CAUSES OF FAILURE OF SUBMERSIBLE EMBANKMENT AND ITS IMPACT ON THE HAOR AREA: A CASE STUDY OF KARCHAR HAOR PROJECT

A Thesis by

Md. Kaisar Alam

In partial fulfillment of the requirement for the degree of

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The thesis titled 'CAUSES OF FAILURE OF SUBMERSIBLE EMBANKMENT AND ITS IMPACT ON THE HAOR AREA: A CASE STUDY OF KARCHAR HAOR PROJECT' submitted by Md. Kaisar Alam, Roll No.M-0409282011, Session: April 2009, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT on September 07, 2015.

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

Md. Kaisar Alam
Roll No. M 0409282011
Session: April, 2009

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Md. Kaisar Alam
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ABBREVIATION AND ACRONYM

BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
BRRI	Bangladesh Rice Research Institute
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CB	Crossing Boundaries
CEGIS	Centre for Environmental and Geographic Information Services
DEM	Digital Elevation Model
FCD	Flood Control Drainage
FCDI	Flood Control, Drainage and Irrigation
FGD	Focus Group Discussion
GIS	Geographic Information System
GOB	Government of Bangladesh
HYV	High Yielding Variety
HWL	High Water Level
ICZMP	Integrated Coastal Zone Management Plan
IRR	Internal Rate of Return
IWFM	Institute of Water and Flood Management
IWM	Institute of Water Modeling
IWRM	Integrated Water Resources Management
KII	Key Informants Interview
LGED	Local Government Engineering Department
LLP	Low Lift Pump
LWL	Low Water Level
MDG	Millennium Development Goal
MoWR	Ministry of Water Resources
NGO	Non Government Organization
NWMP	National Water Management Plan
NWPo	National Water Policy
O&M	Operation and Maintenance

PRA	Participatory Rural Appraisal
PWD	Public Works Department
T. Aman	Transplanted Aman
UNO	Upazilla Nirbahi Officer
UP	Union Parishad
UN	United Nations
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
WARPO	Water Resources Planning Organization
WB	World Bank

GLOSSARY

Aman	Monsoon season rice (direct-seeded or transplanted)
Aus	Rain fed rice in the pre-monsoon season (direct-seeded or transplanted)
Beel	Natural depression (pond) subject to flooding
Boro	Irrigated rice grown in the dry season
Floodplain	Lower land along rivers and khals inundated during flood season by river floods
HHDI	Household Development Index
Khal	Narrow natural or artificial water channel
Kharif I	Cropping season during pre-monsoon (March-June)
Kharif II	Cropping season during monsoon (July-October)
Parishad	Local government institution
Rabi	Cropping season during winter (October-March)
Submersible Embankment	The Submersible embankment is the type of embankment which retards the entry of flood water into the Haor area during the pre-monsoon season (April-May) and allows overtopping of monsoon floodwater into Haor after the harvesting time and gradually the area is inundated.
Union	Administrative unit—subdivision of an upazilla
Upazilla	Administrative unit—subdivision of a district (formerly thana)

ABSTRACT

Flash floods are generated in the steep, upland catchments in the north-eastern region of Bangladesh adjacent to the hilly region of India. The single crop, Boro, is cultivated in this region, which remains under uncertainty of harvesting due to early flash floods. When early (pre-monsoon, up to 15th May) flash floods damage the only crop, then inhabitants remain in a distress condition until the next year's harvest. This is a major concern for the area as well as for the whole nation. To save the crops from pre-monsoon floods BWDB have implemented number of Haor Projects in the area starting from the early sixties. The main component of the Haor Projects is the submersible embankments along with other components like sluices, regulators etc. Submersible embankments are constructed to protect the crops from the pre-monsoon floods upto May 15. The design levels of submersible embankments have been determined considering 1:10 year pre-monsoon flood. The embankments in different Haors have been constructed at different times; some in the early sixties and some recently. The early flash floods of April 2010 caused a colossal damage to lives, crops and properties of the Haor area. Almost all the Boro rice was damaged by flash flood and therefore the economy of the Haor people was severely affected. Karchar Haor is one of the Haors which is surrounded by submersible embankment and in where the Boro rice was also damaged severely by early flash flood of 2010. This study has been conducted to assess the causes of failure of Karchar Haor submersible embankment by taking into consideration the adequacy of design crest level, quality of regular repair and maintenance, effect of change of rainfall and water level pattern etc. This study also assesses the impact of damage and on how the farmers cope with the situation considering the post-damage economic activity. Also a strategy has been formulated for management of the Karchar Haor area.

Maximum pre-monsoon flood level at Station Saktiarkhola (WL-131), Sunamgonj (WL-269) and Shukevpur (WL-072B) in the Jadukata, Surma and Chalti River respectively with 1 in 10 year frequency was estimated. The design crest level of the embankment was then determined (BWDB, 1996) and was compared with the existing crest level in order to assess the adequacy of existing crest level. The HFL (High Flood Level) in 2010 of the surrounding rivers was compared with the existing crest level to check the adequacy of the embankment. Key Informant Interview (KII) was conducted with BWDB officials at Sunamgonj to find out, if there is any other reason of failure of submersible embankment. The impact of damage in agriculture, fisheries and livelihood was assessed and a management strategy was introduced for better future maintenance. Different PRA tools like Focus Group Discussion (FGD), Group Discussion (GD), Key Informant Interview (KII) etc have been used to generate the information regarding the research. It is found that the design crest level is more or less adequate but poor quality repair and maintenance work is the main cause of failure. In 2010 boro production of Karchar haor declined from 11400 metric ton to 1080 metric ton. This means flash flood damaged 90% boro crops of this area in 2010. The damage caused heavy impact on livelihood. The HHDI value of this area has reduced from 0.48 to 0.37 after occurrence of damage. The people of haor area are resilient and able to cope with the damage situation. Management of Karchar Haor through structural intervention is required in order to reduce the vulnerability of damage and thus its impact on the livelihood.

