MULTIPURPOSE USE OF HAZIR KHAL BY MAKING PROVISION FOR COMMUNITY PROPOSED FLOW CONTROL GATE AT A CULVERT

A Thesis by

Sarah Binte Faruque

BUET

April, 2009

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয়
নং 107394
তাং 4.11.09
লাইব্রেরী, ঢাকা

INSTITUTE OF WATER AND FLOOD MANAGEMENT
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
INSTITUTE OF WATER AND FLOOD MANAGEMENT

The thesis titled 'Multipurpose Use of Hazir Khal by Making Provision for Community Proposed Flow Control Gate at a Culvert' submitted by Sarah Binte Faruque, Roll No. MF 10062817, Session: October 2006, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT on April 25, 2009.

BOARD OF EXAMINERS

.... Chairman

Dr. A. K. M. Jahir Uddin Chowdhury
(Supervisor)
Professor
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology
Dhaka

.... Member (Ex-officio)

Dr. Anisul Haque
Professor and Director
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology
Dhaka

.... Member

Dr. Mashfiqus Salehin
Associate Professor
Institute of Water and Flood Management
Bangladesh University of Engineering and Technology
Dhaka

.... Member (External)

Nayeema Nazneen Naz
Senior Assistant Engineer
SSWRDP
Local Government Engineering Department (LGED)
Dhaka

CANDIDATE'S DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree.

Signature of the Candidate

Sarah Binte Faruque
Roll No. MF 10062817
Session. October, 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

BARI	Bangladesh Agricultural Research Institute
B. Aus	Broadcast Aus
BBS	Bangladesh Bureau of Statistics
BARC	Bangladesh Rural Advancement Committee
BWDB	Bangladesh Water Development Board
CARE	Co-operation for American Relief Everywhere
CB	Crossing Boundaries
DAE	Department of Agricultural Extension
DWR	Deep Water Rice
DW	Deep Water
ET	Evapotranspiration
FCDI	Flood Control, Drainage and Irrigation
FGD	Focus Group discussion
HH	Household
HYV	High Yielding Variety
HWL	High water level
HWS	High Water slack
IWL	Internal water level
LWL	Low water level
LWS	Low water Slack
OWL	Outside water level
SWAIWRP	South-West Area Integrated Water Resources Plan Project
SWIWRMP	South West Integrated Water Resources Management Project
LGED	Local Government Engineering Department
LLP	Low Lift Pump
LV	Local Variety
NGO	Non-Government Organization
PWD	Public Works Department
T. Aman	Transplanted Aman
WMCA	Water Management Co-operative Association
WRS	Water retaining structure

ACKNOWLEDGEMENT

The author would like to express her sincere and heartiest gratitude to her supervisor Dr. Jahir Uddin Chowdhury, Professor, Institute of Water and Flood Management (IWFM), Bangladesh University of Engineering and Technology (BUET), for his active support, advice, guidance and supervision throughout the study. The author wishes to express her sincere gratitude to the members of the Defense Committee, Dr. Mashfiqus Salehin, Dr. Anisul Haque (Ex-officio), Professors of IWFM, and Nayeema Nazneen Naz, Senior Assistant Engineer of Local Government Engineering Department of Bangladesh.

The author also wishes to acknowledge all respected teachers of the IWFM. The author would also like to thank Dr. Hamidul Huq, Research Coordinator of Crossing Boundaries (CB) Project for his valuable inputs and suggestions, especially in the social and institutional aspects of the thesis. The author expresses her gratitude to the institute for awarding him South Asian Water Fellowship (SAWA) under the Crossing Boundaries (CB) Project and providing with financial assistance to carry out the study

Sincere thanks are due to Mr. Shahidul Hoque, Ex. Engineer, SSWRDSP-II and Mr Gopal Krishna, Ex. Engineer, Gopalganj of LGED for their suggestions and help with providing data. The author expresses her gratitude to all the staff of LGED, Gopalganj for their help during field survey

The author also acknowledges Mr. Obaidul Munshi and all the villagers of the study area for their constant and sincere help during the field work Sincere thanks are due to Mr. Muhammad Anowar Saadat, Junior Engineer at IWM and a SAWA fellow at IWFM, BUET, for his help with GIS analysis

The author wishes to thank Mr. Md. Ismail, Librarian, IWFM library for his help during the course of work

The author expresses deep gratitude to her beloved parents for their encouragement and support. The author thanks her husband Md. Mamunur Rashid for his support in the completion of the thesis work.

April, 2009

Sarah Binte Faruque

ABSTRACT

Hazir Khal is the main source of surface water in the Munshir Char village located in the South-Central region of Bangladesh. The region is a tidal floodplain, and the source of tidal water in the Hazir Khal is the Shingair River Every year the people of the village construct a temporary earthen cross-dam during mid of April at upstream of a culvert in the Hazir Khal. It is intended mainly to serve three purposes: (i) to prevent saline water intrusion in order to save the dry season crop from flooding by salt water during spring tides, (ii) to maintain low depth flooding during wet season in the agricultural land for cultivation of Deep Water Aman (a local variety of Monsoon rice) and (iii) for fish culture during the wet season. Moreover, the retained water also provides opportunity for domestic uses like livestock watering, bathing, washing utensils and cloth etc. The cross-dam is cut during mid October to drain out the water, which is required at the flowering stage of Aman. This local water management practice has been going on for many years. Now the local people are facing scarcity of construction material from local sources. The villagers have requested the Local Government Engineering Department (LGED), which is responsible for planning, design and implementation of small scale water management project, to construct a sluice gate at the culvert. The LGED responded positively to the request of the people, and decided to construct a gate in 2008. Construction of the gate will provide additional benefits because of the flexibility in the control of water

The local water management practice as mentioned above was the subject matter of present study. A social survey was conducted to collect information on local water management practice, history of Hazir khal, dam construction process, multiple uses of khal, expected additional benefits from the sluice gate and opinion on gate operation Measurement of tidal water level and salinity was carried out in Hazir Khal to assess the tidal characteristics and salinity concentration in the study area. Availability of tidal water during flood tide was assessed to estimate the volume of water that can be retained by closing the gate at each tide during the dry season. The agricultural area that can be served by the available tidal water during the dry season was estimated based on water for dry season crop A round the year gate operation rule was developed according to crop calendar, fish life cycle, tidal cycle, requirement for country boat plying, requirement for water retention, requirement for prevention of saline water intrusion, requirement for drainage, and opinion of the local people.

CHAPTER 1

INTRODUCTION

নং 107394
তাং 4.11.09

1.1 Background

A floodplain channel known as Hazir Khal is the main source of surface water in the Munshir Char village located in the South-West region of Bangladesh. The region is a tidal floodplain, and the water regime of the khal is influenced by tidal flow. The source of tidal water in the Hazir Khal is the Singair River. Because of tidal flow, it is subject to saline water intrusion during the dry season. Every year the local people construct an earthen cross dam on the Hazir Khal just before the monsoon in order to retain rainfall-runoff during the monsoon. The dam is cut just before dry season to drain out the water. The purpose of retaining monsoon water is to create flooding in the agricultural land in order to cultivate local variety deep water monsoon rice. Retention of water in the agricultural land also provides opportunity for culture fisheries In addition, people also use the retained water for domestic purposes (livestock watering, bathing, washing utensils and cloth etc.). Retention of water during the monsoon is a unique practice since the common water management practice in the country is to make provision for drainage of rainfall-runoff during the wet season and retention of water during the dry season. A social survey has been conducted under this study to collect information on this unique local water management practice

Above local water management practice has been going on for many years. Now the local people are facing scarcity of construction material from local source. The villagers have requested the Local Government Engineering Department (LGED), which is responsible for planning, design and implementation of small scale water management project, to construct a sluice gate at the culvert. According to the opinion of local people, they will get more benefit from Hazir Khal if a flow control gate is constructed at the culvert Local women also emphasize on other uses of the khal such as duck rearing, washing, bathing, and country boat plying The LGED has responded positively to the request of the people, and decided to construct a gate at the culvert on Hazir Khal.

The purpose of the proposed gate at a culvert on Hazir Khal is to create favorable condition for multi- purpose use of the khal such as agricultural water supply, fish culture, country boat plying and household use To serve these purposes, a provision is needed for retention of water in the khal and prevention of saline water intrusion in the khal. Opening and closing of the gate will depend on crop calendar, fish life cycle, water storage requirement, drainage requirement, salinity prevention requirement, etc. An operation rule for the proposed sluice gate has been developed in this study to create opportunity for multi purpose use of Hazir Khal The National Water Management Plan of Bangladesh (WARPO, 2001) gives importance to small – scale community managed schemes aimed at resolving local water management problems, through conservation or channel development made to support fisheries and Irrigation. This study intends to make contribution towards this goal.

1.2 Objective of the study

Specific objectives of this study are as follows

i. To assess water use opportunities created from the community initiated temporary cross dam at a culvert on Hazir Khal.
ii. To develop round the year operation rule for the community proposed gate in the culvert for multi – purpose use of Hazir Khal.

1.3 Organization of the thesis

The thesis has been organized in six chapters A brief description of the chapters is given below:

Chapter 1 includes introduction of the study and the objective of the research.

Chapter 2 contains the review of relevant literature on multi – purpose use of water retention structure in some countries.

Chapter 3 describes the description of the study area, including geography, hydrology and socio-economy of the area.

Chapter 4 discusses social survey methods to collect information on the seasonal dam construction, local water management practice and social demand for water control structure

Chapter 5 contains the methodology for measuring tidal level and salinity concentration, tidal characteristics and salinity intrusion characteristics, assessment of available water during each tide in the dry season and irrigable area with the available volume of water.

Chapter 6 discusses water control and supply requirements by the gate, people's opinion on gate operation and formation of required gate operation rule for multi-purpose use of the Hazir Khal.

Chapter 7 presents conclusions and recommendations.

CHAPTER II

COMMUNITY MANAGED MULTI-PURPOSE USE OF SURFACE WATER SUPPLY SYSTEM

A brief review of community managed multipurpose use of water resources was carried out to understand the benefits of multipurpose use of surface water system and ways in which common property water regimes may be suited to accommodate multiple uses of irrigation water. A summary of the review is presented below

Li et al. (2005) studied management of multiple water use at a large irrigation system in Tamil Nadu, India They assessed the technical constraints to integrating aquaculture within irrigation canals. The result of the study shows that the canals originally planned for irrigation purpose, have the potential to provide water for aquaculture, which is a non-consumptive water use that is largely complementary to irrigation requirements.

Li and Gowing (2008) described a good number of irrigation systems, particularly in developing countries, which were originally planned for irrigation supply but presently are serving as multiple-use systems and providing water for a wide range of services besides irrigation, including aquaculture, bathing, laundry, and livestock watering The quantities of water used for these purposes other than irrigation may be small, but these uses have high values in terms of household income, nutrition and health

Meinzen-Dick and Jackson (1996) studied the multiple use and multiple users of water resource. The purpose of the study was to provide an overview of the ways in which common property water regimes may be suited to accommodate multiple uses of irrigation water. Some water use sectors, in particular irrigated agriculture, provide water for many types of water needs besides their primary stated purpose. Although the success of irrigation systems is predominantly evaluated in terms of their ability to provide water for agricultural production, irrigation systems also provide water for other uses. These uses include consumptive uses (such as gardening, drinking water, livestock watering, fodder production and construction), and non-consumptive uses (such as washing and bathing, fishing, and religious and recreational uses). The importance of non-agricultural uses of irrigation water in livelihood strategies has implications for irrigation management. Finally, using irrigation systems as examples, Meinzen-Dick and Jackson examined the potential and challenges of common property management of water resource.

Mudulu (2003) studied the links of poverty with water use in rural Tanzania and found that in most donor-funded projects, pressing uses of water in household, community and village levels are hardly considered He emphasized on redirecting resources and investment in rural water supply towards multiple-use sources rather than just putting emphasis on drinking water Also local communities should be given the choice to select the type of water source they can manage to maintain A small additional cost during designing and managing water supply and irrigation schemes could greatly reduce poverty, increase gender equity, and improve health by making provisions for these multiple uses of water

Osti (2004) studied the local water resource management by community in semi-arid environments in Nepal. He highlighted innovations of community's management for multipurpose water projects, which provided powerful benefits to the rural people. Local people's participation in a project is an effective tool to include all non-irrigation water uses in the project.

Li and Gowing (2008) discussed the importance of non-irrigation uses of irrigation water to the livelihoods of the rural poor living close to irrigation systems, which has generally been ignored both in planning and operating these systems. In this study, two typical types of large-scale irrigation systems were selected as case study sites, the Lower Bhavani Project in Tamil Nadu, India—a canal-based irrigation system, and the Mahaweli System H, Sri Lanka—a tank-based irrigation system. The authors explored the potentials and constraints of the two systems in integrated management of irrigation and aquaculture Irrigation water could be saved from irrigation by more effective responses of water issues to crop water requirements and more efficient use of rainfall available in tank commands. The saved water can provide more opportunities for aquaculture and other non-irrigation uses.

Sekander (2000) described the multipurpose uses of ponds in Bangladesh, which include bathing and washing, drinking, fish farming, raising homestead land, Irrigation, Duck and cattle rearing. Mushtaq et al. (2007) studied the multi-purpose benefit from a pond and also evaluated the cost and benefit of small multi-purpose ponds in the Zhanghe irrigation system in China. Ponds are helpful in reducing floods, recharging groundwater, and providing drainage in high rainfall periods.

Above review of some examples of water management projects shows that the projects were constructed for a single purpose but are presently utilized for multiple purposes because of community demand Irrigation projects also can be used for non-irrigation activities, which in turn improve the livelihood of the rural people. Multiple use of water resources project is beneficial for the people living around the project. People are able to use the water for domestic purpose, fish culture and other income generating purposes, which bring improvement in their economic status. Ensuring multipurpose use of water in projects through community participation is essential for livelihood enhancement

CHAPTER III

THE STUDY AREA

3.1 Geography

3.1.1 Location

The study area comprises of two villages, namely Munshir char and Shingipara (partial), which are situated in Barni union of Tungipara upazilla in the Gopalganj district. These two villages are part of Balajtala-Kalmadanga subproject which is a Flood Management, Drainage and Water Conservation (FMD & WC) subproject of the ADB-funded LGED Second Small scale Water Resources Development Sector Project (SSWRDSP-2) (LGED, 2004a). Figure 3.1 shows the location of the study area. The area lies between latitudes 22°54'30" N and 22°56'26" N and the longitudes 89°51'38" E and 89°52'48" E. The area is about 125 km from the Bay of Bengal and within 3.0 m of the mean sea level. It is a tidal floodplain. Figure 3.2 shows the map of study area.

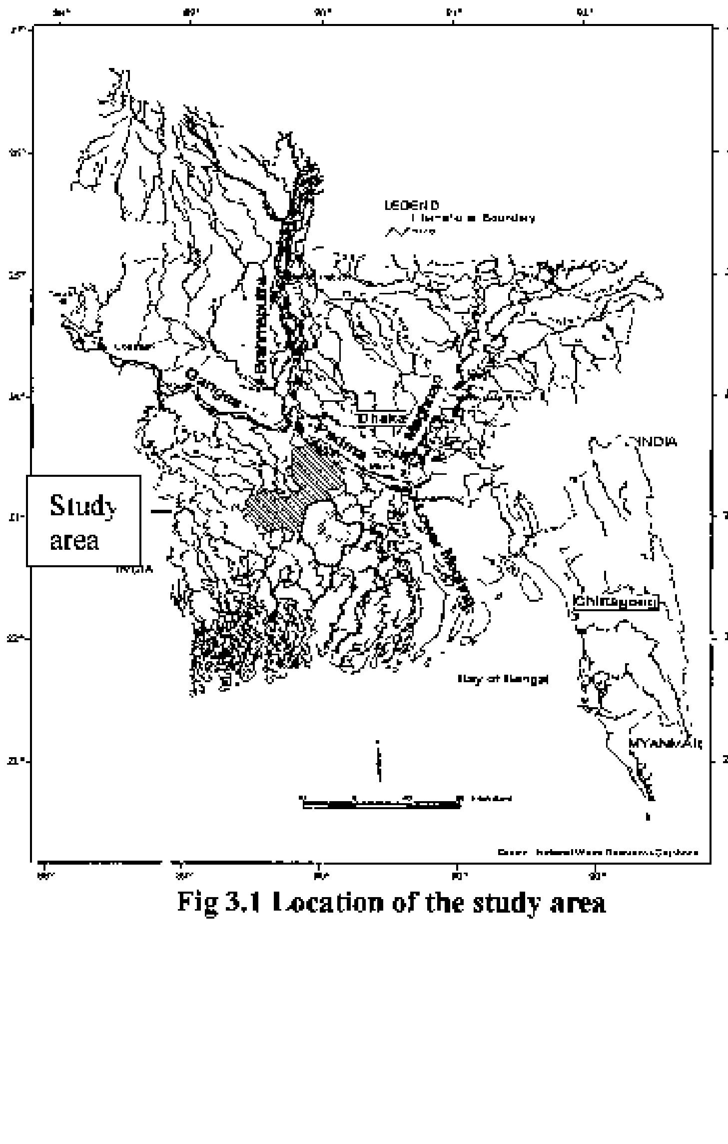


Fig 3.1 Location of the study area

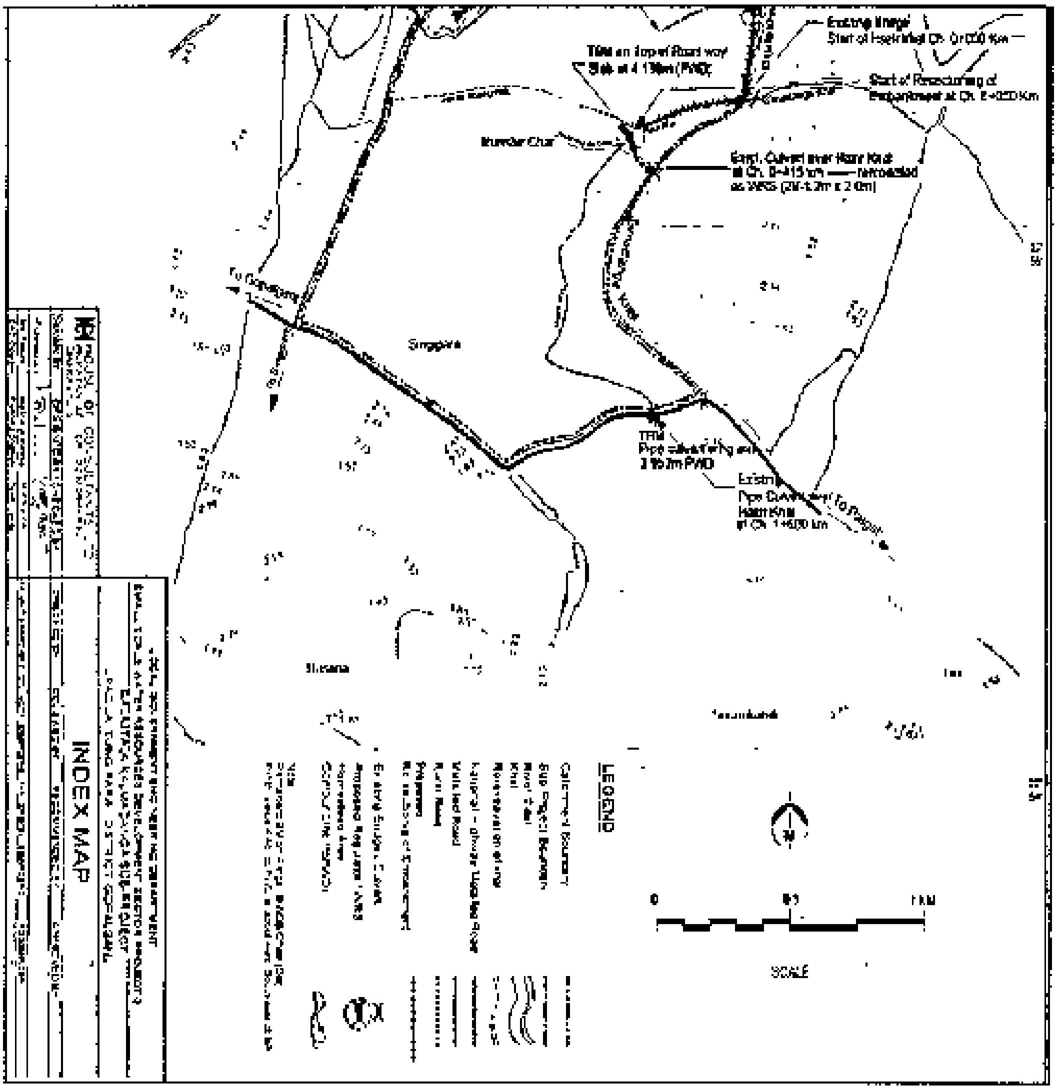


Fig 3.2: Map of the study area and flow system

3.1.2 Topography and soil characteristics

The land elevation varies from 0.91 m PWD to 2.96 m PWD within the study area. A contour map is provided in Figure 3.3.

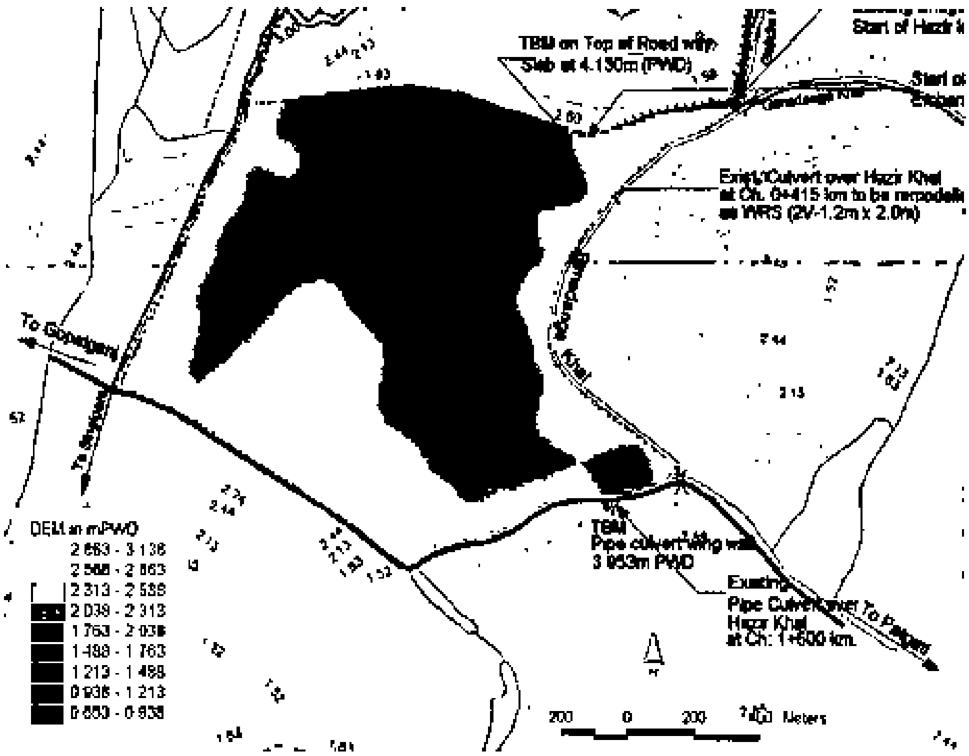


Fig 3.3: The contour map of study area

The average annual flood level in the study area is 2.7m PWD which is used in land type classification of the study area. The study area has four types of land, which are F0 (high), F1 (medium high), F2 (medium low) and F3 (low land) having 15%, 30%, 40% and 15% of land area respectively (LGED, 2004). Soil texture of the study area varies from silty clay loam to silty clay with high content of organic matter (LGED, 2004). Land and soil types of the area are given in Table 3.1.

