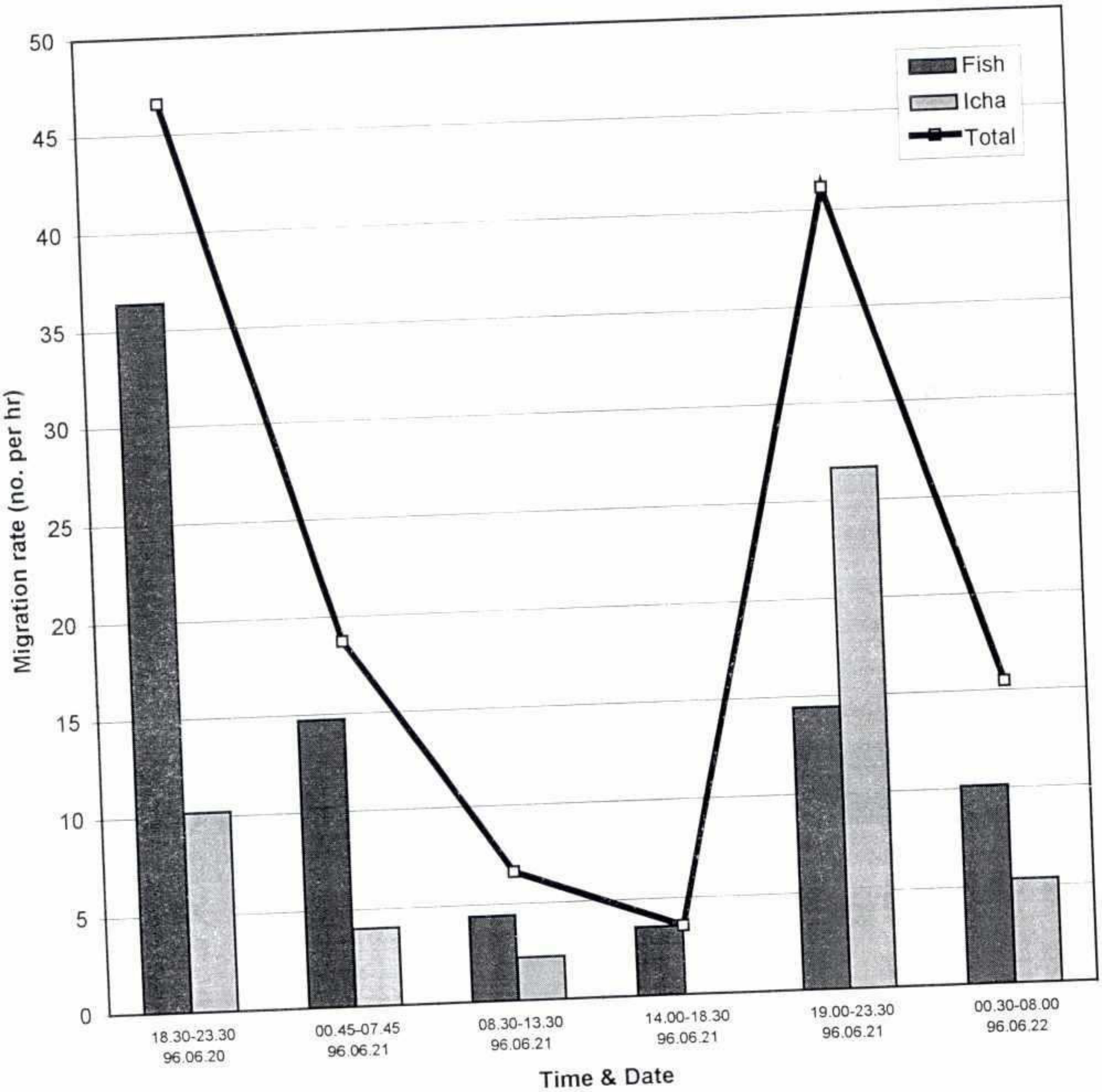


Figure 45: Diurnal Variation in Migration Rate (Year 3: 1997) for River to Haor Movement

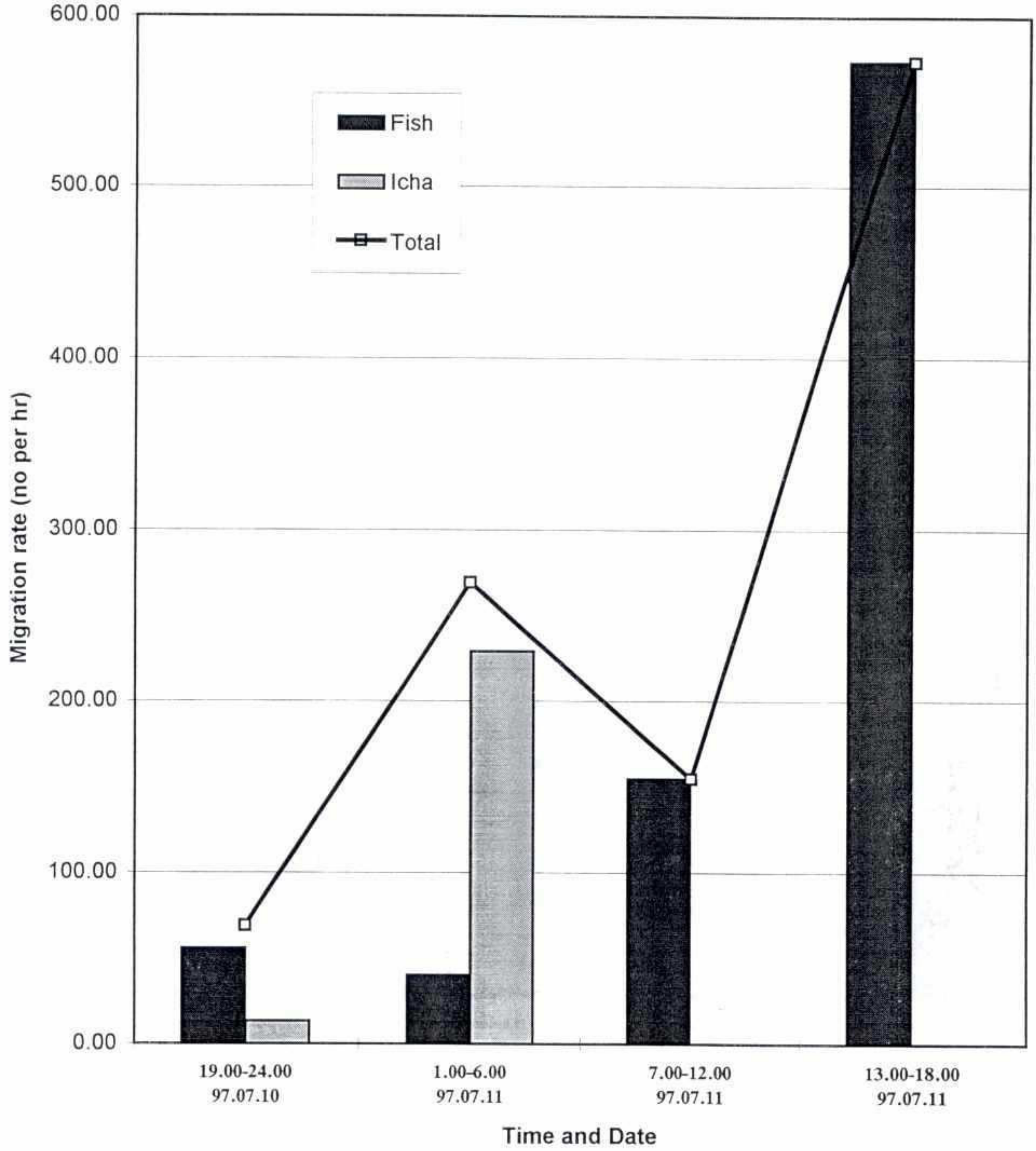


Figure 46: Diurnal Variation in Migration Rate (Year 3: 1997) for Haor to River Movement

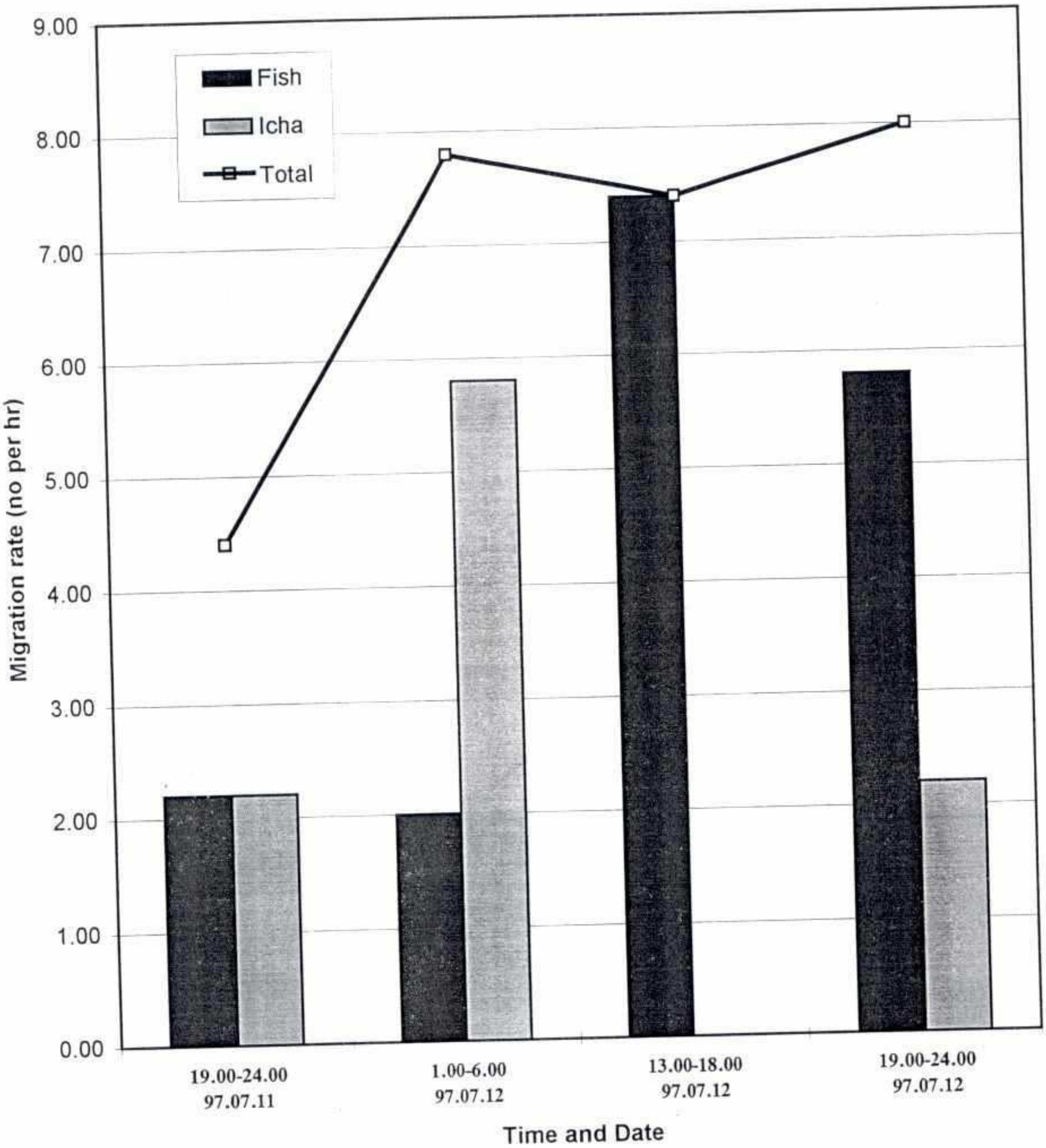
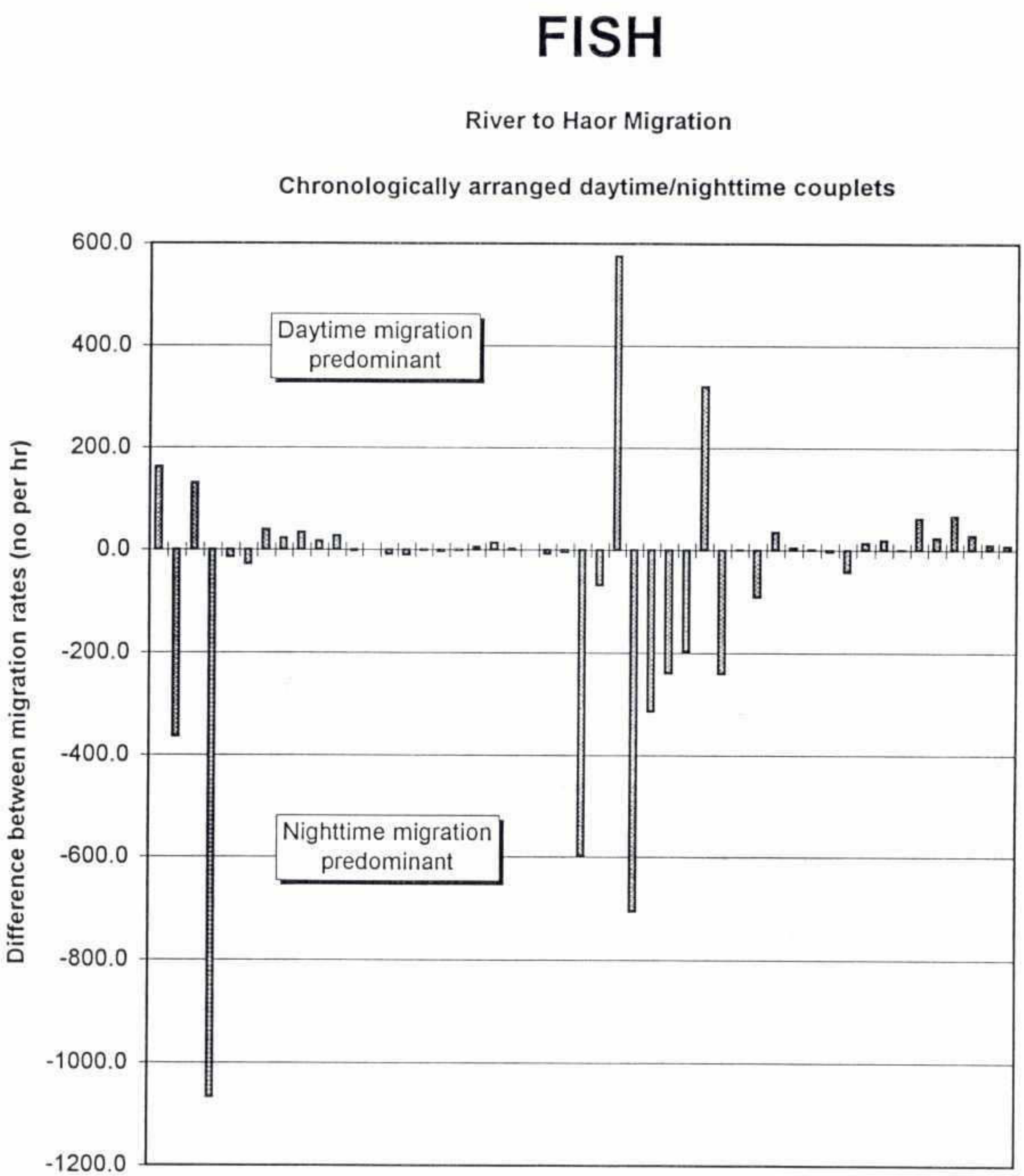


Figure 47: Difference between Daytime and Nighttime Migration Rates for Fish (Year 2: 1996)



218

Figure 48: Difference between Daytime and Nighttime Migration Rates for *Icha* (Year 2: 1996)

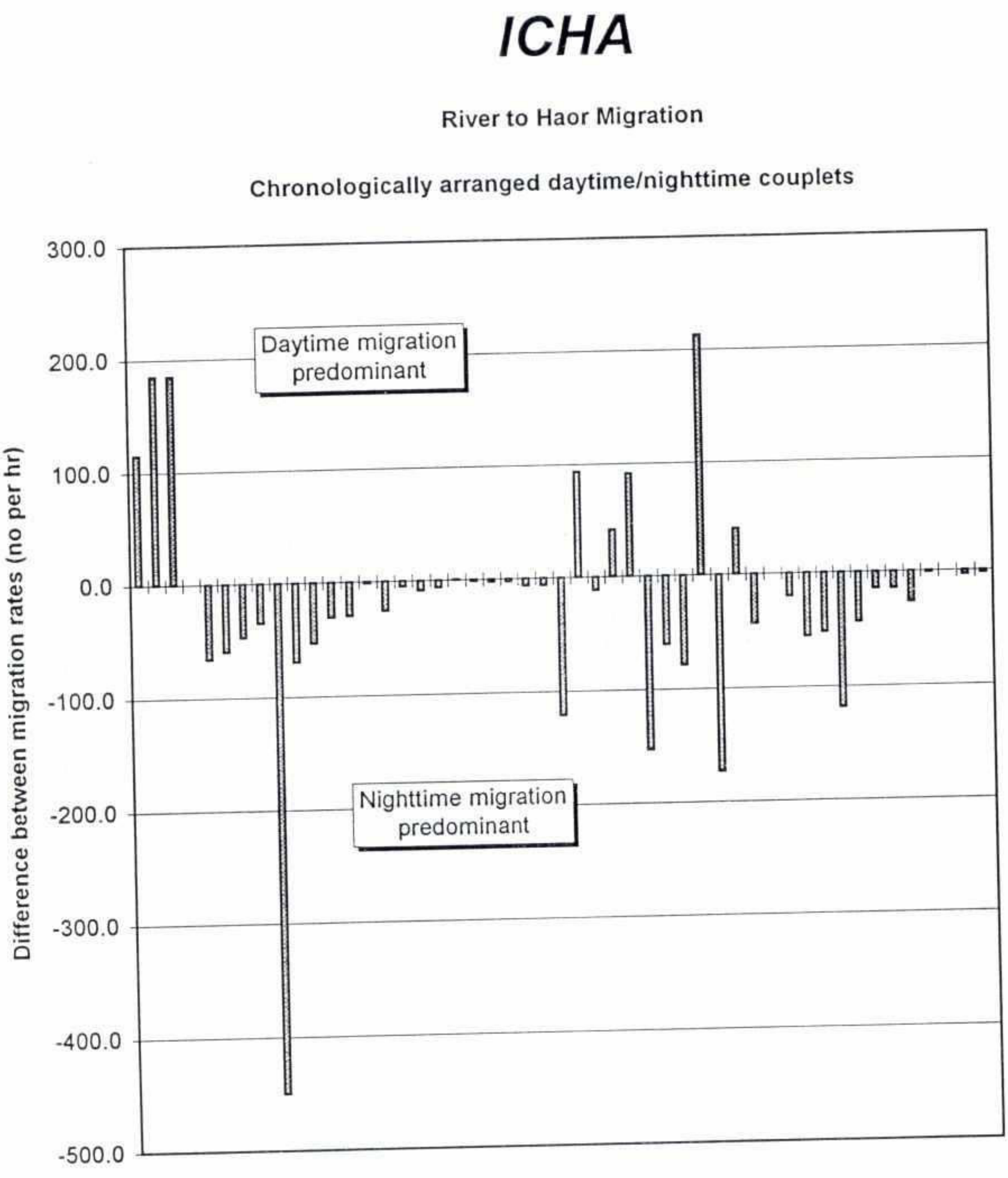


Figure 49: Difference between Daytime and Nighttime Migration Rates for Fish (Year 3: 1997)

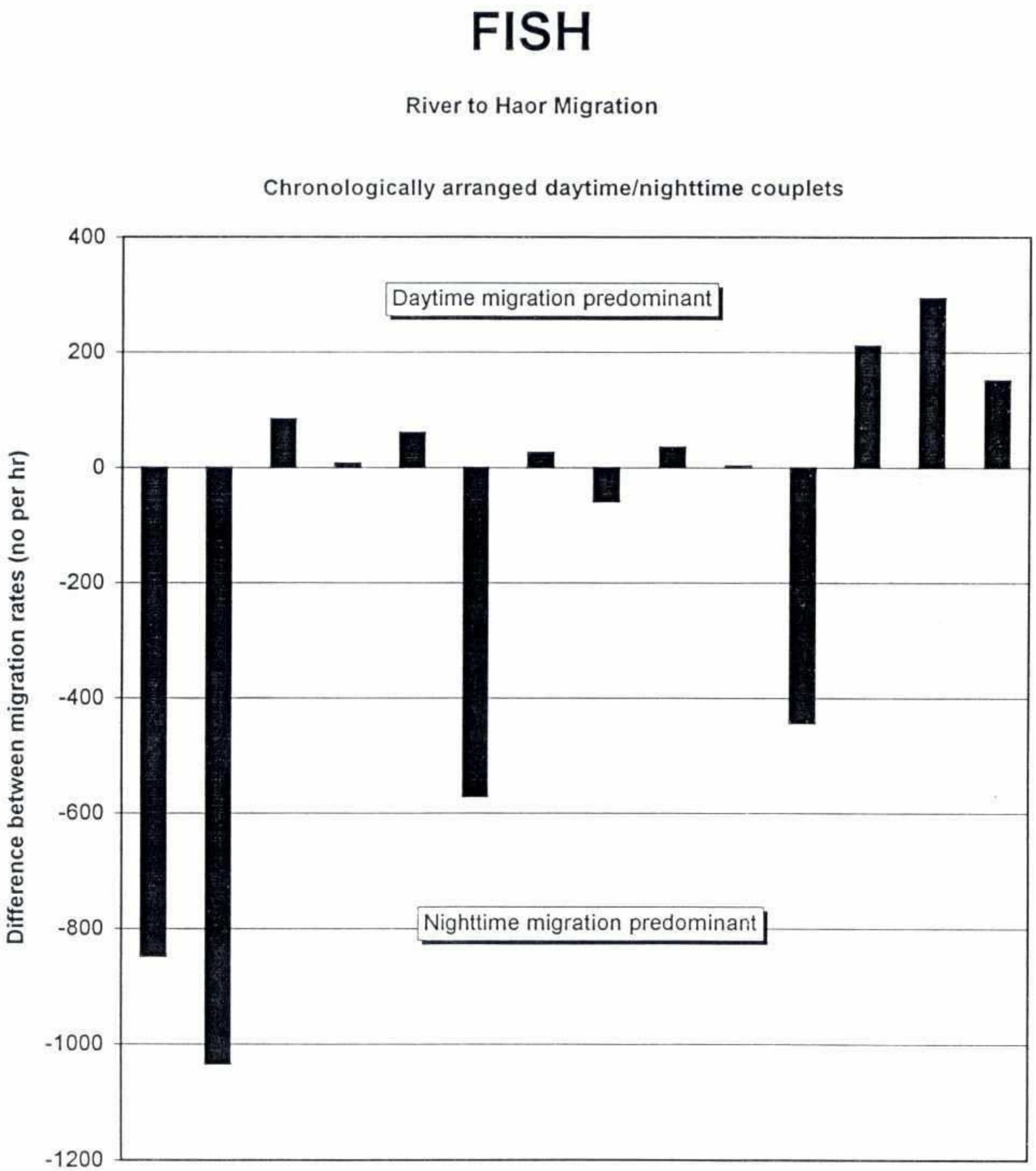


Figure 50: Difference between Daytime and Nighttime Migration Rates for *Icha* (Year 3: 1997)