CHAPTER ONE
INTRODUCTION

1.1 Background Information

The submersible embankment projects (SEP) are kind of Flood Control and Drainage (FCD) project, implemented during late sixties and are designed to retard the entry of flood water into the Haor area during the pre-monsoon season (April-May). The main objective of these embankments is to give opportunity to the farmers to harvest Boro crops during pre-monsoon without any damage by flash flood. Water is allowed to enter inside the embankment immediately after harvesting the Boro through regulators located at strategic locations, minimizing the head difference between inside and outside the embankments, thereby reducing the damage to the embankments when they are overtopped (Saleh and Mondal, 2007). As these projects do not provide protection from the monsoon flood, it is argued that consequently, there is no change in regional flood status and minimal impacts on the environment. The other cited advantages are that they are less expensive, require less land acquisition, have low gestation period and give higher economic returns (Saleh, 1991). A number of studies have shown that SEPs have achieved their desired objective of protecting the Boro crop from pre-monsoon flood and increased the Boro production (Saleh and Mondal, 2007). The vegetation cover of the area increased and fish production is hampered due to the declining trend of water bodies (Salauddin, 2010). The fish biodiversity and fish ecosystem health of the haor area have been impacted due to SEPs (Kafi, 2008). Also the benefits from the SEPs have not been equitably distributed among the community. Most of the benefits go to agro-landowner and majority of poor households are deprived from benefit (Khan, 2010).

The production of Boro has been increased due to implementation of submersible embankment project in the Haor region. This Boro is the main crop annually produced in this area. But flash flood is the biggest challenge regarding its management and protecting the Boro crop from damage. Although every year periodic repair and maintenance of the submersible embankment is done, failure is occurred every 1 in 3 to 4 year frequency that causes almost total destruction to Boro crops of particular Haor area. Also it is observed that every year public cut in several places during flood which are to be repaired after floodwater goes away. This contrast has encouraged taking this study of assessing the actual causes of failure and its impact on the livelihood of people and developing the management system in order to reduce the frequency of failure and its impact.

The Haor areas are frequently affected by the flash flood, generated in the steep upland catchments adjacent to the region in India. Flash flood caused massive damages in 2000, 2002 and 2004 in the area (Salauddin, 2010). The early flash flood of April 2010 caused a colossal damage to lives, crops and properties of the Haor area. The Karchar Haor project is one of the submersible embankment projects in the Sunamgonj area. Its implementation was carried out between 1966 and 1968 (William Halcrow & Partners et al., 1993). The project covers a gross area of 5513 ha and a net area of 4987 ha. The Jadukhali (Chalti) River flows along the east periphery, the Surma flows along the southern boundary of this project and the Rakti River flows along the western side (IWM, 2006). Flash flood approaches towards Karchar Haor from the northern side through small channels and from the Jadukhali River. Major intrusion points are located near Gazaria where several breaches occur in the submersible embankment. These breaches have to be closed each year before the pre-monsoon. After harvesting the crop these portions are mostly cut by local people for shorter navigation route through the Haor (IWM, 2006). In most of the circumstances it is observed that the breach closing is not done in appropriate time and consequently damage to Boro crops occurs due to entering of flash flood water through breach. Moreover in April 2010 overtopping of embankment also occurred along with breaching. Hence, the overall situations of the haor area require an analysis of causes of failure of submersible embankment and its impact on the haor area in order to develop the sustainable management system.

This study emphasizes these issues and anticipates their dimension of changes for the future threat. Different causes of failure/overtopping of submersible embankment before harvesting boro crops and its probable remedial measures have been identified.

Population of the study area are involved in different economic sectors for sustaining their livelihoods. This study reveals the impact of failure of submersible embankment on livelihoods of the population. Changes in livelihood due to failure have been explored in this study

1.2 Objectives of the Study

The major objectives of this study is to analyze the causes of failure of submersible embankments and its impact in the Haor area and to generate the appropriate management strategy considering the Karchar Haor sub-project area as a base area. The specific objectives are:

- To find out the reasons of failure of submersible embankment at Karchar Haor in 2010.
- To analyze the resilience of the farmers and to make an assessment on how they cope with the failure situation.
- To assess economic and livelihood impact of flash flood in the area and develop appropriate strategy for management of the project area.

The outcome of the study will help the planner and policy maker to formulate better management strategy for the Haor areas.