Table 3.1 Land and soil types in the study area

Land types	Covered area (ha)	Soil type	Elevation, m PWD (avg.)
F0 (d<0.3 m) Highland	34.5	Sandy loam	2.40
F1 (0.3<d<0.9 m) Medium high land	69	Clay Loam	1.98
F2 (0.9<d<1.8 m) Medium low land	92		1.52
F3 (d>1.8 m) Lowland	34.5	Silty Clay	0.91
Gross area	230		

Source: LGED (2004)

3.2 Hydrology

3.2.1 Climate

The study area experiences sub-tropical monsoon climate typical of Bangladesh, with hot wet summers from May to September and cooler dry winter months. Table 3.2 shows the mean monthly and 80% dependable rainfall data. It is seen from the table that the rainfall is heavily concentrated during the period from May to September, which accounts for about 79% of the total annual rainfall.

Maximum temperatures vary from 24.6^{0}C to 34.2^{0}C. The highest temperatures are experienced during the pre-monsoon period (April-May). The daily minimum temperature can fluctuate significantly during the year, ranging from about 12^{0}C to 26^{0}C

Table 3.2 The mean monthly climatic data

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Maximum Temp (0C)	24.6	27.8	32.7	34.2	33.5	32.0	31.3	31.3	31.6	31 2	28.7	25 2	30.3
Mean Temp (0C)	18 4	21 1	25 9	28.6	29 0	28.8	28 6	28 7	28.7	27 6	23.8	19.5	25.7
Minimum Temp (0C)	12 1	14 2	19.1	23.0	24 3	25.6	25.8	26.0	25.8	23.8	18 9	13.6	21.0
Relative Humidity (%)	75	68	64	70	79	87	88	87	86	82	78	77	78
Wind speed (knots)	3	3	3	5	4	4	4	4	3	3	2	2	3.3
Sunshine (hrs/d)	8.0	8.4	7.8	7.9	7.6	5.4	4.1	5 4	5.2	7 6	8.0	8.1	7.0
ET0 (mm)	2.73	3.42	4 70	5 81	5.89	4.06	4.42	4.41	4.23	4.03	4.31	2.62	1542
Mean Rainfall (mm)	8	21	45	134	235	325	335	286	256	134	33	11	1825
80% Dependable Rainfall (mm)	3	12	25	93	191	265	278	230	196	91	12	1	1397

Source. ADB, BWDB and WARPO (2004).

3.2.2 Surface water system

A floodplain channel known as Hazir Khal is the main source of surface water in the area. The Khal is subject to tide. Hazir Khal flows across Munshir char village and falls into the Gimadanga Khal which finally falls into the river Shingair. The river Shingair flows along the north-west part of the Balajtala-Kalmadanga subproject of LGED. Figure 3.4 shows the major rivers and khals of the study area.

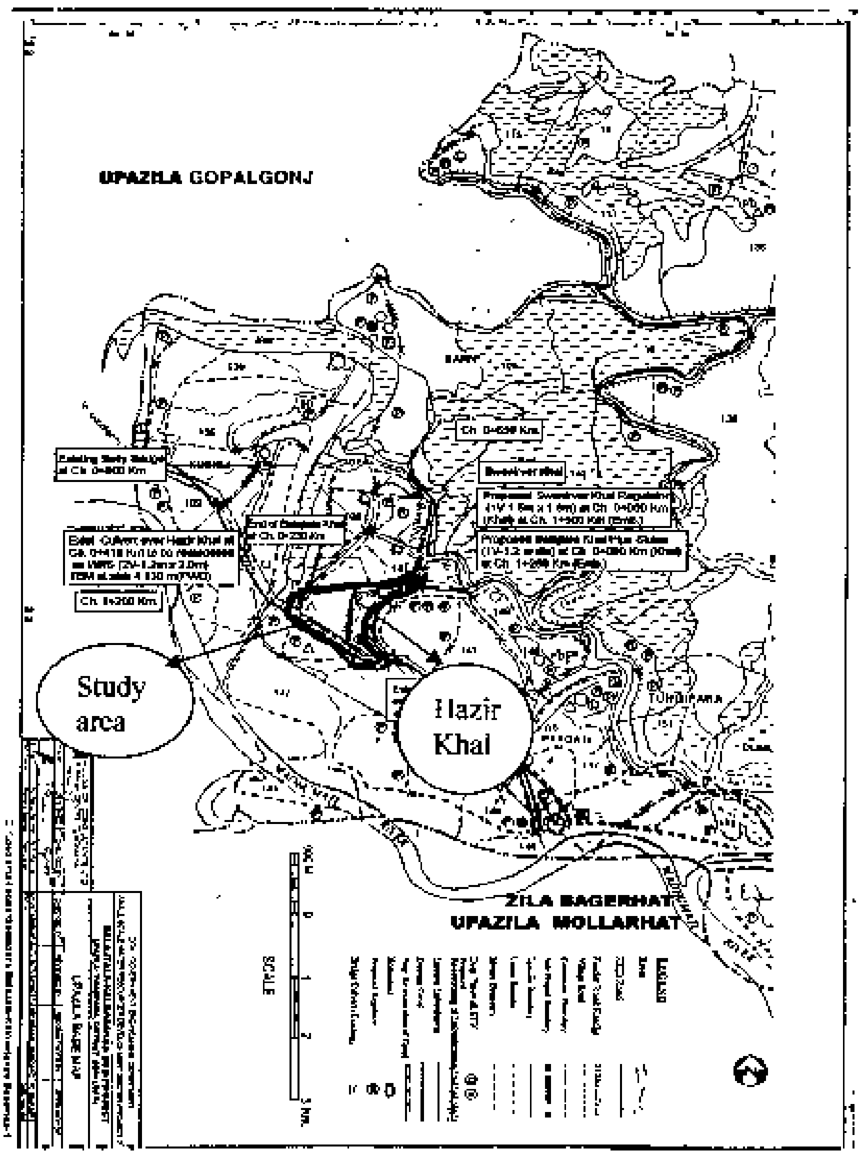


Fig 3.4: Major River and Khal in the study area

The flow in the Hazir Khal is dominated by tidal fluctuation. The linkage of Hazir Khal to the tidal system is shown in Figure 3.5 and described below:

i. Hazir Khal – Gimadanga Khal

Hazir Khal originates from Gimadanga Khal and ends up near Gopalganj-Patgati Road at the south of study area. The tidal flow in Hazir Khal is mainly from Shingair river through Gimadanga Khal.

ii. Shingair-Madhumati

Gimadanga Khal falls into the Shingair River which is flowing along the east side of the study area. Shingair River is originated from Barni Baor and falls into the Madhumati River. Tidal flow enters into the Madhumati River from Balewshar River. Shingair River gets the tidal flow through Madhumati and from Shingair River tidal flow enters into the Gimadanga Khal.

iii. Balewshar

Madhumati River falls into the Balewshar River. The tidal flow from the Bay of Bengal enters into the Baleswar River and from Balewshar River tidal flow enters into the Madhumati system.

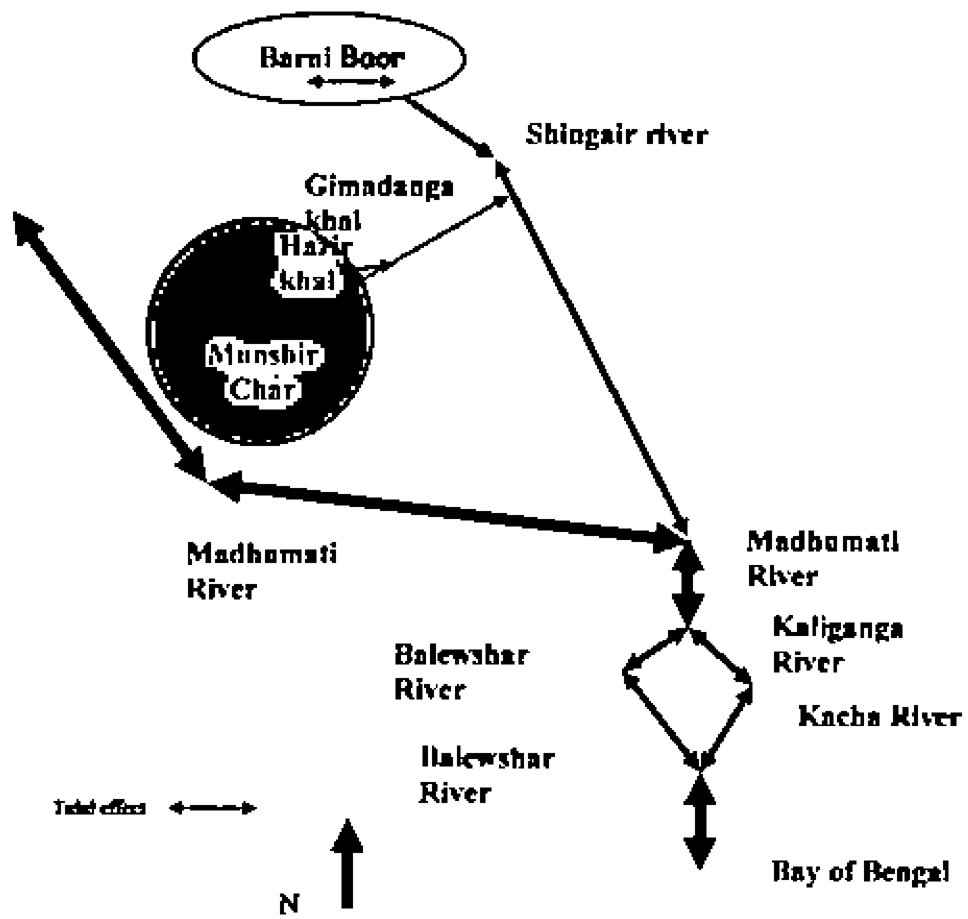


Fig 3.5 Schematic representation of linkage of Hazir Khal to major river system

3.3 Socio-economy

3.3.1 Population

Total population of the two villages of the study area is about 3000. Literacy rate is almost 55% in both the villages. Table 3.3 describes demographic information of each village.

Table 3.3: Village-wise demographic information of the two village

Name of village	No. of Household	Total population	Household size
Munshir Char	225	1350	6.0
Shingi Para	250	1700	6.8

Source: LGED (2004)

3.3.2 Socio – economic characteristics

A majority of the people of the study area live on agricultural activity. The landless, sharecropper's and small farmers operate about 50% of land of Munshir Char village and 65% of land of Shingi Para village. About 38% of total household depend on agriculture labor, while 46.6% household of the study area live under poverty level Table 3.4 and Table 3.5 describe the number of households dependent upon agricultural and non agricultural activity and landownership characteristics respectively.

Table 3.4: Household categories based on agriculture and non agriculture activities

Name of village	No. of Household	HH entirely dependent on Agriculture	HH dependent on Agriculture and other activities	HH entirely dependent on Non - agriculture activities
Munshir Char	225	90	123	12
Shingi Para	250	77	171	2

Source: LGED (2004)

Table 3.5 Land ownership characteristics

Name of village	Munshir char		Shingi Para	
	No.	%	No.	%
Landless: <0.2 ha (< 50 dec.)	85	38	120	48
Marginal farmer: 0.2 – 0.5 ha (50 – 125 dec.)	55	24	65	26
Small holder 0 5 – 1 ha (126 – 250 dec.)	50	22	35	14
Medium size holder: 1 – 2 ha (251 –500 dec.)	20	9	25	10
Large – size holder: 1 – 2 ha (251 –500 dec.)	15	7	5	2
Total Household	225	100	250	100

Source LGED (2004)

3.3.3 Land use

Almost 90% of the land in the study area is agricultural land and the remaining is homestead. There are one khal and 37 ponds in the study area. The khal is the main source of capture fisheries. Presently farmers cultivate Boro (Local/HYV) in low and medium low lands. Aus and Aman are cultivated in 67% area in the high and medium low lands, while the remaining 33% land is relatively high and used for rabi crops, viz pulse, oil seeds, vegetables, jute etc. Table 3.6 describes the land use of the study area, while Figure 3.6 shows the land use map of the study area.

Table 3.6 Land use of the study area

Land type	Cropping pattern		
	Kharif – I (March – July)	Kharif – II (July – November)	Rabi (October – May)
High land (F0)	B. Aus (Local)	B Aman (Local)	Pulse
	Jute	Fallow	Wheat
	Jute	T Aman (HYV)	Mustered
	Fallow	T. Aman (HYV)	Pulses
Medium High Land (F1)	B Aus (Local)	B. Aman (Local)	HYV Boro
	B. Aus (Local)	B. Aman (Local)	Fallow
	Fallow	Fallow	Fallow
Medium Low land (F2)	Fallow	Fallow	HYV Boro
Low land (F3)	Fallow	Fallow	HYV Boro

Source LGED (2004)

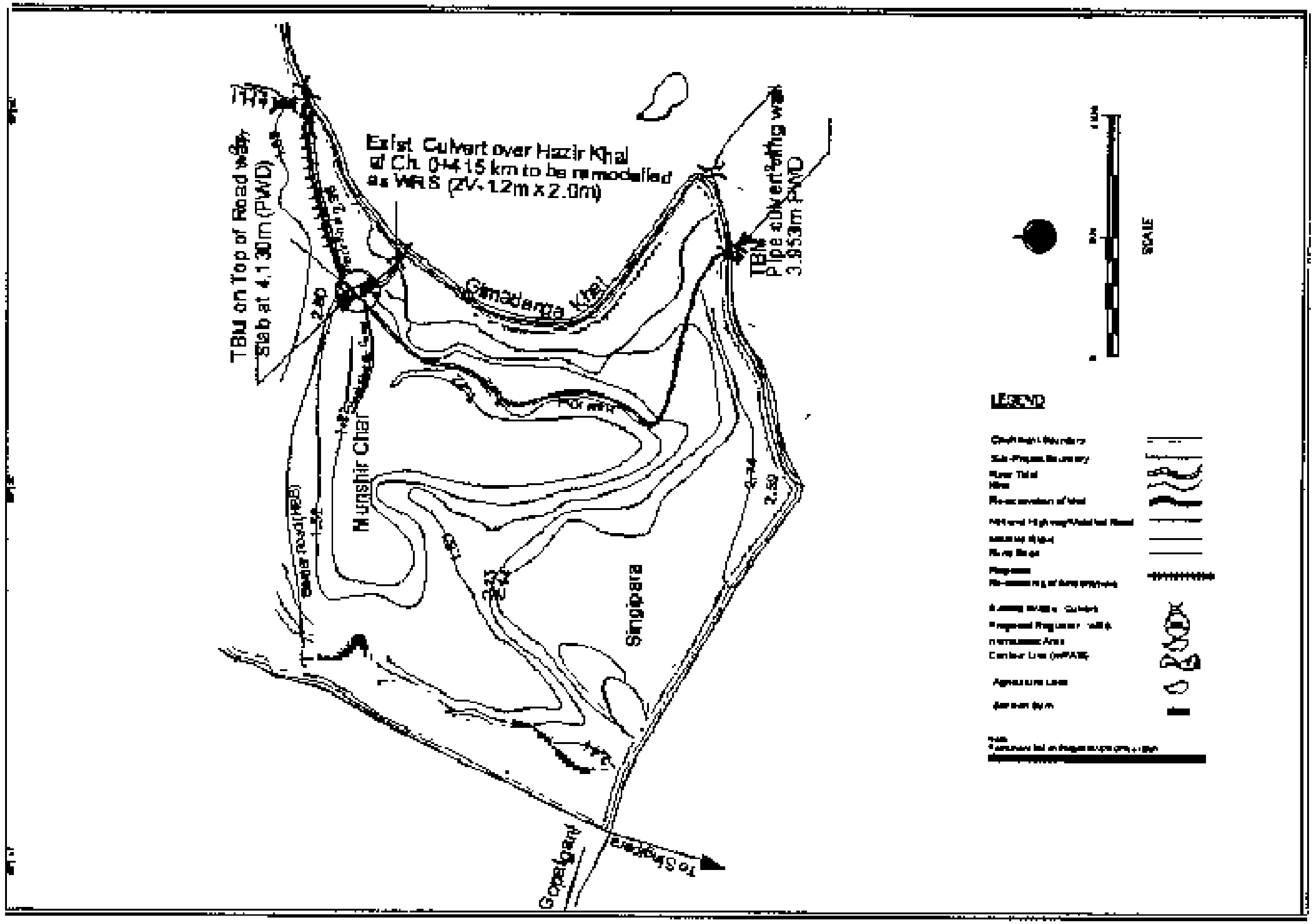


Fig 3.6 Land use map of the study area

CHAPTER IV

SEASONAL DAM CONSTRUCTION AND LOCAL WATER MANAGEMENT PRACTICE

This chapter discusses the social survey that has been carried out to gather information on the local water management practices in the study area. Social survey section explains the details of tools and techniques used in data collection. Focus Group Discussion and questionnaire survey methods were used for collection of primary data. The findings of social survey are also presented, which include the history of Hazir Khal and construction of an earthen dam in the khal, local water management practice and community demand for a seasonal gate.

4.1 Social Survey

4.1.1 Focus group discussion (FGD)

FGDs were conducted in the study area to collect information about local water management practice, history of Hazir Khal, seasonal dam construction process, multiple uses of the khal, expected additional benefits from the sluice gate and opinions on gate operation. A total of 16 FGDs were conducted in the study area, each group consisting of 4-10 persons. Table 4.1 presents a list of FGDs conducted with different groups.

The grouping for discussion was done under four strata: gender, land ownership, occupation and location along the channel reach Participation of females was emphasized while planning the FGDs. Two FGDs were conducted with housewives of farmer's (5 persons) and one with housewives of fishermen (10 persons). They basically informed about the dam construction process and various uses of Hazir Khal. Two FGDs were conducted with agricultural laborers, one with people living downstream of the khal, and another with the end users of the khal They informed about earthen dam construction process, opportunities created due to construction of the dam, benefits in the agricultural sector, and operation of the proposed gate.

Table 4.1 List of FGDs conducted with different groups

Date	Village	Group	Livelihood
12/03/2008	Munshirchar (d/s)	1. Housewives 2. Housewives 3. Rich farmer 4 Day labor 5. Fishermen	1. Fishing 2. Farming 3. Farming 4. Agricultural 5. Fishing
	Shingipara	6 Day labor 7. Medium farmer	6. Agricultural 7. Farming
13/03/2008	Munshirchar	8. Medium farmer 9. Small farmer 10. Marginal farmer	8. Farming 9. Farming 10. Farming
		11. Housewives 12. Landless farmer 13 Small farmer	11. Farming 12. Farming 13. Farming
14/03/2009	Munshirchar	14. Landless farmer 15. Fishermen 16 WMCA	14. Farming 15. Fishing

Land ownership plays a major role in decision making. Based on land ownership, farmers are categorized into landless (<0.2 ha), marginal (0.2 – 0.5 ha), small (0 5-1 ha), medium (1-2 ha) and rich (>2 ha) (BBS, 2004). Two FGDs were conducted with landless farmers, one downstream of the Khal (5 persons) and another with the end users (4 persons). One FGD was conducted with marginal farmers (4 persons), and two FGDs with small farmers at both downstream (6 persons) and end of the Khal (4 persons). In total two FGDs were conducted with medium farmers in both downstream (6 persons) and end of Khal (7 persons) One FGD was conducted with rich farmers in Munshir Char village (5 persons). The farmers provided information on the history of Hazir Khal and earthen dam, management of dam construction, benefit in the agricultural sector due to the construction of dam, additional benefits from proposed gate and gate operation. Two FGDs were conducted with fishermen living in Munshir char village, each consisting of four persons. The fishermen gave information on the management process of culture fisheries, damages in natural fisheries and their problems in fishing in Hazir Khal during the monsoon One FGD was also conducted with the members of Water Management Co-operative Association (WMCA) (12 persons) to understand the management process and the responsibilities of the WMCA.

The discussions were arranged at convenient times and places for the villagers. Checklists were prepared to guide the discussions. Separate checklists were prepared for each group Relevant pictures and the checklists are attached in Appendix – A and Appendix-B, respectively

4.1.2 Questionnaire survey

Sample Size Determination

In the present study, household was taken as the sampling unit. Each household consists of 6-7 members A simplified formula for calculating sample size distribution described by Israel (2003) was used in this study to determine the sample size. The formula is as follows

$n = N/(1+NE^2)$

For the present study,

n = Sample size

N = No of household in Village Munshir Char = 225

E = Level of precision = .1

Now the sample size is,

$n = 225/\{1+(225*.1^2)$

$= 69.2 \sim 70$

Sampling Method

Stratified random sampling was used as the sampling method The total sample population i e. the households were categorized into three groups according to Table 3.5. In total 28 households dependent on agriculture, 38 households dependent on agriculture and other activities, and 4 households dependent on non agricultural activities were surveyed. Table 4.2 describes the list of participants of the survey.

Table 4.2 Date and participants of the survey

Date	Village	Livelihood	No. of HH
14/03/2008 to 19/03/2008	Munshirchar (d/s)	Household dependent on agriculture only	28
		Household dependent on agriculture and other activities	38
		Household dependent on entirely non agricultural activity	4

Development of questionnaire

After a thorough field visit in the study area a semi-structured questionnaire was developed first. A pretest was conducted to test the performance of the questionnaire. The pretest was conducted with 8 farmers and 2 fishermen households of the study area. Based on the response during the pretest, some changes were made in the draft questionnaire. Some confusing questions were modified and some new key questions were included. As the survey was conducted with both literate and illiterate people, for their convenience the questionnaire was developed in Bengali. Both closed and open ended questions were included in the questionnaire. The questionnaire is attached in Appendix - B.

Administration of survey

Information was collected from respondents when they were not busy in the field or it was not their resting time. Early morning and evening were chosen as the farmers were usually not busy at that time.

The social survey provided a clear picture on local water management practice, including the history of Hazir Khal, earthen dam construction process, multiple uses of the Khal by the community, requirement of water for various purposes like irrigation, fishing, domestic needs etc., and agricultural practice of that area. People's opinions on gate operation rule were also identified from the survey.