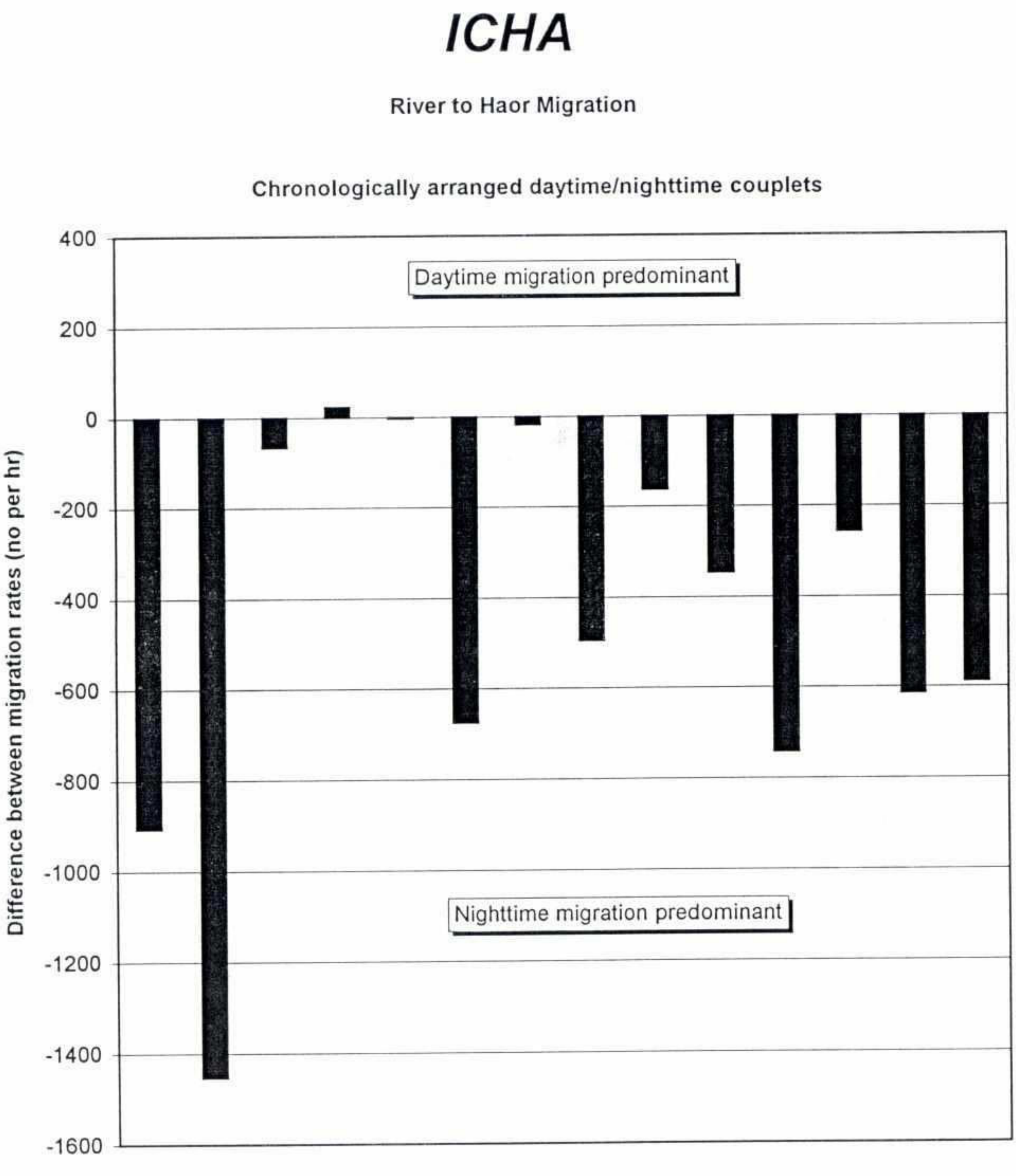


Figure 51: Velocity Measurement Location Map

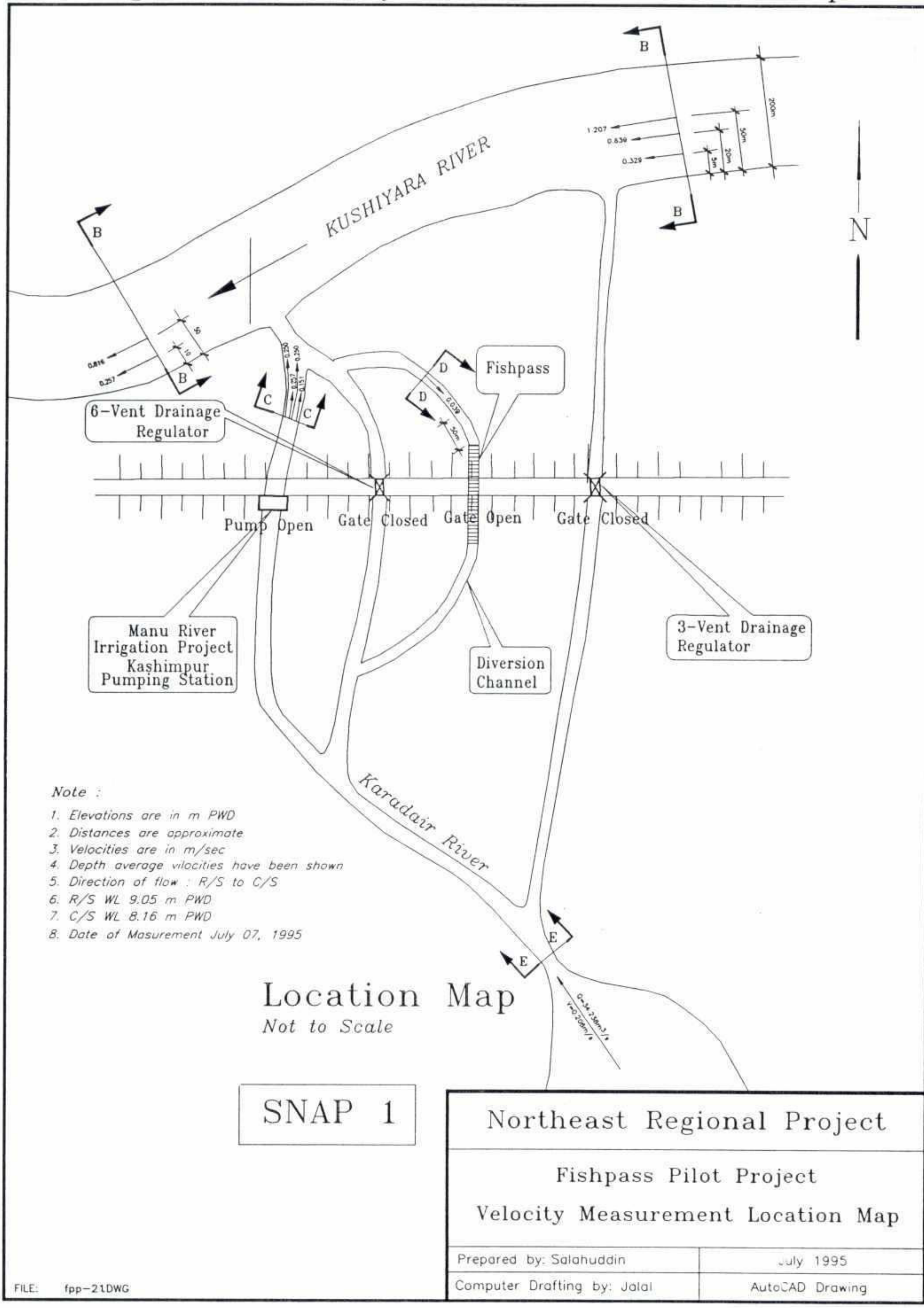
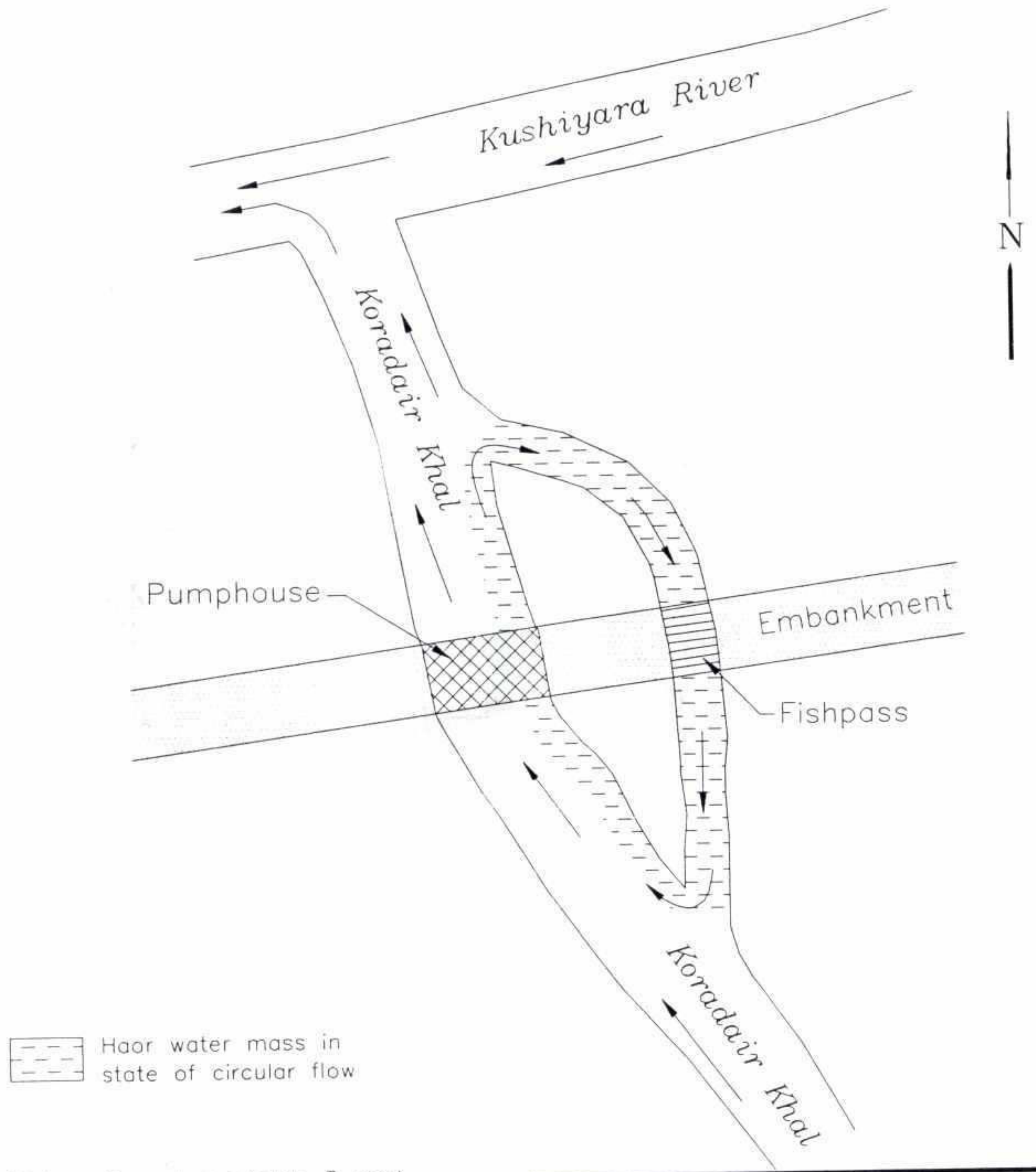


Figure 52

Schematic diagiam of flow pattern between fishpass and pumphouse during first part of monsoon



Note : 6–vent regulator, 3–vent regulator and access channels are not shown (regulators are closed during this period)

Northeast Regional Project	
Fishpass Pilot Project Flow Pattern During First Part of Monsoon	
Prepared by: Salahuddin/GB	November 1995
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: fpp-225.DWG

Figure 53: Number of Species Able to Negotiate Fishpass as a Function of Water Velocity at Slot (Year 2: 1996)

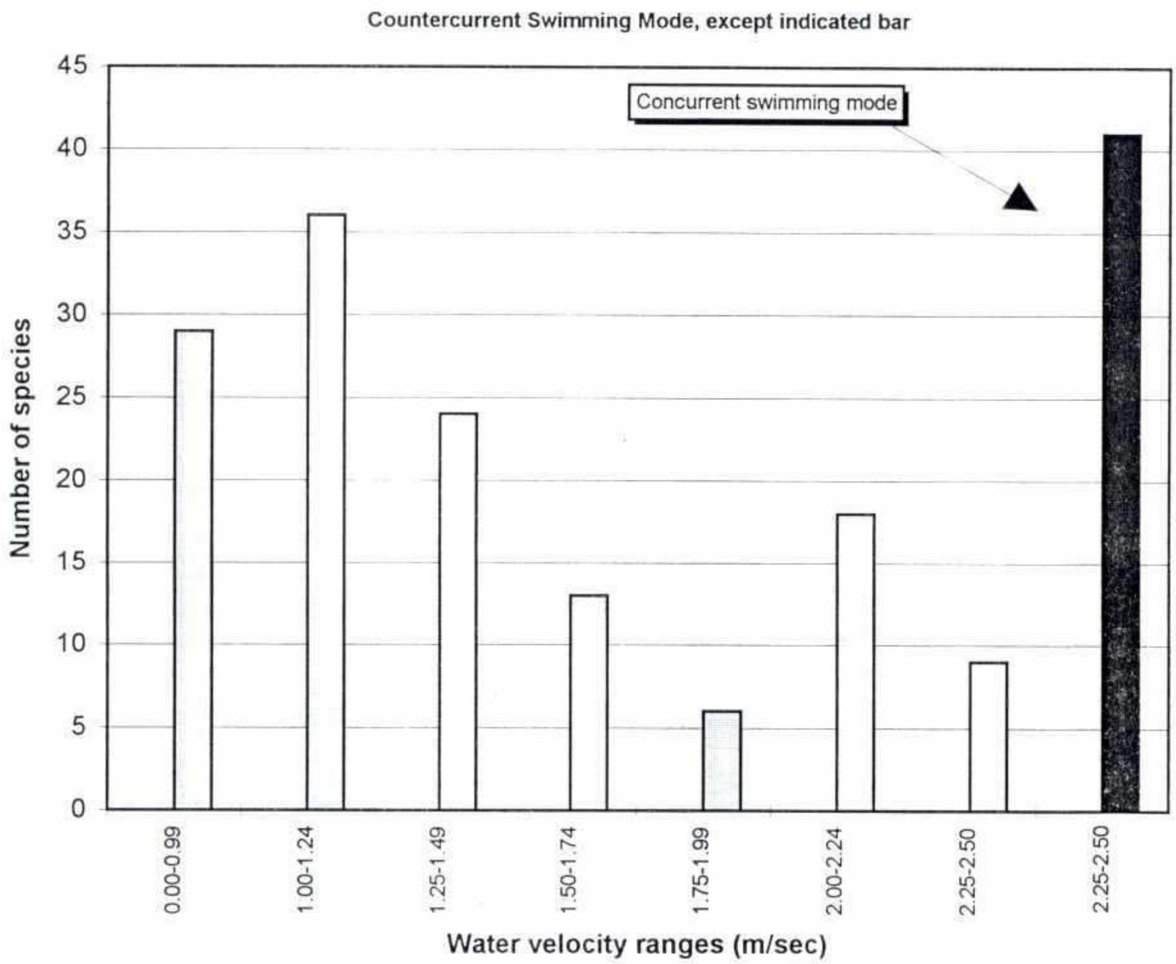


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Figure 54: Number of Species Able to Negotiate Fishpass as a Function of Water Velocity at Slot (Year 3: 1997)