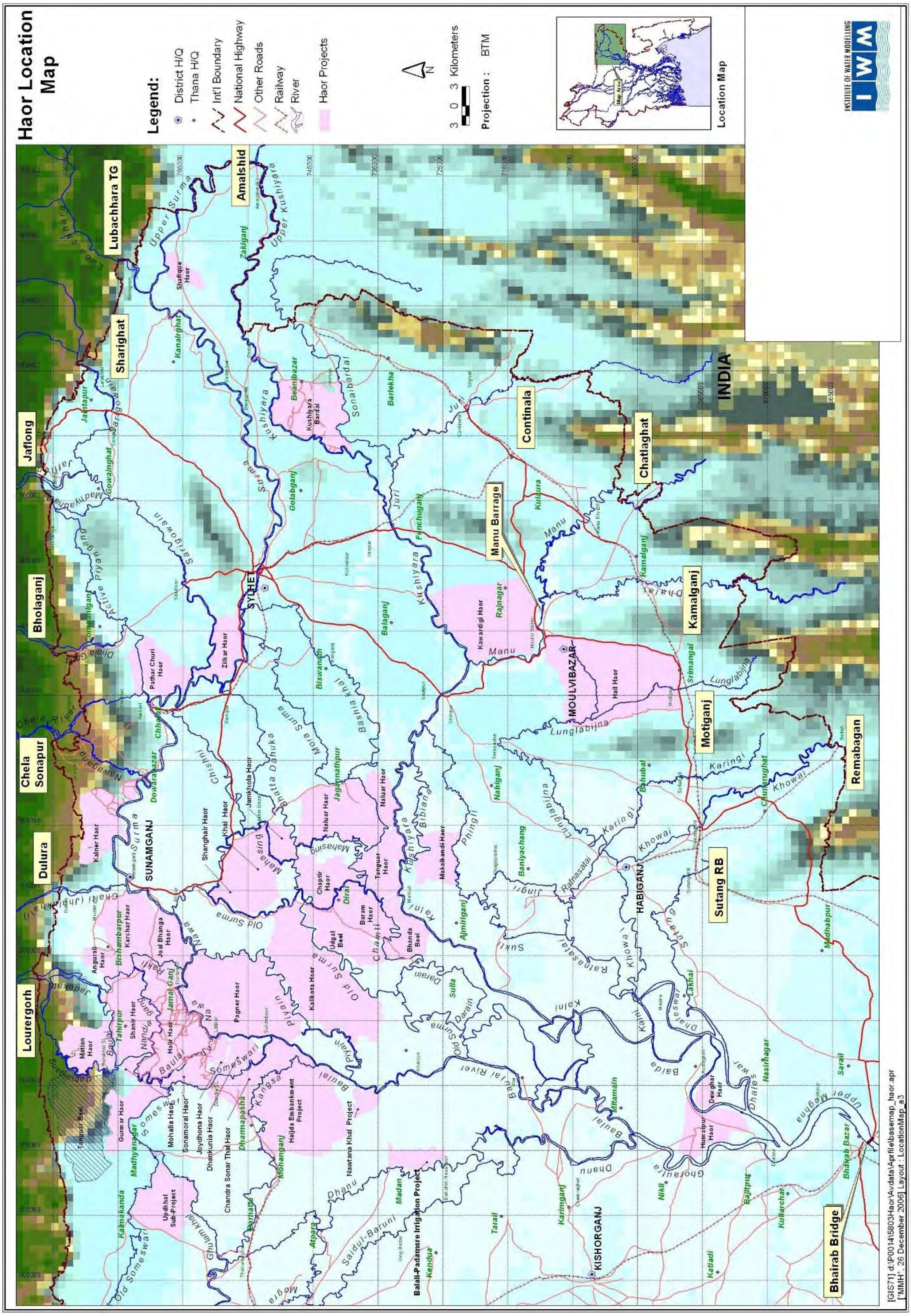


FIGURE 1.1 RIVER NETWORK IN THE HAOR AREA

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

The study focuses on the causes of failure of submersible embankment in the Haor area and its impact on the livelihood of the Haor people. Haors are located in the northeast region of Bangladesh that covers an area of approximately 24,500 sq km. The greater part of this region is taken up by the haor basin, which comprises the floodplain of the Meghna tributaries and is characterized by the presence of numerous large deeply flooded depressions, known as haors, between the rivers (Figure 1.1). A vast alluvial plain possesses some 6,000 shallow permanent water bodies known as beels (usually in the lowest part of haor or in abandoned river channels), surrounded by large area of seasonally flood plain. The basin is bounded to the north by the hill ranges of Meghalaya, to the south by the hills of Tripura and Mizoram and to the east by highlands of Manipur. The numerous rivers rising in this hills cause extensive flooding during the monsoon season with much of the region being flooded to a depth of up to six meters. The drainage is towards south-west via the Surma, Kushiyara, Baulai and Kalni rivers into the Meghna River and ultimately to the Bay of Bengal. Almost all the land above the maximum flood level is under permanent cultivation and human settlement.

A limited number of studies on Haor have been conducted in Bangladesh. A brief review has been presented in this chapter on characteristics of pre-monsoon flash flood, characteristics of submersible embankment, impact of submersible embankment in the Haor area etc. Water management interventions in the Haor basin are briefly reviewed together with their impact on Boro production.

2.2 Characteristics of Submersible Embankment

2.2.1 Description of Submersible Embankment

The hydrological regime in the Haor basin is conducive to growing only Boro rice, which is vulnerable to pre-monsoon flash floods. The concept of protecting Boro rice from pre-monsoon flash flood in Haor basin through constructing submergible embankment was originally initiated by Zamindars (landlords) in the 1920s. The Bangladesh Water Development Board (BWDB) added the scientific dimension to this concept in 1960s. It constructed a total of 1826 km of submersible embankments in 46 project area under six districts (Sunamgonj, Sylhet, Moulvibazar, Hobigonj, Netrokona and Kishorgonj) in the northeast region to protect 289,911 hectares of Boro rice crop from pre-monsoon flash flood..

2.2.2 Concept of Submersible Embankment Project (SEP)

Submersible embankment project is a special type of project design to protect agricultural crops, usually Boro rice, grown in the winter season and harvested during the pre-monsoon. Submersible embankment is constructed along the bank of the rivers and channels to restrict the entrance of pre-monsoon flash flood water into the Haor for a certain period of time (Figure 2.1) so that farmers can have the safe harvest of their only crop Boro.