4.2 History of Hazir Khal

Excavation of Hazir khal

The history of excavation (and re-excavation) of Hazir Khal and other associated major interventions are summarized in Tables 4.3 and 4.4. Hazir Khal was first excavated by local rich farmers to drain out water from the low lands to the river at the end of monsoon. The Khal was named according to the name of the son of one of its excavators. The Khal was excavated approximately 55 years ago However, the local people do not remember the exact date of the excavation It is also found from the Feasibility Report of LGED (2004) that the Khal has existed from the Pakistan period The Khal was re-excavated by the Union Parishad during the Pakistan Period to facilitate navigation (e.g. using country boat to transport crops, transporting goods to and from market etc.).

In the beginning the Khal was 750 m long and the branch was approximately 250 m long. Initially, the villagers had constructed a bamboo bridge on the Khal, which was used as a means of transport. A bridge made up of wood was later constructed over the Khal by the Union Parishad during 1962-63. The road across the Khal was constructed by the Union Parishad during 1972-73. The Khal was re-excavated in 1974 by the Government under the excavation program of an International NGO (CARE Bangladesh). This was followed by the construction of a culvert across the Khal by the Union Parishad in 1978. Re-excavation of Hazir Khal was carried out by the Government to some extent (up to one kilometer) periodically over the period from 1996 to 2001. Major re-excavation of the Khal, however, took place under the Balajtala – Kalmadanga Sub–project of LGED, which was started in the year 2004. Currently, Hazir Khal is approximately 1.6 km long and 2.5 m deep with a bed width of approximately 8.3 m. Figure 4.1 shows the cross-section of Hazir Khal, and Figures 4 2 and 4.3 show photographs of Hazir Khal and the dead end part of Hazir Khal, respectively. The Balajtala-Kalmadanga sub-project also includes re-modeling of the existing culvert and installation of a one vent sluice gate on Hazir Khal at the Culverr. Re-excavation of the Khal and remodeling of the culvert have already been completed The sluice gate was installed in the year 2008.

Table 4.3 Period of excavation (and re-excavation) of Hazir Khal

Year	Excavation	Re-excavation	Supported by
1945 -1971			Excavated by a Local elite and re-excavated by Union Parishad
1971 -1975			Government under canal excavation program of an international NGO
1996 -2001			Union Parishad
2001-2007			LGED

Table 4.4 Major interventions in Hazir Khal

Year / Interventions	1945 - 1971	1971 – 1975	1975 – 1982	1982 – 1990	1991 – 1996	1996 - 2001	2002 - 2008
Bamboo Bridge	■ ■						
Wooden Bridge	● ●	● ● ● ●	●				
Road		▬	▬	▬	▬	▬ ▬	▬
Culvert			▬	■	▬ ■	▬	
Re-modeled culvert							▬ ■

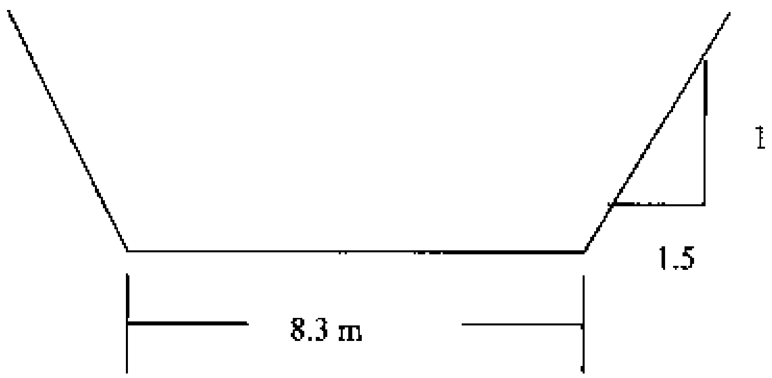


Fig 4.1 Cross-section of Hazir Khal

Fig 4.2 Hazir Khal

Fig 4.3 Dead end of Hazir Khal

Hazir Khal was excavated to mitigate drainage problem at the end of the monsoon season, when there was stagnant water in the low lying areas of the village. Due to Lack of proper drainage facilities, those lands took considerable time to dry out, meaning that farmers were not able to prepare those lands for Boro cultivation even in the month of *Kartik* (October – November). As a consequence, people of that area had to face great loss in crop production each year. According to the local people, the main purposes of Hazir Khal are:

I. Drainage of water at the end of the monsoon from low lying lands;

II. Navigation (basically country boat plying); people use the Khal to carry Jute, Aus and Aman paddy from the field.

4.3 History of Seasonal Dam on Hazir Khal

4.3.1 Earthen dam on Hazir Khal

The local people have constructed a temporary earthen dam on Hazir Khal for 43 years. As mentioned in the previous section, in the beginning there was a bamboo bridge over the Khal at the present site of the culvert. The cross-section of the Khal at that place was rather wide. Hence people used to construct the earthen dam downstream of the Khal at a place called Azimpur Bazar where the cross-section of the Khal was relatively narrow. However, after the construction of the culvert, people started constructing the dam in the upstream side of the culvert, and this has continued for 30 years till now. Figure 4.4 shows the earthen dam with bamboo cages in the Hazir Khal.

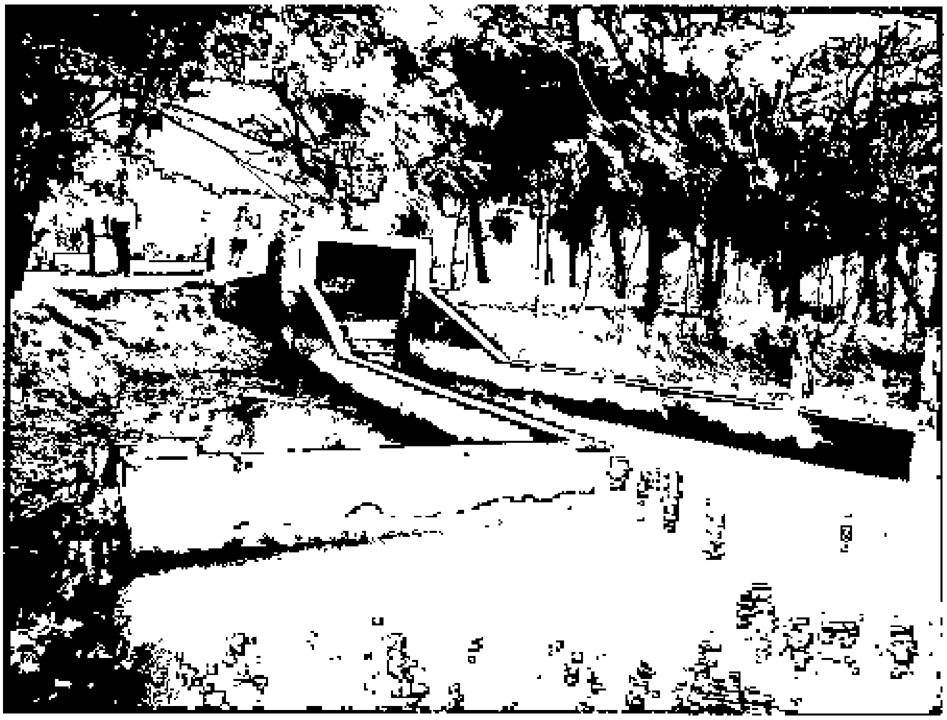


Fig 4.4 Temporary earthen dam with bamboo cages

There was a time when people did not need to construct the earthen dam in Hazir Khal. According to the local people, the depth of flooding was much higher compared to that at present, and was enough to cultivate Deep Water Aman. At that time people used to cultivate the local varieties Rayenda, Beerpala, Kumrugair in low lands and Jabra in medium high lands. Rayenda, Beerpala and Kumragair can tolerate flood depths more than Jabra. Due to decreased flood level, people can not cultivate Rayenda, Beerpala and Kumrugair now; however but by constructing the dam they are able to cultivate Jabra. On the other hand salinity concentration also increased in the Khal with time. So to save the crop from damage due to saline water intrusion, the construction of dam became mandatory.

The main purposes of the earthen cross dam can thus be summarized as –

I. To prevent salinity intrusion at the end of dry season;

II. To create flooding in the agricultural land for Deep Water Aman cultivation during the monsoon.

4.3.2 Construction and cutting period of dam

The earthen dam exists during the wet season starting from the mid of April (according to Bengali calendar *Baishkh* month) up to November (according to Bengali calendar *Kartik* month) i e. just before the beginning of the dry season. The dam is constructed in the middle of April to prevent saline water intrusion. Saline water intrusion causes damage to seedlings of Deep Water Monsoon Rice and also damage dry season crops occasionally. The dam is cut at the end of the monsoon to drain out the water, when the deep water rice is at the flowering stage. The crop is damaged if flooding continues at the flowering stage.

4.3.3 People's participation

Construction of the cross dam has historically been managed by the local people. Local leaders and elderly people are responsible for initiating the discussion, mobilizing the villagers, raising the community fund and facilitating decision making process regarding construction and operation and maintenance of this earthen dam The dam is constructed every year through collective efforts. As per the survey information, 38% of the people provide support by providing labor, 47% supply filling materials (soil) and 16% provide monetary support. Approximately, 15 thousand Taka is needed to construct the dam each time. In recent years, the Union Parishad is also helping by providing financial support Approximate dimensions of the earthen dam include a top width 1 8 m, a bottom width of 2 7 m and a height of 2.5 m, as shown in Figure 4.5 Approximately, 45 m^3 of soil is required to construct the dam.

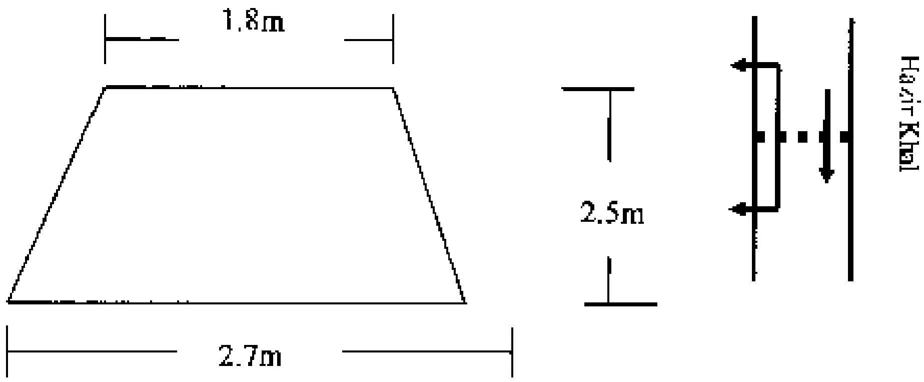


Fig 4.5 Cross-section of the earthen dam

A wooden gate was constructed by the Government in the year 1985 – 1986. But the local people construct the earthen dam in every monsoon, as the water seeps through the wooden gate. The wooden gate became inactive in the year 1995.

4.4 Water Management Practice

4.4.1 Prevention of salinity intrusion

People, since long, have been constructing the earthen dam on Hazir Khal during the end of the dry season to prevent saline water intrusion and hence protect seedlings of Deep Water Aman. Salinity intrusion happens during mid of April (in Bengali calendar *Baishkh* month) to June. Table 4.5 shows the salinity intrusion time and existence of the earthen dam.

Table 4.5 Period of salinity intrusion and status of earthen dam

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Salinity intrusion				● ●	● ●	● ●						
Existence of dam				■ ■	■ ■	■ ■	■ ■	■ ■	■ ■	■ ■		

4.4.2 Creation of flooding for monsoon rice cultivation

Cultivation of Local Variety of monsoon rice in flooded land

The main purpose of the earthen dam on Hazir Khal is to create flooding in agricultural land during the monsoon for cultivation of deep water monsoon rice, the local variety of rice called Jabra. Jabra is long stem rice, and it elongates with the rise of flood water. It can tolerate submergence up to 1-2 weeks and has floating capacity. Jabra is broadcast after the first rainfall in the month of March-April. It has a growing period of 250-270 days. According to the information obtained from the survey, the benefits of this local variety rice Jabra includes:

Economic benefits-

- Low Production cost;
- High Selling price
- Local people are able to process and preserve seeds, hence they do not need to depend on other sources.

Ecological benefits-

- No change in soil quality
- Suitable for fish culture and natural fisheries
- Suitable for growth of aquatic vegetation

Fertilizer and pesticide use-

- Fertilizer requirement low
- Pesticide is not required since Jabra is able to withstand pest so

Flood tolerance-

- Able to tolerate flood

Health benefits-

- High protein contents

The study area consists of low lying floodplains (70% of the total area) and is situated in the Agro-ecological Zone 14, i.e. the Gopalganj Khulna beel area (LGED, 2004). During the rainy season, the whole area is inundated with flood water. The low lying lands become unsuitable for cultivation of High Yield Variety (HYV) rice during the monsoon. So the local people are used to cultivate local variety of Aman rice instead According to local people, Hazir Khal is closed at one end which facilitates storing of water during the wet season for Deep water Aman cultivation. Figures 4 6 and 4.7 present the cropping practice inside and outside the dam, respectively, during the wet season. Table 4.6 shows comparison of Jabra and High Yield Variety (HYV) monsoon rice, as perceived by the local people Table 4.7 shows the crop calendar of monsoon period.

It is important to note here that the according to ADB, BWDB & WARPO (2004), 'water structure' under FCDI projects in Bangladesh are designed and built to 'control flooding' to the crop field and drain out water from the low lands like Beels. But, the local people, in case of Hazir Khal, store rainfall-runoff in their crop fields to create flooding.

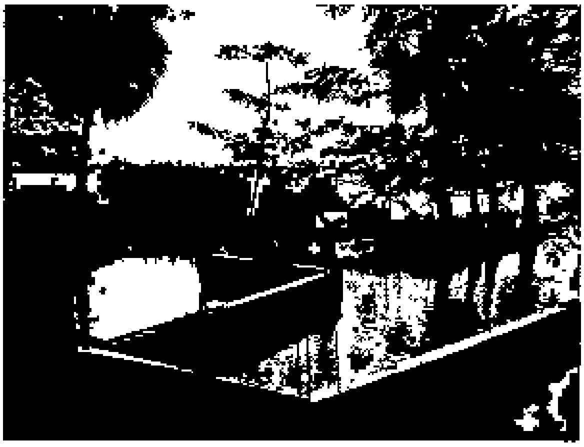


Fig 4.6 Deep water Aman inside the earthen dam during wet season

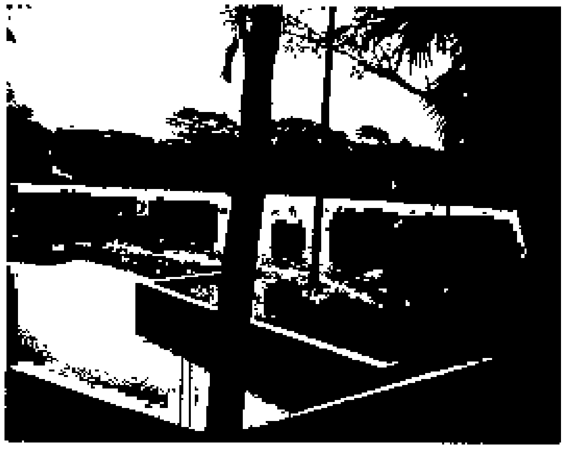


Fig 4.7 Bare land outside the dam during wet season

Table 4.6 Community view on Local variety and High yield variety of monsoon rice

	Local variety	High yield variety
Yield	Low	High
Production Cost	Low	High
Selling price	High	Low
Pest	High tolerance	Low tolerance
Fertilizer	Not required	Required
Flood tolerance	Tolerant	Not tolerant
Weed control	Not needed	Needed
Dietary satisfaction	High	Low
Protein content	High	Low

Table 4.7 Crop calendar and status of dam during monsoon

Month / Variety of crop		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Local variety Aman	Sowing												
	Growing stage												
	Harvesting												
Local variety Aus	Sowing												
	Growing stage												
	Harvesting												
T. Aman	Sowing												
	Growing stage												
	Harvesting												
Earthen dam	Construction												
	Existence												
	Cutting												

Cultivation of local variety Aus rice

Flooding in the agricultural land creates scope for cultivation of local variety B.Aus along with B. Aman. Local B. Aus varieties (such as Nunsaratul, Gararshor) which have moderate elongation ability with gradual increasing depth of water up to certain plant height (about 100 cm) are broadcast together in equal ratio with local variety Aman, usually in the 2nd week of April in the medium high land. In the 1st and 2nd weeks of May, only local Aus are broadcast in the high land. B. Aus rice is normally harvested during the 3rd and 4th weeks of August.

Cultivation of transplanted monsoon rice in higher land

Creation of flooding by the dam also provides opportunity for cultivating transplanted monsoon rice in the relatively high land. Approximately 15% of total agricultural land is of this type. B. Aus and Jute are cultivated in this type of land from April to July. After harvesting Jute and B. Aus, the monsoon rice is transplanted Water from adjacent flooded land is used to provide irrigation to the transplanted monsoon rice.

4.4.3 Fish culture in flooded land

Retention of monsoon rainfall-runoff in Hazir Khal and agricultural lands provides opportunity for fish culture. The spawning period of culture fisheries is in month of June and harvesting is done in November. Culture fisheries are a source of income for the people of that area. Table 4.8 shows stocking time, harvesting time and yield of culture fisheries, while Table 4.9 shows the fish life cycle and status of dam

Table 4.8 Stocking time, Harvesting time and yield of culture fisheries

Fish species	Fingerlings stocking time	Fingerling stocked, kg	Total fish production, ton	Harvest time	Fish yield, ton/ha
Thai sarputi	June (4th week)	120	1.35	December	0 10
Rui		200	2.65		
Katla		160	2.20		
Common carp		720	21.15		
Total		1200	27.35		

(Rahman , 2008)

Table 4.9 Culture fisheries and status of dam

Month / Activities	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Dam construction				■	■							
Fish culture						■	■	■	■	■	■	
Cutting of dam											■	

4.5 Community Demand for Sluice Gate

4.5.1 Reasons for demand

Every year more than 45 m^3 soil is needed for dam construction. In recent years it has become difficult for the local people to manage soil for the construction of the dam. They collect the soil from Khas lands near the Khal and agricultural lands. If they continue this practice, agricultural land will lose its fertility in the long run.

The study area is in a tidal regime. People want to control the flow in the dry season to cultivate Boro. Presently farmers are not able to cultivate Boro in most of the lands of the study area due to lack of irrigation water during the dry season

On a number of occasions, when there was higher water level at downstream of the dam at high tide during the monsoon, the dam was washed away. The dam has failed approximately 8 times during the last 43 years. This indicates that there is nearly a 20% probability of dam failure. Crops suffered damage when the dam failed, leading to sufferings to the farmers.

4.5.2 Flexibility of gate

Construction of the sluice gate will not change the traditional practice of water management by the local people; rather it will add some flexibility. Cultivation of Jabra by retaining the monsoon rainfall-runoff will continue. Additional expected advantages of the sluice gate are as follows:

- The gate can be operated according to the need.
- The gate will be helpful to prevent spring tide flooding during the dry season and also allow to tap water for irrigation of dry season crops and for domestic purposes.
- Permanent sluice gate will be helpful to avoid the risk of occasional failure of the dam.

4.5.3 Response of Local Government Engineering Department (LGED) to community demand

The local people demanded a sluice gate at the Culvert on Hazir Khal to prevent early flood i.e. salinity intrusion and conserve water by tapping tidal flow for irrigation of HYV Boro. They have requested the LGED, which is responsible for planning, design and implementation of small scale water management projects, to construct the sluice gate. LGED has positively responded to the demand. The sluice gate on Hazir Khal is a part of Balajtala-Kalmadanga sub-project of LGED.

4.5.4 Description of proposed gate

The existing culvert is at chainage Ch 0+415 Km which is 1.2 Km downstream from the close end of Hazir Khal. The size of the culvert is 3.28 m X 3.25 m, invert level IL = 0.86 m PWD.