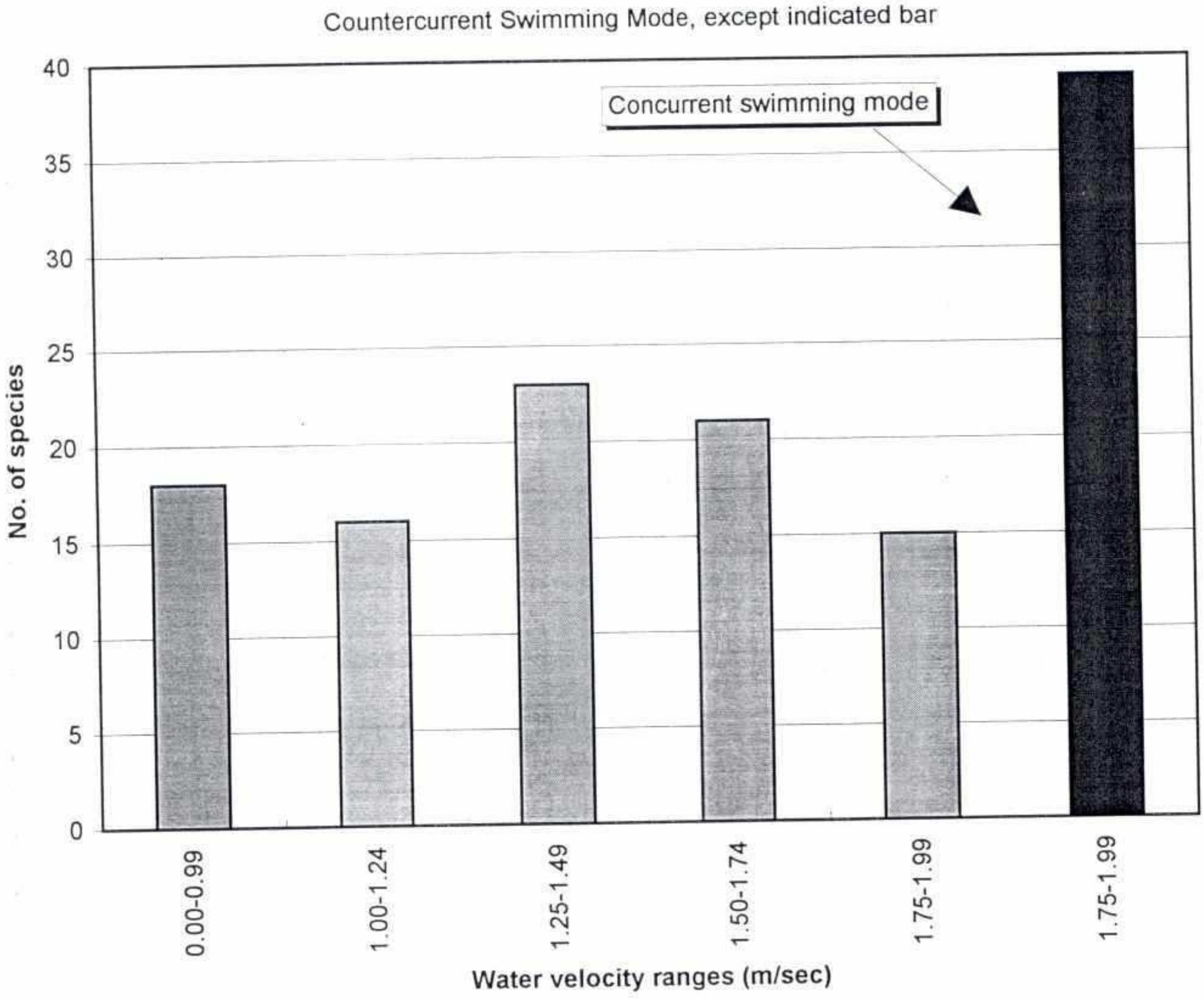


Figure 55: Location of Tree Plantation Areas

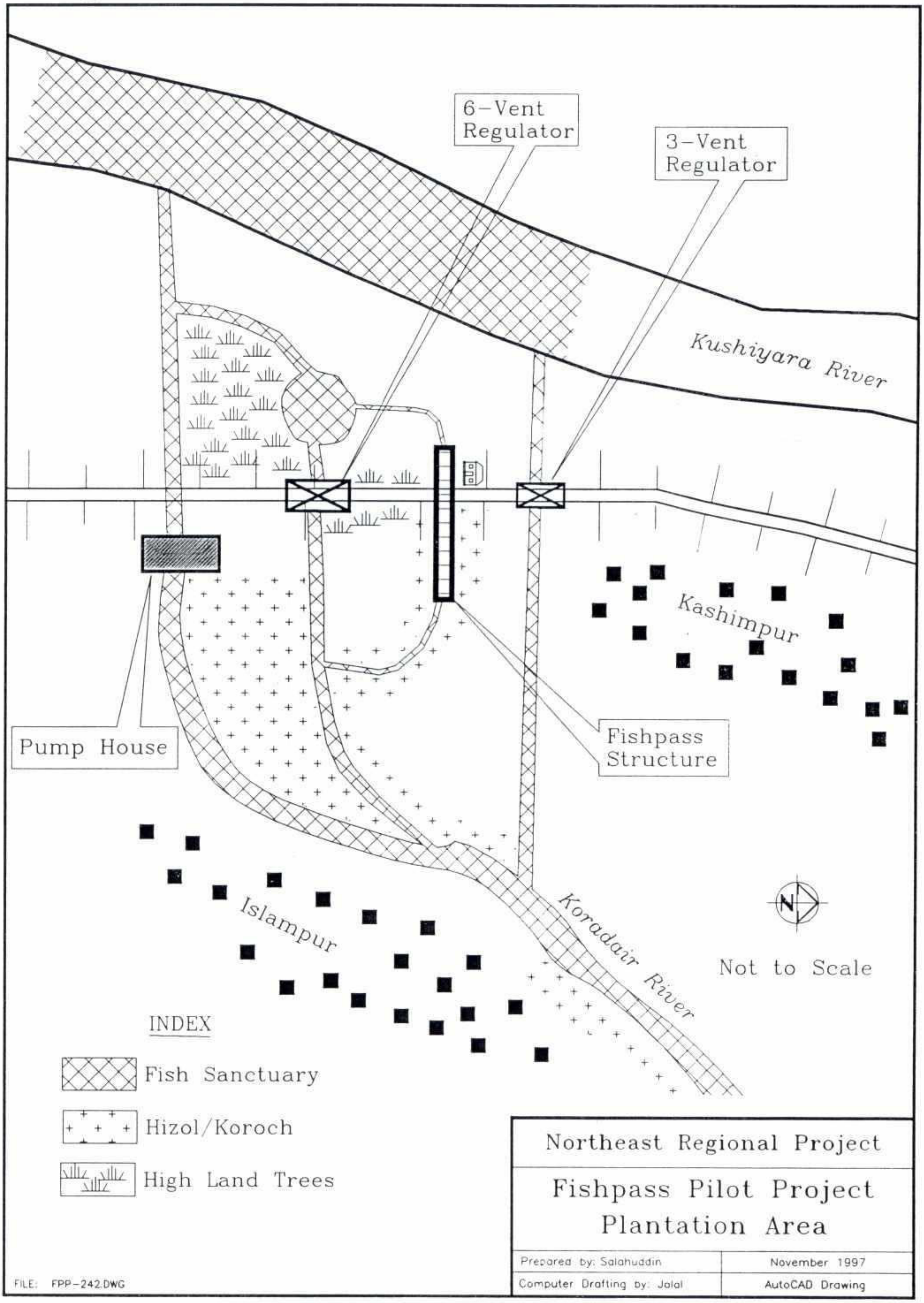


Figure 56: Change in Average Fish Production from Kawadighi Haor

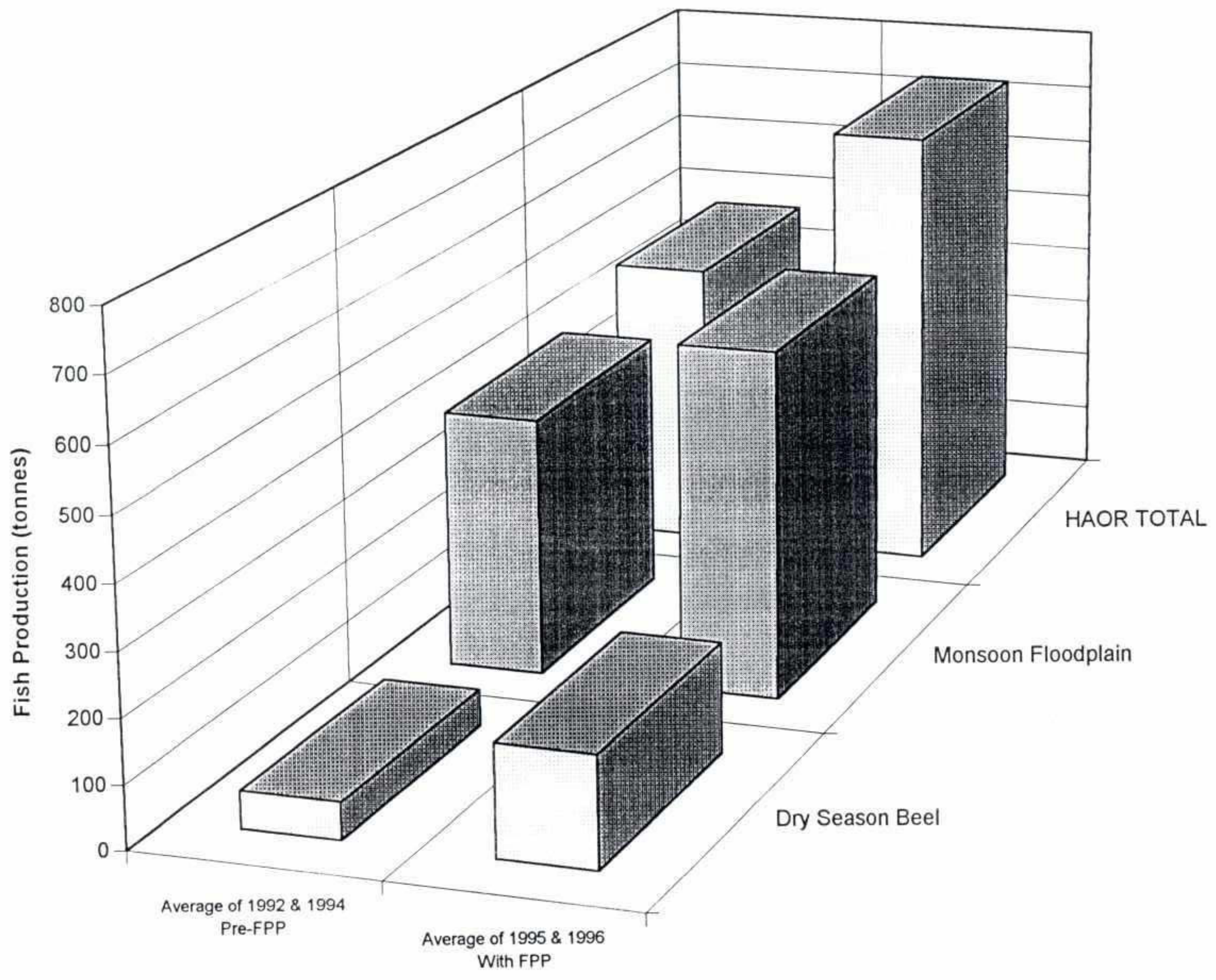


Figure 57: Changes in Average Production of Fish Groups from Kawadighi Haor

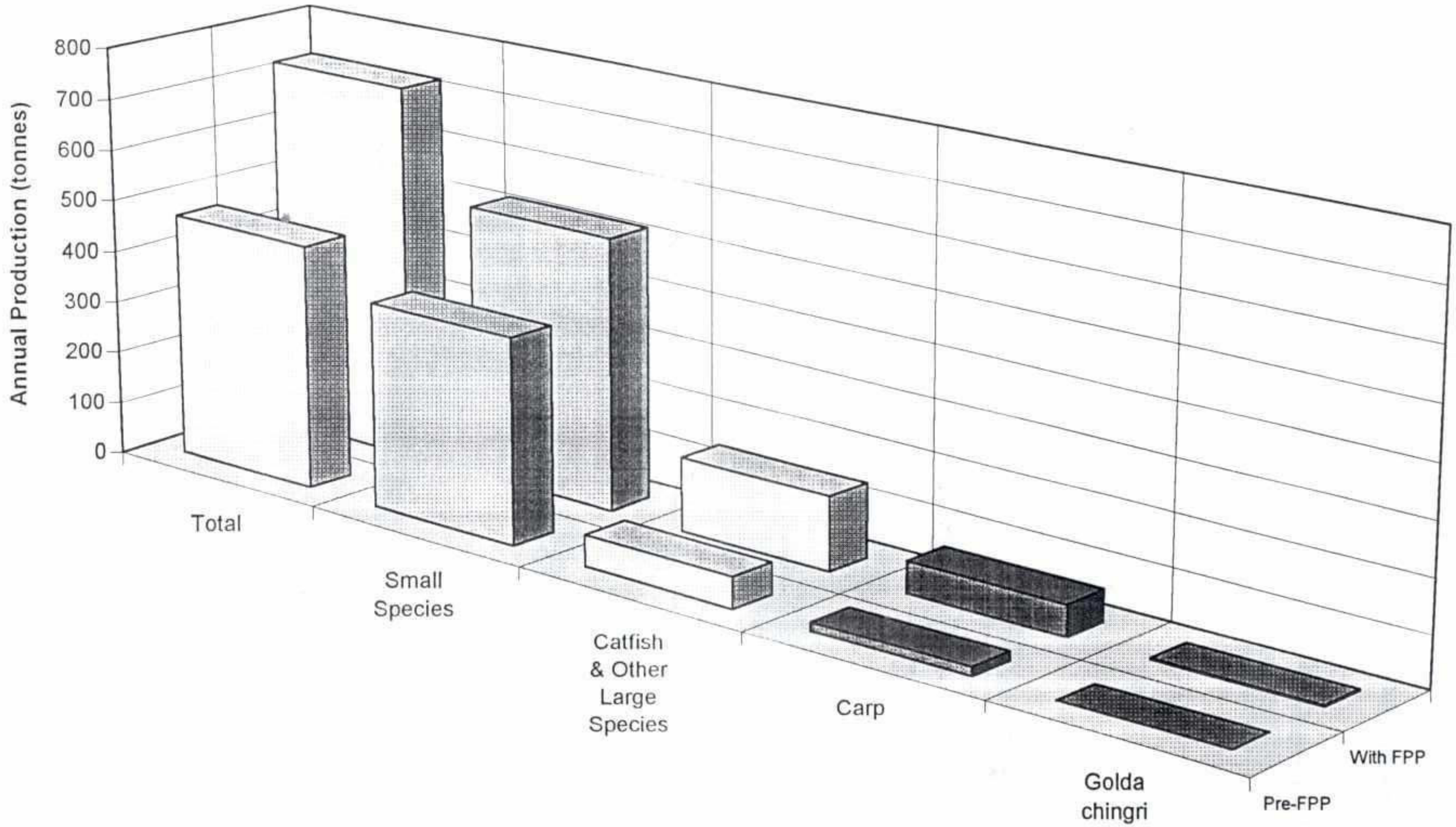


Figure 58: Relationship Between Flood Intensity and Fish Production in Kawadighi Haor

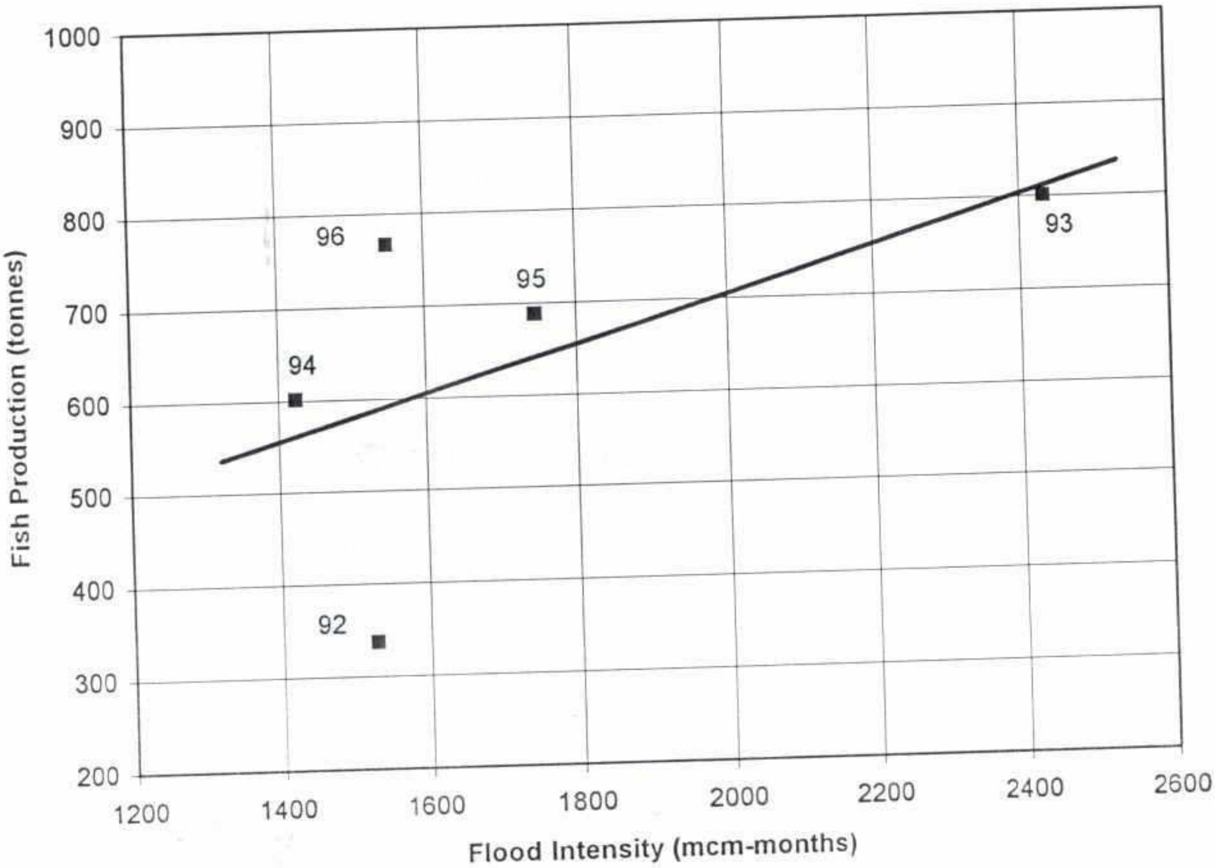


Figure 59: Index of Abudance for *Air* (1992-97)

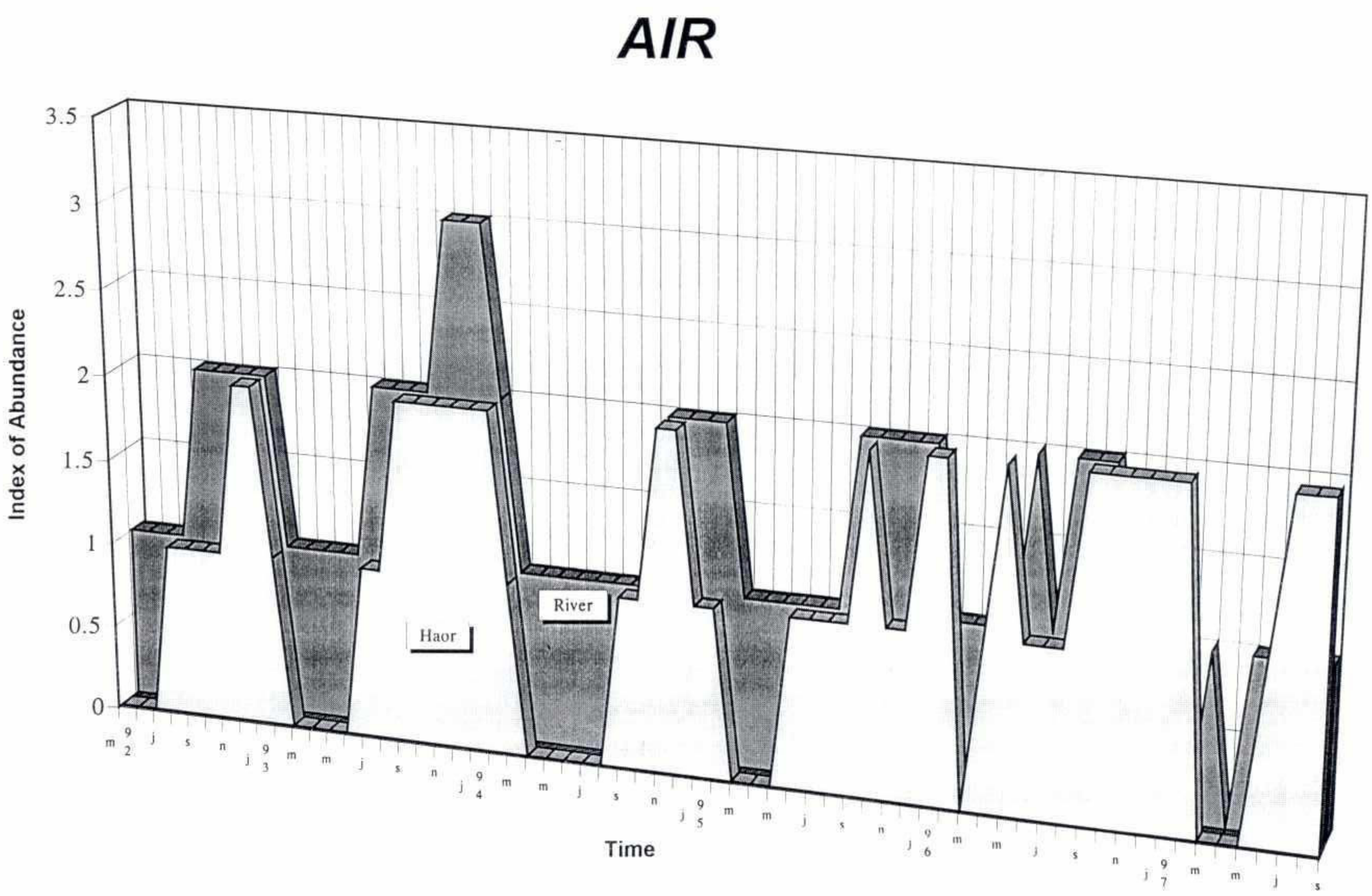


Figure 60: Index of Abudance for *Bacha* (1992-97)

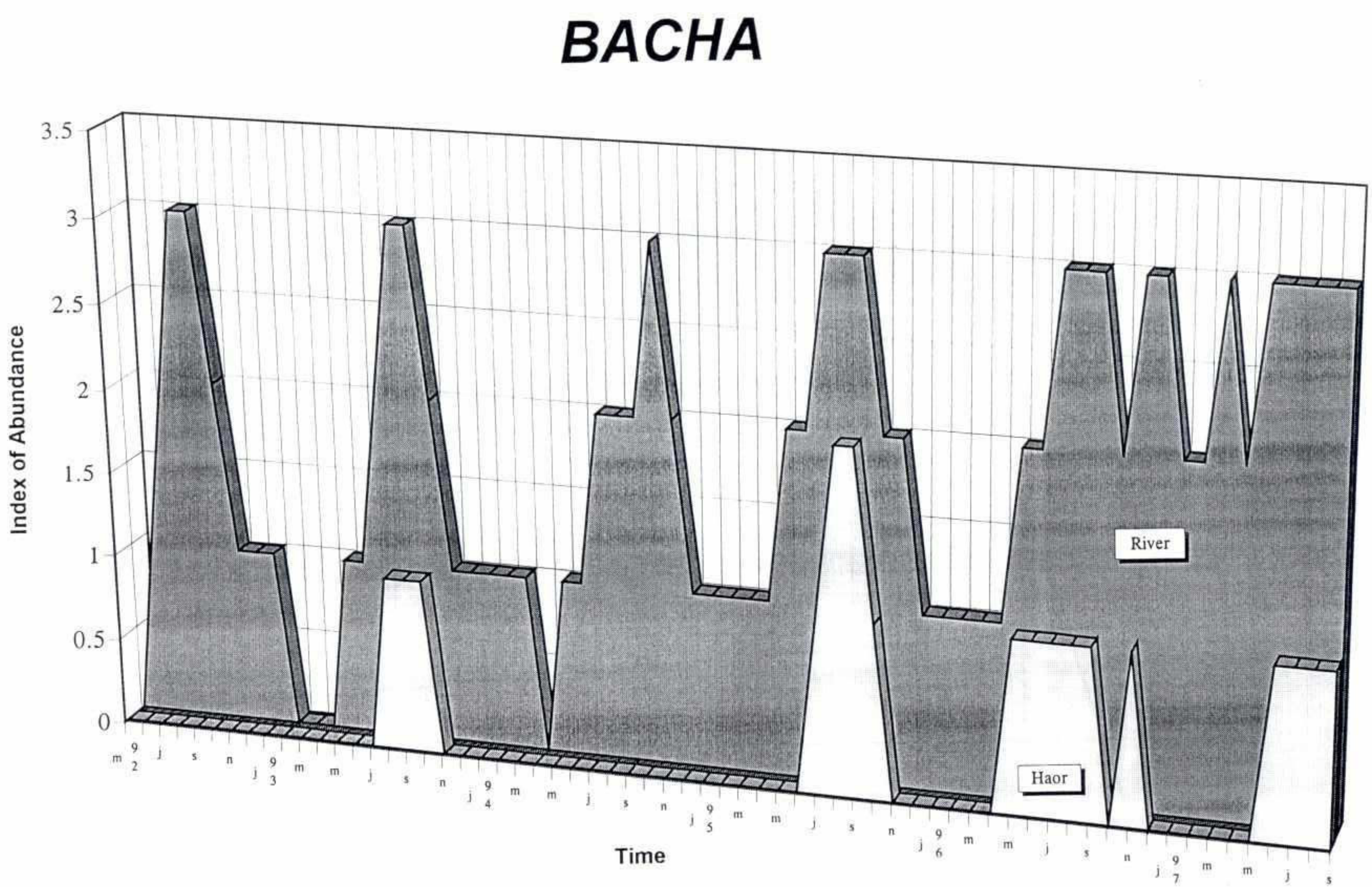
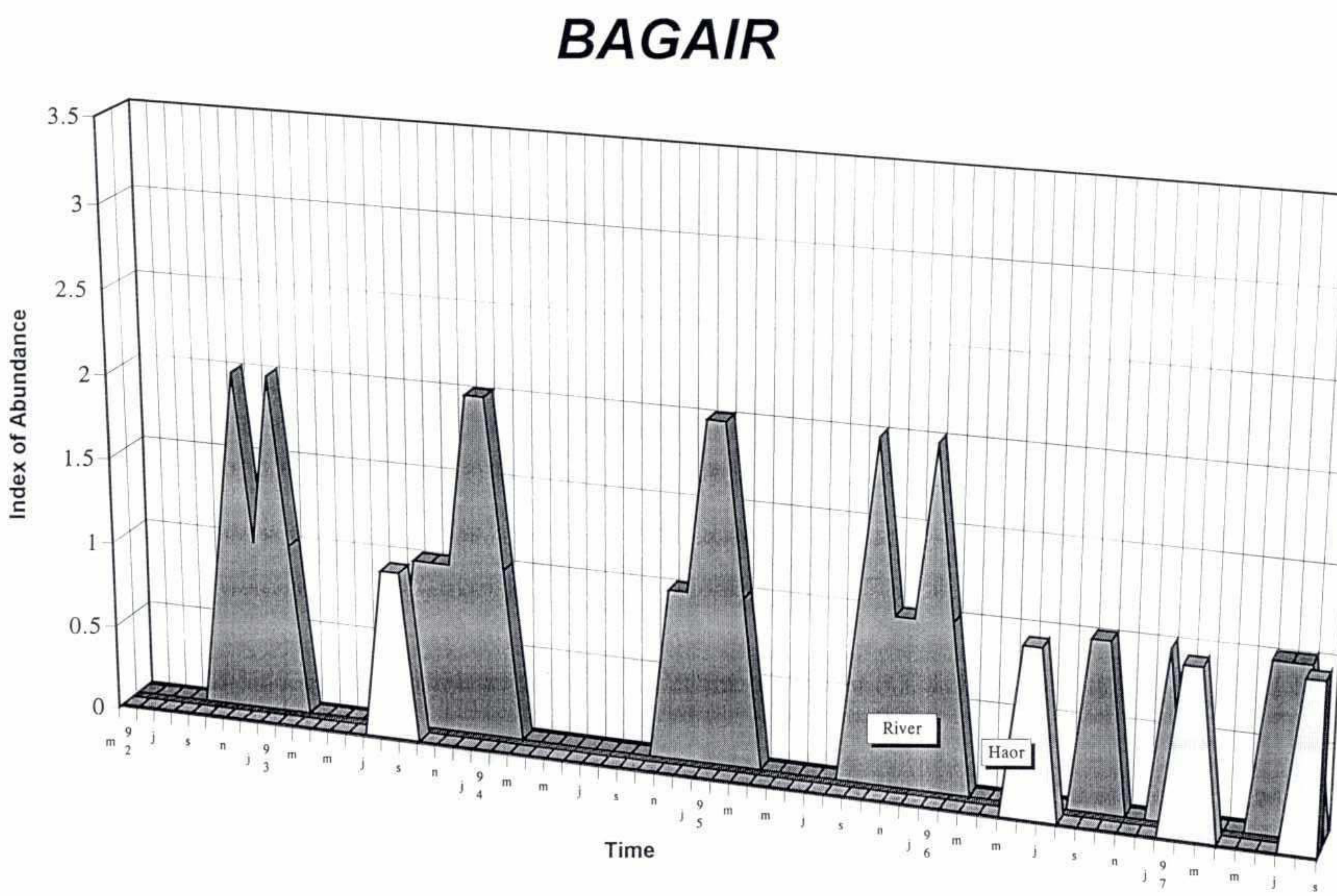


Figure 61: Index of Abudance for *Bagair* (1992-97)



202

Figure 62: Index of Abudance for *Golda chingri* (1992-97)