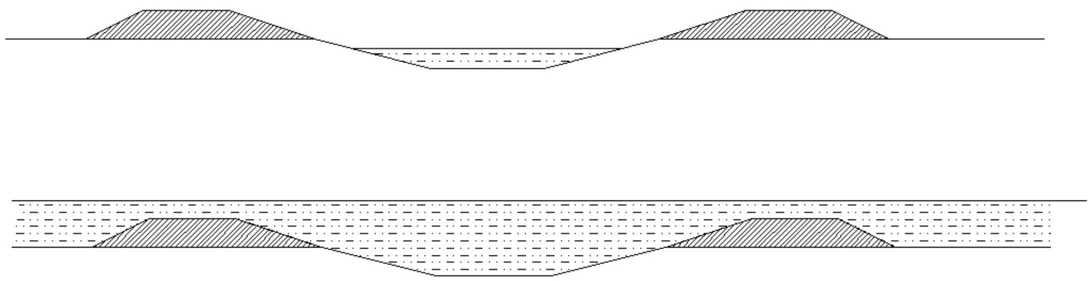


Figure 2.1 Submersible Embankments in Pre-Monsoon and Monsoon

Submersible embankment allows overtopping of monsoon floodwater into Haor after the harvesting time and gradually the area is inundated. During full monsoon, it remains submersed and the monsoon floods pass over it. At the end of the monsoon, water from the basin drains back to the river system through cross drainage structures and embankment cut at different locations.

2.2.3 Design Criteria of Submersible Embankment Project

The submersible embankments in the Haor areas are design to restrict the 1 in 10 year pre-monsoon floodwater from entering the project until 31st May. The embankments are provided with a freeboard of 0.3m to account for possible increase in pre-monsoon flood levels due to confinement effect. The embankments have a crest width of at least 2.5m with side slope of 1V:3H.

Flushing/drainage regulators are provided in the embankments to facilitate (1) filling of the project area with water after the completion of Boro harvest, so as to reduce the damage of embankments during overtopping and (2) drainage in the post-monsoon period. Structure size is determined by pre-monsoon flushing requirements. The capacity of the structures is sufficient to allow the basin to fill in up to the 0.3m below the embankment crest by the time the embankments are overtopped that limit damage to the embankment during overtopping and post-monsoon drainage requirements. The head difference across the structure is designed not to exceed 0.3m to discourage farmers from cutting the embankments to accelerate drainage. The regulators also allow flushing to the internal canals and retain the water for lift irrigation during winter and have provisions for fish passage or allow fish migration.

Although as per the BWDB design manual the submersible embankments are designed to prevent flood water from entering the project till 31st May, review of past studies and feasibility reports shows that the implemented projects have actually been designed to prevent floodwater from entering the project till 15 May (SSISP, 1990).

2.2.4 Operation and Maintenance

Bangladesh Water Development Board (BWDB) is shouldering the responsibility of regular operation and maintenance of the submersible embankments and controlling structures. Local government also facilitates the operation and maintenance on ground. The regulator gate operation is mainly done by the local people in association with BWDB. The gate of regulator is started to open from May 16 and the opening is completed by May 24. There is always conflict among farmer, fisherman and boatman in opening and closing the regulator gate depending on their different water demand. The earthen submersible embankments which are submersed every year in monsoon and experienced severe wave action require regular repair and maintenance. Again embankments are cut at different location for drain out water by farmers and fishermen, which also need to close every year.

2.3 Review on Past Studies

A number of studies have been carried out in the past on the life and livelihood of the farmers and fishermen in the Haor area and the contribution of the submersible embankment to protecting. Followings are the reviews of some of those studies

Alam (2005) found socio-economic background of haor fishermen tremendously squat. Absolute poor was about 48% by Direct Calorie Intake (DCI) method and about 49% and 60% fishermen below the lower and upper poverty lines by Cost of Basic Need (CBN) method respectively. Boat and defecation facilities were significant by odds ratio and odds ratio confidence interval. Education status of the household head and ownership of cultivated land were significant only by odds ratio. He recommended that the Govt. and other agencies (NGO) might consider the significant factors to increase the socioeconomic conditions and particularly to reduce poverty level of the Haor fishermen.

Alam et al (2010) conducted a study in the Haor areas of Bangladesh to assess the land utilization status, delineate the productivity and profitability of growing modern rice, evaluate the existing cropping patterns and assess the prospect of possible cropping patterns. They found that, there are about 1.26 million hectares of cultivated lands in seven Haor districts, of which 66% falls under haor area. Nearly 94 and 87% areas were devoted to MV Boro rice production. Both BRRI dhan 28 and 29 were being the widely adopted rice varieties. On an average, about 33% of the Haor areas were under mechanized irrigation. The cost of production for MV Boro was almost double than that of LV rice. The yield of MV Boro was 79% higher than that of LVs and the return from MVs was 82% higher. Rabi-Fallow-T. Aman, Vegetable-Aus-T. Aman and Rabi-B.Aman patterns were the potential cropping patterns in some selected areas and this could increase both cropping intensity and productivity in those areas. According to the farmers' assessment, lack of flood control dam and lack of short duration varieties etc. are the major hindrance to the adoption of potential cropping patterns. Construction of community harvest and threshing facilities and flood control devices could be the important public interventions for enhanced agricultural productivity in the haor areas.

CEGIS (2012) found that the Haor region had long been lagging behind mainstream of the national development, although the economic development of Bangladesh was moving steadily at a moderate pace. The future challages in the context of climate change and variability are also a major concern for the sustainable development of the region. In that connection it had become imperative to formulate a Master Plan that aims at integrated development of Haor area considering the development potential. The formulated 20-year Master Plan is a framework plan which will be implemented on the short, medium and long term basis. This 'integrated development plan' spells out the means for optimising available resources of the area for future development of potentials by incorporating all relevent social and environmental considerations. Specifically, integrated development would comprise mainly flood management, environmental sustainability, production of crop, fisheries and livestock, expansion of education, settlement and health facilities, road communication, navigation, water supply and sanitation, industry, afforestation and generation of power and energy. The planned investment portfolios have been prepared for seventeen sectors namely Water Resources, Agriculture, Fisheries, Pearl Culture, Livestock, Forest, Education, Health, Transportation, Housing and Settlement, Water Supply and Sanitation, Industry, Energy and Power, Mineral Resources, Biodiversity and Wetland, Tourism and Social Services.