This culvert is going to be remodeled as water retaining structure (WRS) by installing a sluice gate. The sluice gate is of one vent. The size of the gate is (2.9m X 2 m) and the sill level is 0.86 m PWD. The gate is vertical rising type and can be opened at its full height. Figure 4.8 shows the location of the water retaining structure i.e. the sluice gate, and Figure 4.9 shows the dimensions of the gate

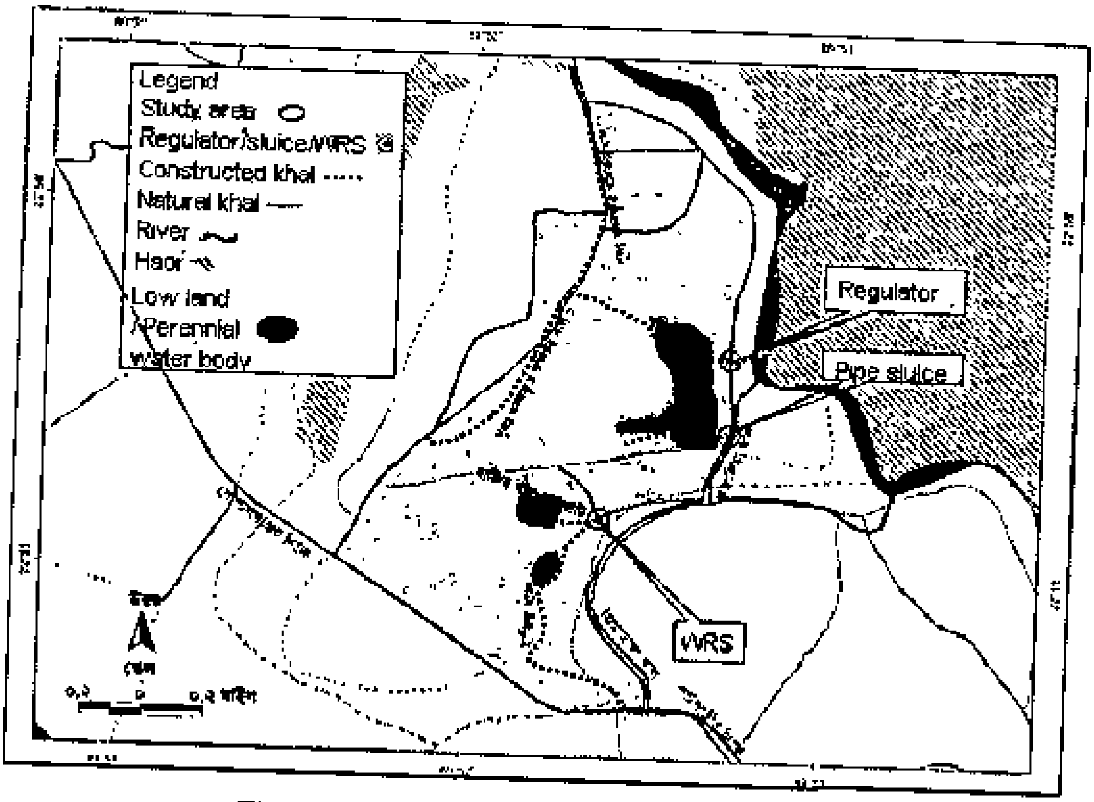
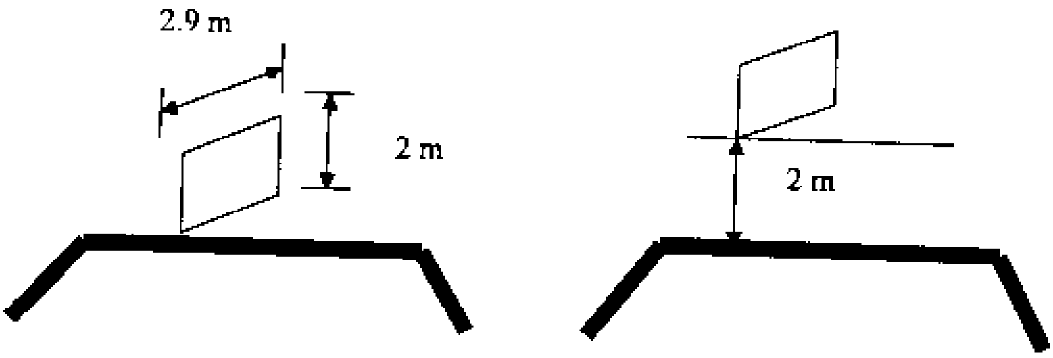


Fig 4.8 Location of WRS on the Hazir Khal



(a) Closed state of gate at Hazir Khal

(b) Opening of the gate

Fig 4.9 Dimension of the gate

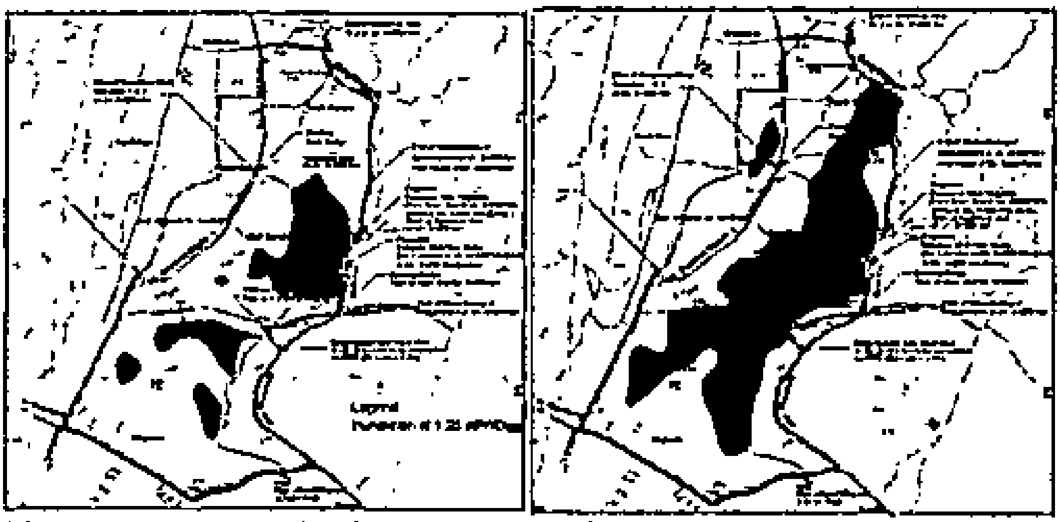
CHAPTER V

ANALYSIS OF TIDAL CHARACTERISTICS AND WATER AVAILABILITY

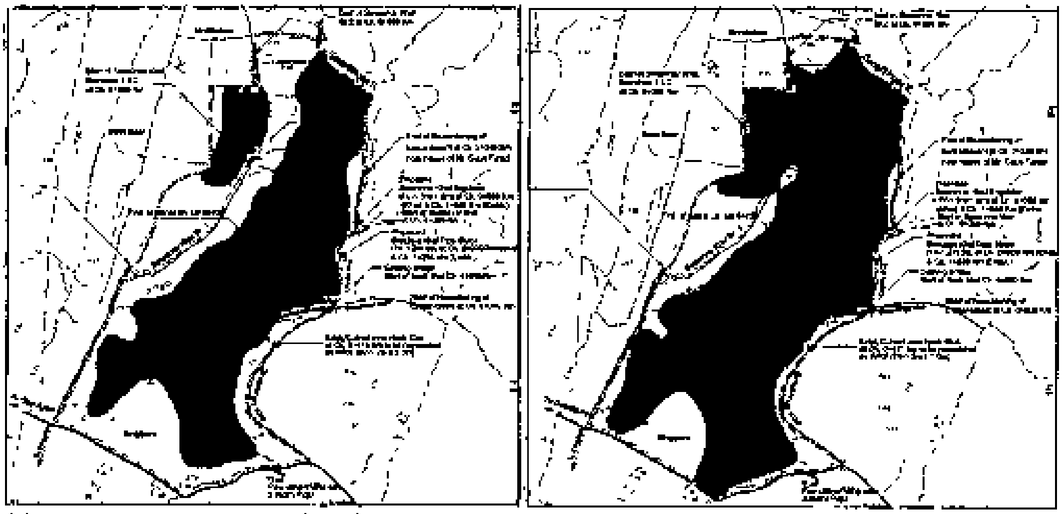
This chapter discusses collection of tidal data, tidal characteristics of the study area, and salinity concentration. It also discusses assessment of water retention volume, requirement of water during the dry season and estimation of irrigable area by the retained water during flood tides. The chapter also includes assessment of volume of water that can be retained by closing the sluice gate during flood tides.

5.1 Inundation area during wet season

People of the study area cultivate deep water Aman in the flooded land during wet season. Inundation areas for different water levels during the wet season derived by Rahman (2008) are shown in Figure 5.1. Figures 5.2-5.4 show the flooding depths at different water levels.



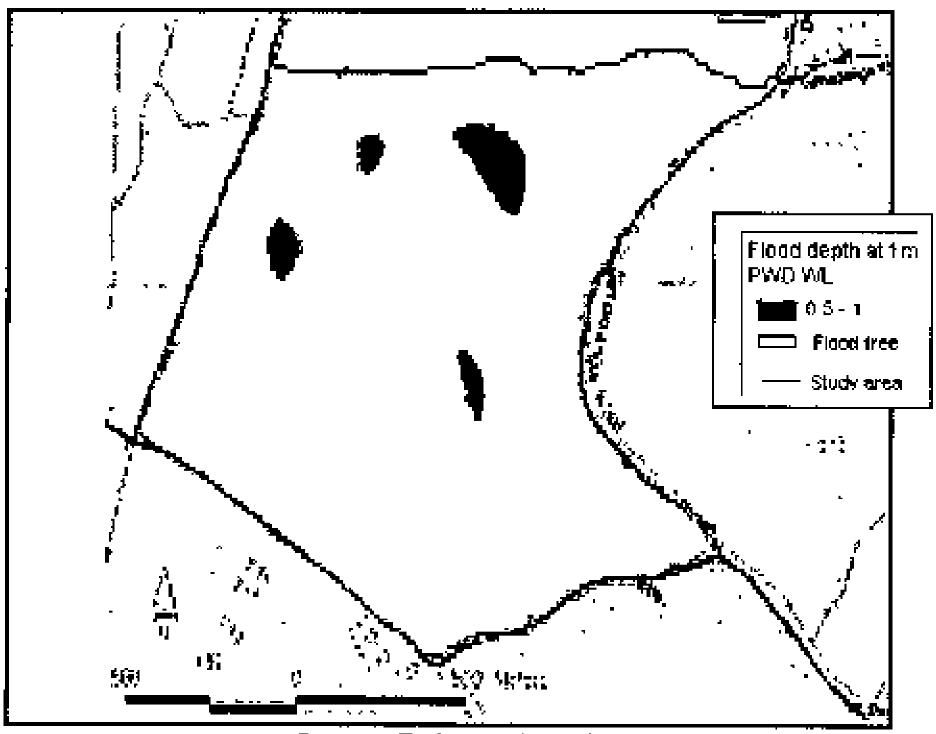
(a) 1.25 m PWD water level (b) 1.75 m PWD water level



(c) 2.25 m PWD water level (d) 2.75 m PWD water level

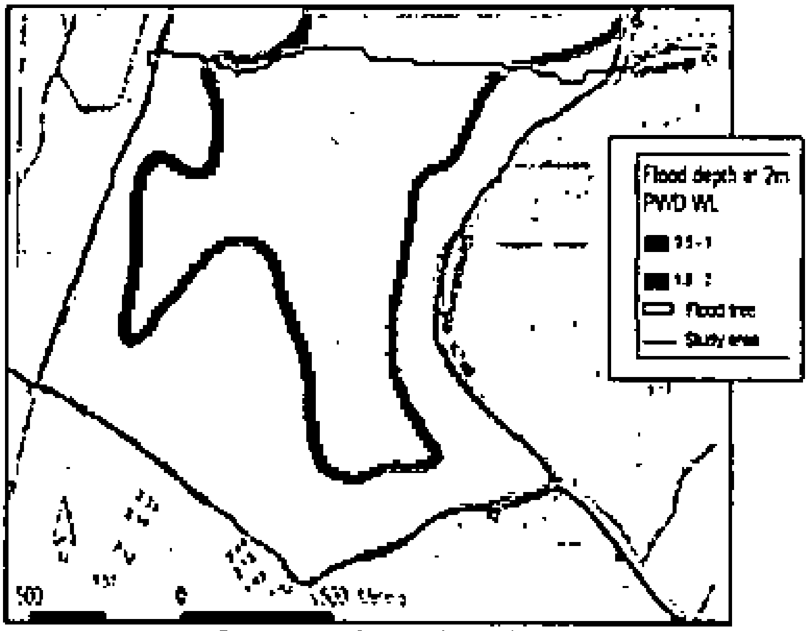
Source: Rahman (2008)

Fig. 5.1 Inundation area at different water levels



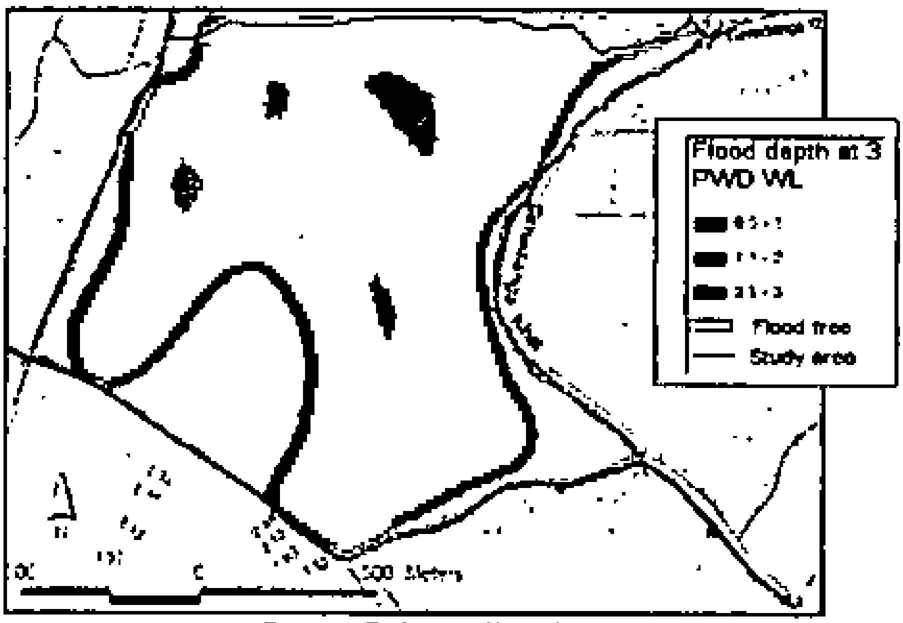
Source: Rahman (2008)

Fig. 5.2 Flooding depth at 1 m PWD water levels.



Source: Rahman (2008)

Fig. 5.3 Flooding depth at 2 m PWD water levels.



Source: Rahman (2008)

Fig. 5.4 Flooding depth at 3 m PWD water levels.

Water requirements during wet season for Culture fisheries

Flooding in the agricultural land for deep Water Aman cultivation created scope for fish culture in the flooded land. Table 5.1 describes the required water height for fish cultivation.

Table 5.1 Required water depth for fish cultivation

Fish type	Temperature °C	Salinity (PPT)	Depth (m)
Shrimp	25-30	5-28	>1
Other than Shrimp	28-31	0-2	>1.5

Source: Harun (2005)

During the wet season all the water requirements are met from tidal water retained in the Khal and from rainfall-runoff. There is no complaint of shortage of water in the monsoon, as found during field visit. People have been following the present agricultural practice for several years and have never faced any problem except the failure of the earthen dam.

5.2 Tidal Data Collection

5.2.1 Measurement of tidal level

There is no water level station of BWDB in the study area. An arrangement for tidal water level measurement in Hazir Khal was set-up. A staff gage made of wood and scaled in centimeters was fitted at the side wall of the culvert at the downstream side. Figure 5.5 shows the staff gage fitted on the sidewall of the culvert.

Fig 5.5 Scale prepared for measuring the water level at the culvert in Hazir Khal

Time of measurement

The water level of the khal was measured hourly from 7 AM to 10 PM every day for a period of nearly 4 months, from the 17th of December 2007 to the 17th of January 2008, from the 5th of March to the 5th of April 2008 and from the 13th of July to the 3rd of September 2008. During the measurement it was ensured that the water body was in an undisturbed stage, meaning that there was no artificial disturbance on the water body due to human activity or due to the activities of ducks or cattle. Table 5.2 shows the summary of tidal level data obtained by hourly measurement.

Table 5.2 Tidal cycle covered by measurement period

Period	Total No of tidal cycle	Flood tide	Ebb tide	Neap	Spring
17th Dec. 07- 17th Jan. 08	34	34	34	2	2
5th Mar -10th April, 2008	35	34	35	2	2
14th Jul - 18th Aug. 2008	33	33	31	2	2

5.2.2 Measurement of salinity

Source of salinity

The source of saline water in the south–west region is the coastal water of the Bay of Bengal The study area is in the tidal regime and during the dry season salinity intrusion occurs in Hazir Khal through the Singair River

Methodology and period of salinity measurement

Measurement of salinity in Hazir Khala was made with an electro-conductivity meter on the 11th of April, 2008, i.e. for one day. In total 5 spots were selected for collection of data. Data were collected at different times (during middle of low tide, starting of high tide and middle of high tide) so as to cover the tidal cycle. Due to time constraint, unfortunately salinity could not be measured during the two high water slacks (HWS) which occur at early morning and at night It posed a little problem since salinity is at its peak during the high water slack. Figure 5.6 shows the timings of salinity measurement made in a day.

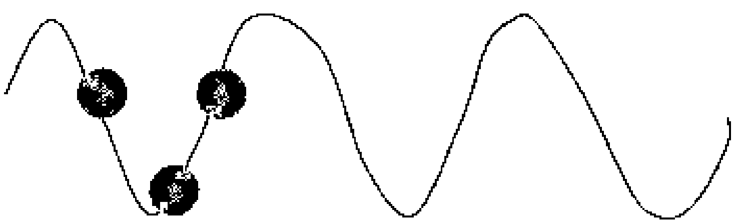


Fig 5.6 Period of data collection in a tidal cycle

Site selection

A total of 5 sites were selected for data collection, which were the junction of Hazir Khal and Gimadanga khal, just downstream of the culvert, just upstream of the culvert, mid point along the Khal and tail end of the Khal Figure 5 7 shows locations of the measurement sites

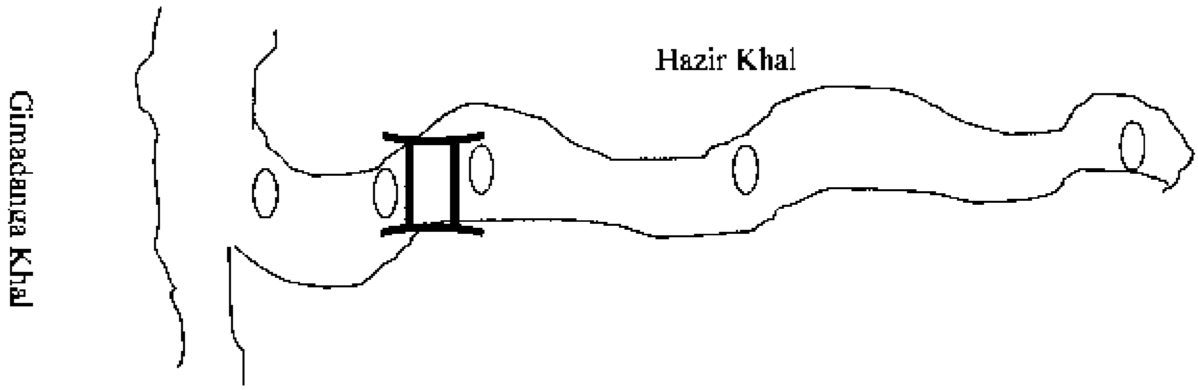


Fig 5.7 Salinity data collection spot

5.2.3 Tidal characteristics

Tidal levels were measured for almost four months to investigate both the dry and wet season tidal characteristics. The level of water after construction of the earthen dam was also collected from the field. Figures 5.8 – 5.10 show the tidal water level hydrographs during the measurement period and Figure 5.11 shows the variation of water level inside the gate when the earthen dam exists. It is clear from the figures that high water level increases from December to March and low water level decreases at the same time in the dry season. Tidal range is also higher during the months of March-April than that during December – January. In the dry season, variation in water level from spring to neap is also significant. The phase shift is approximately one hour. On the other hand variation in water level from spring to neap is not significant in the wet season as there is strong contribution from rainfall-runoff Table 5.3 presents the summary of measured tide level data.