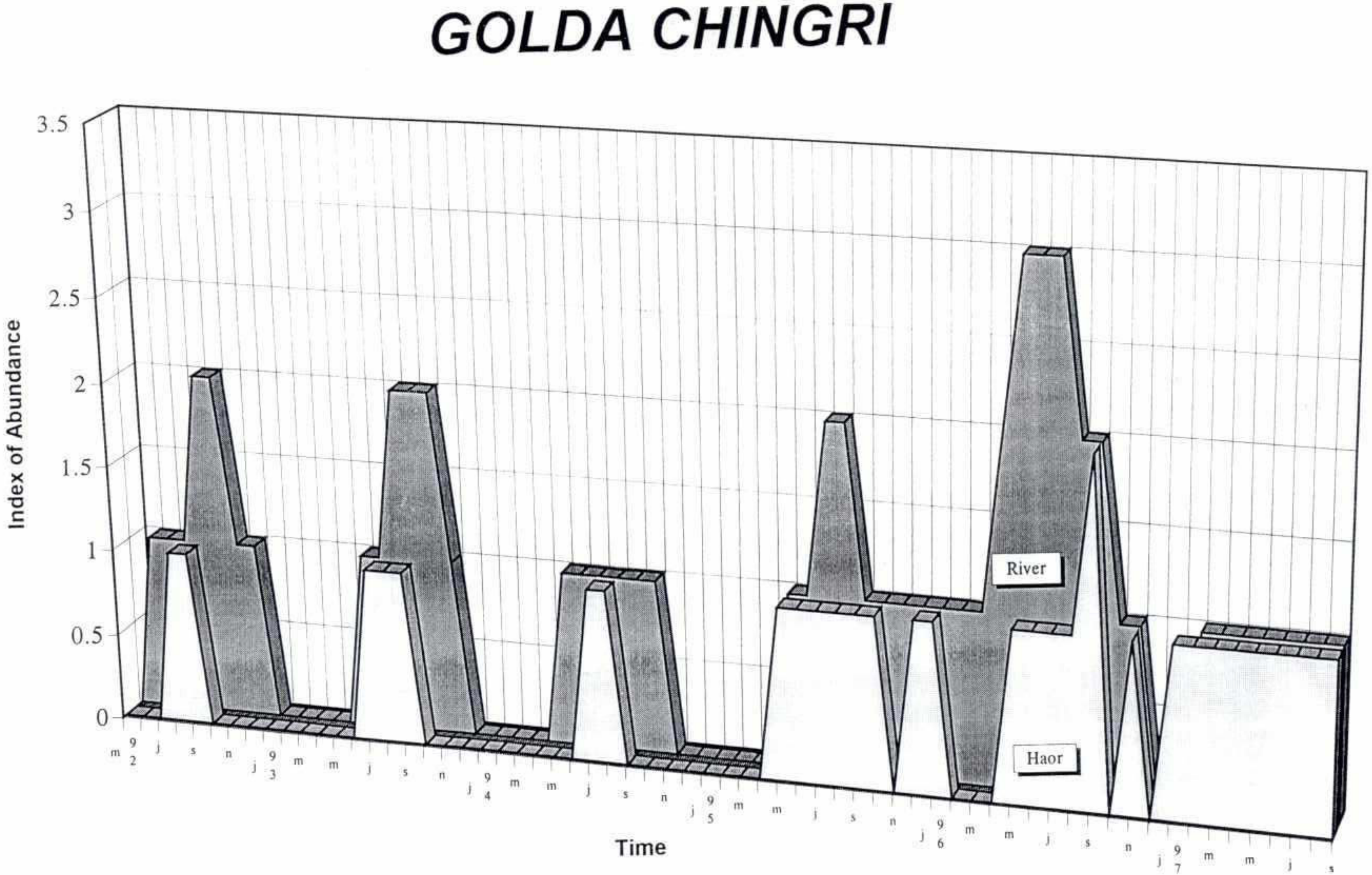
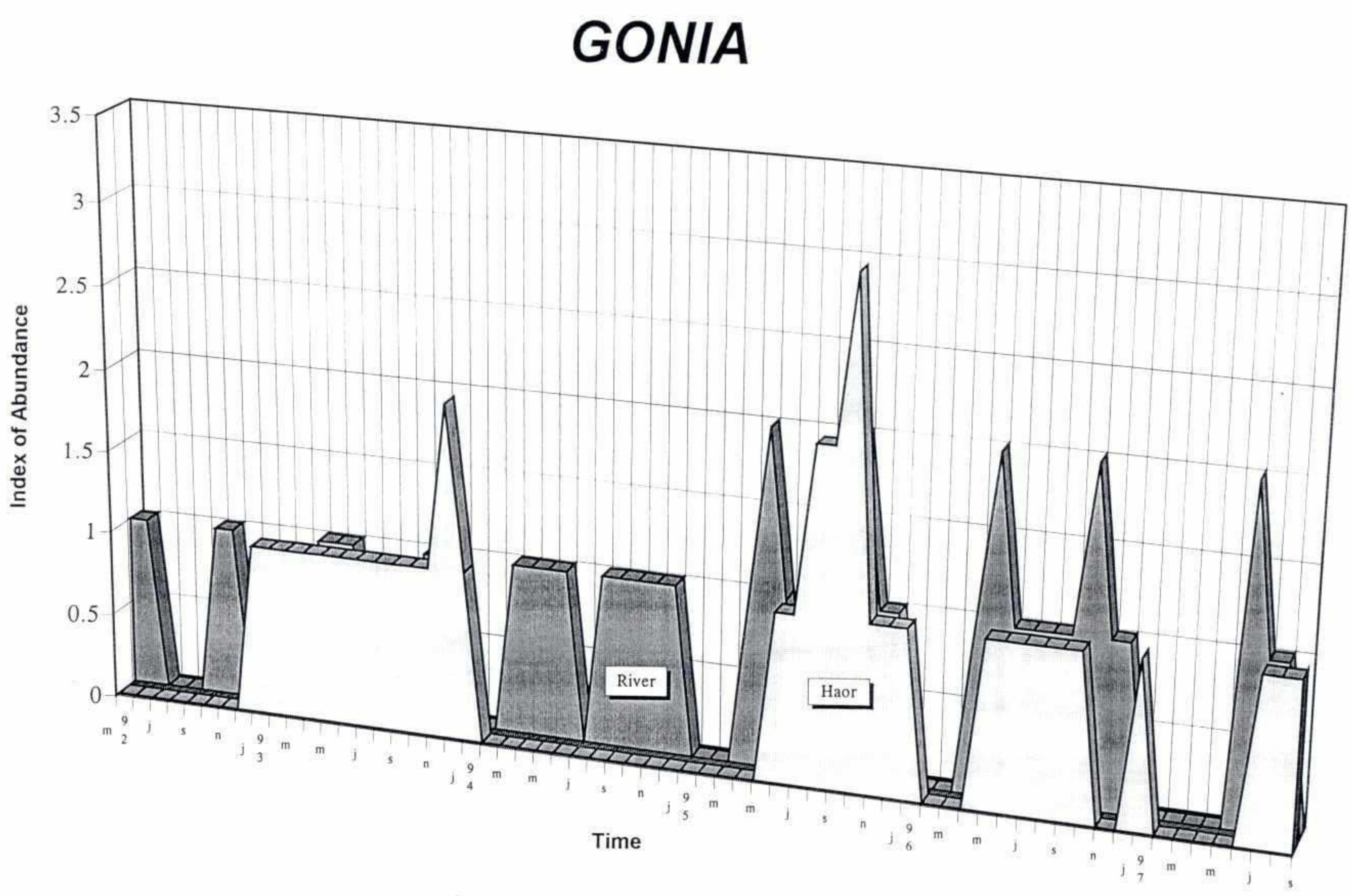
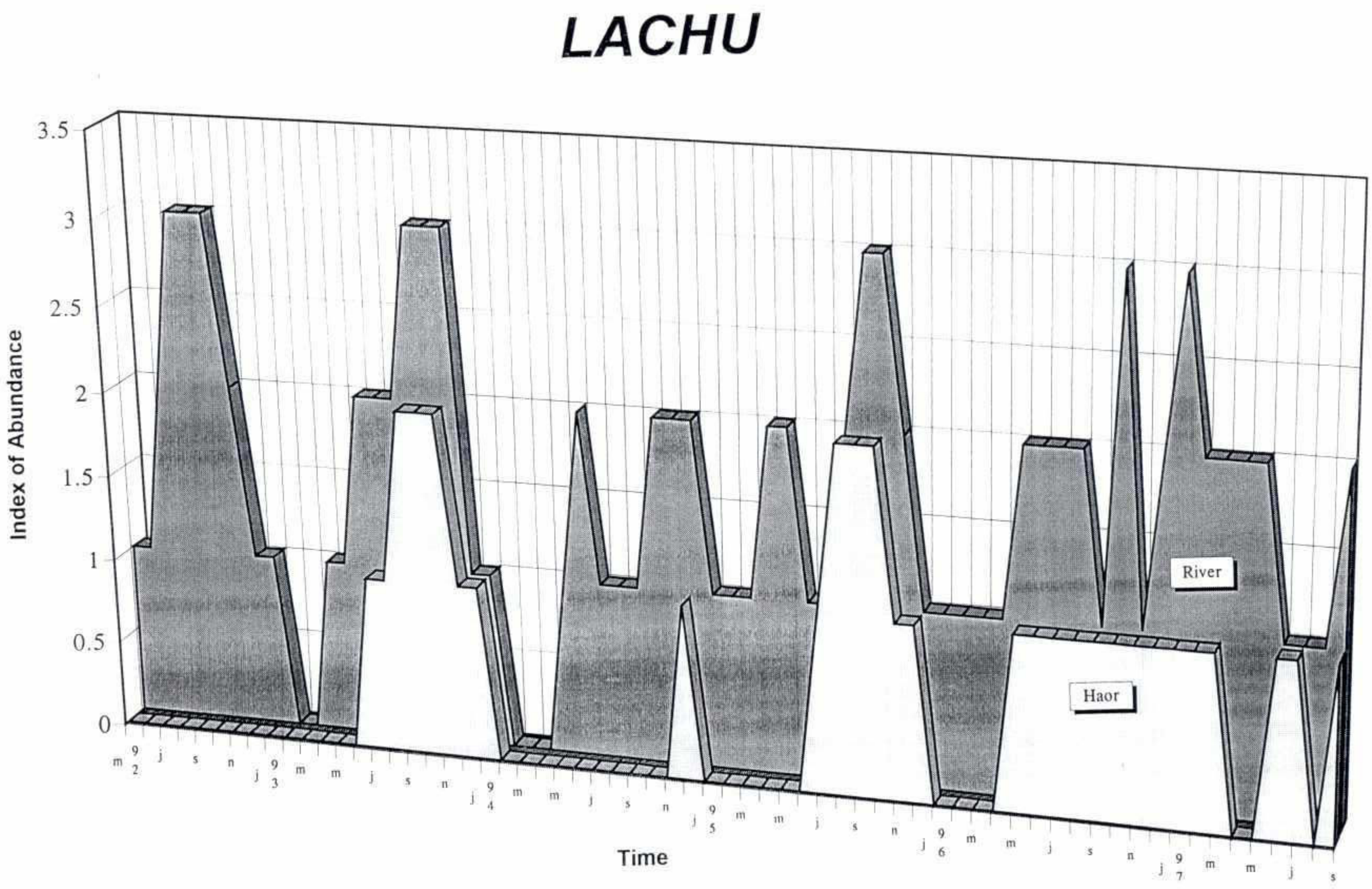


Figure 63: Index of Abudance for *Gonia* (1992-97)



206

Figure 64: Index of Abudance for *Lachu* (1992-97)



P28

Figure 65: Index of Abudance for *Kalibaush* (1992-97)

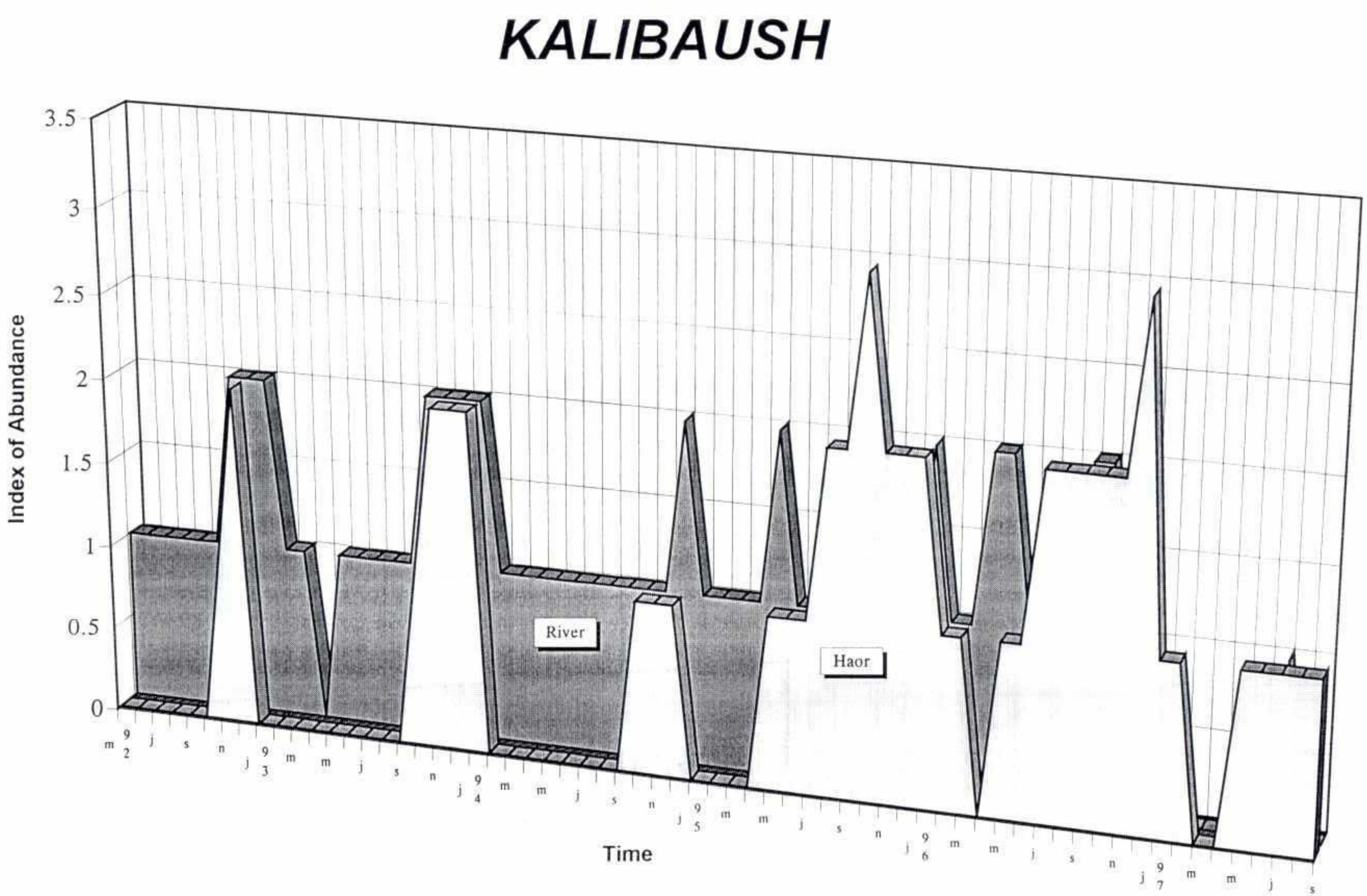


Figure 66: Index of Abudance for *Mola* (1992-97)

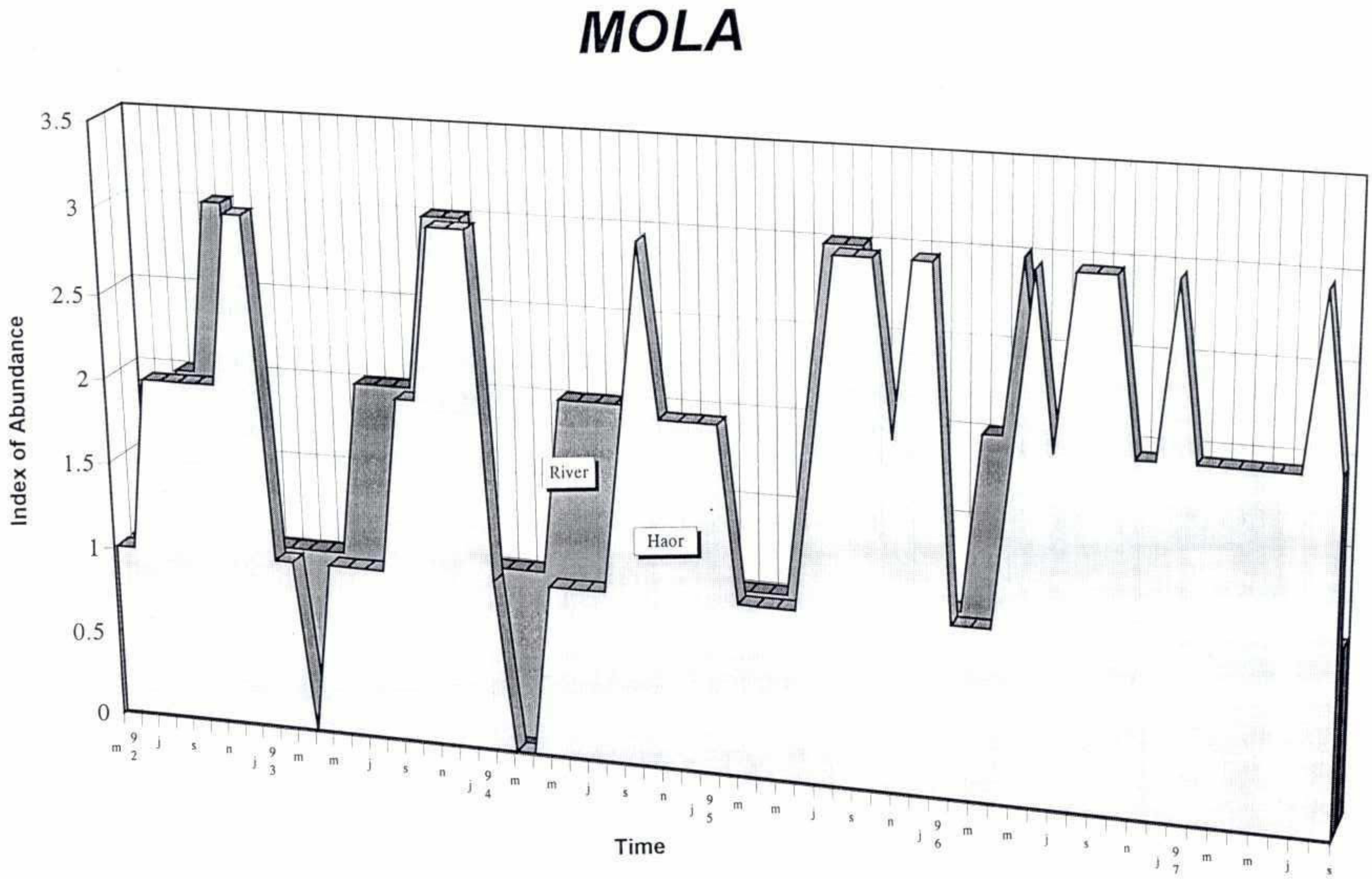
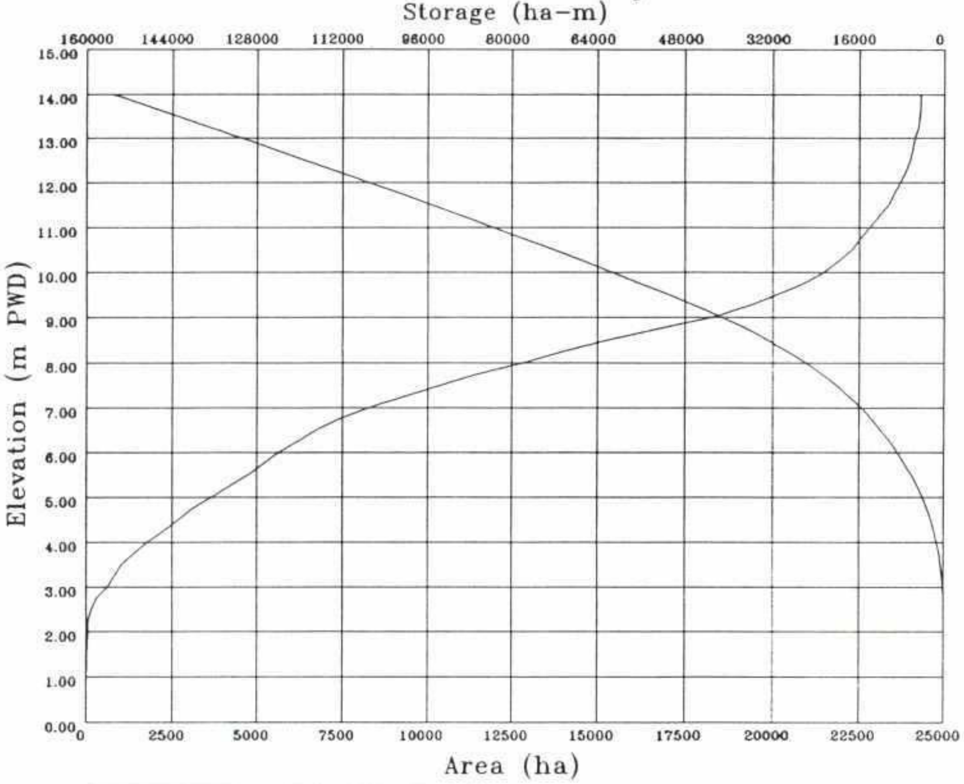


Figure 67: Elevation-Area-Storage Curves for MRIP

Manu River Project



Elevation (m PWD)	Area (ha)	Storage (ha-m)
1.0	0	0
1.2	6	1
1.5	19	4
1.7	26	10
2.0	45	18
2.2	51	30
2.5	140	54
2.7	300	109
3.0	612	223
3.2	816	402
3.5	1,033	633
3.7	1,397	937
4.0	1,773	1,333
4.2	2,251	1,836
4.5	2,679	2,452
4.7	3,081	3,172
5.0	3,667	4,016
5.2	4,209	5,000
5.5	4,745	6,120
5.7	5,185	7,361
6.0	5,644	8,715
6.2	6,193	10,194
6.5	6,716	11,808
6.7	7,367	13,568
7.0	8,279	15,524
7.2	9,254	17,716
7.5	10,377	20,169
7.7	11,493	22,903
8.0	12,807	25,941
8.2	14,000	29,292
8.5	15,301	32,954
8.7	16,761	36,962
9.0	18,268	41,340
9.2	19,274	46,033
9.5	20,122	50,957
9.7	20,850	56,079
10.0	21,475	61,369
10.2	21,927	66,795
10.5	22,304	72,324
10.7	22,546	77,930
11.0	22,808	83,599
11.2	23,095	89,337
11.5	23,522	95,142
11.7	23,350	101,001
12.0	23,720	106,906
12.2	23,854	112,853
12.5	23,987	118,833
12.7	24,070	124,840
13.0	24,134	130,866
13.2	24,230	136,912
13.5	24,274	142,975
13.7	24,300	149,046
14.0	24,300	155,121

Northeast Regional Project

Elevation-Area-Storage
Manu River Project

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-224.DWG

Figure 68: Area Flooded and Flood Depths during Pre-monsoon for MRIP

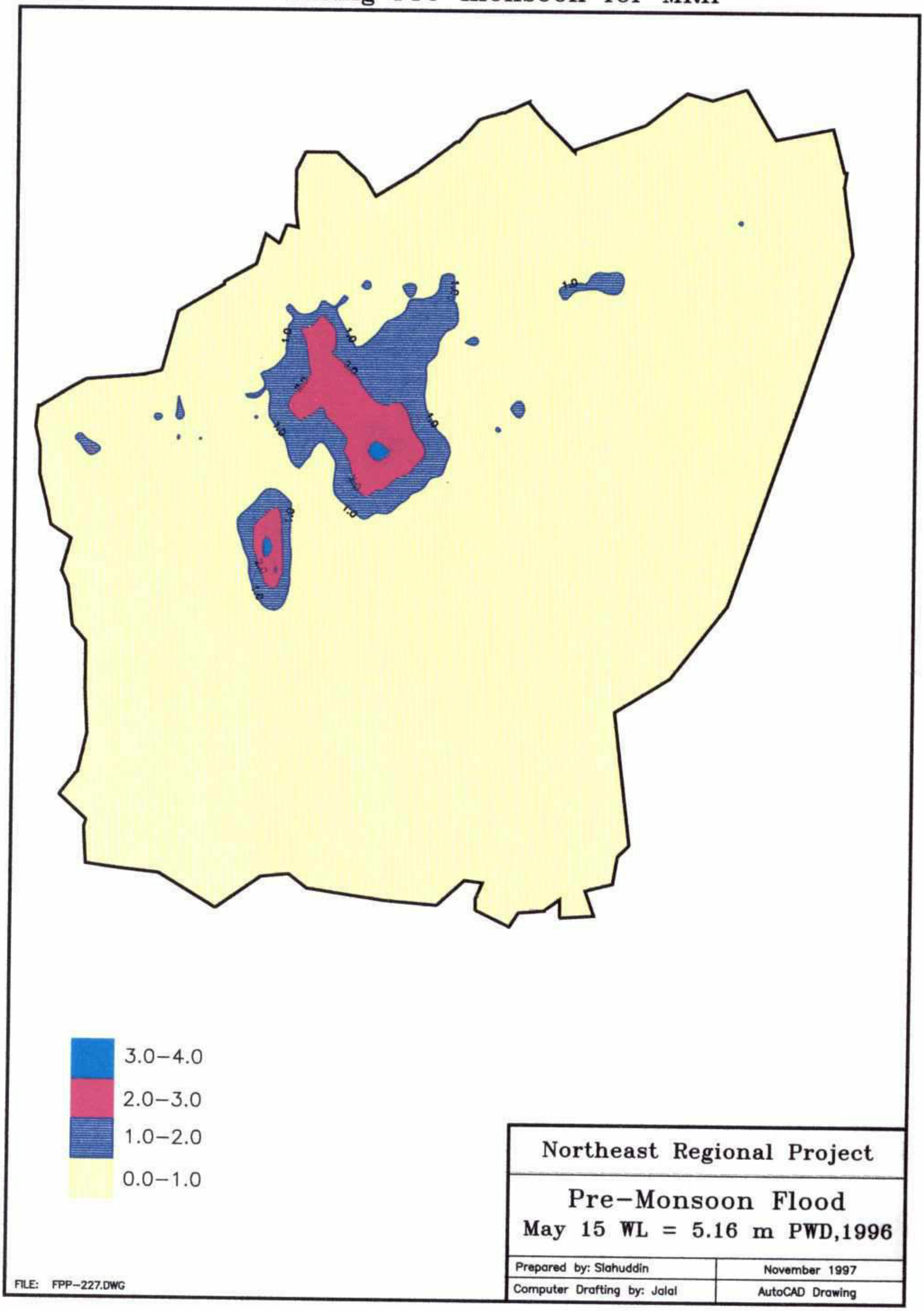
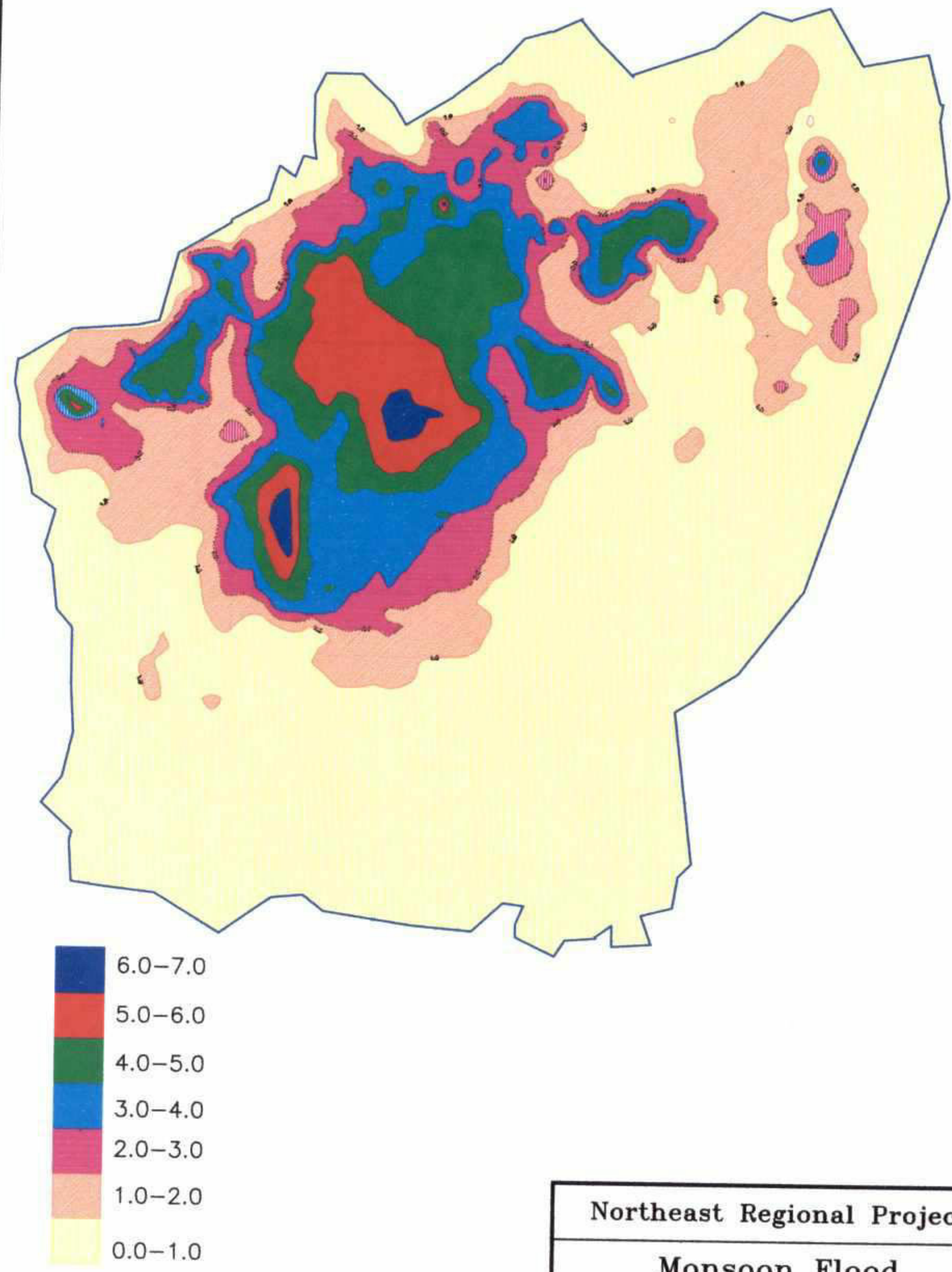