IWM (2006) observed that additional projects taken up in the Haor region will mean that the embankment heights would have to be raised further and would require regular reviewing with the addition of new projects. This also means that the higher the level of embankment the cost of implementation as well as the O&M will increase. This drawback does not end here; higher embankments will mean less stability and greater risk of failure during the pre-monsoon flood. Another important factor is that the dredging options have to be considered actively not only as a measure to reduce the embankment height but also to ensure smooth navigation in the dry period and early drainage of Haor area in postmonsoon period. Thus for sustainability and efficient management of the Haor projects both embankment raising and intelligent dredging options have to be considered together and not in an isolated way.

Kafi (2008) found that embankments and regulators restrict the free movement of fish from rivers to beels and haors and vice versa. Haor are inundated and linked to rivers during the monsoon but are isolated during the dry season. He observed that restricted fish free movement hampers migration of fish species that severely affects fish growth and breeding, which is sign of species declination. He also observed that with the construction of Haor projects, floodplain have become gradually less. This has confined flood water as well as sediments within the river system. The confinement of rivers has led to raised riverbeds, resulting in an increase in peak flood level. Increased inundation during monsoon brings more sediment into the floodplain, including beels, haors and khals. The habitat area available for fish is thus reduced during pre-monsoon and early monsoon period. He found that submersible embankment prohibits the early stage of flooding in order to save Boro crops, resulting in the accumulation of plant nutrients are not likely to dissolve properly by early flooding. That's why the shortage of nutrients is a possibility which would indicate decrease in fish species.

The findings of the study conducted by Kashem et al (2013) revealed that farmers usually cultivate only three HYV *boro* rice varieties (BR 19, BRRI dhan 28 and BRRI dhan 29) in the Haor area. In *aman* season farmers mostly cultivate local varieties and they get minimum yield. Only few vegetables found to cultivate by the farmers in Haor area. The vegetables are: onion, garlic, chilli, bottle gourd, sweet gourd, lady's finger and tomato. Among these onion, garlic and chilli are mostly cultivated. Many farmers reported that during the flood they had to face serious problems in respect of communication, diseases, increased price of different commodities, and lack of adequate government safety net programs/relief. They observed farmers' lack of flood preparedness while some farmers remained uncared about the occurrence of flood and consequently they did not take any preparedness for flood.

Assessment of impact of submersible embankment project in Sonamoral Haor by Khan (2010) indicates that the project has been successful for Boro production. But standard of living of Haor based livelihood groups has not improved though Boro rice production has increased. The average HHDI has declined from 0.53 to 0.43 in post project condition. Agriculture landowners are the main beneficiaries of the submersible embankment project. The negative impacts of the project like reducing ecological resources (fish, aquatic plants) conflict among water users, restricting boat communication and controlling access to the natural resources has affect majority of target households. He recommended that submersible embankment project to prevent pre-monsoon flash flood in the Haor region should not be planed for single purpose of protecting Boro rice only. Project planning should also give attention to the improvement of standard of living of the community as emphasized in National Water Policy.

Mamun et al (2013) observed indiscriminate harvesting of mother fishes, use of agrochemicals, sedimentation on haor basin and habitat destruction were found as major causes of fisheries resources degradation in the study area. Most of the water quality parameters were found good which were within the standard level set by Government of Bangladesh for fisheries. However, they found EC and TDS were higher than the recommended level for fish production.

It was revealed from Salauddin (2010) that the existing scenarios of Haor area and change of patterns from 2000 to 2008 is significant. He observed that the NDVI values are minimums in 2000, 2002 and 2004 are about 0.34, 0.32 and 0.35 respectively whereas in 2003 and 2006 the NDVI values are maximum. It was found that the land cover in the Haor area had been changed significantly since 2000. Analysis revealed that vegetative cover area in 2008 had increased to about 8.35% compared to the 2000 vegetative cover area. He also observed that the access of livelihood groups to livelihood capital i.e. natural capital, physical capital, human capital, social capital and financial capital was changed from 2000 to 2008. The impacts of land cover changes to the livelihood groups of the Haor area is positive trend except the natural capital.

Saleh and Mondal (2007) observed that Boro production had been fluctuated around 0.4 mmt till 1990 but there had been a rising trend afterward. Although the average annual growth rate was about 4.1%, the rate increased to 7.4% after 1990. They found that, even collectively the SEPs had achieved their desired objectives of protecting the Boro crops from pre-monsoon flood, especially after 1990. Both HYV Boro area and production have increased with the increase in SEP coverage. The SEPs did not have any impact on increasing the irrigation coverage, which is overwhelmingly based on surface water. They also found that pre-monsoon rainfall did not create any adverse internal flooding or drainage congestion, which could be detrimental to Boro production. It was suggested that considering SEPs's positive impact on the regional Boro production, adequate annual maintenance and periodic rehabilitation works should be carried out for the sustainability of these projects.

CHAPTER THREE
METHODOLOGY OF STUDY

3.1 Introduction

The study was conducted through an interdisciplinary approach. Different technical and social methods were used to analyze the problem and assess the probable solution. Local people's participation in the research process was ensured by using PRA tools.

A rigorous analysis was done on what was the target of the project and what is the present practice and problem based on the primary data obtained from PRA technique and secondary data from BWDB. Maximum pre-monsoon flood level at Station Saktiarkhola (WL-131), Sunamgonj (WL-269) and Shukdevpur (WL-072B) (Figure 5.4) in the Jadukata, Surma and Chalti River respectively with 1 in 10 year frequency was estimated by fitting an appropriate probability distribution (Chow, 1988) with secondary water level data obtained from BWDB. The design crest level of the embankment was then determined (BWDB, 1996) and was compared with the existing crest level in order to assess the adequacy of existing crest level. For this purpose secondary existing crest level data were collected from BWDB. The HFL (High Flood Level) in 2010 of the surrounding rivers was compared with the existing crest level to check the adequacy of the embankment. Pre-monsoon rainfall distribution at Sunamgonj (R-127) was analyzed based on rainfall data obtained from BWDB in order to find out the correlation of flash flood and rainfall in local catchments. KII was conducted with BWDB official at Sunamgonj to find out, if there is any other reason of failure of submersible embankment.