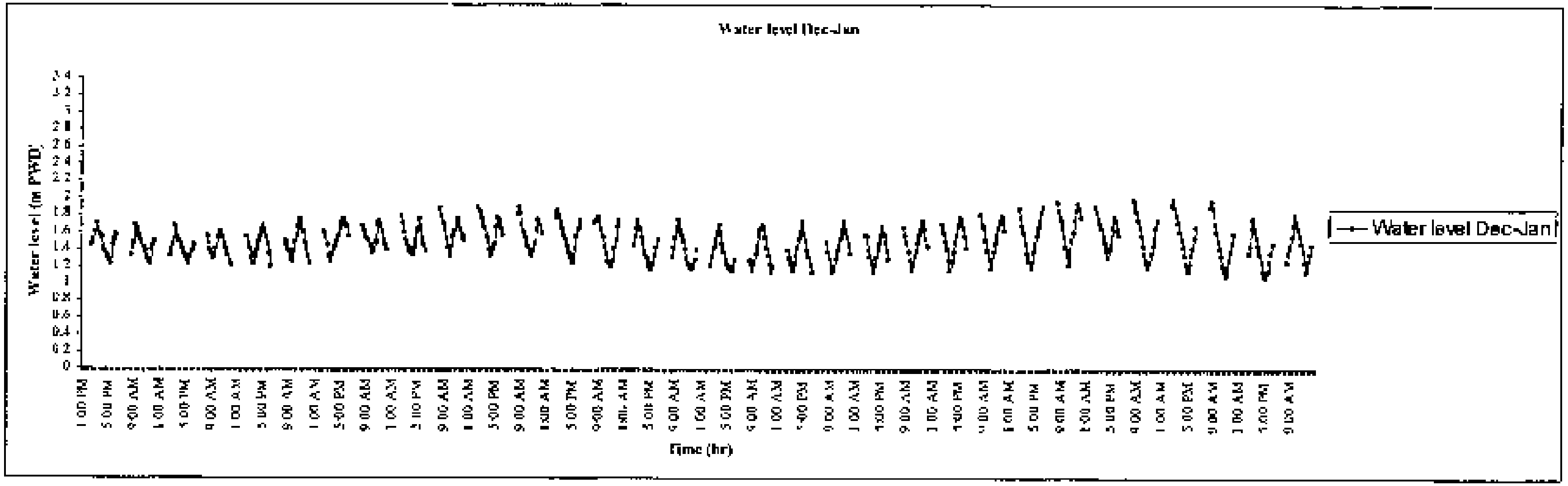


Fig 5.8 Water level during 17/12/2007 to 17/01/2008

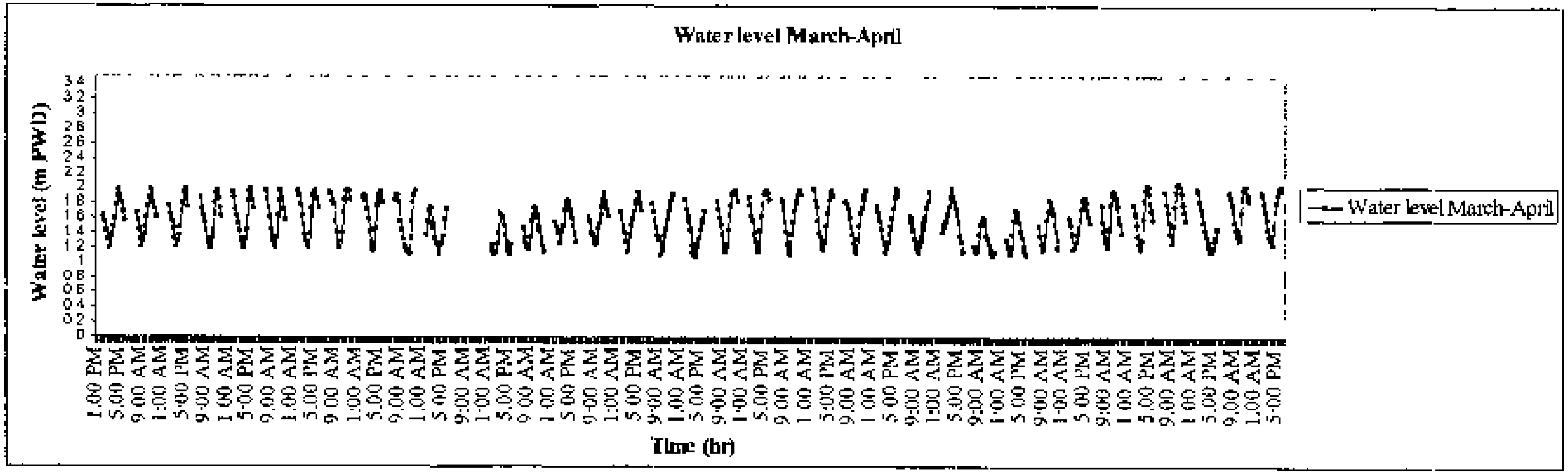


Fig 5.9 Water level during 05/03/2008 to 10/04/2008

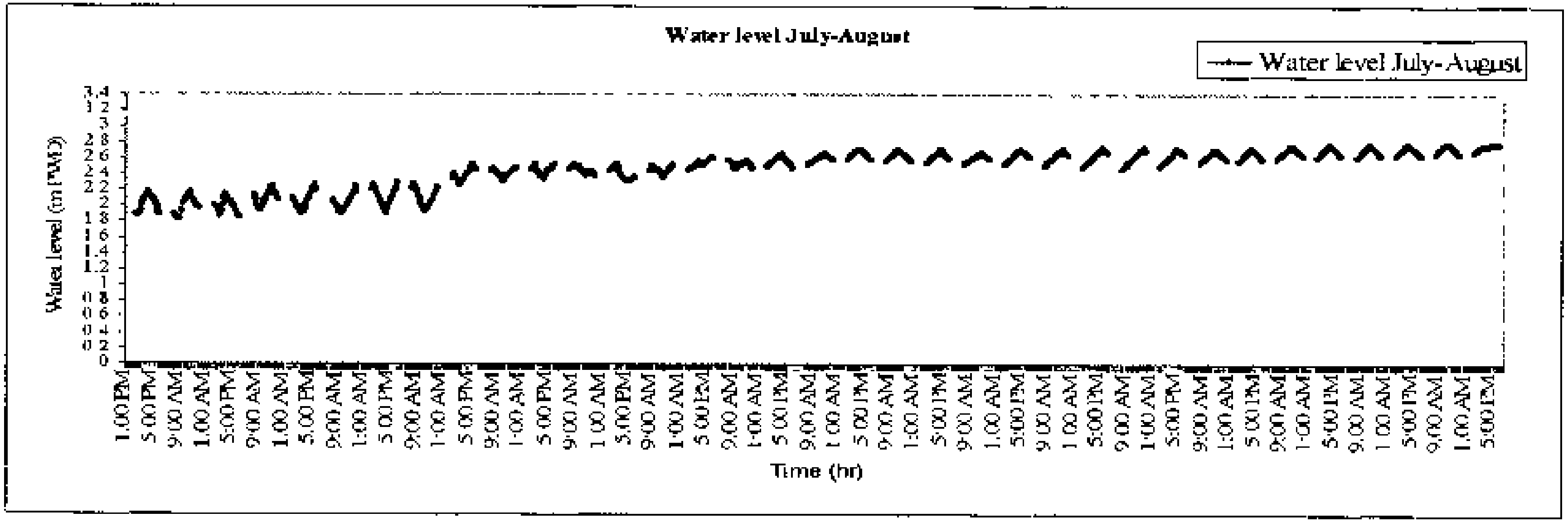


Fig 5.10 Water level during 14/07/2008 – 18/08/2008

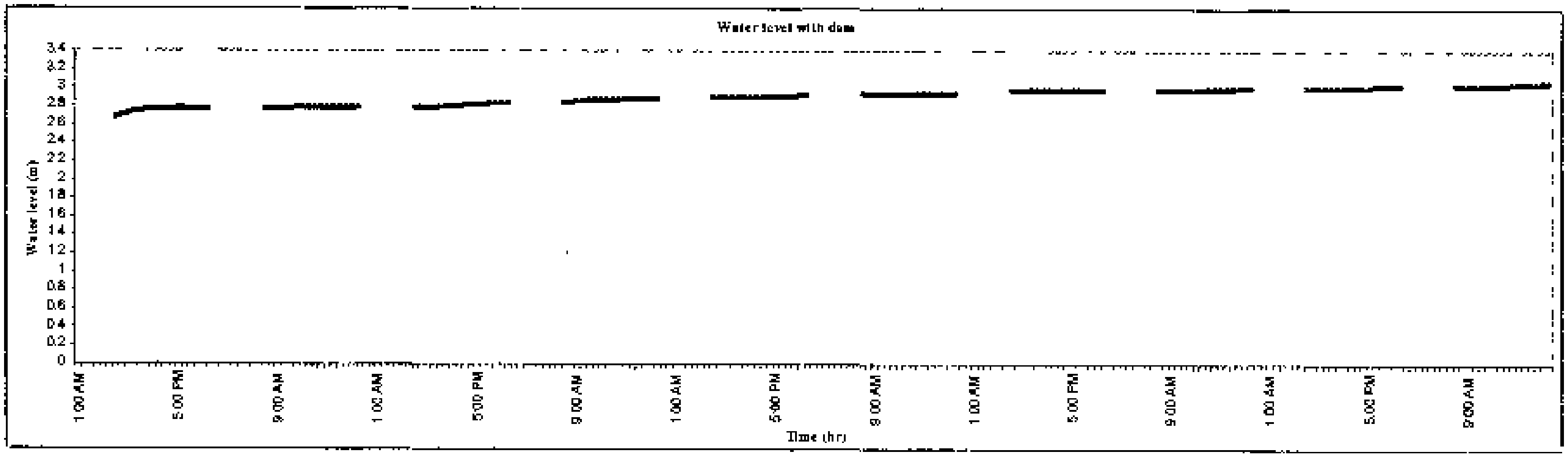


Fig 5.11 Water level during 19/08/2008-28/08/2008 with dam condition inside the Khal

Table 5.3 Tidal characteristics based on observed data

Tidal parameter		Time					
		17th Dec, 07-17th Jan. 08		5th Mar -10th Apr, 2008		14th Jul - 18th Aug, 2008	
		Max	Min	Max	Min	Max	Min
High water level (m, PWD)	Neap	1.73	1.61	1.85	1.61	2.91	2.73
	Mid of neap-spring	1.8	1.67	1.99	1.85	2.94	2.82
	Spring	1 99	1.88	2.03	1 97	2.97	2.9
	Mid of Spring-neap	1.97	1.73	1.98	1.84	2.9	2.84
Low water level (m, PWD)	Neap	1.23	1.13	1.1	0.73	2.69	2.56
	Mid of neap-spring	1.35	1.15	0 87	0 7	2 78	2 67
	Spring	1 33	1	0.89	0.79	2.81	2.75
	Mid of Spring-neap	1.24	1.1	0.78	0.76	2 69	2 52
Mean tidal level (m, PWD)	Neap	1.29	1.20	1 26	1 15	2 83	2.65
	Mid of neap-spring	1.39	1.26	1.51	1.32	2 86	2.75
	Spring	1.5	1.41	1 58	1 47	2 89	2.83
	Mid of Spring-neap	1.41	1 22	1.43	1.32	2.8	2.1
Tidal range (m, PWD)	Neap	0.54	0.32	0.69	0.52	0.33	0 18
	Mid of neap-spring	0.52	0.38	0.81	0.69	0.34	0.12
	Spring	0.86	0 61	0.87	0.75	0.40	0.24
	Mid of Spring-neap	0.61	0 56	0.84	0.6	0.19	0 13

5.2.4 Salinity intrusion characteristics

Salinity measurement revealed that the salinity concentration is in the permissible limit during the low tide and has an increasing trend with the increase of water level during the high tide. Table 5.4 shows the limit of water salinity for irrigation purpose, while Table 5.5 shows the salinity level of Hazir Khal at different times and sites Figure 5.12 shows the trend of salinity in different periods of a tidal cycle.

Table 5.4 Water salinity limit for irrigation

Salinity class	Salinity (Eciw, ds/m)	ppm(1 ds/m = 640 ppm)
Optimum	<0.75	<480
Toxic	0 75-3 0	480-1920
Extremely Toxic	>3.0	>1920

Source Chowdhury (2007)

Table 5.5 Salinity at different time and site of Hazir Khal

Time	Tidal cycle	Salinity in ds/m						Suitability for irrigation
		Spot 1	Spot 2	Spot 3	Spot 4	Spot 5	Average	
11:00AM	Middle of ebb tide	0.57	0.58	0.57	0.58	0.57	0.57	Suitable
2:50 PM	Low water slack	0.55	0.56	0.55	0.56	0.55	0.55	Suitable
5:18 PM	Middle of flood tide	0.6	0.6	0.59	0.6	0.6	0.60	Suitable
Average salinity in ds/m along the Khal		0.57	0.58	0.57	0.58	0.57		

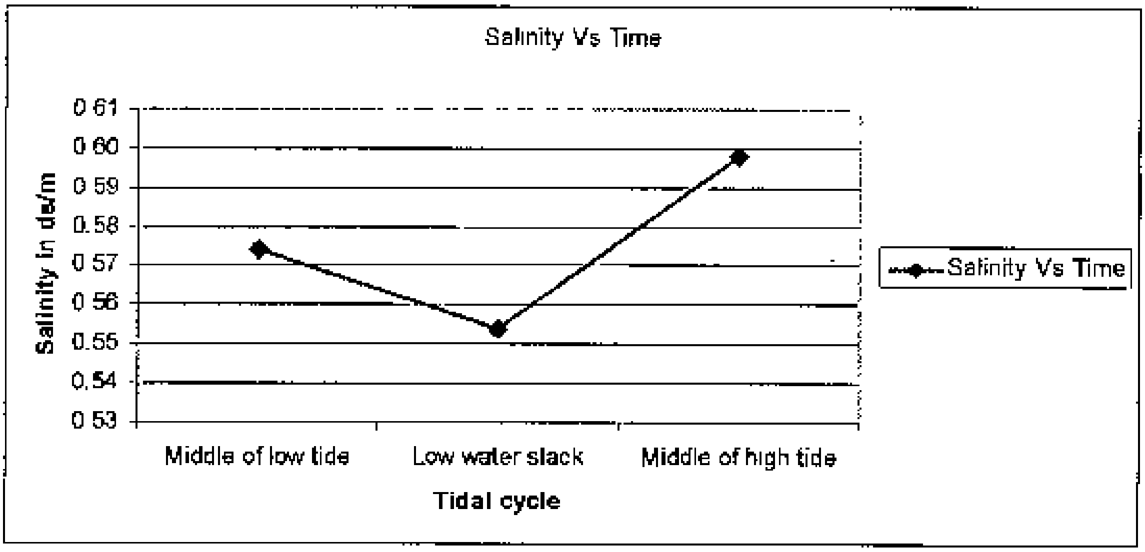


Fig 5.12 Trend of salinity intrusion with change in tidal status

From Tables 5.4 and 5.5, it is seen that salinity in the study area is below the toxic limit during the time of measurement. The toxic limit of water salinity for agriculture is 0.75-3.0 ds/m, whereas the salinity concentration in Hazir Khal was within 0.56-0.60 ds/m. However, there is a rising trend in salinity concentration from the low tide to the high tide, as evident in Figure 5.14. It is clear that salinity concentration will increase during the high water slack. In absence of measured peak salinity data during the high water slack, salinity concentration of a nearby station, Athatrbanki (location is shown in Figure 5.13) in the upstream was collected in order to get idea about possible salinity concentration during the high water slack. Table 5.6 and Figure 5.14 present the maximum salinity concentration in Athatrbanki station.

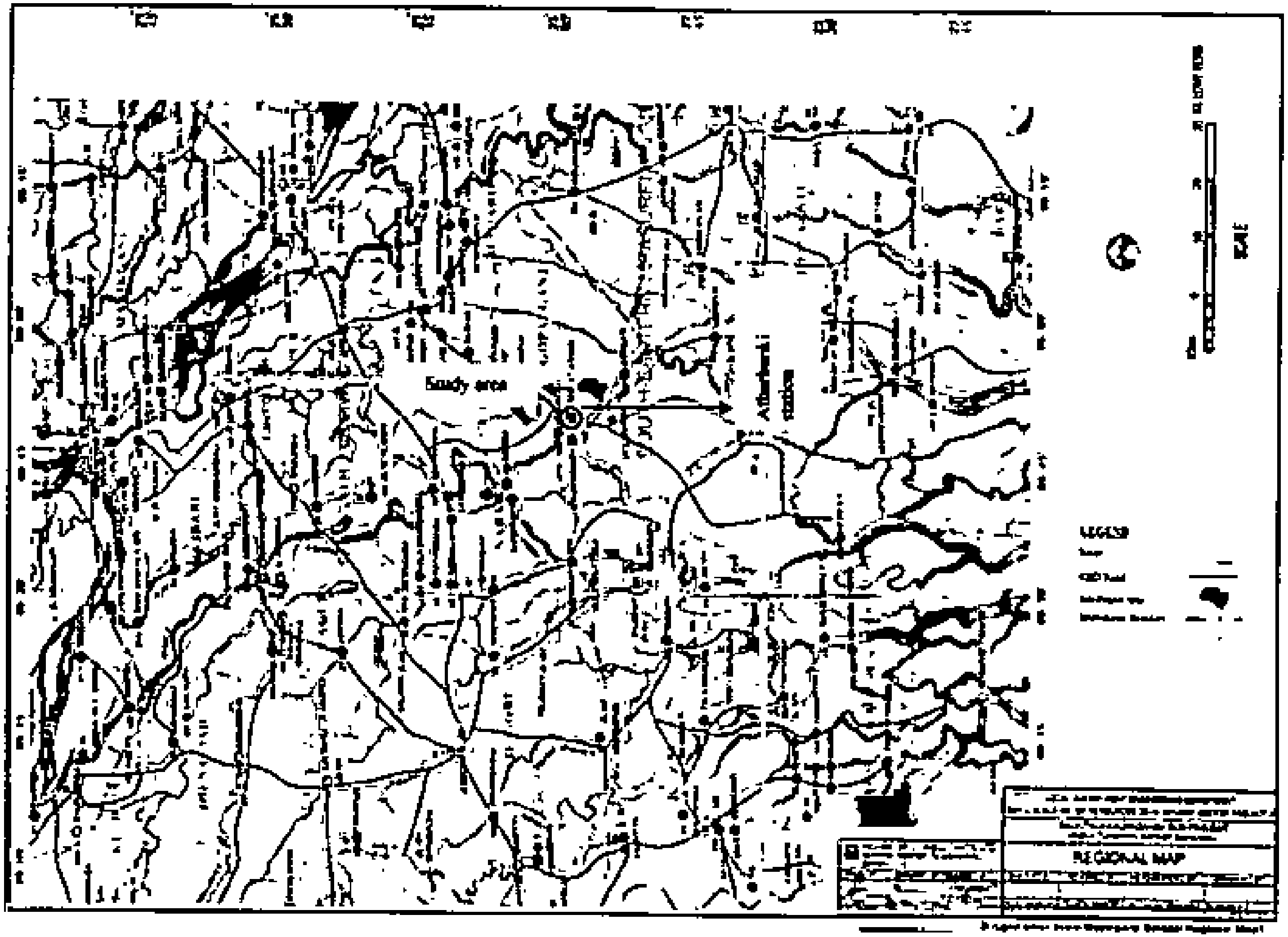


Fig 5.13 Location of salinity measurement station

Table 5.6 Salinity in Athatrbanki station

Month	Salinity in μ-Mhos	Salinity in ds/m	Suitability for irrigation
Jan	486	0.49	Tolerable
Feb	583	0.58	Tolerable
March	921	0.92	Toxic
April	1376	1.38	Toxic
May	1267	1.27	Toxic
June	438	0.44	Tolerable
July			
August			
September			
October			
November	321	0.32	Tolerable
December	449	0.45	Tolerable

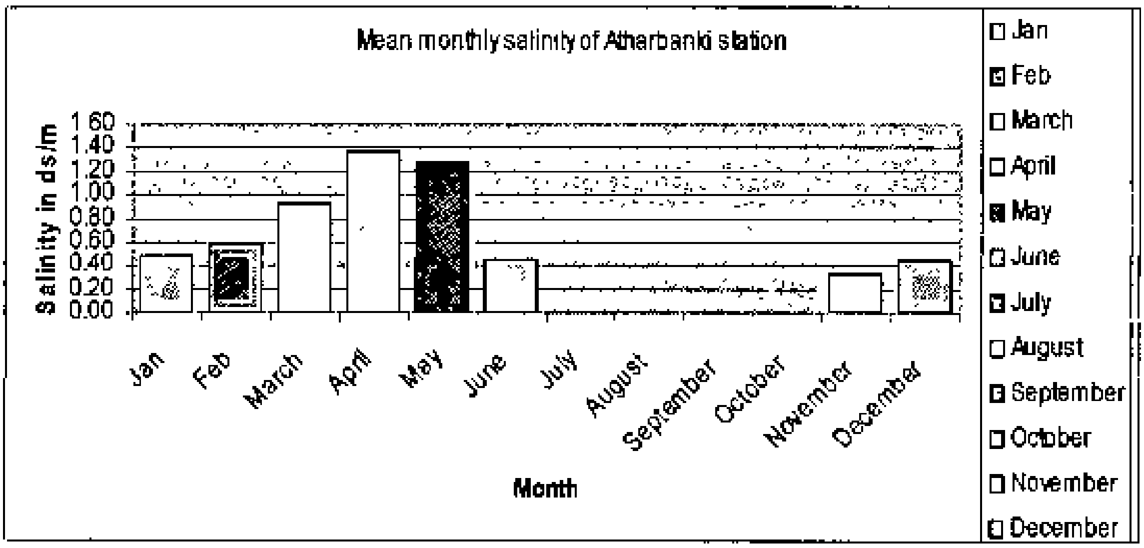


Fig 5.14 Mean monthly salinity in Atharbanki station

From the above data it is seen that salinity intrusion reaches its peak during the month of April and starts falling during the month of June. From the month of March the river water becomes unsuitable for irrigation due to high concentration of salinity and it continues up to the month of May. Due to time constraint it was not possible to measure the salinity level during month of April (mid) up to June. However, it came out from the field survey that in the study area salinity intrusion starts at the end of March and the concentration in Hazir Khal becomes toxic during mid April, which continues up to mid June unless there is heavy rainfall in that area. The data of Atharbanki station gives a similar understanding of the variation of salinity levels in Hazir Khal. The observations made in LGED (2004) about early flood (i.e. salinity intrusion) from Shingair River damaging young B. Aman, standing vegetables and matured Boro crops are also in line with the information obtained from the local people.

It appears that a regular salinity monitoring system is required in the study area. The local people have their own knowledge to identify the toxic limit of salinity. A low cost salinity measurement instrument should be available in the field and the WMCA should be entrusted with the responsibility of measuring and monitoring salinity concentration. Monitoring of salinity concentration is very important for that area during the dry season.

5.3 Availability of Tidal Water During Dry season

5.3.1 Estimation of available water during flood tide

The volume of water available at each tidal cycle was calculated using the continuity equation

$\delta Q/\delta x + W (\delta h/\delta t) = 0$ ....(5.1)

The continuity equation can be used to compute the volume of water available during each tide in a tidal channel if tidal level data and discharge data at one of the boundary sections is known. Figure 5.15 shows the continuity equation applied in a tidal channel with one end closed (similar to Hazir Khal) As the length of the khal is relatively small, the water level throughout the khal was considered to be the same as the level measured at the culvert. At the closed end of the khal the inflow, $Q_1 = 0$.

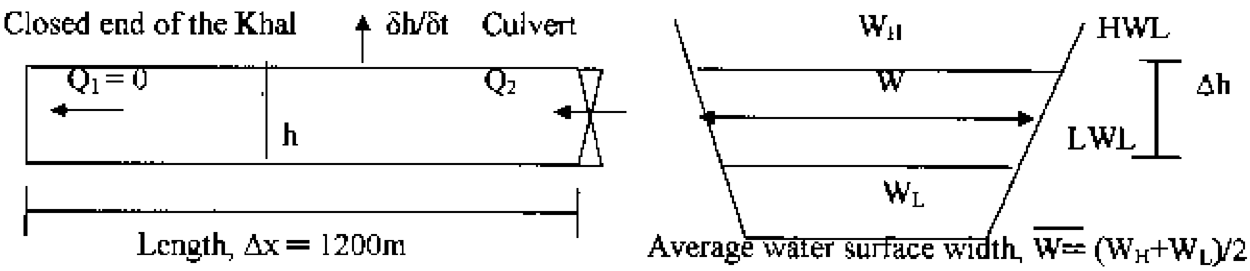


Fig 5.15 Continuity equation applied to Hazir khal

The continuity equation can be discretized as:

$\Delta Q / \Delta x + \overline{W}(\Delta h / \Delta t) = 0$ .. ..(5.2) or $(Q_2 - Q_1)/\Delta x + \overline{W}(\Delta h/\Delta t) = 0$

or $(Q_2 - Q_1)\Delta t + \overline{W}\Delta h \Delta x = 0$

where, Q_1 = Discharge at closed end of Khal

Q_2 = Discharge at the culvert

W_H = Width of water surface during HWL, m

W_l = Width of water surface during lowest allowable depth, m

$\overline{W}$ = Average width of water surface during a tide, m

Δx = Length of the Khal from culvert to the closed end, m

Δh = Rise of water level from lowest allowable level to HWL with time Δt, m

Δt = Time

With the boundary condition, $Q_1 = 0$ at the closed end of the Khal, the equation reduces to:

$Q_2\Delta t = -\overline{W}\Delta h\Delta x = 0$

or $\Delta V = -\overline{W}\Delta h\Delta x = 0$ . ...(5.3)

(the negative sign implies that the flow is in opposite direction from upstream to downstream)

where, ΔV= Available volume of water during each tide, m^3

The gate will be kept closed at ebb tides to avoid draining out of tidal water and open at flood tides to retain tidal water during the dry season. In the analysis, the cross section of the Khal was considered uniform. The design made by LGED (2004) also shows a uniform cross-section of the Khal. It was also assumed that the Khal has a negligible slope. The bottom width of the Khal is 8.3 m and side slope is 1:1.5. The lowest allowable water level was found to be 1.0m PWD, which is suitable for survival of fishes (Shrimp, Koi, Magur, Shing, Shoul etc) and for country boat plying. Based on the above data and assumptions, equation (5.4) was used to calculate the available volume of water during each tide. It may be noted here that ADB, BWDB & WARPO (2004) used a similar method to estimate the availability of surface water during average tide in existing excavated Khals in Narail and Chenchuri beel subproject areas. As discussed earlier, tidal data was collected for 16 hrs at 1 hour interval in a day, meaning that the whole tidal cycle was not covered. For the analysis, it was assumed that high water level during each flood tide in a day was the same. Tables 5.7-8 show the retained volume of water at different tidal levels at different times and months during the dry season.