Figure 69: Area Flooded and Flood Depths during Monsoon for MRIP



Northeast Regional Project

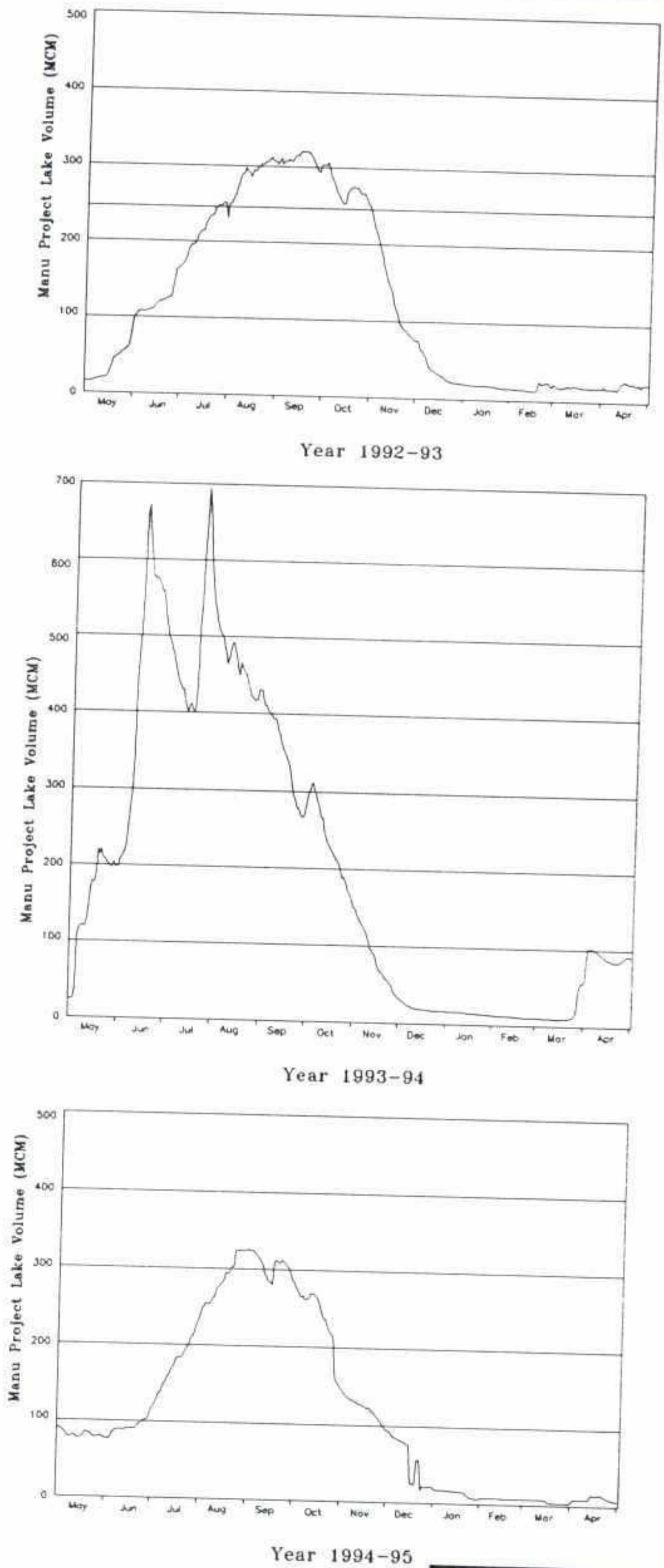
Monsoon Flood

Highest Flood Level = 8.52 m PWD,1996

Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-226.DWG

Figure 70: MRIP Flood Volumes (1992-94)



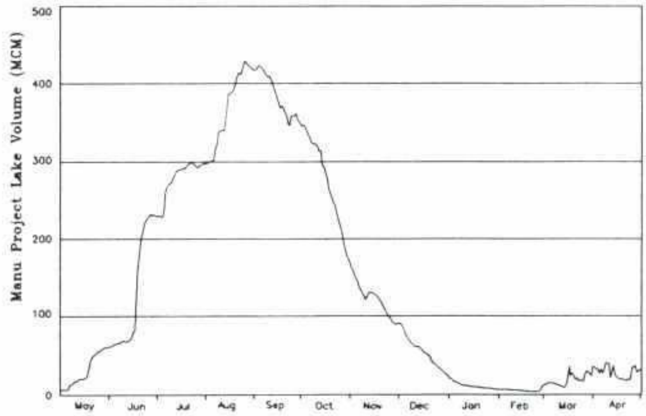
Northeast Regional Project

Manu River FCDI Project
Volume Flooded

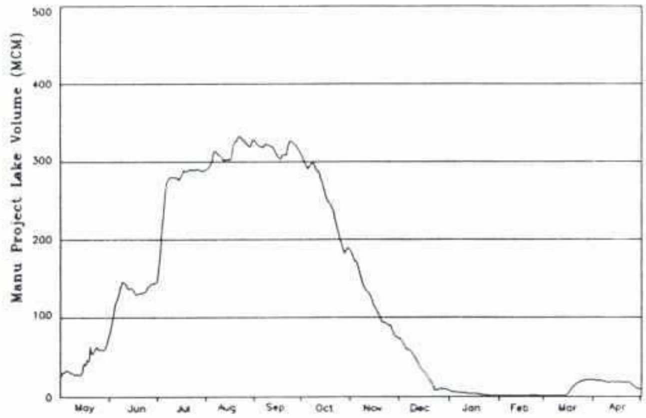
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-228.DWG

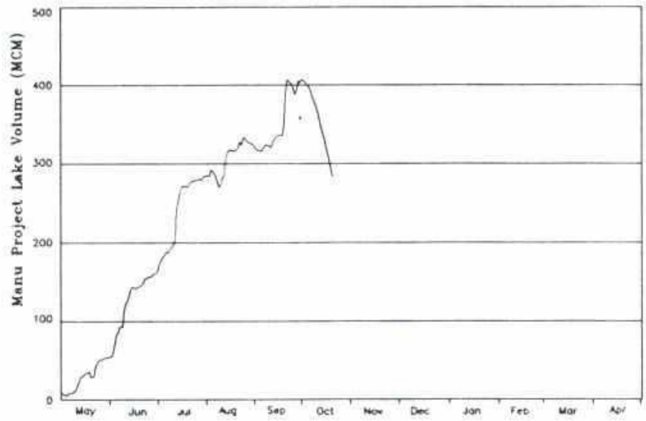
Figure 71: MRIP Flood Volumes for years 1 to 3 (1995-97)



Year 1995-96



Year 1996-97



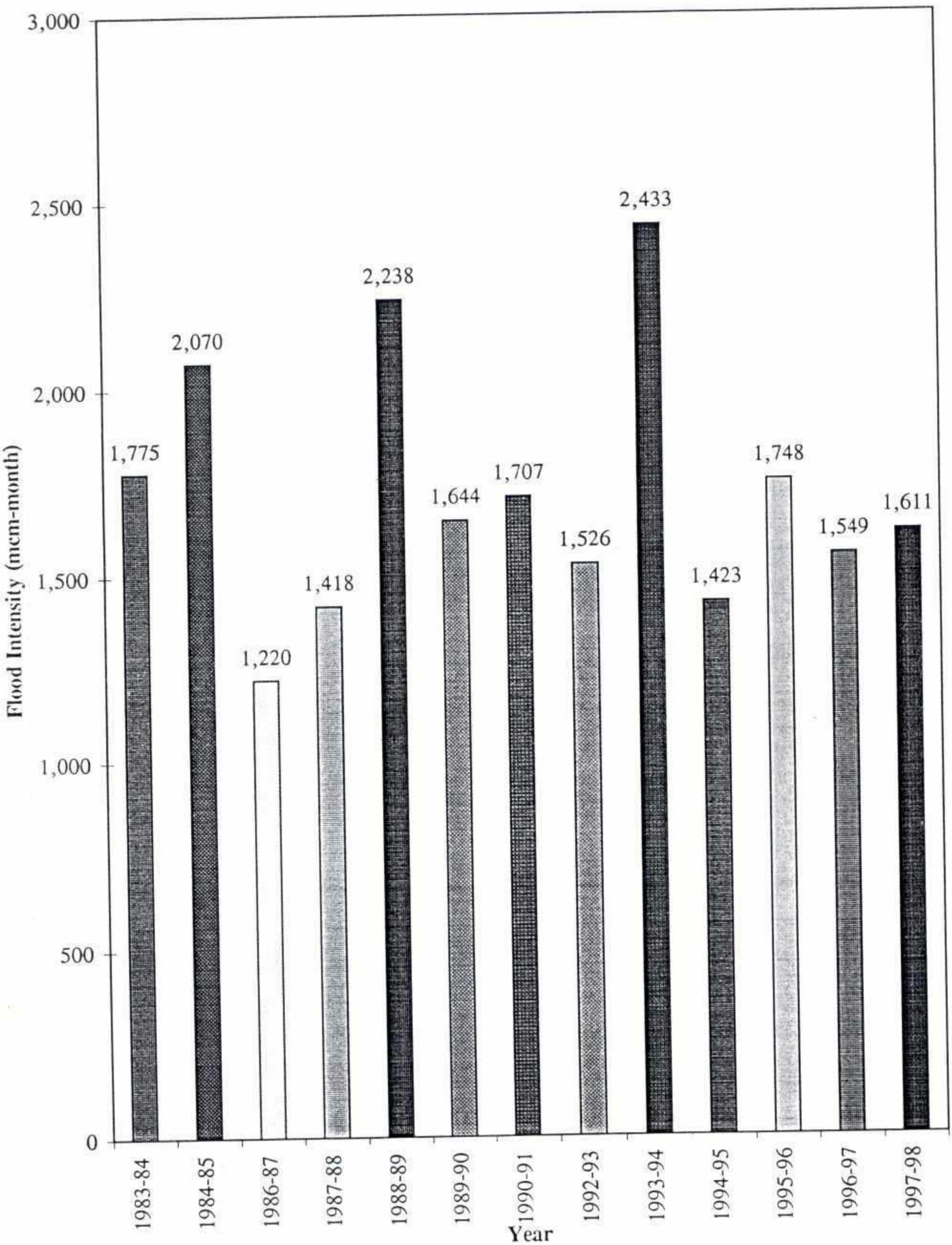
Year 1997-98

Northeast Regional Project	
Manu River FCDI Project Volume Flooded	
Prepared by: Salahuddin	November 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-229.DWG

222

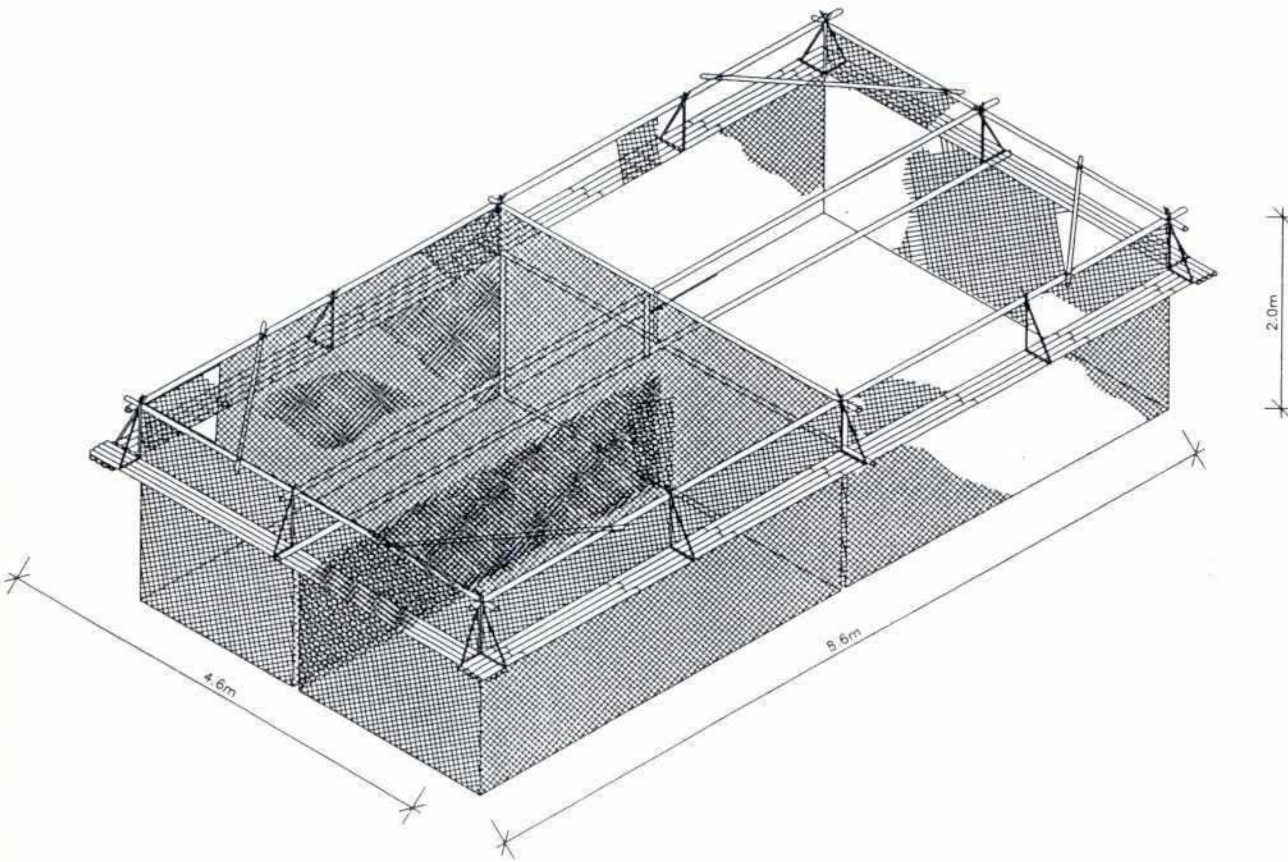
Figure 72: MRIP Flood Intensities (1983-97)



Note: High values for 1984-85, 1988-89 and 1993-94 due to breach in embankment

Note: 1997-98 value extrapolated for period Oct 21, 1997 to April 30, 1998

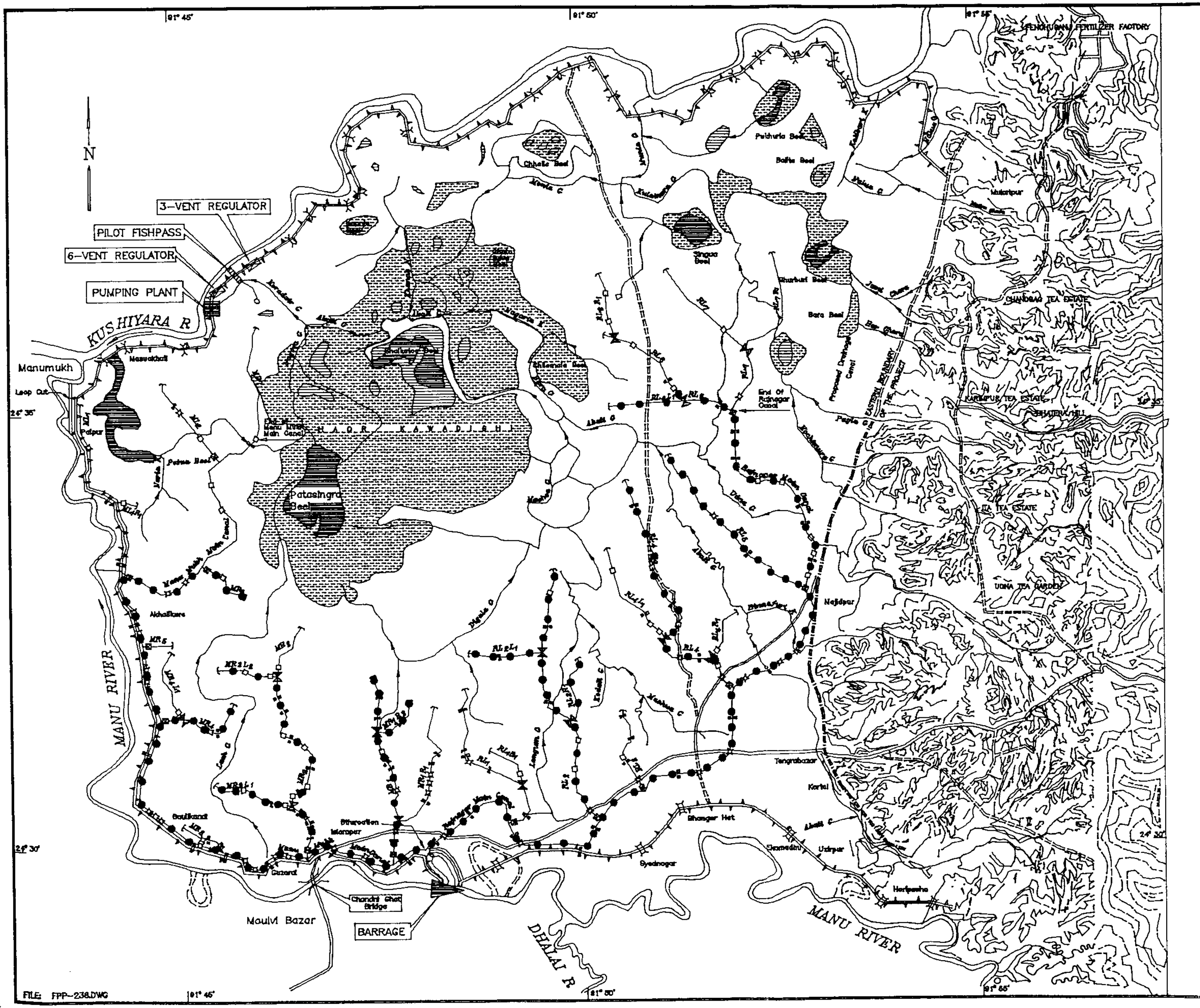
Figure 73: Design of Floating Cage for Fish Rearing



Northeast Regional Project	
Design of Floating Cage with Four Seperate Compartments	
Prepared by: Tariqul	December 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-275.DWG

Figure 74

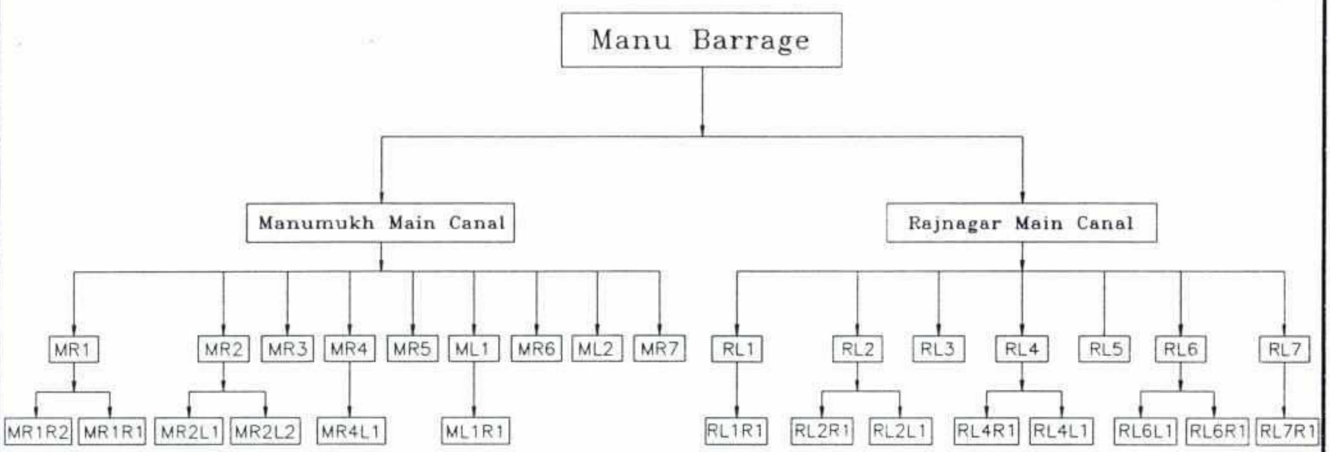


Northeast Regional Project

Irrigation System of Manu River Irrigation Project

Prepared by:	Salahuddin	December 1997	
Drawn by:	Jalal	AutoCAD Drawing	

Figure 75



Northeast Regional Project

Schematic Flow Diagram of Irrigation System of MRIP

Prepared by: Salahuddin	December 1997
Computer Drafting by: Jalal	AutoCAD Drawing

FILE: FPP-239.DWG

209

ANNEX A

TABLES

Table A.1: Monthly and Annual Mean Rainfall

Station Name & Number	May (mm)	Jun (mm)	Jul (mm)	Aug (mm)	Sep (mm)	Oct (mm)	Annual Mean (mm)
Moulvibazar (R-122)	446	528	437	396	295	152	2,714
Chandbagh (R-104)	529	635	528	434	362	181	3,172
Langla (R-117)	485	552	420	410	304	176	2,826
Manumukh (R-119)	482	640	497	416	317	159	2,897
Average	486	589	470	414	320	167	2,902

218

Table A.2: Fish Species Present in Greater Project Area (Kushiyara River and MRIP)

Sl No	Family	Local name	English name	Scientific name
		INDIGENOUS SPECIES		
1	Dasyatidae	Shakush	Gangetic stingray	*Himantura fluviatilis*
2	Notopteridae	Chitol	Knife fish	*Notopterus chitala*
3	"	Foli	Knife fish	*Notopterus notopterus*
4	Anguilidae	Bamosh	Freshwater eel	*Anguila bengalensis*
5	Ophichthidae	Kharu	Snake-eel	*Pisodonophis boro*
6	Clupidae	Ilish	Hilsha	*Hilsa ilisha*
7	"	Chapila	Sardine	*Gudusia chapra*
8	"	Ketchki	Sardine	*Corica soborna*
9	"	Koiputi	Gizzard shad	*Andontosoma chacunda*
10	"	Gonichapila	Gizzard shad	*Gonialosa manmina*
11	"	Chouka	Pellona	*Pellona ditchela*
12	Cyprinidae	Catla	Carp	*Catla catla*
13	"	Mrigel	Carp	*Cirrhinus mrigala*
14	"	Lachu	Carp	*Cirrhinus reba*
15	"	Kalabata	Carp	*Crassocheilus latius*
16	"	Angrot	Carp	*Labeo angra*
17	"	Bata	Carp	*Labeo bata*
18	"	Boga	Carp	*Labeo boga*
19	"	Kalibaush	Carp	*Labeo calbasu*
20	"	Gonia	Carp	*Labeo gonius*
21	"	Nandina	Carp	*Labeo nandina*
22	"	Longu	Carp	*Labeo pangusia*
23	"	Rui	Carp	*Labeo rohita*
24	"	Darkina	Rasbora	*Esomus danricus*
25	"	Darkina	Rasbora	*Rasbora daniconius*
26	"	Darkina	Rasbora	*Rasbora rasbora*
27	"	Chebli	Rasbora	*Danio devario*
28	"	Barali	Rasbora	*Barilius barila*
29	"	Piali	Rasbora	*Aspidoparia morar*
30	"	Puti	Barb	*Puntius sophore*
31	"	Puti	Barb	*Puntius ticto*
32	"	Puti	Barb	*Puntius gelius*
33	"	Puti	Barb	*Puntius conchonius*
34	"	Puti	Barb	*Puntius chola*
35	"	Puti	Barb	*Puntius phutunio*
36	"	Puti	Barb	*Puntius guganio*
37	"	Puti	Barb	*Puntius cosuatis*
38	"	Puti	Barb	*Puntius terio*
39	"	Mola	Barb	*Amblypharyngodon microlepis*
40	"	Mola	Barb	*Amblypharyngodon mola*
41	"	Dhela	Barb	*Rohtee cotio*