PRA technique such as FGD and KII was applied to collect information regarding post-damage economic activity in order to analyze the resilience of the farmers and assess on how they cope with the situation after damage. Different resilience options was identified and ranked according to priority and also adaptability and transformability was assessed using PRA data (Walker et al., 2009). Household Development Index (HHDI) was calculated (Lodha and Gosain, 2005) to identify and compare the livelihood situation in pre and post damage condition using PRA data. The impact of failure on different economic sector such as crop production, fisheries, infrastructure etc was identified by using primary data obtained by PRA as well as secondary data collected from the Upazilla Agricultural, Fisheries and Land office.

An appropriate strategy for management of Karchar haor area regarding O&M activity, breach closing timing and economic & livelihood activities was developed based on PRA data.

3.2 Steps of the Study

3.2.1 Analysis of the Causes of Failure

To find out the causes of failure primary data collection was carried out by field investigation and PRA technique and secondary data was collected from BWDB. Based on PRA data the socio-economic, socio-technical, socio-political causes of failure were assessed. Based on secondary water level data from BWDB the design crest level was estimated and compared with existing crest level in order to assess whether the existing crest level is sufficient against failure or not. The secondary rainfall data was analyzed for making correlation of flash flood and rainfall in local catchments.

3.2.2 Estimation of Design Crest Level.

In this step, relevant data was collected from different sources. The historical Water Level data in different gauge station of the Jadukata, Surma and Chalti River was collected from Bangladesh Water Development Board (BWDB). The maximum water level in each year is identified. Then an appropriate probability distribution was fitted to the historical yearly peak water level data and it was found that Extreme Value Type I (EVI) distribution fitted to the water level data for all the stations.

According to EVI distribution the values of veriate X with return period T is

$$x_T = \bar{x} + K_T \sigma_x$$

where

$$K_T = \frac{(y_T - 0.577)}{1.2825}$$

$$y_T = -\ln.\ln \frac{T}{T-1}$$

$$\sigma_x = \sqrt{\frac{\Sigma(x-\bar{x})^2}{N-1}}$$ and

$\bar{x}$ is the mean of sample

Considering 0.3m freeboard as per BWDB standard design manual the design crest level for the flood level with 1 in 10 years return period is estimated by the following equation.

Design Crest Level $= \bar{x} + K_T \sigma_x + 0.3$

3.2.3 Drawing Long-Profile of Existing Crest Level

Relevant data was collected from the BWDB field office in Sunamgonj which was measured for the purpose of yearly repair and maintenance. The Long-Profile of existing crest level was determined by plotting the obtained crest level against chainage. A comparison was then made between existing crest level and calculated design crest level. Also it was assessed whether actual design crest level by BWDB is sufficient or not.

3.2.4 Determination of Correlation between Rainfall and Flash Flood

In this step, relevant data have been collected from different primary and secondary sources. Rainfall data of Sunamgonj and Water level data of Chalti and Rokti River were collected from Bangladesh Bangladesh Water Development Board. Water level above the design crest level of Karchar Haor submersible embankment before 15-May was assumed as flash flood. The analysis for decadal rainfall and water level was done. The area-elevation curve was established and comparison of inundation due to rainfall and up-stream runoff was made.

3.2.5 Assessment of Post-damaged Economic Activity and Resilience of Farmer

Assessment was made based on the primary data obtained from group discussion and focus group discussion. In this step a discussion after failure on economic activity and how they response to bounce back to the original economic position in pre-failure situation was made.

3.2.6 Determination of House Hold Development Index

In this step primary data for the value of different livelihood development indicators of different livelihood group was collected using questionnaire survey. The development indicators include income, food security, employment opportunity in main occupation, employment opportunity in other occupation, protein intake and access to ecological resources. Then the household development Index is calculated using the following equations.

$$(HHDI)_p = \frac{\sum_{k=1}^{l} w_k \times (HHDI)_k}{l}$$ (Lodha and Gosain, 2005)

Where, l is the number of livelihood groups and w_k is the weight age factor of k-th livelihood groups of the project area

.

$$(HHDI)_k = \frac{\sum_{i=1}^{m} (HHDI)_i}{m}$$

Where, m is the number of households of *k-th* livelihood group

$$(HHDI)_j = \frac{\sum_{i=1}^{n} D_{ij}}{n}$$

Where, *n* is the number of indicators

$$D_{ij} = \frac{(X_{ij} - \min X_{ij})}{(\max X_{ij} - \min X_{ij})}$$

Where X_{ij} is the individual value of the i-th indicator for the j-th household and $\min X_{ij}$ and $\max X_{ij}$ are the corresponding minimum and maximum values of the indicator of corresponding livelihood group (Lodha and Gosain, 2005).

3.2.7 Assessment on Impact of Livelihood

The higher value of HHDI indicates higher standard of living and vice versa. So based on the household development index in pre and post damaged condition as calculated in previous section the impact of livelihood was assessed in post damage condition due to failure of embankment by flash flood.

3.3 Applied PRA Tools

Primary data were collected through PRA tools.