Table 5.7 Volume of surface water available during Dec-Jan daily

	Type	Water level (m PWD)	Difference in Water Level, Δh (m)	Length of the Reach, Δx (m)	Water surface Width (m)	Average water surface width, W (m)	Available volume of Water per tide, ΔV (m³)	Volume of Water daily (m³)	Month and decade
Neap	LWL	1	0.61	1200	9.63	10.04	7349	14699	Dec-2nd
	HWL	1.61		1200	10.45				
Mid of neap-spring	LWL	1	0.67	1200	9.63	10.08	8104	16208	Dec-3rd
	HWL	1.67		1200	10.53				
	LWL	1	0.75	1200	9.63	10.13	9120	18240	
	HWL	1.75		1200	10.63				
	LWL	1	0.75	1200	9.63	10.13	9120	18240	
	HWL	1.75		1200	10.63				
	LWL	1	0.73	1200	9.63	10.12	8865	17730	
	HWL	1.73		1200	10.61				
	LWL	1	0.79	1200	9.63	10.16	9631	19263	
	HWL	1.79		1200	10.69				
Spring	LWL	1	0.88	1200	9.63	10.22	10792	21584	
	HWL	1.88		1200	10.81				
	LWL	1	0.89	1200	9.63	10.23	10922	21844	
	HWL	1.89		1200	10.82				
Mid of Spring-Neap	LWL	1	0.56	1200	9.63	10.01	6724	13448	
	HWL	1.56		1200	10.38				
Neap	LWL	1	0.67	1200	9.63	10.08	8104	16208	Jan-1st
	HWL	1.67		1200	10.53				
	LWL	1	0.73	1200	9.63	10.12	8865.12	17730.24	
	HWL	1.73		1200	10.61				
	LWL	1	0.72	1200	9.63	10.11	8737	17475	
	HWL	1.72		1200	10.59				
Mid of neap-spring	LWL	1	0.67	1200	9.63	10.08	8104	16208	
	HWL	1.67		1200	10.53				
	LWL	1	0.73	1200	9.63	10.12	8865	17730	
	HWL	1.73		1200	10.61				
	LWL	1	0.77	1200	9.63	10.15	9375	18751	
	HWL	1.77		1200	10.66				
Spring	LWL	1		1200	9.63	10.17	9760	19520	
	HWL	1.8	0.8	1200	10.70				
	LWL	1	0.9	1200	9.63	10.23	11052	22104	
	HWL	1.9		1200	10.83				
	LWL	1	0.95	1200	9.63	10.27	11704	23408	Jan-2nd
	HWL	1.95		1200	10.90				
	LWL	1		1200	9.63	10.27	11704	23408	
	HWL	1.95	0.95	1200	10.90				

Table 5.8 Volume of surface water available during March-April in each tidal cycle

	Type	Water level (m PWD)	Difference in Water Level, Δh (m)	Length of the Reach, Δx (m)	Water surface Width (m)	Average water surface width, W (m)	Available volume of Water per tide, ΔV (m³)	Volume of Water daily (m³)	Month and decade
Mid of spring-neap	LWL	1	0.95	1200	9.63	10.27	11704	23408	Mar-2nd
	HWL	1.95		1200	10.90				
	LWL	1	0.66	1200	9.63	10.07	7978	15956	
	HWL	1.66		1200	10.51				
Neap	LWL	1	0.74	1200	9.63	10.13	8992	17985	
	HWL	1.74		1200	10.62				
	LWL	1	0.85	1200	9.63	10.20	10404	20808	
	HWL	1.85		1200	10.77				
Mid of neap to spring	LWL	1	0.93	1200	9.63	10.25	11443	22885	
	HWL	1.93		1200	10.87				
	LWL	1	0.93	1200	9.63	10.25	11443	22885	Mar-3rd
	HWL	1.93		1200	10.87				
	LWL	1	0.91	1200	9.63	10.24	11182	22364	
	HWL	1.91		1200	10.85				
	LWL	1	0.97	1200	9.63	10.28	11966	23932	
	HWL	1.97		1200	10.93				
Spring	LWL	1	0.97	1200	9.63	10.28	11966	23932	
	HWL	1.97		1200	10.93				
	LWL	1	0.97	1200	9.63	10.28	11966	23932	
	HWL	1.97		1200	10.93				
	LWL	1	0.99	1200	9.63	10.29	12228	24457	
	HWL	1.99		1200	10.95				
Mid of spring-neap	LWL	1	0.97	1200	9.63	10.28	11966	23932	
	HWL	1.97		1200	10.93				
	LWL	1	0.99	1200	9.63	10.29	12228	24457	
	HWL	1.99		1200	10.95				
	LWL	1	0.95	1200	9.63	10.27	11704	23408	
	HWL	1.95		1200	10.90				
Neap	LWL	1	0.61	1200	9.63	10.04	7349	14699	Apr-1st
	HWL	1.61		1200	10.45				
	LWL	1	0.71	1200	9.63	10.11	8611	17222	
	HWL	1.71		1200	10.58				
Mid of neap to spring	LWL	1	0.85	1200	9.63	10.20	10404	20808	
	HWL	1.85		1200	10.77				
	LWL	1	0.87	1200	9.63	10.21	10663	21325	
	HWL	1.87		1200	10.79				
	LWL	1	0.97	1200	9.63	10.28	11966	23932	
	HWL	1.97		1200	10.93				
	LWL	1	1.04	1200	9.63	10.33	12838	25775	
	HWL	2.04		1200	11.02				
	LWL	1	1.07	1200	9.63	10.35	13285	26570	

	Type	Water level (m PWD)	Difference in Water Level, Δh (m)	Length of the Reach, Δx (m)	Water surface Width (m)	Average water surface width, W (m)	Available volume of Water per tide, AV (m3)	Volume of Water daily (m3)	Month and decade
	HWL	2.07		1200	11.06				Apr-1st
	LWL	1	0.99	1200	9.63	10.29	12228	24457	
	HWL	1.99		1200	10.95				
	LWL	1	1.03	1200	9.63	10.32	12756	25511	
	HWL	2.03		1200	11.01				
	LWL	1	1.03	1200	9.63	10.32	12756		
Spring	HWL	2.03		1200	11.01			25511	

5.3.2 Retention requirement to meet agricultural water demand

Dry season water requirement

Water requirement in the dry season includes both consumptive and non consumptive uses. Consumptive uses include irrigation, domestic and evaporation requirement and non consumptive uses include water requirement for fisheries and country boat plying.

Consumptive use

In Dry season wheat and Boro rice is the major crop. Agricultural water demand has been estimated from Table 5.9 In the absence of evapotraspiration rate of Gopalganj area data from near by station which is situated in Faridpur has been used here.

Table 5.9 10-day average evapotranspiration (mm/day) at Faridpur

Month	Decade	ET_0
December	1	2.18
	2	2.12
	3	2.02
January	1	2.11
	2	2.16
	3	2.27
February	1	2.79
	2	3.04
	3	3.1
March	1	4.01
	2	4.51
	3	4.58
April	1	5.55
	2	5.6

Source: Mondal (2005)

In the absence of seepage and percolation data at Gopalganj, data of the nearest place Pangsha, Rajbari was used in the analysis According to Mondal (2000) seepage and percolation loss is 5.3 mm/day in Pangsha, Rajbari. Mondal (2005) used a 70% water use efficiency for Ganges delta within Bangladesh portion The study area is situated in the Ganges delta within Bangladesh. Hence, an irrigation efficiency of 70% was used to estimate the demand for irrigation The irrigation requirement was thus calculated as·

Irrigation requirement = (ET+S & P)/.7

The irrigation requirement was multiplied by the whole area under dry season crop cultivation to estimate the daily water requirement for irrigation According to LGED (2004), 100% land area under land type F2 (0.9 m<d<1 8 m) and F3 (d>1 8 m) and 80% of land area under land type F1 (0.3 m<d<0.9 m) will be cultivated for HYV Boro after completion of the project. According to the local people of Munshir char village, they will cultivate Boro in F2 and F3 lands, which would mean almost 126.5 ha area to be brought under HYV Boro cultivation in Munshir char village in the post project condition. This estimate of cultivable land was used in calculating the irrigation water requirement Evaporation data was collected from the BWDB of Faridpur (station ID- CL406) for the year 2007-2008

The daily water requirement for the domestic and drinking purpose was estimated from the survey data. Table 5.10 presents water requirements for the drinking and domestic purpose.

Table 5.10 Water requirement for drinking and domestic purpose

Total no of HH	% of HH using Hazir Khal for drinking and domestic purpose	No of HH	No of Pots	Volume of each pot (L)	Total volume of water	Volume of water extracted from khal (L)	Volume of water extracted from khal (m3)
225	45	101	6	16	96	9720	9.72

Source Field Survey (2008)

Table 5.11 summarizes the daily water requirements for different consumptive water uses, as discussed above, during the dry season.

Table 5.11 Daily water requirement during dry season

Month	Decade	Evapotranspiration, mm/day	Seepage & percolation loss, mm/day	ET_0+S&P, mm/day	(ET_0+S&P)/.7, mm/day	Area to be cultivated, ha	Total irrigation water requirement, m^3	Domestic water requirement, m^3	Evaporation, m^3	Total demand of water, m^3
December	1	2 18	5 3	7.48	10 69	126.5	13517	9 72	14.58	13542
	2	2 12	5.3	7 42	10.60	126.5	13409	9.72	14.58	13433
	3	2.02	5 3	7.32	10 46	126.5	13228	9 72	14.58	13253
January	4	2.11	5.3	7 41	10.59	126.5	13391	9.72	13.5	13414
	5	2.16	5.3	7 46	10.66	126.5	13481	9.72	13.5	13505
	6	2.27	5.3	7.57	10.81	126.5	13680	9.72	13.5	13703
February	7	2 79	5.3	8.09	11.56	126 5	14620	9.72	10.48	14640
	8	3.04	5.3	8.34	11.91	126.5	15072	9.72	10.48	15092
	9	3.1	5.3	8 4	12.00	126 5	15180	9.72	10.48	15200
March	10	4.01	5.3	9.31	13.30	126 5	16825	9.72	23.33	16858
	11	4.51	5 3	9.81	14 01	126.5	17728	9.72	23.33	17761
	12	4 58	5.3	9 88	14.11	126.5	17855	9 72	23.33	17888
April	13	5.55	5 3	10.85	15 50	126.5	19608	9 72	32.64	19650
	14	5 6	5.3	10.9	15.57	126.5	19698	9 72	32.64	19740

Minimum depth requirement (non consumptive use)

A minimum depth of water should be maintained in the khal for existence of natural fisheries and for country boat plying. According to Harun (2005), suitable water depth for Cat and Jeol fish is 0.8 m and the growth rate of carp decelerated below 1 8 m. During field visit it was found that Cat and Jeol fish (i.e Koi, Shing, Magur, Shol, and Taki) and other small fishes are available in the Khal during dry season as the water level is low due irrigation of Boro 1m PWD (Bed level .19 m PWD) is suitable for both the purpose. Agriculture is the main occupation of the people of the study area. Hence irrigation demand gets priority than other non-consumptive use like fish and country boat plying. If the water level is maintained 1 m PWD (bed level 0.19 m PWD) it will serve all the purposes and also provide required water for irrigation during dry season.

5.3.3 Irrigable area

Irrigation in the study area is totally dependent on surface water, with low lift pumps being used for irrigation According to LGED (2004), the subproject will mainly have benefits on Aman and Boro crops production. It will protect mainly Aman crop from early flood during pre-monsoon period (up to the end of June) by remodeling of existing culvert on Hazir Khal, and the water retention structure on Hazir khal will remain closed during the lean period to conserve water for Boro production People of the study area want to retain tidal water at flood tides during the dry season for Boro cultivation in a total of 126.5 ha of land. But the irrigable area depends on the availability of water. The available amount of water is the lowest during neap tide Hence, an analysis was made of the area that can be served by the available amount of water during neap tide. Tables 5.12 and 5.13 illustrate how much water is available during the dry season and percentage of area that can be served.

Table 5.12 Available water during neap and spring tide and percentage of area that can be served during Dec-Jan

Month and decade		Volume of Water each tide, m^3	Volume of Water daily tide, m^3	Demand of water during dry season, m^3	Excess amount of water, m^3	Area served by available water, %
Dec-2nd	Neap	6861.28	13722.56	13433.30	289 26	100
Dec-3rd	Mid of neap-spring	8104.32	16208.64	13252.59	2956.05	100
		9120 00	18240.00	13253.59	4986.41	100
		9120.00	18240.00	13254.59	4985 41	100
		8865.12	17730.24	13254.59	4475.65	100
		9631.68	19263.36	13255.59	6007 77	100
	Spring	10792 32	21584.64	13255.59	8329.05	100
		10922.08	21844.16	13256.59	8587.57	100
	Mid of Spring-Neap	6724.48	13448.96	13256.59	192.37	100
Jan-1st	Neap	8104.32	16208.64	13414 15	2794 49	100
		8865 12	17730 24	13415.15	4315.09	100
		8737 92	17475 84	13416 15	4059.69	100
	Mid of neap-spring	8104.32	16208.64	13417.15	2791.49	100
		8865.12	17730.24	13418 15	4312.09	100
		9375.52	18751.04	13419.15	5331.89	100
	Spring	9760.00	19520.00	13420.15	6099.85	100
		11052.00	22104.00	13421.15	8682 85	100
		11704.00	23408.00	13504 51	9903.49	100
Jan-2nd		11704.00	23408 00	13505 51	9902 49	100

Table 5.13 Available water during neap and spring tide and percentage of area that can be served during March-April

Month & decade		Volume of Water each tide, m³	Volume of Water daily tide, m³	Demand of water during dry season, m³	Excess amount of water, m³	Area served by available water, %
Mar-2nd	Mid of spring-neap	11704.00	23408.00	17761.12	5646.88	100
	Neap	7978.08	15956.16	17761.12	-1804.96	89.84
		8992.48	17984 96	17761 12	223.84	100
		10404 00	20808 00	17761.12	3046.88	100
	Mid of neap to spring	11442.72	22885.44	17761 12	5124.32	100
Mar-3rd		11442.72	22885.44	17887.62	4997.82	100
		11182.08	22364.16	17887.62	4476 54	100
	Spring	11965 92	23931.84	17887.62	6044 22	100
		11965.92	23931 84	17887 62	6044 22	100
		11965.92	23931.84	17887 62	6044.22	100
		12228.48	24456.96	17887.62	6569.34	100
	Mid of spring-neap	11965 92	23931.84	17887 62	6044.22	100
		12228 48	24456.96	17887 62	6569.34	100
		11704.00	23408.00	17887.62	5520.38	100
Apr-1st	Neap	7349.28	14698.56	19649.86	-4951.30	74.80
		8610.88	17221.76	19649.86	-2428.10	87 64
	Mid of neap to spring	10404.00	20808.00	19649 86	1158.14	100
		10662.72	21325.44	19649 86	1675.58	100
		11965.92	23931.84	19649 86	4281.98	100
		12887.68	25775.36	19649.86	6125.50	100

Month & decade		Volume of Water each tide, m^3	Volume of Water daily tide. m^3	Demand of water during dry season, m^3	Excess amount of water. m^3	Area served by available water, %
Apr-1st	Mid of neap to spring	13285.12	26570.24	19649.86	6920 38	100
	Spring	12228 48	24456.96	19649.86	4807.10	100
		12755.52	25511.04	19649 86	5861.18	100
		12755 52	25511.04	19649.86	5861.18	100

From the above table it is seen that the required amount of water is higher than the available water in the khal at each tide during the dry season. But if the gate remains open during both the flood tides, the storage will be double which is enough to meet the demand. From Table 5 17 it is clear that during December-January the demand is relatively low and the available storage is enough to meet the demand even at neap tide.

On the other hand, the available water is not enough to serve the intended area during the 2nd decade of March and the 1st decade of April at neap tide. Water demand is high at this period. The worst situation happens when neap tide coincides with the highest demand The highest demand occurs towards the end of March and up to the 1st week of April. From Table 5.18 it is seen that during the 2nd decade of March, 89% of land can be served by the available amount of water and 1804 m^3 water is required to irrigate the rest of the area On the other hand, during the time from mid of spring to neap there is available water for irrigation and other purposes and just one day before neap tide there is 5646 m^3 of excess water in the khal. If the gate is closed during mid of spring-neap and remain closed during neap tide, the excess water can be stored to meet up the deficiencies in irrigation. A low lift pump can be used to pump water inside the gate from outside at that period to cope up with the water demand at neap tides.

During the 1st decade of April at neap tide, water demand is higher than the available volume of water and 74% area can be irrigated at that time. During April at neap tide, two days are found when water availability is lower than the demand. At that time 7379 m^3 (4951+2428) of excess water is required for 100% irrigation On the other hand just one day before neap tide, 5520 m^3

of excess water remain in the khal after serving full irrigation and other demands. The gate can be closed before neap tide to store excess amount of water and at neap tide water can be pumped inside the khal from outside to meet the demand

From the above analysis, it is clear that water is to be stored twice daily to meet demand during the dry season. At neap tide during March and April the gate should be closed and water is needed to be pumped inside the khal from outside to meet the requirement of water. But during spring tide the volume of water in the khal at gated condition is higher than the required amount of water. Clearly, the gate operation during March and April at the transition period from spring to neap is very critical, implying that extra care is needed in management of the gate.

CHAPTER VI

DEVELOPMENT OF GATE OPERATION RULE FOR MULTI-PURPOSE USE OF HAZIR KHAL

This chapter discusses requirements of water control by the sluice gate in different seasons. development of a gate operation rule based on water retention requirement, seasonal water requirement, crop calendar, fish life cycle, saline water intrusion prevention, drainage requirement and people's opinion

6.1 Water Control and Supply Requirements

6.1.1 Prevention of saline water intrusion

Salinity intrusion starts during mid April in the study area and it damages the seedlings of Deep Water Aman The sluice gate is to be kept closed to prevent salinity intrusion from the mid of April to the end of June to save the crop

6.1.2 Creation of flooding for deep water rice cultivation during wet season

The gate will be kept closed during the monsoon to store rainfall-runoff for Deep Water rice cultivation. Local variety Aman and Aus are sown in medium high lands In the month of July, people harvest Jute and L.Aus and transplant Aman in relatively high lands. The required water for T.Aman cultivation is met from the surrounding flooded land

6.1.3 Culture fisheries

Creation of flooding in the agricultural land by closing the gate will facilitate culture fisheries The fish stocking starts during the 4th week of June and fish is harvested in late November.

6.1.4 Capture fisheries

Capture fish migration process from the river to the Khal or rice fields are partially hampered by construction of the earthen cross dam in the Khal during the flood season.

According to LGED (2004), there are various fish species in the Khal, such as Rui, Katla, Mrigel, Koi, Shing, Magur, Shol, Boal, Taki, Puti and Mola. A water level of 1 m PWD (bed level 0.19m PWD at culvert) is to be maintained in the Khal for survival of capture fisheries during the dry season.

6.1.5 Tidal water taping for rice cultivation during dry season

The local people irrigate Boro crops during the flood tide as the flow of water, during ebb tide is too low to irrigate the agricultural land. In the dry season, especially during the months of December-January, the flow is very low. On the other hand people are not able to cultivate Boro rice in all of the land due to lack of irrigation water. Water can be retained by closing the sluice gate for irrigation of Boro crop. It requires entry of tidal water during the flood tide and prevention of outflow during the ebb tide.

6.1.6 Domestic use

Storage of water by the gate also helps domestic activities like bathing, sanitation, cleaning, washing clothes and utensils, livestock watering and duck rearing in the study area Almost 95% of the people of the study area depend on Hazir Khal for using water in domestic activities During the dry season, most of the ponds are dried up, and tube well water gets lowered as well. But, the villagers can store water in the canal by means of the gate on Hazir Khal during the flood tide, which ensures water availability also in the ebb tide during the dry season, and enables the villagers to accomplish their domestic activities, livestock watering, and collection of drinking water at their desired times during the dry season. If the gate is not operated in such way, sometimes when the flow is very low in Hazir Khal, people are bound to go to the Shingair river, which is 1.5 km away from the study area This practice is an efficient management of water locally that serves the purposes beyond the official purposes of the project.

As groundwater is contaminated with arsenic and iron, Hazir Khal is the source of drinking water in the Munshir char Village. According to the survey, a total 45% of household depends on Hazir Khal for drinking water. Especially, the poor people depend on Hazir Khal for drinking purpose. During the dry season, it is possible to store required water for drinking purpose in the Khal by closing the gate.

6.1.7 Country boat plying

People use country boats to carry crops from the field and necessary commodities from hat and also for fishing Almost 70% people of Munshir char village have there own boats During the wet season, the sluice gate remains closed as a result people can not pass their boats through the culvert But they are able to use the boats for fishing (capture fisheries) inside the gate. Also people who live inside the gate are able to fetch crops from the field to their houses On the other hand, as the gate is kept open at the flood tide during dry season, people can easily transport goods and other necessary commodities and also can use the Khal for fishing (capture fisheries).

6.2 People's opinion on gate operation

People's opinion

The gate on Hazir Khal is the outcome of people's demand to LGED. According to the people they will get some additional facilities from the proposed gate. Table 6 1 shows the opinion of people regarding gate operation.

Table 6.1 People's opinion on gate operation

Month	Status of gate	Reasons	Cropping Pattern
Baishakh (Apr – May)	Closed	To Control saline water intrusion in that area.	Field Preparation for Aus / Aman
Jaistha (May – June)	Closed if there is no need	Same as above	Aus, / Aman + Fish
Ashar (june – July)	Open for few days	When turbid water enter in to the khal at mid of June	Aus, / Aman + Fish
Shraban (July – Aug)	Closed	Fresh water needed for production of Aus/ Aman.	Aus, / Aman + Fish
Bhadra (Aug – Sept)	Closed		Aus, / Aman + Fish
Ashwin (Sept – Oct)	Closed	To retain water in the field for growth of both crop and fish	Aus, / Aman + Fish
Kartik (Oct – Nov)	In the middle of the month gate is opened to drain out water from the field The gate will again be closed in he 1st week of November during ebb tide.	Opened for Harvesting fish and crop. Closed to prevent tidal flooding in the low and medium low lands where pulses are broadcast.	Harvest crop and fish
Aghrahayan (Nov – Dec)	Closed up to November	To prevent tidal flooding in the low and medium low lands where pulses are broadcast.	broadcast kalai
Paush (Dec – Jan)	Open during flood tide allowing entry of tidal water and gate remains closed during ebb tide to store water	Retain water for irrigation of Boro	Boro irrigation
Magh (Jan – Feb)	Open during flood tide allowing entry of tidal water and gate remains closed during ebb tide to store water	Retain water for irrigation of Boro	Boro irrigation
Falgun (Feb – March)	Open during flood tide allowing entry of tidal water and gate remains closed during ebb tide to store water	Retain water for irrigation of Boro	Boro irrigation
Chaitra (March – April)	Open during flood tide allowing entry of tidal water and gate remains closed during ebb tide to store water	Retain water for irrigation of Boro	Boro Harvesting

107394

The gate will be kept closed starting from mid April up to the month of June to prevent salinity intrusion in the agricultural land, especially during spring tide. In the month of July the local people will close the gate to flood the agricultural land where Deep Water Aman is cultivated. They will keep the gate closed up to month of November. They will open the gate in the month of November as flooding at that time causes harm to Deep Water Aman, which are at the flowering stage.

According to the local people, they will close the gate during the 2nd week of November to cultivate pulses in the low lands Flood tides during spring cause occasional flooding in the low lands and destroy the pulses From the month of December people will start storing water for irrigation, domestic and drinking purposes by allowing the entry of tidal water during flood tides and closing the gate during ebb tides. They will continue this practice during the whole Boro season from December to Mid of April.