Table A.2: Fish Species Present in Greater Project Area (Kushiyara River and MRIP)

Sl No	Family	Local name	English name	Scientific name
42	"	Kashkhaira	Barb	*Chela laubuca*
43	"	Chela	Minnows	*Oxygaster gora*
44	"	Chela	Minnows	*Salmostoma bacaila*
45	"	Chela	Minnows	*Salmostoma phulo*
46	Cobitidae	Gutum	Loach	*Lepidocephalus guntea*
47	"	Pahari gutum	Loach	*Semileptes gongota*
48	"	Gutum	Loach	*Neoeucirrhichthys maydelli*
49	"	Rani	Loach	*Botia dario*
50	"	Putul	Loach	*Botia lohachata*
51	"	Matibangra	Loach	*Nemacheilus botia*
52	Balitoridae	Dari	River Loach	*Nemacheilus scaturigina*
53	Siluridae	Boal	Catfish	*Wallago attu*
54	"	Pabda	Catfish	*Ompok bimaculatus*
55	"	Pabda	Catfish	*Ompok pabda*
56	Claridae	Magur	Catfish	*Clarias batrachus*
57	Chacidae	Chaka	Catfish	*Chaca chaca*
58	Schilbedae	Bacha	Catfish	*Eutropiichthys vacha*
59	"	Kotibacha	Catfish	*Clupisoma murius*
60	"	Garua	Catfish	*Clupisoma garua*
61	"	Muribacha	Catfish	*Clupisoma naziri*
62	"	Batashi	Catfish	*Pseudotropius atherinoides*
63	"	Kazoli	Catfish	*Ailia coila*
64	"	Bashpata	Catfish	*Ailia punctata*
65	Bagridae	Air	Catfish	*Aorichthys aor*
66	"	Guizza	Catfish	*Aorichthys seenghala*
67	"	Tengra	Catfish	*Batasio tengana*
68	"	Gulsha	Catfish	*Mystus bleekeri*
69	"	Kabasi tengra	Catfish	*Mystus cavasius*
70	"	Nuna tengra	Catfish	*Mystus gulio*
71	"	Ghagla	Catfish	*Mystus menoda*
72	"	Buzuritengra	Catfish	*Mystus tengara*
73	"	Tengra	Catfish	*Mystus vittatus*
74	"	Lia	Catfish	*Rama chandramara*
75	"	Rita	Catfish	*Rita rita*
76	Heteropneustidae	Shing	Stinging catfish	*Heteropneustes fossilis*
77	Sisoridae	Bagair	Sisorid catfish	*Bagarius yarrellii*
78	"	Kauwa	Sisorid catfish	*Gagata cenia*
79	"	Kutakanti	Sisorid catfish	*Hara hara*
80	"	Kutakanti	Sisorid catfish	*Eristhistes pussilus*
81	"	Jainzza	Sisorid catfish	*Gagata youssoufi*
82	"	Gang tengra	Sisorid catfish	*Gagata viridescens*
83	Hemiramphidae	Ekthuita	Halfbeak	*Hyporhamphus gaimardi*
84	"	Kothota	Halfbeak	*Dermogenys pusillus*

Table A.2: Fish Species Present in Greater Project Area (Kushiyara River and MRIP)

Sl No	Family	Local name	English name	Scientific name
85	Belonidae	Kaikka	Needle fish	*Xenentodon cancila*
86	Cyprinidontidae	Kanpona	Killifish	*Applocheilus panchax*
87	Synbranchidae	Kuchia	Mud eels	*Monopterus cuchia*
88	"	Bamosh	Freshwater eel	*Ophisternon bengalense*
89	Mugilidae	Khorsula	Mullet	*Rhinomugil corsula*
90	"	Bata	Mullet	*Sicamugil cascasia*
91	Mastacembilidae	Tarabaim	Spiny eel	*Macrognathus aculeatus*
92	"	Baim	Spiny eel	*Mastacembelus armatus*
93	"	Chirkabaim	Spiny eel	*Mastacembelus pancalus*
94	Belontiidae	Kholisa	Gouramy	*Colisa fasciatus*
95	"	Kholisa	Gouramy	*Colisa labiosus*
96	"	Kholisa	Gouramy	*Colisa lalia*
97	"	Boicha	Gouramy	*Colisa sota*
98	"	Naptani	Gouramy	*Ctenops nobilis*
99	Anabantidae	Koi	Climbing perch	*Anabas testudineus*
100	Scianidae	Poa	Croaker	*Johnius cujus*
101	"	Koitor	Croaker	*Johnius koitor*
102	Gobiidae	Baila	Goby	*Glossogobius giuris*
103	"	Nuna baila	Goby	*Brachygobius nunus*
104	Nandidae	Bheda	Mud perch	*Nandus nandus*
105	"	Napitkoi	Mudperch	*Badis badis*
106	Ambasiidae	Chanda	Glassfish	*Chanda baculis*
107	"	Chanda	Glassfish	*Chanda nama*
108	"	Chanda	Glassfish	*Chanda ranga*
109	Channidae	Gozar	Snakehead	*Channa marulius*
110	"	Cheng	Snakehead	*Channa orientalis*
111	"	Taki	Snakehead	*Channa punctatus*
112	"	Shole	Snakehead	*Channa striatus*
113	Tetraodontidae	Potka	Puffer	*Tetraodon cutcutia*
114	Palaemonidae	Golda chingri	Giant river prawn	*Macrabrachium rosenbergii*
115	"	Icha	Small prawns	*Macrobrachium spp.*
116	Alpheidae	Icha	"	*Caridina sp.*
		NON-INDIGENOUS SPECIES		
117	Cyprinidae		Silver carp	*Hypophthalmichthys molitrix*
118	"	Carpio	Common carp	*Cyprinus carpio*
119	"		Grass carp	*Ctenopharyngodon idella*

Table A.3: Project Affected Area Population

Thana	Union	Social Catchment				Population			Percentage	
		Percentage of area	Number of Villages	Area (ha)	Number of Households	Total	Male	Female	Area	Pop
Rajnagar	Rajnagar	100.00	28	2,381	3,339	20,010	10,118	9,892		
	Monsurnagar	86.31	28	1,738	2,948	18,017	9,198	8,819		
	Uttarbhag	68.95	33	5,530	3,116	19,942	10,043	9,899		
	Pachgaon	100.00	33	2,906	2,952	18,847	9,490	9,357		
	Munshibazar	83.12	27	2,872	2,984	17,485	8,919	8,566		
	Fatepur	100.00	27	4,626	3,404	21,295	10,896	10,399		
	Sub-total		**176**	**20,054**	**1,8743**	**115,596**	**58,664**	**56,932**	**76**	**73**
Moulvibazar	Ekatuna	100.00	43	2,117	2,211	14,895	7,607	7,288		
	Chandnighat	48.29	19	1,228	2,049	11,697	6,116	5,581		
	Akailkura	100.00	38	2,913	2,638	16,182	8,172	8,010		
	Manumukh	*	1	*	68	365	177	188		
	Sub-total		**101**	**6,258**	**6,966**	**43,139**	**22,072**	**21,067**	**24**	**27**
Total			**277**	**26,311**	**25,709**	**158,735**	**80,736**	**77,999**	**100**	**100**

Source: 1991 Population Census, BBS

Note: * Manumukh village is included in Chanpur *mouza*, which is part of Akailkura union, and the area thereof has been shown in Akhailkura.

Table A.4: Population Growth Rate

Census Year	Project Population	Annual Growth Rate (%)	
		Project Area	Bangladesh
1901	25,206		
1911	27,802	0.99	0.94
1921	34,753	2.26	0.60
1931	60,122	5.63	.074
1941	69,020	1.39	1.70
1951	74,680	0.79	0.50
1961	82,633	0.98	2.26
1974	118,216	2.82	2.48
1981	142,322	2.69	2.35
1991	158,735	1.10	2.17
1995	16,9930	1.72	1.77
1901-1991		2.07	1.51
1974-1991		1.75	2.25

Source: BBS, 1995

Table A.5: Villages Covered by the Reconnaissance Survey

Thana	Union	Village	Households
Rajnagar	Fatehpur	Betahunja	500
		Antehari	219
		Zahidpur	210
		Mohammadpur	268
		Charkarpar	72
		Rashidpur	29
		Hamidpur	142
		Mujaffarpur	82
		Kashimpur	71
		Berkuri	235
		Shahpur	308
		Abdullahpur	39
		Sonapur	60
	Rajnagar	Uttar Gaorgaon	347
		Dakhin Gaorgaon	253
	Pachgaon	Amirpur	238
		Rokta	118
		Kubja	66
		Khaldar	35
	Monsurnagar	Banari	288
		Jaua	36
		Bisonkirti	136
Moulvibazar	Akhailkura	Chandpur	49
		Kadipur	145
	Monumukh	Monumukh Sumarai	115
	Ekatuna	Karimullahpur	51
Total		**26**	**4,112**

Source: Reconnaissance Survey, NERP, 1995

Table A.6: Ethnic Distribution of Households

Community	Caste	Households	
		Number	Percentage
Muslim	Maimol	1,964	47.8
	Bangal	1,067	25.9
	Abadi	288	7.0
	Sub-total	**3,319**	**80.7**
Hindu	Das	376	9.1
	Namasudra	259	6.3
	Nath	60	1.5
	Barman	40	1.0
	Brahmin	21	0.5
	Ghosh	20	0.5
	Boidya	17	0.4
	Sub-total	**793**	**19.3**
Total		**4,112**	**100.0**

Source: Reconnaissance Survey, NERP, 1995

Table A.7: Distribution of Fishermen By Cultivable Holding

Stratum	Full-time Fishermen		Seasonal Fishermen		Total Fishermen	
	Number	%	Number	%	Number	%
Landless	40	60	59	44	99	49
Small farmer	24	36	53	39	77	38
Medium farmer	2	3	18	13	20	10
Large farmer	1	1	5	4	6	3
Total	**67**	**100**	**135**	**100**	**202**	**100**

Source: Fishermen Survey, NERP, 1996

Table A.8: Occupational Pattern of Male Population

Main Occupation	Full-time Fishermen		Seasonal Fishermen	
	Number	%	Number	%
Fishing	88	66	47	17.7
Farming	16	12	141	53.0
Trading	20	15	29	10.9
Londoni	4	3	10	3.8
Farm labour	3	2	37	13.9
Others	2	2	2	0.8
Total	133	100	266	100.0
Total households	67		135	
Total population	401		769	
Average household size	6.0		5.7	
Civilian labour force	151		322	
Employment rate (%)	88		83	

Source: Fishermen Survey, NERP, 1996

223

Table A.9: Ownership of Fishing Gear and Boat Among Full-time Fishermen

Gear	Ownership		Percentage	
	Individual	Joint	Individual	Joint
Footpine jal *	4	28	6	42
Hook	32	-	48	-
Pai jal	8	4	12	6
Fanda jal	1	-	1	-
Ural jal	16	-	24	-
Rek jal	7	7	10	10
Bel jal	1	1	1	1
Kapri jal	-	9	-	13
Baro jal	1	-	1	-
Boat	26	-	39	-
Total	**67**	**67**	**100**	**100**

Source: Fishermen Survey, NERP, 1996

Note: * *jal* - net

Table A.10: Ownership of Fishing Gear and Boat Among Seasonal Fishermen

Gear	Ownership		Percentage	
	Individual	Joint	Individual	Joint
Footpine jal *	-	6	-	4
Hook	49	10	36	7
Pai jal	1	-	1	-
Fanda jal	29	3	21	2
Kapri jal	-	14	-	10
Boro jal	5	4	4	3
Chai	12	-	9	-
Chhoto jal	12	-	9	-
Afa jal	3	-	2	-
Boat	69	6	51	4
Total	**135**	**135**	**100**	**100**

Source: Fishermen Survey, NERP, 1996

Note: * *Jal* - net

Table A.11: Full-time Fishing Households - Involvement In Cooperatives and NGOs

Involvement	Membership in Fishing Cooperatives (Male)		Membership in NGOs (Female)	
	Number	%	Number	%
Member	14	21	16	24
Non-member	53	79	51	76
Total	**67**	**100**	**67**	**100**

Source: Fishermen Survey, NERP, 1996

22K

Table A.12: Statistics on Women's Groups

Village	Partner Agency	Number of Group Members	Activities
Gaorgaon	BRAC	90	grocery, fish trading
Bisonkirti	GB	30	poultry, net making, cow rearing, goat rearing, small trading, dry fish trading
	BRAC	40	Poultry, cow and goat rearing, vegetable cultivation, net making, dry fish trading, rice trading,
Khaldar	BRAC	25	Poultry, cow and goat rearing, net making, rice trading, *pan-supari* trading
Kubja	BRAC	20	rice trading, *muri* making
Shahpur	GB	40	
Abdullahpur	GB	10	
Chanpur	Unnayan sahayak Sangtha	54	dry fish, poultry, *muri* making
Hamidpur	GB	40	fish trading, agriculture
Rokta	BRAC	30	poultry, net making, cow rearing, rice trading, dry fish trading
Banari	BRAC	75	poultry, net making, cow and goat rearing, rice trading, dry fish trading
	ASA	35	poultry, net making, cow and goat rearing, rice trading, dry fish trading
Jaua	GB	9 (included in Bisonkirti groups)	small trading, poultry, net making, cow rearing, dry fish trading
Poshchim Berkuri	GB	35	rice trading
Kadipur	BRAC	70	poultry, fish drying, *muri* making
Charkarpar	GB	10 (included in Zahidpur groups)	rice trading
Zahidpur	GB	25	poultry
Betahunza	GB	30	rice trading, vegetables selling
Total		**668**	

Source: Reconnaissance Survey, NERP, 1995

Table A.13: Patterns of Shifting Monsoon Fishing Sites on the Haor (1995 & 1997)

Number of Times Site(s) Shifted	1995						1997					
	Full-time Fishermen		Seasonal Fishermen		Total		Full-time Fishermen		Seasonal Fishermen		Total	
	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%	Nos.	%
1	17	29	2	2	19	10	8	16	4	3	12	7
2	15	26	15	12	30	17	21	43	27	22	48	28
3+	26	45	106	86	132	73	20	41	91	75	111	65
Total	**58**	**100**	**123**	**100**	**181**	**100**	**49**	**100**	**122**	**100**	**171**	**100**

Source: Fishermen Survey, NERP, 1995 & 1997

Table A.14: Comparison Monsoon Fishing Days (1995 & 1997)

Fisher Category	1995			1997		
	Fishermen Nos.	Fishing Days	Average Fishing Days	Fishermen Nos.	Fishing Days	Average Fishing Days
Fulltime Fishermen	58	6,670	115	49	4,553	93
Seasonal Fishermen	123	15,006	122	122	12,953	106
Total	**181**	**21,676**		**171**	**17,506**	

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.15: Comparison of Fishing Days in Dry Seasons of 1994-95 & 1996-97

Fishing Period (days)	1994-95		1996-97	
	Fishermen Number	% of Fishermen	Fishermen Number	% of Fishermen
1-30	2	4	20	32
31-60	32	63	21	34
61-90	13	25	21	34
90+	4	8	0	0
Total	**51**	**100**	**62**	**100**

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.16: Fishing Sites in 1994-95 and 1996-97 Dry Season

Number of Times Site(s) Shifted	1994-95		1996-97	
	Fishermen Number	% of Fishermen	Fishermen Number	% of Fishermen
1	15	29	20	32
2	34	67	21	34
3 & more	2	4	21	34
Total	**51**	**100**	**62**	**100**

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.17: Wage Earned From Dry Season Catch of 1994-95 & 1996-97

Fishing Year	No. of Fishermen Engaged	Total Wage (Tk)	Average Seasonal Wage per Fisher (Tk)	Average Daily Wage per Fisher (Tk)
1994-95	51	1,94,178	3,807	61
1996-97	62	2,43,947	3,934	98

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.18: MRIP Cultivated Area by Crops in 1997

Season	Rice Crops								Other Crops					
	High Yield Variety Rice (ha)			Local Variety Rice (ha)					Potato (ha)	Mustard (ha)	Winter Vege-table (ha)	Summer Vege-table (ha)	Jute (ha)	Others (ha)
	Boro	T. Aus	T. Aman	Boro	L.T Aus	B. Aus	L.T Aman	B. Aman						
Rabi	4,509	-	-	3,859	-	-	-	-	47	3	47	-	-	60
Kharif I	-	2,853	-	-	638	310	-	-	-			82	5	87
Kharif II	-	-	13,260	-	-	-	618	3,863	-				-	30
Sub-total	**4,509**	**2,853**	**13,260**	**3,859**	**638**	**310**	**618**	**3,863**	**47**	**3**	**47**	**82**	**5**	**177**
Total			**20,622**					**9,288**						**361**
% of Total Cropped Area			**68%**					**31%**						**1%**

Source: BWDB, Moulvibazar, 1997

Note: Net cultivable area of MRIP in 1997 was 19,278 ha.
Gross cropped area of MRIP in 1997 was 30,271 ha.
Cropping intensity of MRIP in 1997 was 157%

Table A.19: Occupational Distribution of Households

Occupation	Households*	
	Number	Percentage
Agriculture	2,093	50.9
Fishing	1,675	40.7
Fish trade	1,064	25.9
Farm labour	643	15.6
Londoni	179	4.4
Services	54	1.3
Trading (non-fish)	46	1.1
Leasee	40	1.0
Others	65	1.6
Total	**4,112**	**100.0**

Source: Reconnaissance Survey, NERP, 1995

Note: * Multiple responses have been recorded

208

Table A.20: Telephone and Telegraph Facilities in the Project Affected Area

Thana	Service Distribution System
Rajnagar	BT&T * (telephone, telegraph, and card phone)
	BRTA ** (telephone/commercial use)
Balaganj	BT&T (telephone, telegraph, and card phone)
	BRTA (telephone/commercial use)
Kazirbazar	BRTA (telephone/commercial use)
Moulvibazar	BT&T (telephone, telegraph and card phone)
	BRTA (telephone/commercial use)
Rajnagar, Fathepur Union, Kashimpur Pumphouse	BT&T (BWDB's telephone)

Source: Infrastructure Survey, NERP, 1997

Note: * BT&T - Bangladesh Telephone and Telegraph
** BRTA - Bangladesh Rural Telecommunication Authority

Table A.21: Postal Facilities in the Project Affected Area

Thana	Union	Village	Nos.
Rajnagar	Rajnagar	Rajnagar Sadar	1
	Rajnagar	Gargaon	1
	Pachgaon	Pachgaon	1
	Fathepur	Moquambazar	1
	Munsurnagar	Munsurnagar	1
Moulvibazar	Monumukh	Monumukh	1
	Ekatona	Ekatona	1
	Ekatona	Barokapon	1
	Akailkura	Paguria	1
	Total		9

Source: Infrastructure Survey, NERP, 1997

Table A.22: Monsoon Season Transportation

Destination	Distance (km)	Mode of Transport
Kashimpur to Kazibazar	8	Engine boat
Kazibazar to Balagang to Fenchugang	32	Launch & Engine boat
Balagang to Sherpur	21	Engine boat & Launch
Antehari to Sonapur to Kashimpur	8	Country boat
Antehari (Kadipur) to Kazibazar	5	Country boat

Source: Infrastructure Survey, NERP, 1997

Table A.23: Dry Season Transportation

Destination	Distance (km)	Mode of Transport
Kashimpur to Kazibazar	8	Rickshaw
Sherpur to Balagang to Fenchugang	32	Engine boat & Launch
Balagang to Sherpur	21	Engine boat
Berkuri to Rajnagar to Moulvibazar	33	Bus/Baby Taxi
Antehari to Ekatona to Moulvibazar	12	Baby Taxi/ Rickshaw

Source: Infrastructure Survey, NERP, 1997

Table A.24: Source of Drinking Water in the Project Affected Area

Source	Percentage of Households (%)	
	Survey Villages	**Bangladesh**
Pipeline	0	4
Tubewell	19	76
Open Well	1	9
Pond	55	8
River/canal	25	3
Total	**100**	**100**

Source: Reconnaissance Survey, NERP, 1995;
Bangladesh Population Census, 1991

Table A.25: Sanitation Facilities in the Project Affected Area

Type of Sanitation Facility	Percentage of Households (%)	
	Survey Villages	**Bangladesh**
Sanitary (ring-seal & concrete pit latrine)	8	13
Unsanitary (earthen pit & hanging latrine)	71	53
Open space (no latrine)	21	34
Total	**100**	**100**

Source: Reconnaissance Survey, NERP, 1995;
Bangladesh Population Census, 1991

2o8

Table A.26: Primary Health Care and Family Planning Services for the Project Affected Area

Thana	Union	Service Delivery Point		
		Thana Health Complex	Union Health Centre	Union Family Welfare Centre
Rajnagar	Rajnagar Sadar	1	-	1
	Pachgaon	-	1	1
	Munsurnagar	-	1	-
	Fathepur	-	-	1
Moulvibazar	Ekatona	-	-	1
	Akailkura	-	-	1
	Monumukh	-	1	1
Total		**1**	**3**	**6**

Source: Infrastructure Survey, NERP, 1997

Table A.27: Summary of Fishpass Operation Time

Month	No. of days	Elapsed hours	POP (hrs)	POP ratio (%)	AOP (hrs)	AOP ratio (%)	Cause of interruption of AOP
		a	b	b/a	c	c/b	
CALENDAR YEAR 1 (1995)							
Jan	31	744	0	0.0%	0.0	0.0%	
Feb	28	672	0	0.0%	0.0	0.0%	
Mar	31	744	0	0.0%	0.0	0.0%	
Apr	30	720	0	0.0%	0.0	0.0%	
May	31	744	312	41.9%	125.5	40.2%	Farmer protest
Jun	30	720	720	100.0%	671.0	93.2%	Farmer protest
Jul	31	744	744	100.0%	452.0	60.8%	Farmer protest
Aug	31	744	744	100.0%	412.0	55.4%	Farmer protest
Sep	30	720	720	100.0%	591.0	82.1%	Farmer protest
Oct	31	744	744	100.0%	744.0	100.0%	
Nov	30	720	624	86.7%	480.0	76.9%	Low water
Dec	31	744	0	0.0%	0.0	0.0%	
Total 95	365	8,760	4,608	52.6%	3,475.5	75.4%	
CALENDAR YEAR 2 (1996)							
Jan	31	744	0	0.0%	0.0	-	
Feb	29	696	0	0.0%	0.0	-	
Mar	31	744	221	29.7%	19.0	8.6%	Construction
Apr	30	720	552	76.7%	83.6	15.1%	Farmer protest
May	31	744	744	100.0%	504.0	67.7%	Farmer protest
Jun	30	720	720	100.0%	720.0	100.0%	
Jul	31	744	744	100.0%	744.0	100.0%	
Aug	31	744	744	100.0%	744.0	100.0%	
Sep	30	720	720	100.0%	720.0	100.0%	
Oct	31	744	744	100.0%	744.0	100.0%	
Nov	30	720	384	53.3%	120.0	31.3%	Low water
Dec	31	744	0	0.0%	0.0	0.0%	
Total 96	366	8,784	5,573	63.4%	4,398.6	78.9%	
CALENDAR YEAR 3 (1997)							
Jan	31	744	0	0.0%	0	0.0%	
Feb	28	672	0	0.0%	0	0.0%	
Mar	31	744	72	9.7%	0	0.0%	Farmer protest
Apr	30	720	0	0.0%	0	0.0%	
May	31	744	264	35.5%	240	90.9%	
Jun	30	720	720	100.0%	720	100.0%	
Jul	31	744	744	100.0%	744	100.0%	
Aug	31	744	744	100.0%	744	100.0%	
Sep	30	720	720	100.0%	720	100.0%	
Oct **	31	744	480	64.5%	480	100.0%	End of project
Nov	30	720	-	-	-	-	
Dec	31	744	-	-	-	-	
Total 97	365	8,760	3,744	42.7%	3,648	97.4%	

* First operation of fishpass was on 24 May 1995

** Data collection was terminated 20 Oct 1997

POP = Potential operation period of fishpass

AOP = Actual operation period of fishpass

Table A.28: Maximum Water Levels in MRIP and Kushiyara River (1983 to 1997)

Year	Maximum Water Level (m PWD)	
	River WL	Project WL
1983	9.45	8.81
1984	9.61	9.36
1986	9.13	8.54
1987	9.29	8.36
1988	10.03	9.67
1989	9.65	8.71
1990	9.21	8.98
1992	8.83	8.44
1993	10.38	10.00
1994	8.88	8.48
1995	9.36	9.08
1996	9.02	8.52
1997	9.30	8.96