3.3.1 Transect Walk

Several transect walks (TW) have been carried out with a team consisting of local inhabitants in the study area for detail observation about impact. First transect walk has been conducted at Madartek village just after a focus group discussion. Second and third transect walks have been conducted on Zirak Tahirpur and Ratanchiri in December 2011. During TW, they helped to identify resources, impacted areas, damaged embankment, condition of sturctures, land use pattern and social situation of the study area. These TWs facilitated the research to overview and validate the raw information.

3.3.2 Group Discussion

Group discussion was conducted mainly to collect primary data regarding household level indicators such as income, food security, working opportunity in main occupation, working opportunity in other occupation, protein intake and access to natural resources as per unit defined in Table.

Table 3.1: Name of indicator and selected unit

Sr No	Indicator	Unit
1	Income	Tk/Year
2	Food Security	Months/Year
3	Working opportunity in main occupation	Months/Year
4	Working opportunity in other occupation	Months/Year
5	Protein intake	Days/Week
6	Access to natural resources	Months/Year

Most of the group discussions (GD) were informally held at the field (Table-3.2). GD was conducted at the time of field visit of the study. The populations living in different places of the study area were affected irrespective of their socio-economic status. So, classification in social caste, race, gender, religion, economy, livelihoods became insignificant in GD. Group discussions were mainly location dependent where the participants (10-15) were gathered to continue the session. In every GD, at least one third women participation was tried to be insured.

Table 3.2: Schedule of group discussion (GD)

Date	Place	Participants	No. of Participants
05-12-2011	Madartek	Directly affected population	13
06-12-2011	Zirak Tahirpur	Indirectly affected population	11
07-12-2011	Ratanchiri	Directly affected population	14

3.3.3 Focus Group Discussion

Every focus group discussion (FGD) was conducted through pre-planned arrangement rather than location dependent arrangement in case of GD. All of the FGDs were conducted quite sometime after the occurring of damage due to flash flood in 2010. The target groups were selected on the basis of the following criteria:

- Geographically identical with respect to habitat, land elevation, land use pattern and distance from the embankment.
- Livelihoods and change of livelihoods almost similar.
- Comparable in social status, gender, caste, religion and culture of the community.
- Economic and political classes were also considered.

FGDs were conducted with approximately 9-15 homogenous people engaged in a particular place on scheduled time. Most of the FGDs were held for one and half hour in average at a common place like institutional ground, homestead or fallow ground. Detail information about the FGDs has been given in Table-3.2 where, the places, number and target group are mentioned. Discussion with the focused group like farmers, fishers, women, labors etc at different time and locality helped to account present impact and future economy and livelihood dimension for such a disaster.

Table 3.3: Schedule of focus group discussion (FGD)

Date	Place	Target Group	No of Participants
05-12-2011	Madartek	Fisher	6 M, 6F
05-12-2011	Madartek	Day labor	10 M, 5 F
06-12-2011	Zirak Tahirpur	Farmer	9M
06-12-2011	Zirak Tahirpur	Women	9 F
07-12-2011	Ratanchiri	Farmer	13 M
07-12-2011	Ratanchiri	Women	14 F
07-12-2011	Ratanchiri	Fisher	6 M, 5F

Note: M-male and F-female

3.3.4 Key Informant Interview

Key Informant Interview (KII) was used as an important tool to gather appropriate information. It helped to verify and evaluate the field survey data. KII was conducted with selected persons in different time and places from the beginning to end of the field research. The participants of KII have been mentioned in Table-3.4.

Table 3.4: Participants for key informant interview (KII)

Serial No	Designation
1	Upazilla Agricultural Officer
2	Upazilla Fisheries Officer
3	BWDB Executive Engineer
4	High School Teacher
5	Chairman, Fatehpur Union Parisad

3.4 Secondary Data Collection

A number of secondary data have been obtained for this study. The data providing agencies and the types of data or information are summarized in Table-3.5.

Table 3.5: Secondary data and sources

Agencies	Type of Information
1. Bangladesh Water Development Board (BWDB)	Water Level, Discharge, Existing Crest Level
2. Bangladesh Meteorological Department (BMD)	Rainfall
3. CEGIS, CGC, IWM, Practical Action and WARPO	Haor Reports, Books, Reports, Papers, DEM data
4. Upazilla Fisheries Office	Fish Production
5. Upazilla Agriculture Office	Agricultural Production
6. Local NGO’s	Field aggregated data
7. Institute of Water and Flood Management, BUET	Haor Reports, Books, Reports, Papers, Projects report, Journals,

CHAPTER FOUR
STUDY AREA

4.1 Introduction

The Karchar Haor Sub-project comprises Palash, Dakshin Badaghat and Fatehpur Unions of Bishawamvarpur Upazilla and Gourarang Union of Sunamgonj Sadar Upazilla of Sunamgonj district. The Sub-project is bounded by the rivers Ghatghotia and Rakti to the west and the Chalti and Surma to the east and also by several number of Haor Sub-project in the surrounding periphery (Figure 4.1).

The Sub-project is designated as a Flood Control and Drainage Project in the Consultant's Terms of Reference (MPO Inventory No 184). The concept of the sub-project like all other Haor sub-projects is to provide flood protection to the main crop, Boro, against early flash flood of the surrounding rivers by the provision of submersible embankments and to provide early drainage to haor land by means of drainage sluices and regulators in the post monsoon. The sluices and regulators also serve for flushing water into the sub-project to reduce the head difference between inside and outside of the polder at the time of overtopping and so reduce the damage to the embankments. Along the eastern boundary the embankment is raised to full flood embankment between the discontinuous high land and used as village road. Some water is retained in the Haor in the post monsoon period for the purpose of irrigating the Boro crop and to conserve the soil moisture. Irrigation from the peripheral rivers is also practised to a limited extent and is generally provided by LLP and irrigation inlets. A 4-vent RCC flushing sluice has been build to flush water from the Chalti river inside the sub-project to irrigate the Boro HYV by gravity, or by LLP's along the Sonapur Khal and Gazaria Gang.