Wet season operation requirement

Deep water Aman cultivated in the wet season requires flooding in the land for its growth. By closing the gate it is possible to maintain flooding in the land The local people have been practicing it for many years and now the installed gate will make it easier. The gate will be open during the month of November to drain out the flood water from the agricultural land, and to harvest culture fisheries

Dry season operation requirement

People will retain water by closing the gate during ebb tides in the dry season for irrigation purpose. People will also use the water for domestic and drinking purposes. The gate will be open during flood tides and closed during ebb tides. At the end of the dry season i e during mid April, the gate should be closed to prevent saline water intrusion in the study area.

Allowable flood level

During the field visit people indicated the allowable flood level on the installed staff gage on Hazir Khal and the indicated level correspond to 3.0 m PWD. If the water level exceeds 3.0 m PWD the gate should be open to drain out flood water to save the crop, especially the HYV Aman. On the other hand, the surrounding community will also be affected if the water level exceeds 3.0 m PWD. Figure 5 6 also illustrates that maximum flooding of agricultural land takes place at a flood level of 3.0 m PWD.

Extreme events

The gate operation rule developed in this study covers the operation of the gate round the year But there would be some extreme cases once in a several years when the gate should be kept closed at any cost to avoid uncertain damages

According to the local people and LGED (2004), salinity intrusion reaches its toxic level at mid of April. But the worst situation will take place if the salinity intrusion starts from the end of March as the water demand is highest in March and April. Presently in the study area salinity intrusion starts from March and reaches toxic level during mid of April. However, there are some sites near the study area where salinity level reaches the toxic limit at the end of March. In such cases, there are possibilities of partial loss in Boro production, as found from the survey, and should salinity intrusion starts in late March in the study area, the gate should be closed earlier. According to the local people, they will close the gate as soon as they understand that the salinity level has reached the toxic level.

According to the local people, they will also close the gate whenever there is any depression in the Bay of Bengal, since the water level gets higher than the normal level flooding the agricultural land, which is harmful for the standing crops in the field. In the Bay of Bengal the depression occurs during the period of April-May and in month of November. April-May is the season of harvesting of Boro and broadcasting of Deep Water Aman and flooding in the agricultural land is not allowed at that time. On the other hand month of November is the periods of Aman harvesting and cultivation of pulses and flooding is also harmful for crop at that time. Hence the gate will be kept closed during the depression period.

6.3 Rule for Gate Operation

6.3.1 Provision for salinity prevention

The local people observe the salinity condition in the water by their experience and knowledge. Towards the end of the dry season the gate will be closed to prevent saline water intrusion in the study area. As discussed in Chapter 5, salinity intrusion starts in that area during month of March and reaches the toxic level in the middle of April such that the water becomes unsuitable for irrigation and other uses.

6.3.2 Provision of retention during wet season

The sluice gate will be closed to retain water to flood the agricultural land during the wet season. The retention of monsoon rainfall runoff is required for cultivation of monsoon rice in that area. LGED (2004) also emphasizes that the subproject will mainly have benefits on Aman and Boro crops production. It will mainly protect Aman crops from early flood during pre-monsoon period (up to the end of June). Due to implementation of the project, the net incremental cereal production will be 1,349.1 tons for the increased production of B Aman by 526 tons Rahman (2008) estimated the depth of required water for Deep Water Aman cultivation, which is presented Table 6.2.

Table 6.2 Estimated desired water levels during monsoon season

Months	Average flooding depth (cm)			
	High land, F0	Medium high land, F1	Medium low land, F2	Low land, F3
April (2nd week)-May	Saturation	Saturation	Saturation to 10	Saturation to 30
June	Saturation	Saturation	46	107
July (1st week)	Saturation	15	61	122
July (3rd week)	1	43	89	150
August (1st week)	3	45	91	152
August (3rd week)	8	50	96	157
August (4th week)	8	50	96	157
September	13	55	101	162
October	4	46	92	153
November	-	31	77	138

Source: Rahman (2008)

The gate will be closed in the middle of April to prevent saline water intrusion and it will be kept closed up to the month of November. The gate will prevent salinity intrusion up to the month of June and after that it will used for retaining desired level of water in the agricultural land. The retained water also creates a scope for culture fisheries in the flooded agricultural land. Fingerlings of thai sarputi, rohu, catla, were preliminarily stocked in the Khal during the 4th week of June, and later on reared in the inundated rice field up to November. Fish can feed on natural food and by-products available in rice fields Table 6.3 shows the salinity intrusion period, crop calendar, culture fisheries and status of gate

Table 6.3 Salinity intrusion period, Crop calendar during monsoon, culture fisheries and status of the gate

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sluice gate closed				● ●	● ● ●	● ● ●	● ●	● ● ●	● ● ●	● ●		
Salinity intrusion period			▬ ▬	▬	▬	▬						
Salinity concentration			Permissible	Toxic	Toxic	Toxic						
B. Aman				═══	═══	═══	═══	═══	═══	═══	═══	
B. Aus				▪ ▪	▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪					
T Aman								▪ ▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪	▪ ▪ ▪ ▪	▪ ▪
Culture fisheries spawning period						● ●	●					
Growing stage of culture fish							= = =	= = = = =	= = = = =	= = = = =	= =	
Harvesting period of fish											▪ ▪ ▪	
Opening of gate										▪		

6.3.3 Provision of drainage during wet season

During the month of November the gate will be open to drain out water from the field. The time of gate opening depends on the flowering stage of Aman rice Generally Aman rice reaches its flowering stage during November (in Bengali calendar month of *Kartik*). On the other hand fishes are harvested during the end of November to December. Flooding in the agricultural land makes it difficult to catch fish from the large inundated land. As a result draining out of water from the flooded land is required during the end of October or 1st week of November with provision of fish net at the Khal.

On the other hand if the water level in the Khal exceeds 3 m PWD, the gate should be open to drain out the excess flood water. During field visit it has been identified that 3 m PWD during month of August is desirable, but more than 3 m PWD is harmful for the crops and surrounding community.

6.3.4 Provision for entry of tidal water during dry season

The present problem regarding water use in the study area is the scarcity of water during the dry season. Boro rice and wheat are cultivated in this season in the study area. HYV Boro is cultivated in medium high lands, medium low lands and low lands. Wheat is cultivated in the high land as it requires relatively small amount of water. People have to irrigate during the flood tide as the flow of water is too low during the ebb tide. Low lift pumps (LLPs) are used for irrigation in the study area. People want to store water during flood tides to use it during ebb tides. So the gate will be open during the period of flood tides and will be closed during the period of ebb tides. Presently the farmers are not able to cultivate Boro in most of the land because of scarcity of irrigation water. Retention of water by closing the gate during the ebb tide will create scope for irrigation in most of the land. According to LGED (2004) the sub-project will increase HYV Boro production by 775.1 tons. Table 6.4 illustrates the crop calendar during the dry season and desired status of opening or closing the sluice gate

Table 6.4 Crop calendar during dry season and status of gate

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Salinity intrusion period			▬▬	▬▬	▬▬ ▬	▬ ▬						
Closing of gate				▬	▬▬▬	▬▬▬	▬▬▬	▬▬▬	▬▬▬	▬▬▬	▬	
Open during flood tide and closed during ebb tide	• • • •	• • • • •	• • • • •	• •								• • • •
Broadcast pulses	▬▬▬	▬▬▬									▬▬▬	▬▬▬
HYV Boro	═══	═══	═══	═								═══
Wheat	- - -	- - - -	- -									- - -

6.3.5 Round the year gate operation rule

As discussed in Chapter IV, the local people have constructed the earthen dam on Hazir Khal for 43 years to prevent salinity intrusion at the end of dry season and retain rainfall-runoff during monsoon period for cultivation of Deep Water Aman. The villagers demanded for a sluice gate at the culvert, because scarcity of construction material for the dam was increasing day by day and also the dam was washed away several times during the past 43 years In response to the people's demand, LGED started Balajtala-Kalmadanga sub-project in the year 2004, which included construction of a sluice gate on Hazir Khal. The project was completed in the year 2008

People need to operate the sluice gate for different purposes in different times of the year; hence an operation rule for the gate will be helpful for them to serve the purposes. The operation rule discussed below was developed in this study as per the opinions of the local people During the wet season the operation of the gate will depend on the time i.e season, crop calendar and drainage requirement. The water level should not exceed 3.0 m PWD inside the gate during the wet season; otherwise the gate should be open to drain out the excess water.

During the month of November operation of the gate will be the most critical Drainage of flood water is required to keep the desired water level for the Aman rice, which is at the flowering stage and to harvest culture fisheries The gate will be closed during the flood tide to avoid inflow of tidal water and inside water level will be maintained at 1.9 m PWD

On the other hand during the dry season operation of the gate depends on the tidal condition i.e. flood & ebb tide and neap & spring tide In the dry season, the gate will be operated daily to retain water for Boro irrigation and other purposes. The gate will be open during flood tides and closed during ebb tides. It should be carefully observed that the inside water level (IWL) should be lower than the outside water level (OWL) when the gate remains open during flood tides. If the inside water level is greater than outside water level, the gate should not be opened. Again when the tidal cycle shifts from spring to neap the water level starts to decrease. Hence, a proper care during gate operation is needed at that time. Because at that time, there are strong possibilities that IWL will be higher than the OWL even during flood tides. On the other hand when the tidal cycle shifts from neap to spring, the water level starts to increase and generally it is relatively safe to open the gate at flood tides as the IWL is less than the OWL. Table 6.5 shows the operation rule for the sluice gate

During field survey, the desired water levels in different months of the year were collected from the local people. The scale prepared for measurement of tidal water levels was used for this purpose. The local people were asked to indicate the desired water depths in different months on the scale. The average water levels for the months of December, January, March, July and August were identified through a combination of measured data and people's opinions. Figure 6.1 summarizes the water levels in different months and the crop calendar. A discussion of the figure is provided below.

April

The gate will be kept closed from the 15th April to prevent salinity intrusion. The expected water level at that time, according to the local people, is 1 9 m PWD in the Khal. Water requirement for irrigation up to 1st week of April and reduction of water will be caused by evaporation and domestic use.

May

The gate will remain closed. The expected water level is 1.9 m PWD. Loss of water is due to evaporation and domestic use.

June

The gate will be closed and the desired water level inside the Khal is 2 m PWD according to the local people. Loss of water is due to evapotranspiration from the agriculture land and domestic water use

July

The desired water level inside the gate is 2.5 m PWD according to the local people. Most of the agriculture land will be flooded at that time. Aus and Jute is harvested at that time.

August

The desired level of water during this period is 2 52 m PWD. T. Aman is transplanted at that time The gate will be open if the water level crosses 3.0 m PWD

September

During the month of September, the desired water level is 2.55 m PWD.

October

The desired water level during this period is 2 45 m PWD and contribution from runoff is 0.04 cm. Depending on the flowering stage of Deep water Aman, the gate will be open at the end of October.

November

The gate will be open in the 1st week of November to drain out excess flood water from agricultural lands. The desired water level at gated condition is 1.9 m PWD.

December -March

The gate will be open at flood tides and closed during ebb tides daily to store water for irrigation and other purposes during this period. The average water level during flood tides is -1.76 m PWD, 1.81 m PWD and 1.93 m PWD in December, January and March respectively. According to the local people during February water level remains about 1 85 m PWD Water demand is high during this period and the highest demand occurs during March. Loss of water is due to irrigation, domestic water requirements and evaporation.

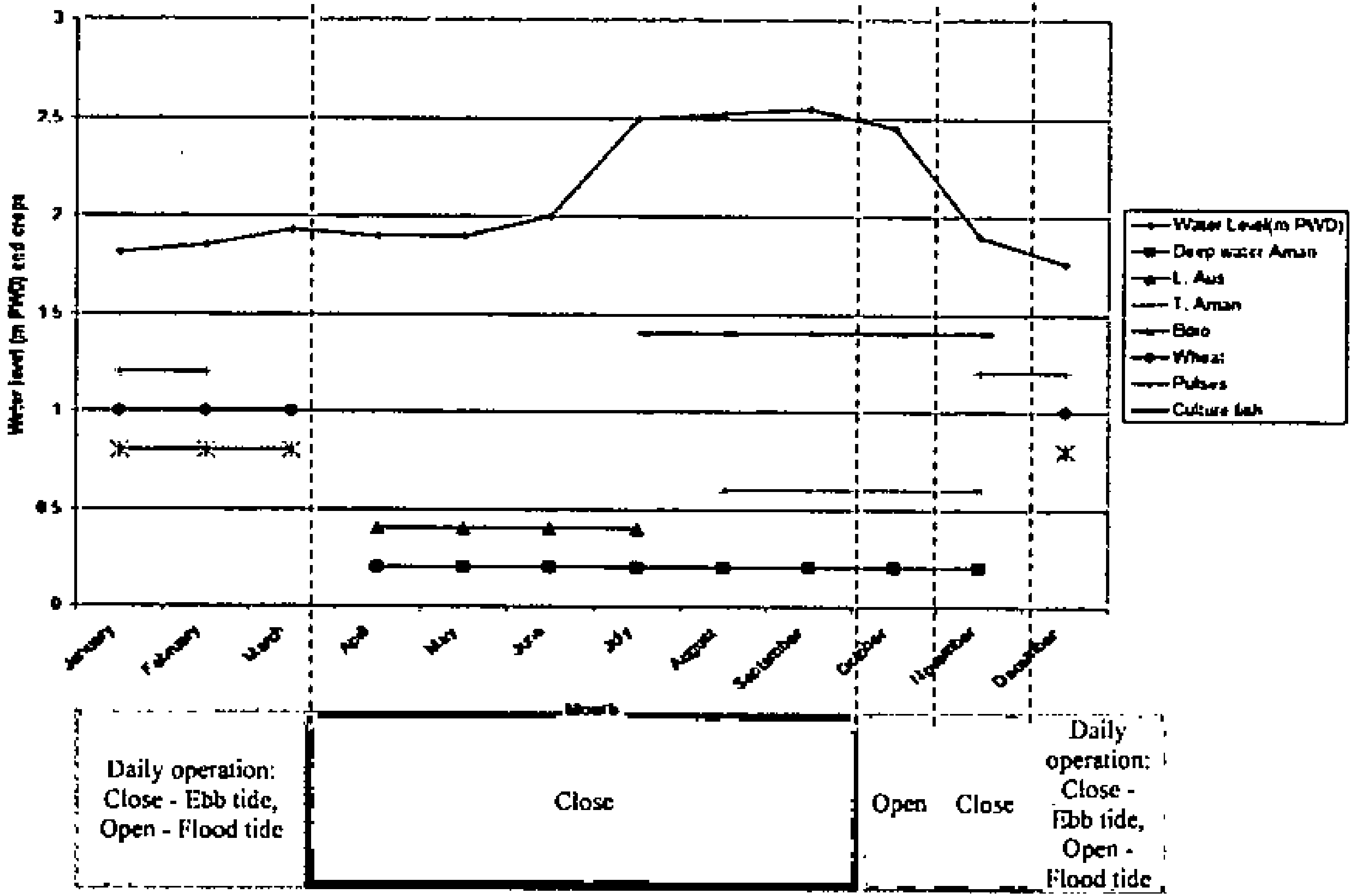


Fig 6.1 Monthly water level and seasonal crops

Table 6.5 Round the year Gate operation rule

(a) Operation rule for the period of Mid April to October

Continuous gate closure			Intermittent gate opening			Uses
Indicator for closing	Period of closing	Main purpose	Indicator for opening	Period of opening	Main purpose	
Gate is to be closed when salinity concentration exceeds 0.75 ds/m	As long as inside water level remain below 3.0 m PWD.	Prevention of salinity intrusion and retention of rainfall runoff	Gate is to be opened when inside water level exceeds 3.0 m PWD	As long as inside water level remains above 3.0 m PWD and inside water level is greater than outside tide level	Drainage of excess flood water	Flooding for Deep water Aman cultivation, water supply for HYV Aman cultivation, natural fisheries, culture fisheries domestic and drinking water,
			Gate is to be opened when salinity concentration remain below 0.75 ds/m and inside water level is less than outside tide level	As long as inside water level remains below outside tide level	To allow inflow of non-saline water	

(b) Operation rule for the month of November

Gate closure			Gate opening			Uses
Indicator for closing	Period of closing	Main purpose	Indicator for opening	Period of opening	Main purpose	
Flood tide	Entire flood tide	To prevent inflow of tidal water	Ebb tide, inside water level is greater than 1.9 m PWD and inside water level is greater than outside tide level (Three indicators are to be satisfied simultaneously)	During ebb tide as long as inside water level remains above 1.9 m PWD	Drainage of flood water from low lying lands	Harvesting of Deep water and HYV Aman, Harvesting culture fish and cultivation of pulses

Continued.

c) Operation rule for the period of December to Mid April

Daily gate closure for each of two tides in a day			Daily gate opening for each of two tides in a day			Uses
Indicator for closing	**Period of closing**	**Main purpose**	**Indicator for opening**	**Period of opening**	**Main purpose**	
Start of ebb tide	Entire ebb tide	To prevent outflow	When inside water level is less than outside water level during flood tide	The period when inside water level remains lower than outside tide level during flood tide	To allow inflow of tidal water	Irrigation of Boro rice and wheat, domestic purposes, Drinking water, homestead gardening, duck rearing, natural fisheries, and country boat plying.
Start of flood tide and inside water level is greater than outside tide level	Part of flood tide duration when inside water level is greater than outside tide level					

Domestic purpose: Bathing, cleaning, washing, water for cooking, sanitation and livestock watering and cleaning.

6.4 Contribution of current research to SAIWRPMP

This thesis work was conducted under the support of the South Asian Water Fellowship (SAWA) program of the Crossing Boundaries (CB) Project of IWFM, BUET. The research program of the CB project is being carried out in collaboration with an on-going project of BWDB and LGED so that the research findings have useful contributions to the project, and help enhance sustainable water management in the area. The project is the "Southwest Area Integrated Water Resources Planning and Management Project" (SAIWRPMP), which is co-funded by the Asian Development Bank, the Government of the Netherlands, and the Government of Bangladesh, and implemented by BWDB and LGED (ADB, BWDB and WARPO, 2004). The selected districts in the southwest areas for the project are Faridpur, Gopalganj, Jessore, Magura, Narail, and Rajbari. The selected study region for the research program of the CB project covers the districts of Narail, Gopalganj and Faridpur.

Present study was focused to small – scale community managed schemes aimed at resolving local water management problems to support fisheries and irrigation An operation rule for the proposed sluice gate was developed in this study to create opportunity for multi purpose use of Hazir Khal. The operation rule is intended to facilitate fisheries, wet season flooding requirement for cultivation of monsoon rice and dry season irrigation requirements for rice cultivation, thus satisfying the local people's needs. The operation rule also facilitates domestic activities, homestead gardening, duck rearing, country boat plying etc This will enhance the livelihood condition of the local people and as the operation rule was developed according to the local people's need The local people's participation was emphasized in the study to resolve existing conflicts and to eradicate poverty by multiple uses of water resources The research program of CB project emphasizes research with an impact. Present study is an attempt towards this Implementation of the proposed gate operation rule through LGED would contribute to the objective of the SAIWRPMP.

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The conclusions of the study can be summarized as –

- Retention of monsoon rainfall-runoff by seasonal cross dams on Hazir Khal to create flooding in agricultural land is an exceptional water management practice Flooding of agricultural land is made to cultivate a local variety of monsoon rice and also for fish culture. This local water management practice is an example of using agricultural land for both rice production and fish culture Another remarkable aspect is that a local variety of long stem monsoon rice is being preserved by the community through this practice. People prefer to cultivate the local variety monsoon rice instead of high yield variety rice in the study area, as it has some special quality like – low production cost, high protein content, dietary satisfaction, high selling price, environmental benefit and tolerance to high flooding.
- The proposed water retention structure in the khal is the result of community demand. The local people will manage the gate according to their traditional practice. The gate will add some facilities during the dry season water management. According to people's opinion a rule for operation of the gate was developed in this study.
- The tidal characteristic of the study area was studied from the measured data The study shows that spring and neap ranges are higher in March-April than December-January. On the other hand there is little variation in spring and neap ranges during the months of July-August. The phase shift is around 1 hr.
- The volume of water that can be retained by closing the gate during each tide was estimated. The lowest volume of available water in each tide at neap occurs during the month of December and the volume is 7349 m^3. But the flood tide occurs twice daily meaning that water can be stored twice daily and the available

volume becomes double. During December- January the water demand is not so high and the available water is enough for irrigation and other requirements. On the other hand during March-April the demand of water is high and during neap tide the available volume of water is not sufficient for irrigating 100% land under Boro cultivation.

- The gate operation rule was developed in the study by examining the crop calendar, fish life cycle, tidal cycle, drainage requirement, water retention requirement, minimum depth requirement and opinion of local people. Sluice gate will be closed from mid April to avoid salinity intrusion in the study area up to the month of June and after that the gate will remain closed to store rainfall-runoff for Deep Water Aman cultivation. The gate will be open during October or the 1st week of November to drain out flood water from the land. But if the water level inside the gate exceeds 3 m PWD, the gate should be open. After draining out flood water the gate will again be closed during November to cultivate pulses (Kalai). Because during spring tide at flood tide the low lying land is flooded and damage pulses. From December to March the gate will be operated daily, with the gate closed during ebb tides and open during flood tides. Before opening the gate, it should be carefully checked that the IWL must be lower than the OWL. In addition to that the gate must be closed at neap tide during March-April to store enough water to meet the various demands, as the demand at that period is high and the available water during neap tide is not enough for irrigation and other requirements.
- People will get multiple facilities from the gate During the wet season people can cultivate Deep water Aman, L. Aus, T. Aman in relatively higher land and fish culture in the flooded land. At present the farmers are not able to cultivate Boro in most of the land due to scarcity of irrigation water. Retaining water by closing the gate will create a facility for irrigation during the dry season. On the other hand the khal is also a source of water for the domestic purpose. During the dry season as the khal is open at flood tide, country boat plying also gets facilitated during period. The retained water facilitates the domestic use like bathing, washing utensils, laundering, livestock watering and duck rearing.

7.2 Recommendations

Following recommendations are made:

- An operation rule was developed in this study for the sluice gate. LGED may take proper measure to ensure the implementation of the operation rule. LGED may hand over the authority of gate management to the Water Management Cooperative Association (WMCA) of Balajtala-Kalmadanga subproject. The WMCA will be responsible for operation of the gate LGED can monitor it regularly for better performance of the gate.
- In this study it was found that people use surface water, originally planned for irrigation purpose, to meet multiple needs After the installation of the gate people will get multiple benefits from the gate, which were not included in the project planning During planning and designing a water resource development project the multipurpose use of water body may be considered
- A low cost instrument for measurement of salinity intrusion should be provided in the study area to measure the concentration during the dry season and the WMCA will be responsible for monitoring and measuring the salinity concentration.
- A study on the impacts of the proposed gate operation rule on the study area can be undertaken after the installation of the gate control structure
- A detailed study on salinity intrusion characteristics and probable solution to the problems of irrigation for Boro due to early salinity intrusion can be undertaken.