Table A.29: Maximum Head Difference Between MRIP and Kushiyara River for Flow from R/S to C/S (1983 to 1997)

Year	Head Diff. (m)	River WL (m PWD)	Project WL (m PWD)
1983	3.26	7.22	3.96
1984	0.91	8.27	7.35
1985	3.78	8.17	4.39
1986	2.41	6.59	4.18
1987	2.48	6.53	4.04
1988	1.80	8.57	6.77
1989	3.22	7.34	4.12
1990	3.25	7.43	4.12
1992	2.82	8.05	5.23
1993	2.47	6.71	4.24
1994	2.41	7.87	5.46
1995	2.34	7.49	5.15
1996	3.17	8.15	4.98
1997	1.83	7.53	5.70

Table A.30: Maximum Head Difference between MRIP and Kushiyara River for Flow from C/S to R/S (1983 to 1997)

Year	Head Diff. (m)	Project WL (m PWD)	River WL (m PWD)
1983	1.34	6.83	5.49
1984	0.88	9.61	8.72
1986	0.77	7.46	6.68
1987	1.62	7.38	5.77
1988	1.25	7.75	6.50
1989	0.96	7.28	6.32
1990	0.96	7.37	6.41
1992	0.99	6.78	5.79
1993	0.56	10.27	9.71
1994	1.00	6.56	5.56
1995	1.17	6.99	5.82
1996	1.38	7.34	5.96
1997	0.95	8.18	7.23

Table A.31: Frequency of Occurences of Velocity Ranges at Critical Slots

Year 1

Velocity Range (m/sec)	Percent of Occrence (%)		
	R/S to C/S	C/S to R/S	Total
0.00-0.25	0.98	0.00-0.25	2.17
0.26-0.50	11.71	16.95	13.62
0.51-0.75	16.10	0.98	16.72
0.76-1.00	12.20	25.27	17.34
1.01-1.25	11.22	9.32	10.53
1.26-1.50	6.83	14.41	9.60
1.51-1.75	17.07	5.93	13.00
1.76-2.00	6.83	5.08	6.19
2.01-2.25	7.80		5.57
2.26-2.50	2.93		1.24
2.51-2.75	5.37		3.41
2.76-3.00	0.98		0.62

Year 2

Velocity Range (m/sec)	Percent of Occurrence (%)		
	R/S to C/S	C/S to R/S	Total
0.00-0.25	2.40	1.90	2.30
0.26-0.50	9.20	1.00	7.20
0.51-0.75	11.90	3.80	10.00
0.76-1.00	7.00	9.60	7.70
1.01-1.25	24.80	18.30	23.20
1.26-1.50	8.30	28.80	13.20
1.51-1.75	5.50	5.80	5.60
1.76-2.00	10.40	6.70	9.50
2.01-2.25	11.30	7.70	10.40
2.26-2.50	9.20	3.80	7.90
2.51-2.75		3.8	0.90
2.76-3.00		8.7	2.10

Year 3

Velocity Range (m/sec)	Percent of Occurrence (%)		
	R/S to C/S	C/S to R/S	Total
0.00-0.25	0.00	1.89	0.66
0.26-0.50	0.00	16.98	5.96
0.51-0.75	13.27	13.21	13.25
0.76-1.00	7.14	26.42	13.91
1.01-1.25	19.34	9.43	15.89
1.26-1.50	33.67	15.09	27.15
1.51-1.75	20.41	9.43	16.56
1.76-2.00	6.12	1.83	4.64
2.01-2.25		3.77	1.32
2.26-2.50		1.89	0.66

Table A.32: Discharge Measurement

Measurement No.	R/S WL (m PWD)	C/S WL (m PWD)	Head Diff. (m)	Discharge (m^3/sec)
Year 1				
1	9.05	8.11	0.94	0.76
2	8.49	8.26	0.22	0.30
3	8.28	8.56	-0.28	0.91
4	9.16	8.85	0.31	0.45
5	9.11	8.97	0.14	0.90
6	8.18	8.58	-0.40	1.22
7	8.38	8.61	-0.23	0.87
8	8.08	8.29	-0.21	0.75
9	7.52	7.97	-0.45	0.57
10	6.52	7.42	-0.90	0.96
Year 2				
1	8.24	5.12	3.12	1.12
2	7.63	5.53	2.10	0.82
3	8.14	5.95	2.19	1.03
4	8.61	6.83	1.78	1.32
5	7.80	6.64	1.16	0.73
6	7.48	6.68	0.80	0.58
7	7.38	6.94	0.44	0.44
8	9.02	8.10	0.92	1.15
9	9.01	8.15	0.86	1.01
10	8.97	8.23	0.74	0.91
11	8.79	8.21	0.58	0.85
12	8.72	8.27	0.45	0.74
14	8.70	8.44	0.26	0.61
15	8.87	8.48	0.39	0.63
16	8.54	8.45	0.09	0.29
17	8.42	8.45	-0.03	0.32
20	7.37	7.90	-0.53	1.34
21	7.32	7.90	-0.58	1.42
22	8.07	8.48	-0.41	1.31
23	7.96	8.43	-0.47	1.36
24	7.93	8.37	-0.44	1.43
25	7.74	8.24	-0.50	1.55
26	8.06	8.29	-0.23	0.74
27	7.85	8.20	-0.35	1.24
28	7.08	7.91	-0.83	1.99
29	6.62	7.70	-1.08	2.25
30	6.21	7.48	-1.27	2.67

Table A.33: Fish Sampling Gear used in Fishpass

Dates	Hydrological Period	Gear	Gear Position
May 24-Jun 6 95	Pre-monsoon	Bamboo trap	C/S
Jun 15-Jun 30 95	Early monsoon	Rigid basket	R/S & C/S
Jul 1-Jul 11 95	Mid monsoon	Rigid basket	C/S
Jul 13-Jul 26 95	Mid monsoon	Rigid basket	R/S
Jul 26-Aug 6 95	Mid monsoon	Rigid basket	C/S
Aug 8-Sep 24 95	Mid monsoon	Rigid basket	R/S
Sep 29-Oct 4 95	Late monsoon	Collapsible basket	R/S
Oct 14-Oct 26 95	Late monsoon	Collapsible basket	R/S
Oct 18-Oct 26 95	Late monsoon	Rigid basket	C/S
1996	Entire monsoon	Metal cages (with square traps)	R/S & C/S
1997	Entire monsoon	Metal cages (with slot traps)	R/S & C/S

Table A.34: Impact of Fishpass on Biodiversity of Kawadighi Haor

Species	Kushiyara River	Kawadighi Haor pre-FPP	Kawadighi Haor with FPP	Recorded in Fishpass		
				Year 1	Year - 2	Year 3
	1992 to 1997	*1992 to 1994*	*1995 to 1997*	*1995*	*1996*	*1997*
Species recorded in river and in haor (both before and after fishpass construction)						
Potka	1	1	1	1	1	1
Kaikka	1	1	1	1	1	1
Shole	1	1	1	1	1	1
Rui	1	1	1	1	1	1
Mrigel	1	1	1	1	1	1
Gonia	1	1	1	1	1	1
Lachu	1	1	1	1	1	1
Kalibaush	1	1	1	1	1	1
Jatiputi	1	1	1	1	1	1
Titputi	1	1	1	1	1	1
Geliputi	1	1	1	1	1	1
Mola	1	1	1	1	1	1
Dhela	1	1	1	1	1	1
Chela	1	1	1	1	1	1
Gutum	1	1	1	1	1	1
Rani	1	1	1	1	1	1
Boal	1	1	1	1	1	1
Foli	1	1	1	1	1	1
Shing	1	1	1	1	1	1
Chaka	1	1	1	1	1	1
Bacha	1	1	1	1	1	1
Batashi	1	1	1	1	1	1
Air	1	1	1	1	1	1
Gulsha	1	1	1	1	1	1
Tengra	1	1	1	1	1	1
Chapila	1	1	1	1	1	1
Baim	1	1	1	1	1	1
Tarabaim	1	1	1	1		1
Chirkabaim	1	1	1	1	1	1
Boicha	1	1	1	1	1	1
Kholisa	1	1	1	1	1	1
Baila	1	1	1	1	1	1
Bheda	1	1	1	1	1	1
Namachanda	1	1	1	1	1	1
Lalchanda	1	1	1	1	1	1
Icha (Macrobrachium)	1	1	1	1	1	1
Icha (Caridina)	1	1	1	1	1	1
Golda chingri	1	1	1	1	1	1
Chitol	1	1	1	1		
Bamosh (Anguilla)	1	1	1		1	1
Taki	1	1	1		1	1
Chalaputi	1	1	1		1	1
Fulchela	1	1	1		1	1

Table A.34: Impact of Fishpass on Biodiversity of Kawadighi Haor

Species	Kushiyara River	Kawadighi Haor pre-FPP	Kawadighi Haor with FPP	Recorded in Fishpass		
				Year 1	Year - 2	Year 3
	1992 to 1997	*1992 to 1994*	*1995 to 1997*	*1995*	*1996*	*1997*
Darkina	1	1	1		1	1
Madhupabda	1	1	1		1	1
Magur	1	1	1		1	1
Bagair	1	1	1		1	1
Garua	1	1	1		1	1
Guizza	1	1	1		1	1
Buzuritengra	1	1	1		1	1
Jainzza	1	1	1		1	1
Ilish	1	1	1		1	1
Ketchki	1	1	1		1	1
Koi	1	1	1		1	1
Napitkoi	1	1	1		1	1
Kanpona	1	1	1		1	1
Gozar	1	1	1		1	1
Silvercarp	1	1	1			1
Mola (A. microlepis)	1	1	1			1
Ghorachela	1	1	1			1
Darkina (R. daniconius)	1	1	1			1
Darkina (R. rasbora)	1	1	1			1
Kanipabda	1	1	1			1
Kazoli (A. punctata)	1	1	1			1
Batashitengra	1	1	1			1
Kabasi tengra	1	1	1			1
Nuna baila	1	1	1			1
Bata (mugilid)	1	1	1			1
Kuchia	1	1	1			1
Catla	1	1	1			
Carpio	1	1	1			
Grasscarp	1	1	1			
Chebli	1	1	1			
Ekthuita	1	1	1			
Subtotals =	74	74	74	39	54	67
Species recorded in river, and in haor only before fishpass construction						
Rita	1	1		1		
Angrot	1	1				
Nandina	1	1				
Subtotals =	3	3	0	1	0	0

Table A.34: Impact of Fishpass on Biodiversity of Kawadighi Haor

Species	Kushiyara River	Kawadighi Haor pre-FPP	Kawadighi Haor with FPP	Recorded in Fishpass Year 1	Year - 2	Year 3
	1992 to 1997	*1992 to 1994*	*1995 to 1997*	*1995*	*1996*	*1997*
Species recorded in river, and in haor only after fishpass construction						
Bamosh (Ophisteron)	1		1	1	1	1
Bata (Labeo)	1		1	1	1	1
Kazoli	1		1	1	1	1
Naptani	1		1	1	1	1
Poa	1		1	1	1	1
Kanchonputi	1		1		1	1
Matibangra	1		1		1	1
Kotibacha	1		1		1	1
Boga	1		1			1
Phutaniputi	1		1			1
Molaputi	1		1			1
Cosuaputi	1		1			1
Teriputi	1		1			1
Muribacha	1		1			1
Gang tengra	1		1			1
Kholisa (C. labiosus)	1		1			1
Lal kholisa	1		1			1
Chanda baculis	1		1			1
Khorsula	1		1			1
Subtotals =	19	0	19	5	8	19
Species recorded only in river (never in haor)						
Longu	1					
Kalabata	1					
Kash khaira	1					
Piali	1					
Kothota	1					
Gutum (Neoeucirrhichthys)	1					
Putul	1					
Ghagla	1					
Lia	1					
Koiputi	1					
Gonichapila	1					
Koitor	1					
Dari	1					
Kawa	1					
Chouka	1					
Kharu	1					
Kutakanti (H. hara)	1					
Ghorpoia	1					
Barali	1					
Kutakanti (Eristhistes)	1					
Subtotals =	20	0	0	0	0	0

Table A.34: Impact of Fishpass on Biodiversity of Kawadighi Haor

Species	Kushiyara River	Kawadighi Haor pre-FPP	Kawadighi Haor with FPP	Recorded in Fishpass		
				Year 1	Year - 2	Year 3
	1992 to 1997	*1992 to 1994*	*1995 to 1997*	*1995*	*1996*	*1997*
Species recorded only in haor (never in river)						
Pahari gutum		1	1		1	1
Cheng		1	1			1
Sarputi		1				
Subtotals =	0	3	2	0	1	2
GRAND TOTALS	116	80	95	45	63	88

Table A.35: Nominal Cruising and Burst Swimming Speeds of Fish Species

Species	Type	First Maturity *			Maximum Size **		
		TL (cm)	Vc (m/sec)	Vm (m/sec)	TL (cm)	Vc (m/sec)	Vm (m/sec)
CARP							
Rui	P	50	1.8	3.5	91	3.2	6.4
Catla	P	43	1.5	3.0	90	3.2	6.3
Mrigel	P	38	1.3	2.7	80	2.8	5.6
Kalibaush	P	28	1.0	2.0	63	2.2	4.4
Gonia	P	23	0.8	1.6	40	1.4	2.8
Lachu	P	17	0.6	1.2	25	0.9	1.8
Sarputi	P	14	0.5	1.0	25	0.9	1.8
Carpio	P	24	0.8	1.7	50	1.8	3.5
Silver Carp	P	38	1.3	2.7	80	2.8	5.6
Grass Carp	P	53	1.9	3.7	85	3.0	6.0
LARGE CATFISH							
Boal	B	50	0.4	0.8	180	1.4	2.7
Air	B	50	0.4	0.8	90	0.7	1.4
Ghagot	B	43	0.3	0.6	80	0.6	1.2
Bagair	B	80	0.6	1.2	180	1.4	2.7
Rita	B	33	0.2	0.5	55	0.4	0.8
OTHER LARGE SPECIES							
Chitol	P	43	1.5	3.0	100	3.5	7.0
Ilish	P	28	1.0	2.0	45	1.6	3.2
Baim	B	38	0.3	0.6	80	0.6	1.2
Golda chingri	B	15	0.1	0.2	27	0.2	0.4
SMALL CYPRINIDS							
Puti	P	6.0	0.2	0.4	15	0.5	1.1
Mola	P	4.5	0.2	0.3	9.9	0.3	0.7
Chela	P	5.5	0.2	0.4	15	0.5	1.1

Table A.35: Nominal Cruising and Burst Swimming Speeds of Fish Species

Species	Type	First Maturity *			Maximum Size **		
		TL (cm)	Vc (m/sec)	Vm (m/sec)	TL (cm)	Vc (m/sec)	Vm (m/sec)
SMALL CATFISH							
Kani pabda	P	11	0.4	0.8	18	0.6	1.3
Pabda	P	14	0.5	1.0	25	0.9	1.8
Bacha	P	17	0.6	1.2	30	1.1	2.1
Garua	P	16	0.6	1.1	25	0.9	1.8
Bashpata	P	7.5	0.3	0.5	10	0.4	0.7
Batashi	P	5.5	0.2	0.4	11.3	0.4	0.8
Tengra	B	9.0	0.1	0.1	15	0.1	0.2
Gulsha	B	11	0.1	0.2	24.2	0.2	0.4
OTHER SMALL SPECIES							
Rani	B	7.5	0.1	0.1	12	0.1	0.2
Chirka baim	B	14	0.1	0.2	25	0.2	0.4
Tarabaim	B	14	0.1	0.2	28	0.2	0.4
Foli	P	21	0.7	1.5	27	0.9	1.9
Kaikka	P	18	0.6	1.3	25	0.9	1.8
Chapila	P	11	0.4	0.8	19.2	0.7	1.3
Chanda	P	4.0	0.1	0.3	10	0.4	0.7
Icha	B	4.0	0.03	0.1	13.9	0.1	0.2

Notes:

P = Pelagic species

B = Benthic species

TL = Total length (cm)

* Average size at first maturity

** Average size of largest individuals in stock

Vc = Cruising swimming speed (m/s), estimated as 3.5 times body length per sec for pelagic species, and 0.75 times body length per sec for benthic species.

Vm = Burst swimming speed (m/s), estimated as 2 times cruising speed.

Table A.36: Cultivated Area of Rice Crops in MRIP (1994 to 1997)

Rice Crops	1994*	1995		1996		1997	
	Cultivated Area (ha)	Cultivated Area (ha)	Percent Changed over 1994 (%)	Cultivated Area (ha)	Percent Changed over 1994 (%)	Cultivated Area (ha)	Percent Changed over 1994 (%)
<u>Boro (Rabi)</u>							
HYV Boro	5,117	4,619	(-) 10	6,300	(+) 23	4,509	(-) 12
L.Boro	923	274	(-) 70	4,019	(+) 335	3,859	(+) 318
Total Boro	**6,040**	**4,893***	**(-) 19**	**10,319**	**(+) 71**	**8,368**	**(+) 39**
<u>Aus (Kh-I)</u>							
HYV t.Aus	1,882	1,470	(-) 22	5,080	(+) 170	2,853	(+) 52
L.t.Aus	204	300	(+) 47	2,000	(+) 880	638	(+) 213
B.Aus	319	118	(-) 63	1,127	(+) 253	310	(-) 3
Total Aus	**2,405**	**1,888***	**(-) 22**	**8,207**	**(+) 241**	**3,801**	**(+) 58**
<u>Aman (Kh-II)</u>							
HYV t.Aman	5,064	7,820	(+) 54	6,903	(+) 36	13,260	(+) 162
L.t.Aman	1,638	1,286	(-) 21	986	(-) 40	618	(-) 62
B.Aman	2,368	1,777	(-) 25	1,376	(-) 42	3,863	(+) 63
Total Aman	**9,070**	**10,883**	**(+) 20**	**9,265**	**(+) 2**	**17,741**	**(+) 96**
Total	**17,515**	**17,664**	**(+) 1**	**27,791**	**(+) 59**	**29,910**	**(+) 71**

Source: BWDB (Moulvibazar) and Agriculture Officer (Rajnagar Thana), 1997

Note: * For MRIP agriculture production, 1994 is considered the base-line year, preceding opening of the Fishpass

Table A.37: Production of Rice Crops in MRIP (1994 to 1997)

Rice Crops	1994*	1995		1996		1997	
	Production (tonnes)	Production (tonnes)	Percent Changed over 1994 (%)	Production (tonnes)	Percent Changed over 1994 (%)	Production (tonnes)	Percent Changed over 1994 (%)
Boro (Rabi)							
HYV Boro	19,445	18,892	(-) 3	24,696	(+) 27	18,307	(-) 6
L. Boro	1,975	603	(-) 69	9,204	(+) 366	9,107	(+) 361
Total Boro	**21,420**	**19,495***	**(-) 9**	**33,900**	**(+) 58**	**27,414**	**(+) 28**
Aus (Kh-I)							
HYV t. Aus	7,340	5,704	(-) 22	20,066	(+) 173	11,355	(+) 55
L. t. Aus	412	612	(+) 49	4,200	(+) 919	1,327	(+) 222
B. Aus	472	177	(-) 63	1,769	(+) 275	484	(+) 3
Total Aus	**8,224**	**6,493**	**(-) 21**	**26,035**	**(+) 217**	**13,166**	**(+) 60**
Aman (Kh-II)							
HYV t. Aman	20,053	31,358	(+) 56	24,851	(+) 24	**	
L. t. Aman	3,767	2,894	(-) 23	2,504	(-) 34	**	
B. Aman	4,973	3,874	(-) 22	3,096	(-) 38	**	
Total Aman	**28,793**	**38,126**	**(+) 32**	**30,451**	**(+) 6**		
Total	**58,437**	**64,114**	**(+) 10**	**90,386**	**(+) 55**		

Source: BWDB (Moulvibazar) and Agriculture Officer (Rajnagar Thana), 1997

Note: * For MRIP agriculture production, 1994 is considered the base-line year, preceding opening of the Fishpass.
** Indicates harvesting of Aman crops not yet completed.

Table A.38: Average Yield per Hectare of Rice Crops in MRIP (1994 to 1997)

Paddy	1994*	1995		1996		1997	
	Average Yield (tonne/ha)	Average Yield (tonne/ha)	Percent Changed over 1994 (%)	Average Yield (tonne/ha)	Percent Changed over 1994 (%)	Average Yield (tonne/ha)	Percent Changed over 1994 (%)
Boro (Rabi)							
HYV Boro	3.80	4.09*	(+) 8	3.92	(+) 3	4.06	(+) 7
L. Boro	2.14	2.20*	(+) 3	2.29	(+) 7	2.36	(+) 10
Aus (Kh-I)							
HYV t. Aus	3.90	3.88	(-) 1	3.95	(+) 1	3.98	(+) 2
L. t. Aus	2.02	2.04	(+) 1	2.10	(+) 4	2.08	(+) 3
B. Aus	1.48	1.50	(+) 1	1.57	(+) 6	1.56	(+) 5
Aman (Kh-II)							
HYV t. Aman	3.96	4.01	(+) 1	3.60	(-) 9	**	
L. t. Aman	2.30	2.25	(-) 2	2.54	(+) 10	**	
B.Aman	2.10	2.18	(+) 4	2.25	(+) 7	**	

Source: BWDB (Moulvibazar) and Agriculture Officer (Rajnagar Thana), 1997

Note: * For MRIP agriculture production, 1994 is considered the base-line year, preceding opening of the Fishpass
** Indicates harvesting of Aman crops not yet completed.