References

Abernethy, C L., Jinapal, K., and Makin, I. W. (2001), Assessing the opinions of user of Water Projects, *The journal of the International Commission on Irrigation and Drainage*, Vol - 50(3).

ADB, BWDB and WARPO, (2004). Southwest area integrated water resources planning and management Project. TA NO 4079-BAN. Asian Development Bank, Bangladesh Water Development Board and Water Resources Planning Organization, Final report, 2004.

ADB, BWDB and WARPO (2004), Southwest area integrated water resources management project, District Level Integrated Water resources Management Plans Annex B- Faridpur, TA NO 4079-BAN, Asian Development Bank, Bangladesh Water Development Board and Water Resources Planning Organization, Phase I interim Report, 2004.

Hossain A., F., M , A., Hasan M., Neawaz S., M , S , and Mridha G., C., (2008), An integrated approach to solve the drainage congestion – A case study in the south- western part of Bangladesh, Paper Presented in 3rd South Asia Water Research conference' Innovative Modeling approach for IWRM 24-26 May, 2008.

BARC (2001), Contract Research Project on Application of Agroecological Zones Daabase in Drought Management and Water Availability, Bangladesh Agricultural Research Council, Ministry of Water resources, Government of Bangladesh, Dhaka.

BARI (1987), Irrigation water measurement manual, Agricultural Engineering Department, Bangladesh Agricultural Research Institute, Joydevpur, Gazipur.

BBS, (2004), Yearbook of agricultural statistics of Bangladesh Bangladesh Bureau of Statistics, Ministry of Planning.

BWDB (1997), Salinity distribution in the estuary, Meghna Estuary Study, Technical note MES – 004, January 1997.

BWDB (1997), Analysis of water level data and harmonic components, Meghna Estuary Study, technical note MES – 003, May 1997.

BWDB (1997), Tidal volume and sediment transport patterns, Meghna Estuary Study, technical note MES – 001, June 1997.

BWDB and WARPO (2005), Southwest area integrated water resources planning and management Project, Annex B – water management Infrastructure (Chenchuri Beel and Narail Subproject), Bangladesh Water Development Board, and Water resource Planning Organization, Ministry of Water Resources.

Yu-chuan, C., Chun-e, K , Ching-tien, C., and Sheng-feng, K. (2007), Enhancement of water storage capacity in wetland rice fields through deepwater management practice, *The journal of the International Commission on Irrigation and Drainage*, Vol-(56)

Chowdhury J U., and Haque M. A. (1989), Numerical simulation of tides and saline water intrusion in the Meghna Delta, Final report, R03/89, IFCDR, BUET.

Chowdhury A. K M. A (2007), Relation between salinity and crop production in different hydrological regimes downstream of Muhuri regulator, M.Sc. Thesis, Institute of Water and Flood Management, BUET, 2007.

Cox D. T., Tissol P., and Michaud P. (2002), Water Level observations and short term predictions including events for entrance of Galveston Bay, Texas, *Journal of Waterways, Port, Coastal, and Ocean Engineering*, Vol. 128, No 1.

Dean, R. G., and Dalrymple, R. A. (2002), Coastal process with engineering application, Cambridge University press, 2002.

FAO (1992), Irrigation water management training manual small-scale pumped Irrigation: Energy and cost, Food and Agriculture Organization of the United Nations, Rome

FAP 4 (1993), South west area integrated water resources management project, Final report Vol-5, Hydrology, Hydrogeology and RAOM, Flood Action Plan, Ministry of irrigation, water development and flood control.

FAP 4 (1993), South west area integrated water resources management project, Final report Vol-6, Land resources, agriculture and fisheries, Flood Action Plan, Ministry of irrigation, water development and flood control.

Godin G. (1991), Tidal hydraulics of Saint John River", *Journal of Waterways, Port, Coastal, and Ocean Engineering*, Vol. 117, No 1.

Garg S K (1985), Hydrology and water resources engineering, Khanna Publishers, Delhi,.

Garg S.K. (1997), Irrigation Engineering and Hydraulic Structures, Khanna Publishers, Delhi.

Fipps G., Irrigation Water Quality Standards and Salinity Management, B-16674-03, Texas A & M University Systems.

Harun, M A Y (2005), Effects of small scale water development projects on fisheries, M.Sc. Thesis, Institute of Water and Flood Management, BUET, 2005.

IECO (1980), South-west regional plan, Supplement E, Saline water intrusion and tidal hydraulics, Special studies Directorate, BWDB.

Islam, A (2005), Changes in farming pattern with change in flow and salinity of Gorai River, M. Sc. (WRD) Thesis, Institute of Water and Flood Management, Bangladesh University of Engineering and Technology, 2005.

Islam, Q. R., and Bennett, S. L. (1998), Role of Deepwater Rice (Oryza sativa) to Maintain Aquatic Environment in Deeply Flooded Wetlands, Proceedings, 10th European Weed Research Society Symposium on Aquatic Weeds 1998, Lisbon.

Kulkarni, S., Ahmed, S., Arya, S., Joy, K., J., and Parajape, S (2007), Women, water and livelihoods: A review of policy towards evolving a gender-just vision for water, Women and Water Network and SOPPECOM, Pune, india.

LGED (2004 a). Local Government Engineering Department, Final Appraisal Report Combined Summary Appraisal Report and Summary EIA Project. Balajtala-Kolmadanga Sub-project, Tungipara, Gopalganj. SSWRDSP-2.

LGED (2004 b) Local Government Engineering Department, PRA Report. Balajtala-Kolmadanga sub-project, Tungipara, Gopalganj, SSWRDSP-2.

Linsley, R. K , Kholar, M A., & Paulhus, J L. H. (1982), Hydrology for engineers, McGRAW-HILL Book company.

Li, Q., Gowing, J. W., and Mayilswami, C. (2005), Multiple use management in a large irrigation system: An assessment of technical constraints to integrating aquaculture within irrigation canals, *The journal of the International Commission on Irrigation and Drainage*, Vol 54(1).

Li, Q., and Gowing, J. W. (2008). Investigation of integrated management of large –scale irrigation and aquaculture systems, *Journal of Hydrologic Engineering*, Vol 13 (5)

Khan, M. S. (2000), Multiple use of ponds, in Rahman, A. A., Huq, S., and Coway, G. R. (eds.), Environmental Aspects of Surface Water Systems of Bangladesh, Chapter 14, The University Press Ltd.

Madulu N. F. (2003), Linking poverty levels to water resource use and conflicts in rural Tanzania, *Physics and Chemistry of the Earth*, Vol 28

Maleza, M. C., and Nishimura Y. (2007), Participatory processes and outcomes: the case of national irrigation system management in Bohol, Philippines, *The journal of the International Commission on Irrigation and Drainage*, Vol 56 (1).

Martin, Q W. (1983), Optimal operation of multiple reservoir systems, *Journal of Water Resources Planning and Management,* Vol 109 (1).

Matin, I. (1948), Study of tidal characteristics of Meghna Delta, M.Engg. Thesis, Department of Water Resources Engineering, Bangladesh University of Engineering and Technology.

Mondal, M. S. (2000), Performance evaluation of some deep and shallow tubewells in irrigation development, M Sc. thesis, Department of Water Resources Engineering, BUET, 2000.

Mondal, M. S. (2005), Risk based evaluation of performance in water management for the Ganges Delta within Bangladesh, PhD thesis, Faculty of Informatics & Communication, Central Queensland university, 2005

Mushtaq, S., Dawe, D., and Hafeez, M. (2007), Economic evaluation of small multi-purpose ponds in the Zhanghe irrigation system, China, *Agricultural Water Management Journal*, Vol - 91.

Odd N. (1982), One dimensional analysis of the tidal hydraulics of Delta, Hydraulic Research Station, Wallingford, Report No. OD 44, July, 1982

Rahman, M S. (2008), Water management of integrated rice-fish farming in inundated floodplains of Balajtala-Kalmadanga subproject, M.Sc. Thesis, Institute of Water and Flood Management, BUET.

Subramanya, K.(1999), Engineering Hydrology, Tata McGraw-Hill Publishing Company Ltd., New Delhi.

Cuesta, T. S., Cancela, J J , Dafonte, J., Valcarcel, M., and Neira, X. X. (2005), Social aspects influencing water management in the Lemos vally irrigation districts, Spain, *The journal of the International Commission on Irrigation and Drainage*, Vol 54.

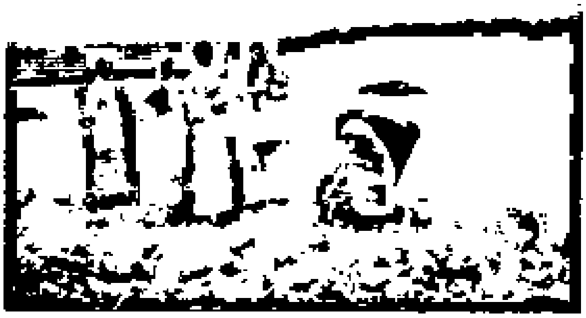
WARPO (2001), National Water Management Plan Volume 2: Main Report, water Resource planning Organization, , Ministry of Water resources, Dhaka, Bangladesh.

William, J. C., and Rijsderman, F. R., (2000), World Water Vision Making Water Every body's business, Earthscan Publication Ltd, London.

Appendix-A

Photographs of FGD

FGD with women folks of fisher family



FGD with medium farmer

FGD with small farmers

FGD with Fishermen

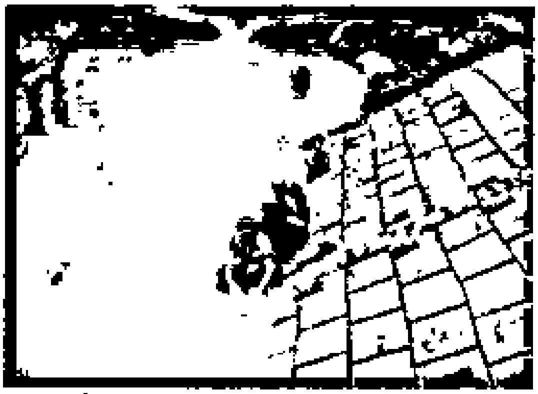
FGD with agriculture laborer

Photographs of different uses of Hazir Khal

16 HP Pump used for irrigation from Hazir Khal

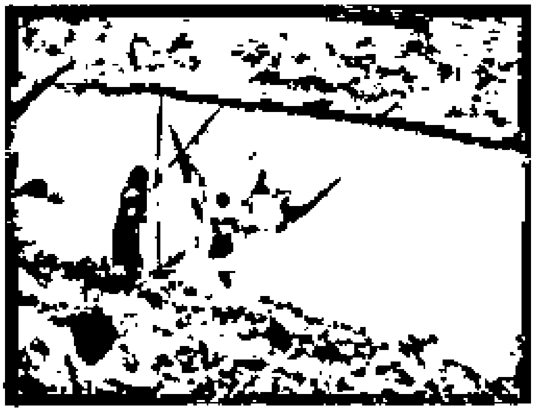
Ladder in the Khal

People using boat for different in the Khal

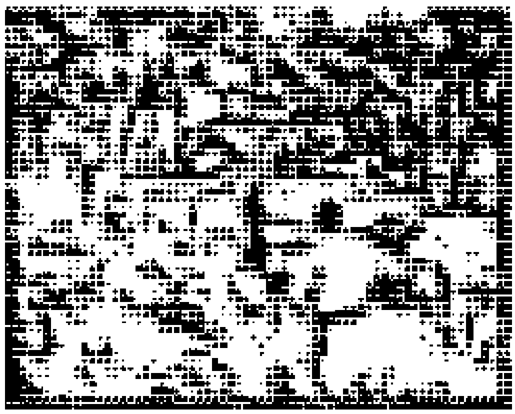


Use of Hazir Khal for bathing and washing cloth

Cleaning Livestock in the Khal



Fishing for daily consumption



Fishing by fishermen by constructing obstruction in the khal during dry season

Fishing during wet season

Natural fishes from Hazir Khal

Culture fish from Hazir Khal

Appendix-B

Checklist for Focus group discussion:

Group Type: Farmer / Fishermen / Agri-labour / housewives / WMCA

Purpose of FGD:

I. To find out the opportunities created due to construction of dam.
II Opinion of local people on gate operation rule.

1. Farmer:
    - Cropping pattern.
    - History of hazir Khal.
    - Why the construct dam?
    - When and how thy construct the earthen dam?
    - Before dam and after dam agricultural practices.
    - Before and after dam problem regarding water use in agricultural.
    - Why they prefer to cultivate Local variety Aman?
    - Irrigation system during dry season.
    - Before and after dam livelihood opportunities.
    - Benefit and cost sharing from culture fisheries.
    - Do they have boats and when they need it?
    - Is re-excavation of khal needed and how frequently they need to re-excavate and who bears the cost
    - Cost sharing structure of LGED sub-project..
    - Process of selection of WMCA member.
    - Rules and responsibilities of WMCA.
    - Shares and savings.
    - Benefit or profit sharing
    - What advantage they get from gate.
    - Why they demanded gate?
    - Opinion of people regarding gate operation?

2 Fishermen:

    - History of hazir Khal.
    - Why the construct dam?
    - When and how thy construct the earthen dam?
    - Are there any changes in open water fisheries due to dam construction?
    - What is the present condition of open water fishermen?
    - How are you benefited from dam?
    - Before and after dam problem regarding water use in fisheries.
    - Country boat plying.
    - Are there any conflict in Water users and occupational groups?
    - Any employment group getting much facility
    - Cost sharing structure of LGED sub-project.

- Process of selection of WMCA member.
- Rules and responsibilities of WMCA.
- Shares and savings.
- Benefit or profit sharing
- What advantage they get from gate.
- Why they demanded gate?
- Opinion of people regarding gate operation?

3. Agro day labor

- History of hazir Khal.
- Why the construct dam?
- When and how thy construct the earthen dam?
- How you are benefited from Dam?
- Is there any increase of coverage area?
- Before dam and after dam agricultural practices.
- Why they prefer to cultivate Local variety Aman?
- Before and after dam scope of work in agriculture.
- Before and after dam livelihood opportunities.
- Is there any loss of livelihood opportunity and who are the sufferers?
- Which group deprived?
- Benefit and cost sharing from culture fisheries.
- Cost sharing structure of LGED sub-project..
- Process of selection of WMCA member.
- Rules and responsibilities of WMCA.
- Shares and savings.
- Benefit or profit sharing
- What advantage they get from gate.
- Why they demanded gate?
- Opinion of people regarding gate operation?

4. House wives:

- History of hazir Khal.
- Why the construct dam?
- When and how thy construct the earthen dam?

- Describe before and after dam water use problems in domestic purpose.
- Benefit of dam in domestic water use.
- Describe before and after dam problems and benefit regarding water use for poultry, livestock and duck rearing.
- What is the source of water for irrigation, domestic and drinking purpose and who is responsible for fetching water?
- Opportunities of livelihoods before construction of dam.
- Loss of livelihood opportunity due to construction of dam.

- Scope or opportunities created due to dam construction.
- Are there any conflict in Water users and occupational groups?
- Process of selection of WMCA member.
- Rules and responsibilities of WMCA
- Shares and savings.
- Benefit or profit sharing
- What advantage they get from gate.
- Why they demanded gate?
- Opinion of people regarding gate operation?

5. WMCA member

- History of hazir Khal and Dam
- Role in Dam construction.
- Cropping pattern
- Total no of member and their responsibilities.
- Selection process
- Role of WMCA pre and post project condition.
- Shares, savings and loan disbursement process
- Role in Fish culture.
- Profit sharing from culture fisheries.
- What advantage they get from gate.
- Why they demanded gate?
- Opinion of people regarding gate operation?

জরিপ প্রশ্নপত্র -"এলাকায় জনগনের উদ্যোগে তৈরিকৃত অস্থায়ী বাধের সুবিধা অসুবিধা নিরুপন প্রশ্নপত্র"
উত্তরদানকারীর পরিচিতিঃ
গ্রামঃ
নামঃ
বয়সঃ
শিক্ষাঃ
পেশাঃ
অভিজ্ঞতাঃ
পরিবারের সদস্য সংখ্যাঃ
আয়ের প্রধান উৎসঃ
নিজস্ব জমির পরিমানঃ

F0 (High Land)	F1 (Meduium High land)	F2 (Medium Low land)	F3 (Low Land)

কৃষিকার্যে সুবিধাঃ

১. কত বছর ধরে বাধ তৈরি করেন ?

২. বাধ তৈরির কারণে জমির মূল্যেও কোন পরিবর্তন হয়েছে কিনা?

৩. বাধ কত দিন পর্যন্ত থাকে?

৪. কি কারণে আপনি বাধ দিতে চান ?

৫. বাধ তৈরির কারণে আপনার কৃষিকার্যে কোন প্রকার পরিবর্তন এসেছে কি?

ক. ইতিবাচক।
খ. নেতিবাচক
গ. কোন পরিবর্তন নাই।

৬. বাধ দেয়ার ফলে শুষ্ক মৌসুমে কৃষি কাজে কি কোন ধরনের সুবিধা হয়েছে?

৭. শুষ্ক মৌসুমে সেচেরও পানির জন্য কি আপনাদের টাকা দিতে হয় ?

৮. সেচের জন্য কত টাকা করে দিতে হয় ?

৯. সেচের জন্য বরাদ্দ কৃত ফি কি আপনার কাছে গ্রহনযোগ্য?

যদি না হয় তবে আপনি কিভাবে আপনার জমি চাষ করেন ?

১০. বাধ দেয়ার ফলে আপনার সেচ কৃত জমির পরিমানঃ-
ক. বেড়েছে
খ. কমেছে
গ. কোন পরিবর্তন নাই।

১১. আপনি কি মনে করেন যে সেচের জন্য ব্যবহৃত পানির অপচয় হচ্ছে?
ক. হ্যা
খ. না

যদি অপচয় হয় তবে তা কি ভাবে কমানো যায়-

১২. সেচের জন্য কি আপনার জোয়ার ভাটার উপর নির্ভর করতে হয় ?

১৩. বর্ষাকালে বাধ আপনাকে কিভাবে সাহায্য করে?

মৎস চাষে সুবিধা অসুবিধা-

১৪. বাধ নির্মানের কারণে কোন ধরনের মৎস সম্পদ বেশি সুবিধা পাচ্ছে ?

ক) প্রাকৃতিক মৎস খ) চাষকৃত মাছ, গ)উভয়ই

১৫. বাধ নির্মানের কারণে মৎস সম্পদের কোন পরিবর্তন এসেছে ?

	বাধ হওয়ার পূর্বে		বাধ হওয়ার পরে	
	+	-	+	-
চাষকৃত মৎস				
প্রাকৃতিক মৎস				

১৬. আপনি কি সারা বছর মাছ ধরতে পারেন ?

১৭.আপনার দৈনন্দিন মাছ খাওয়ার উৎস কি ?

ক. পুকুর খ. হাজীর খাল গ. নদী ঘ. বাজার থেকে কিনে।

১৮. আপনার কি মাছ চাষ, মাছ ধরা এবং, বিক্রয়ের সাথে কোন প্রকার সংযোগ আছে?

জীবন-জীবিকাতে বাঁধের প্রভাবঃ-

১৯. বাধ তৈরির কারনে আপনি আর কি কি সুবিধা পাচ্ছেন ?

২০. বাধ তৈরির ফলে আপনি কি কোন ধরনের সুবিধা হতে বঞ্চিত হয়েছেন ?

২১. বাধ তৈরির কারণে আপনার কর্মসংস্থান এর ক্ষেত্রে কোন পরিবর্তন এসেছে কি?

ক. বেড়েছে খ. কমেছে গ. কোন পরিবর্তন নাই।

কর্মসংস্থান বেড়ে থাকলে ক্ষেত্রগুলো কি কি?

২২. বাধ তৈরির পূর্বে ও পরে খালের পানির ব্যবহার গুলো কি কি ?

	কার্যক্রম	বাঁধ হওয়ার পূর্বে		বাঁধ হওয়ার পরে		
		হ্যা	না	হ্যা	না	
১	গোসল					
২	কাপড় চোপড় ও বাসন কোসন ধোয়া					
৩	গৃহপালিত পশুর পানির ও গোসল					
৪	বাড়ীর পাশে বাগান					
৫	পোলট্রি					
৬	হাস পালন					
৭	বিনোদন মূলক ব্যবহার					
৮	ক্ষুদ্র-শিল্প					

২৩. খালের পানি ব্যবহারের জন্য আপনাদের কি জোয়ার ভাটার উপর নির্ভর করতে হয় ?

২৪. খাবার পানির উৎস কি?

ক. টিউবওয়েল খ. পুকুর গ. খাল ঘ. ডিপ টিউবওয়েল ঙ. অন্যান্য.

মন্তব্য-

২৫. আপনি কি খাবার পানি খাল থেকে সংগ্রহ করেন?

২৬. কিভাবে পানি বিশুদ্ধ করেন ?

২৭. দৈনিক কত কলসী পানি আপনার প্রয়োজন হয় ?

২৮. সাধারণত কে /কারা আপনার ঘরে খাবার পানি সংগ্রহ করে ?

২৯. খালের পানি খাবার কারণে কি আপনার কোন অসুখ বিসুখ হয় ?
৩০. খালে কি সিড়ি আছে ?
নৌ চলাচলে প্রভাব-
৩১. আপনার কি নৌকা আছে?
৩২. কেন আপনার নৌকা প্রয়োজন হয় ?
ব্যবহার
মাছ ধরা
ব্যবসার জন্য মালামাল পরিবহন
শাক-সবজি হাটে নেয়া আনা
শাপলা শালুক কুড়ানো
যাতায়াতের মাধ্যম
শস্য সংগ্রহ
শস্য সংগ্রহ ও বাড়ীতে আনা
৩৩. কোন মৌসুমে নৌকা আপনার জন্য অপরিহার্য হয়ে পায় ?
৩৪. নৌকা চলাচলের ক্ষেত্রে বাঁধের ভূমিকা কি ?
ক. বাধা দিচ্ছে খ. কোন সমস্যা নাই।
৩৫. যদি বাধ নৌ চলাচলে বাধা দেয় তবে সমাধানের উপায় কি?
পানির ব্যবহারে প্রভাব-
৩৬. খালের পানি ব্যবহারের ক্ষেত্রে আপনারা কি ধরনের সমস্যার সম্মুখীন হয়েছেন ?
৩৭.উহা সমাধানের উপায় কি ?

বাংলাদেশ প্রকৌশল বিশ্ববিদ্যালয় লাইব্রেরী, ঢাকা
নং. 107394
তাং. 4.11.09