Table A.39: Knowledge About Fishpass

Source	Full-time Fishermen		Seasonal Fishermen	
	Number	Percentage (%)	Number	Percentage (%)
Local discussion	20	41	15	16
Fishermen discussion	16	33	58	62
Seen	7	14	3	3
NERP staff	5	10	17	18
Leasee	1	2		
Total responses	**49**	**100**	**93**	**100**

Source: Fishermen Survey, NERP, 1996

Table A.40: Income from Fishing

Season	Average Daily Cash Income/Wage (Tk)		
	1995	1996	1997
Dry Season	61	82	98
Monsoon Season	96	130	127

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.41: Monsoon Catch and Consumption
Year-Wise Comparison - 1995, 1996 & 1997

Economic Strata	Average Daily Catch per Fisher (kg)			Average Daily per Capita Consumption (g)		
	1995	1996	1997	1995	1996	1997
Landless	3.4	3.5	3.5	74	76	75
Small	3.6	3.7	3.3	64	71	68
Middle	4.9	4.4	5.5	90	92	110
Large	3.8	4.2	4.5	71	75	74

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.42: Fish Consumption from Catch & Purchase Year-Wise Comparison

Economic Strata	Per Capita Daily Consumption (g)			
	1995-96 Dry Season	1996-97 Dry Season	1996 Monsoon Season	1997 Monsoon Season
Landless	59	49	99	82
Small	35	36	81	92
Medium	42	62	89	109
Large	142	0	106	131
Weighted average	**52**	**44**	**91**	**89**

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.43: Percentage of Fish Consumption from Catch & Purchase by Species Year wise Comparison

Species	Percentage per All Economic Strata of Households (%)			
	1995-96 Dry Season	1996-97 Dry Season	1996 Monsoon Season	1997 Monsoon Season
Puti	18.8	15.5	23.3	21.1
Taki	12.6	10.7	13.8	11.9
Mola	11.2	6.9	10.5	7.2
Icha	11.1	6.1	9.3	8.4
Ilish	0.4	5.7	8.4	6.4
Chanda	6.7	5.8	6.5	2.8
Chapila	0.0	0.2	6.5	1.1
Shol	4.3	4.5	4.4	3.4
Bheda	0.0	2.5	4.1	5.7
Shing	13.2	4.8	2.9	3.5
Chela	1.8	1.6	2.7	0.11
Koi	0.0	2.9	2.2	1.5
Tengra	0.0	4.3	1.6	3.1
Foli	0.0	3.7	1.6	1.0
Gojar	0.0	3.8	0.8	2.3
Rui	12.6	1.2	0.3	2.3
Magur	0.5	1.8	0.3	0.6
Boal	0.0	2.1	0.3	0.7
Nola	0.0	4.8	0.2	1.2
Karfu	1.0	3.0	0.1	0.3
Baim	2.6	4.7	0.1	12.4
Kholisha	0.0	0.5	0.1	0.6
Gojya	0.7	0.0	0.0	0
Baush	0.7	1.4	0.0	0.2
Kaikka	0.7	0.8	0.0	1.9
Baila	0.7	0.7	0.0	0.7
Total	**100**	**100**	**100**	**100**

Source: Fishermen Survey, NERP, 1996 & 1997

Table A.44: Capital Cost of FPP

Sl. No.	Item	Fishpass structure million Taka		Engineering and Administration million Taka		Development Cost million Taka		Total million Taka	
		Financial	*Economic*	*Financial*	*Economic*	*Financial*	*Economic*	*Financial*	*Economic*
1	Skilled labor	1.31	1.14	0.00	0.00	0.00	0.00	1.31	1.14
2	Unskilled labor	1.31	0.93	0.00	0.00	0.00	0.00	1.31	0.93
3	Materials			0.00	0.00	0.00	0.00	0.00	0.00
	a. Cost for local materials	0.77	0.67	0.00	0.00	0.00	0.00	0.77	0.67
	b. Taxes and duties	1.92	0.00	0.00	0.00	0.00	0.00	1.92	0.00
	c. F.E.C	1.92	2.11	0.00	0.00	0.00	0.00	1.92	2.11
4	Transportation	0.46	0.40	0.00	0.00	0.00	0.00	0.46	0.40
5	Local cost	0.00	0.00	1.15	1.00	0.40	0.35	1.55	1.35
6	Total	7.69	5.25	1.15	1.00	0.40	0.35	9.24	6.60

Note:

1. Development cost includes replacement cost of sampling cages in Year 2 and construction of walkway, guard shed, electrification, etc.
2. FEC: Foreign Exchange Component

Table A.45: Operation and Maintenance Cost

Sl. No.	Item	O&M Cost of Fishpass million Taka		Engineering and Administration million Taka		Total million Taka	
		Financial	*Economic*	*Financial*	*Economic*	*Financial*	*Economic*
1	Skilled labor	0.03	0.03	0.00	0.00	0.03	0.03
2	Unskilled labor	0.08	0.06	0.00	0.00	0.08	0.06
3	Materials						
	a. Cost for local materials	0.02	0.02	0.00	0.00	0.02	0.02
	b. Taxes and duties	0.00	0.00	0.00	0.00	0.00	0.00
	c. F.E.C	0.02	0.02	0.00	0.00	0.02	0.02
4	Transportation	0.00	0.00	0.00	0.00	0.00	0.00
5	Pumping cost *	0.50	0.44	0.00	0.00	0.50	0.44
6	Total	0.65	0.56	0.00	0.00	0.65	0.56

* For bailing out of excess flows through fishpass for the period March to september

Table A.46: Total Gear Replacement Cost

Item	Number		Unit price	Total (M. Tk)		Incremental Cost
	Pre-proj.	*With-proj.*	*(Tk)*	*Pre-proj.*	*With-proj.*	*(M.Tk)*
A. FINANCIAL						
a. Life time (5 Year)						
1. Konajal/Tanaber/Hatujal	80	160	8000.0	0.64	1.28	0.64
2. Castnet	75	85	1200.0	0.09	0.10	0.01
3 . Vashaljal	40	73	3000.0	0.12	0.22	0.10
4 . Boat	440	496	8000.0	3.52	3.97	0.45
Total				4.37	5.57	1.20
b. Life time (4 Year)						
1. Gillnet	450	470	400.0	0.18	0.19	0.01
2 . Utherjal	28	28	4000.0	0.11	0.11	0.00
Total				0.29	0.30	0.01
c . Life time (3 Year)						0.00
1. Pushnet	900	900	150.0	0.14	0.14	0.00
Total	900	900	150.0	0.14	0.14	0.00
d. Life time (2 Year)						
1. Garijal	20	23	30000.0	0.60	0.69	0.09
Total	20	23	30000.0	0.60	0.69	0.09
B. ECONOMIC						
a. Life time (5 Year)						
1. Konajal/Tanaber/Hatujal	80	160	6960.0	0.56	1.11	0.56
2. Castnet	75	85	1044.0	0.08	0.09	0.01
3 . Vashaljal	40	73	2610.0	0.10	0.19	0.09
4 . Boat	440	496	6960.0	3.06	3.45	0.39
Total				3.80	4.85	1.04
b. Life time (4 Year)						
1. Gillnet	450	470	348.0	0.16	0.16	0.01
2 . Utherjal	28	28	3480.0	0.10	0.10	0.00
Total				0.25	0.26	0.01
c . Life time (3 Year)						
1. Pushnet	900	900	130.5	0.12	0.12	0.00
Total	900	900	130.5	0.12	0.12	0.00
d. Life time (2 Year)						
1. Garijal	20	23	26100.0	0.52	0.60	0.08
TOTAL	20	23	26100.0	0.52	0.60	0.08

Table A.47: Annual Economic Benefits from Fish

Fish Species	Production	Economic Prices	Gross Value	Total Harvest Cost	Gross Margin
	(tonne)	*(Tk/tonne)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*
A. Pre-Project (1992)					
1. Carp	8.75	59160	0.52	0.14	0.37
2. Catfish & other large species	46.99	47850	2.25	0.77	1.48
3. Golda Chingri	0.00	130500	0.00	0.00	0.00
4. Small fish	281.06	26100	7.34	5.01	2.33
Total	336.80		10.10	5.92	4.18
B. Pre-Project (1994)					
1. Carp	26.09	59160	1.54	0.43	1.11
2. Catfish & other large species	73.37	47850	3.51	1.20	2.32
3. Golda Chingri	0.00	130500	0.00	0.00	0.00
4. Small fish	501.83	26100	13.10	8.94	4.16
Total	601.29		18.15	10.57	7.59
C. Pre-Project (Average)					
1. Carp	17.42	59160	1.03	0.29	0.74
2. Catfish & other large species	60.18	47850	2.88	0.98	1.90
3. Golda Chingri	0.00	130500	0.00	0.00	0.00
4. Small fish	391.45	26100	10.22	6.97	3.24
Total	469.05		14.13	8.24	5.89
D. With-Project (1995)					
1. Carp	65.70	59160	3.89	1.21	2.68
2. Catfish & other large species	93.85	47850	4.49	1.73	2.76
3. Golda Chingri	2.50	130500	0.33	0.05	0.28
4. Small fish	526.14	26100	13.73	9.70	4.03
Total	688.19		22.44	12.69	9.75
Net Incremental Benefit					3.86
E. With-Project (1996)					
1. Carp	55.96	59160	3.31	1.03	2.28
2. Catfish & other large species	188.86	47850	9.04	3.48	5.56
3. Golda Chingri	4.02	130500	0.52	0.08	0.45
4. Small fish	518.24	26100	13.53	9.56	3.97
Total	767.08		26.40	14.15	12.25
Net Incremental Benefit	298.03				6.37

247

Table A.48: Annual Financial Benefits from Fish

Fish Species	Production	Market Prices	Gross Value	Total Harvest Cost	Gross Margin
	(tonne)	*(Tk/tonne)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*
A. Pre-Project (1992)					
1. Carp	8.75	68000	0.60	0.17	0.43
2. Catfish and other large	46.99	55000	2.58	0.88	1.70
3. Golda Chingri	0.00	150000	0.00	0.00	0.00
4. Small fish	281.06	30000	8.43	5.76	2.68
Total	336.80		11.61	6.80	4.81
B. Pre-Project (1994)					
1. Carp	26.09	68000	1.77	0.49	1.28
2. Catfish and other large	73.37	55000	4.04	1.37	2.66
3. Golda Chingri	0.00	150000	0.00	0.00	0.00
4. Small fish	501.83	30000	15.05	10.28	4.78
Total	601.29		20.86	12.15	8.72
C. Pre-Project (Average)					
1. Carp	17.42	68000	1.18	0.33	0.85
2. Catfish and other large	60.18	55000	3.31	1.13	2.18
3. Golda Chingri	0.00	150000	0.00	0.00	0.00
4. Small fish	391.45	30000	11.74	8.02	3.73
Total	469.05		16.24	9.47	6.76
D. With-Project (1995)					
1. Carp	65.70	68000	4.47	1.39	3.08
2. Catfish and other large	93.85	55000	5.16	1.99	3.17
3. Golda Chingri	2.50	150000	0.38	0.06	0.32
4. Small fish	526.14	30000	15.78	11.15	4.63
Total	688.19		25.79	14.59	11.20
Net Incremental Benefit					4.44
E. With-Project (1996)					
1. Carp	55.96	68000	3.81	1.18	2.62
2. Catfish and other large	188.86	55000	10.39	4.00	6.39
3. Golda Chingri	4.02	150000	0.60	0.09	0.51
4. Small fish	518.24	30000	15.55	10.98	4.56
Total	767.08		30.34	16.26	14.08
Net Incremental Benefit	298.03				7.32

Table A.49: Annual Cost-Benefit Stream (no conditions)

Year	Capital Cost	O&M Cost	Incremental Replacement Cost of Gear	Total Cost	Incremental Benefit	Cash-flow
	(M. Tk)	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*
1	6.25	0.00	0.00	6.25	0.00	-6.25
2	0.35	0.00	0.00	0.35	0.00	-0.35
3		0.56	1.13	1.69	3.86	2.17
4		0.56	0.00	0.56	6.37	5.81
5		0.56	0.08	0.64	6.37	5.73
6		0.56	0.00	0.56	6.37	5.81
7		0.56	0.09	0.65	6.37	5.72
8		0.56	1.04	1.60	6.37	4.77
9		0.56	0.08	0.64	6.37	5.73
10		0.56	0.00	0.56	6.37	5.81
11		0.56	0.09	0.65	6.37	5.72
12		0.56	0.00	0.56	6.37	5.81
13		0.56	1.12	1.68	6.37	4.69
14		0.56	0.00	0.56	6.37	5.81
15		0.56	0.09	0.65	6.37	5.72
16		0.56	0.00	0.56	6.37	5.81
17		0.56	0.08	0.64	6.37	5.73
18		0.56	1.04	1.60	6.37	4.77
19		0.56	0.09	0.65	6.37	5.72
20		0.56	0.00	0.56	6.37	5.81
21		0.56	0.08	0.64	6.37	5.73
22		0.56	0.00	0.56	6.37	5.81
23		0.56	1.13	1.69	6.37	4.68
24		0.56	0.00	0.56	6.37	5.81
25		0.56	0.08	0.64	6.37	5.73
26		0.56	0.00	0.56	6.37	5.81
27		0.56	0.09	0.65	6.37	5.72
28		0.56	1.04	1.60	6.37	4.77
29		0.56	0.08	0.64	6.37	5.73
30		0.56	0.00	0.56	6.37	5.81

IRR	48%
NPV @ 12% (M. Tk.)	27.39
BCR	3.41

Note: Includes loss of potential incremental fish production due to closure of fish pass for farmer protest in Years 1 and 2

Table A.50: Annual Cost-Benefit Stream (under condition of 30% loss)

Year	Capital Cost	O&M Cost	Incremental Replacement Cost of Gear	Total Cost	Incremental Benefit less Production lost	Cash-flow
	(M. Tk)	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*
1	6.25	0.00	0.00	6.25	0.00	-6.25
2	0.35	0.00	0.00	0.35	0.00	-0.35
3		0.56	1.13	1.69	3.86	2.17
4		0.56	0.00	0.56	6.37	5.81
5		0.56	0.08	0.64	4.46	3.82
6		0.56	0.00	0.56	4.46	3.90
7		0.56	0.09	0.65	4.46	3.81
8		0.56	1.04	1.60	4.46	2.86
9		0.56	0.08	0.64	4.46	3.82
10		0.56	0.00	0.56	4.46	3.90
11		0.56	0.09	0.65	4.46	3.81
12		0.56	0.00	0.56	4.46	3.90
13		0.56	1.12	1.68	4.46	2.78
14		0.56	0.00	0.56	4.46	3.90
15		0.56	0.09	0.65	4.46	3.81
16		0.56	0.00	0.56	4.46	3.90
17		0.56	0.08	0.64	4.46	3.82
18		0.56	1.04	1.60	4.46	2.86
19		0.56	0.09	0.65	4.46	3.81
20		0.56	0.00	0.56	4.46	3.90
21		0.56	0.08	0.64	4.46	3.82
22		0.56	0.00	0.56	4.46	3.90
23		0.56	1.13	1.69	4.46	2.77
24		0.56	0.00	0.56	4.46	3.90
25		0.56	0.08	0.64	4.46	3.82
26		0.56	0.00	0.56	4.46	3.90
27		0.56	0.09	0.65	4.46	3.81
28		0.56	1.04	1.60	4.46	2.86
29		0.56	0.08	0.64	4.46	3.82
30		0.56	0.00	0.56	4.46	3.90

IRR	41%
NPV @ 12% (M. Tk.)	17.81
BCR	2.57

Note: Under condition of fishpass closure due to farmer protests resulting in loss of 30% potential incremental fish production above observed level in 1995 and 1996

Table A.51: Annual Cost-Benefit Stream (under condition of 40% loss)

Year	Capital Cost	O&M Cost	Incremental Replacement Cost of gear	Total Cost	Incremental Benefit less Production lost	Cash-flow
	(M. Tk)	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*	*(M. Tk)*
1	6.25	0.00	0.00	6.25	0.00	-6.25
2	0.35	0.00	0.00	0.35	0.00	-0.35
3		0.56	1.13	1.69	3.86	2.17
4		0.56	0.00	0.56	6.37	5.81
5		0.56	0.08	0.64	3.82	3.18
6		0.56	0.00	0.56	3.82	3.26
7		0.56	0.09	0.65	3.82	3.17
8		0.56	1.04	1.60	3.82	2.22
9		0.56	0.08	0.64	3.82	3.18
10		0.56	0.00	0.56	3.82	3.26
11		0.56	0.09	0.65	3.82	3.17
12		0.56	0.00	0.56	3.82	3.26
13		0.56	1.12	1.68	3.82	2.14
14		0.56	0.00	0.56	3.82	3.26
15		0.56	0.09	0.65	3.82	3.17
16		0.56	0.00	0.56	3.82	3.26
17		0.56	0.08	0.64	3.82	3.18
18		0.56	1.04	1.60	3.82	2.22
19		0.56	0.09	0.65	3.82	3.17
20		0.56	0.00	0.56	3.82	3.26
21		0.56	0.08	0.64	3.82	3.18
22		0.56	0.00	0.56	3.82	3.26
23		0.56	1.13	1.69	3.82	2.13
24		0.56	0.00	0.56	3.82	3.26
25		0.56	0.08	0.64	3.82	3.18
26		0.56	0.00	0.56	3.82	3.26
27		0.56	0.09	0.65	3.82	3.17
28		0.56	1.04	1.60	3.82	2.22
29		0.56	0.08	0.64	3.82	3.18
30		0.56	0.00	0.56	3.82	3.26

IRR	38%
NPV @ 12% (M. Tk.)	14.61
BCR	2.29

Note: Under condition of 40% loss of potential incremental fish production against agricultural production loss

Table A.52: Annual Cost-Benefit Stream at Switching Value

Year	Capital Cost	O&M Cost	Incremental Replacement Cost of gear	Total Cost	Incremental Benefit	Cash-flow
	(M. Tk)	(M. Tk)	(M. Tk)	(M. Tk)	(M. Tk)	(M. Tk)
1	6.25	0.00	0.00	6.25	0.00	-6.25
2	0.35	0.00	0.00	0.35	0.00	-0.35
3	0.00	0.56	1.13	1.69	3.86	2.17
4	0.00	0.56	0.00	0.56	6.37	5.81
5	0.00	0.56	0.08	0.64	0.91	0.27
6	0.00	0.56	0.00	0.56	0.91	0.35
7	0.00	0.56	0.09	0.65	0.91	0.26
8	0.00	0.56	1.04	1.60	0.91	-0.69
9	0.00	0.56	0.08	0.64	0.91	0.27
10	0.00	0.56	0.00	0.56	0.91	0.35
11	0.00	0.56	0.09	0.65	0.91	0.26
12	0.00	0.56	0.00	0.56	0.91	0.35
13	0.00	0.56	1.12	1.68	0.91	-0.77
14	0.00	0.56	0.00	0.56	0.91	0.35
15	0.00	0.56	0.09	0.65	0.91	0.26
16	0.00	0.56	0.00	0.56	0.91	0.35
17	0.00	0.56	0.08	0.64	0.91	0.27
18	0.00	0.56	1.04	1.60	0.91	-0.69
19	0.00	0.56	0.09	0.65	0.91	0.26
20	0.00	0.56	0.00	0.56	0.91	0.35
21	0.00	0.56	0.08	0.64	0.91	0.27
22	0.00	0.56	0.00	0.56	0.91	0.35
23	0.00	0.56	1.13	1.69	0.91	-0.78
24	0.00	0.56	0.00	0.56	0.91	0.35
25	0.00	0.56	0.08	0.64	0.91	0.27
26	0.00	0.56	0.00	0.56	0.91	0.35
27	0.00	0.56	0.09	0.65	0.91	0.26
28	0.00	0.56	1.04	1.60	0.91	-0.69
29	0.00	0.56	0.08	0.64	0.91	0.27
30	0.00	0.56	0.00	0.56	0.91	0.35

IRR	--
NPV @ 12% (M. Tk.)	0.00
BCR	1.00

Table A.53: Analysis of Fish Production Benefit

Sl No	Item	Unit	All Fishermen			Monsoon Floodplain Subsistence Fishermen			Dry Season Professional *Beel* Fishermen		
			Pre-project	*With project*	*% change*	*Pre-project*	*With project*	*% change*	*Pre-project*	*With project*	*% change*
1	**Total project benefit** *	Tk	6,773,640	14,078,285		5,937,744	10,407,285		835,896	3,671,000	
2	Incremental project benefit	Tk		7,304,645			4,469,541			2,835,104	
3	**Total fisheries area** **	ha	16,833	16,833		16,833	16,833		833	833	
4	Benefit per hectare	Tk	402	836		353	618		1,003	4,407	
5	Incremental benefit per hectare	Tk		434			266			3,403	
6	**Total fishermen**	nos	4,868	4,868		3,252	3,252		1,616	1,616	
7	Benefit per fisherman	Tk	1,391	2,892	107.8%	1,826	3,200	75.3%	517	2,272	339.2%
8	Incremental benefit per fisherman	Tk		1,501			1,374			1,754	
9	**Total fisherman days**	days	784,431	879,693	12.1%	155,306	185,858	19.7%	629,125	693,835	10.3%
10	Incremental fishermen days	days		95,262			30,552			64,710	
11	**Total fish production**	tonne	470	767		412	567		58	200	
12	Incremental fish production	tonne		297			155			142	
13	Catch per fisherman	tonne	0.10	0.16	63.2%	0.13	0.17	37.6%	0.04	0.12	244.8%
14	Incremental catch per fisherman	tonne		0.06			0.05			0.09	

Note: * Based on average gross margin fish prices of 14,412 Tk/tonne (pre-project) and 18,355 Tk/tonne (with project) calculated from Table A.48.

** Dry season beel area (833 ha) is contained within the monsoon season flooded haor area (16,833 ha).

2Y9

Table A.54: Global Cost Recovery

Sl. No.	Item	Unit	Capital cost	O&M cost	Total cost
1	Total Project cost	(M. Tk)	9.24	0.65	9.89
2	Capital recovery factor @ 12% interest rate		12.52%	100%	
3	Per year recovery target	(M. Tk)	1.16	0.65	1.81
4	Total benefited area	(ha)	16,833	16,833	16,833
5	Recovery incidence per hectare	(Tk)	69	39	107
6	Net cash benefit per hectare	(Tk)	435	435	435
7	Total fish production	(M. Tk)	767	767	767
8	Recovery target	(Tk/M. tonne)	1,509	847	2,356
9	Incremental fish production	(M. tonne)	298	298	298
10	Recovery target per unit of incremental fish production	(Tk/M. tonne)	3,883	2,181	6,064

Table A.55: Growth of *Air* and *Kalibaush* During Fish Fattening Cage Culture Trials

AIR

	21-Jul-97		5-Aug-97		20-Aug-97		4-Sep-97	
	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)	Length (cm)	Weight (g)
	8.6	5.4	9.4	9.8	33.5	210	35.2	237
	13.4	27	13.5	20	24.7	80	19.4	64
	11.7	18.9	20.3	65	20	48	27	115
	18.9	40.2	12	24	21.5	58	28.5	127
	9.5	7.8	24.1	82	22.3	68	21	60
	14.8	35.9						
	17.8	49.5						
	10.5	19.8						
	11.7	19						
	12.5	23						
	19.8	63						
	21.5	23.4						
	13.3	18.5						
	14	33						
	13.7	35						
	17.8	50						
Means	14.3	29.3	15.9	40.2	24.4	92.8	26.2	120.6

Parameter		Date				Change over period	
		21-Jul-97	5-Aug-97	20-Aug-97	4-Sep-97	Amount	%
Days elapsed		0	15	30	45		
Mean length	cm	14.3	15.9	24.4	26.2	11.87625	83%
Mean weight	g	29.3	40.2	92.8	120.6	91.3	312%

Kalibaush

Parameter		Date				Change over period	
		21-Jul-97	5-Aug-97	20-Aug-97	4-Sep-97	Amount	%
Days elapsed		0	15	30	45		
Fish #1	cm	8.9	13.2	18	19.8	10.9	122%
Fish #2	cm	11.4	15.1	18.2	21	9.6	84%
Fish #1	g	15.8	49.8	80	112	96.2	609%
Fish #2	g	28.4	63	88	121	92.6	326%

Table A.56: Growth of Grass Carp and *Carpio* During Fingerling Grow-out Cage Culture Trials

GRASS CARP

Cage 1, Compartment 1 — Total fish released: 120

	18-Jul-97		1-Aug-97		16-Aug-97		31-Aug-97		16-Sep-97	
	Length (cm)	Weight (g)	Length (c	Weight (g)	Length (c	Weight (g)	Length (c	Weight (g)	Length (cm)	Weight (g)
	16.2	47	22	100	23	105	24.1	111	25.2	113.7
	17	51	18.2	61	19.1	63.5	18.9	67	19.3	84
	18	55	19.3	83	19	80	20.8	83	22.5	107
	18.3	57.2	18.2	67	21	103.7	21.5	107	20	83.8
	19	60	20.7	68	19.8	85	19.9	83	19.1	81
	18.8	59								
	19.2	62								
	19.5	64								
	20	87.8								
	20.2	90								
	20.7	96								
	23.4	140								
Means	19.19	72.42	19.68	75.8	20.38	87.44	21.04	90.2	21.22	93.9

Parameter		Date					Change over period	
		18-Jul-97	1-Aug-97	16-Aug-97	31-Aug-97	16-Sep-97	Amount	%
Days elapsed		0	14	29	44	60		
Mean length	cm	19.19	19.7	20.4	21.0	21.22	2.03	11%
Mean weight	g	72.4	75.8	87.4	90.2	93.9	21.48	30%

CARPIO

Cage 1, Compartment 4 — Total fish released: 358

	18-Jul-97		1-Aug-97		16-Aug-97		31-Aug-97		16-Sep-97	
	Length (cm)	Weight (g)	Length (c	Weight (g)	Length (c	Weight (g)	Length (c	Weight (g)	Length (cm)	Weight (g)
	12	20	14	25.3	15	28.5	15.3	30	16	31.5
	12.1	21	14.2	24	11.7	20	12.1	21	13	28.5
	12	18	11.7	20	13	27	13.2	28.7	16.7	33.2
	13.4	22.2	13.3	30	14.8	29	15	29.2	15	29
	13	22	12.8	25	13.7	25	14.9	30	14.8	29.7
	14	25	18	36						
	15	30	11.5	19.3						
	14.3	27								
	15.2	33								
	14.8	28.7								
Means	13.58	24.69	13.64	25.65	13.64	25.9	14.1	27.78	15.1	30.38

Parameter		Date					Change over period	
		18-Jul-97	1-Aug-97	16-Aug-97	31-Aug-97	16-Sep-97	Amount	%
Days elapsed		0	14	29	44	60		
Mean length	cm	13.58	13.6	13.6	14.1	15.1	1.52	11%
Mean weight	g	24.7	25.7	25.9	27.8	30.38	5.69	23%

Cage 2, Compartment 2 — Total fish released: 180

	9-Aug-97		23-Aug-97		6-Sep-97			
	Length (cm)	Weight (g)	Length (c	Weight (g)	Length (c	Weight (g)		
	8.5	8.4	8.6	8.8	12.75	32.79		
	8.3	9	8.4	9.8	9	9.7		
	10.7	18	11	19.7	17	55.9		
	12.8	28	16.2	55	11	20.3		
	15.1	52	10.5	18	16.5	57.1		
	15.9	48	17	55.8	10.3	21		
	10.9	18						
	8.6	9						
	16.1	46						
	9.2	10.2						
Means	11.6	24.66	11.95	27.85	12.76	32.8	15.1	30.38

Parameter		Date			Change over period	
		9-Aug-97	23-Aug-97	6-Sep-97	Amount	%
Days elapsed		0	14	28		
Mean length	cm	13.58	13.64	13.64	0.06	0.4%
Mean weight	g	24.7	25.7	25.9	1.21	4.9%