Karchar Haor Sub-project as implemented in 1966-68 comprises the following components:

- Road-cum-embankment from Amirpur to Alipur, between high ground to the north, 5.5 km
- Road from Alipur to Bishawamvarpur to the north and northwest 10.0 km

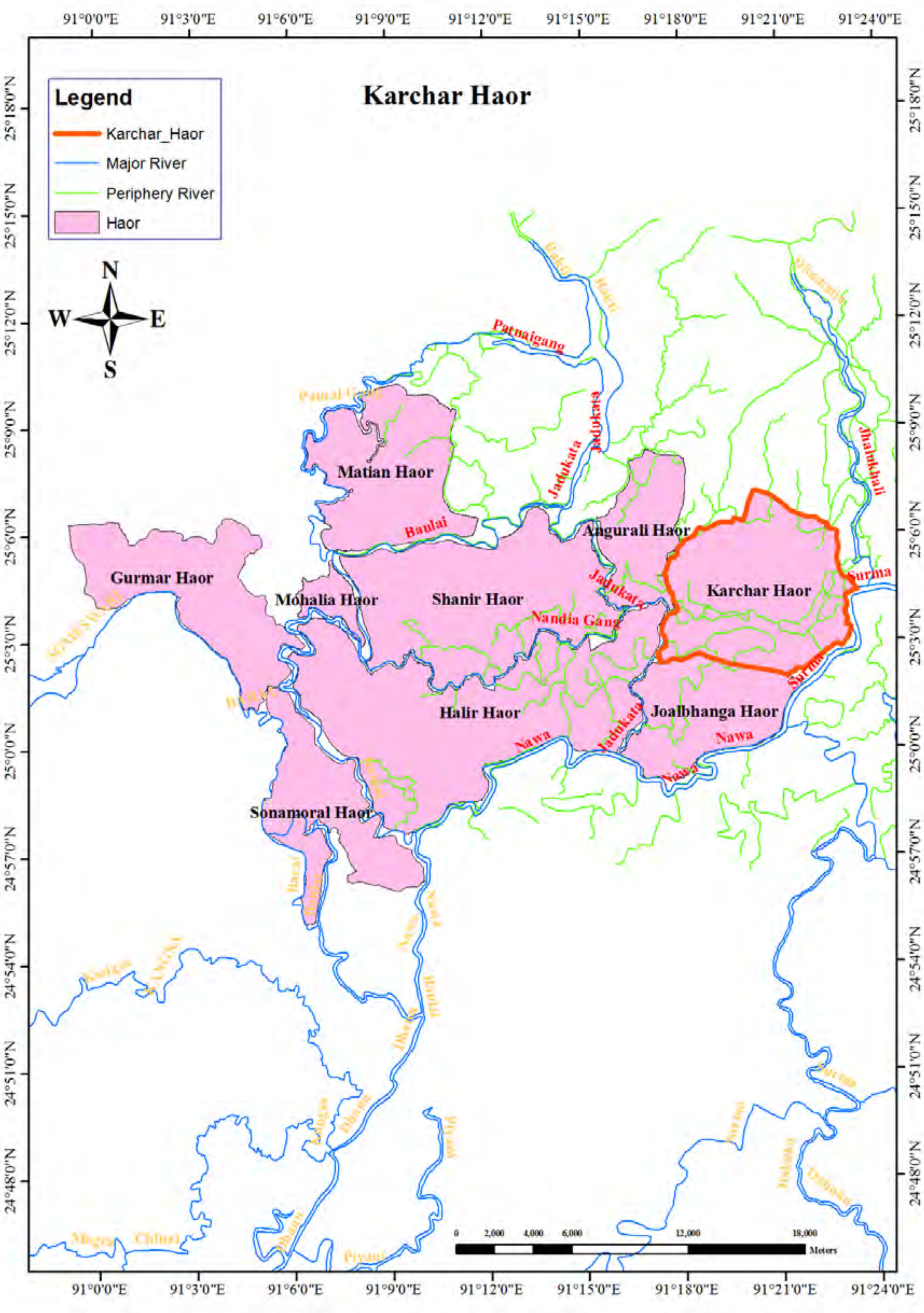


Figure 4.1 Karchar Haor and the Surroundings

- ➢ Submersible embankment to the remainder of the Haor between Amirpur to Bishawamvarpur, 22 km
- ➢ A 4-vent pipe sluice at Sonapur

- Ghatia Regulator, A 4-vent RCC box regulator near Jirag Tahirpur.

The engineering infrastructure has not provided the expected benefits due to breaching of embankments, illegal cuts and malfunctioning of the sluice and regulator. Breaching of the embankment is a serious problem in the northeast where three major breaches regularly occur due to flood in the Chalti river. Inflow of flood water through these breaches has resulted in sand-carpeting of agricultural land in the area as well sedimentation in the Karchar Beel.

4.2 Location and Topography

The selected Karchar haor sub-project is situated in the north-west of Sunamgonj town and started just after crossing the Surma River, adjacent to the town and lies between longitude 91 17 E and 91 23 E, latitude 25 02 N and 25 08 N.

Around 80% area of Karchar haor is located in Bishomborpur upazilla and the remaining portion in Sunamgonj Sadar upazilla under Sunamgonj district. There are several haor project such as Shanir haor and Halir haor in west, Joalbhanga haor in the south, Kalner haor in the north-east and Angurail haor in the north-west (Figure 4.1). The topography of the north eastern corner of the Karchar haor (Figure 4.2) is relatively highly elevated and the southern part is low.

The topographical variation in the sub-project area ranges from 4.00 to 6.00 m with a major depression in the southern side of the project. The Karchar Haor project is one of the submersible embankment projects in the Sunamgonj area (William Halcrow & Partners et al., 1993).

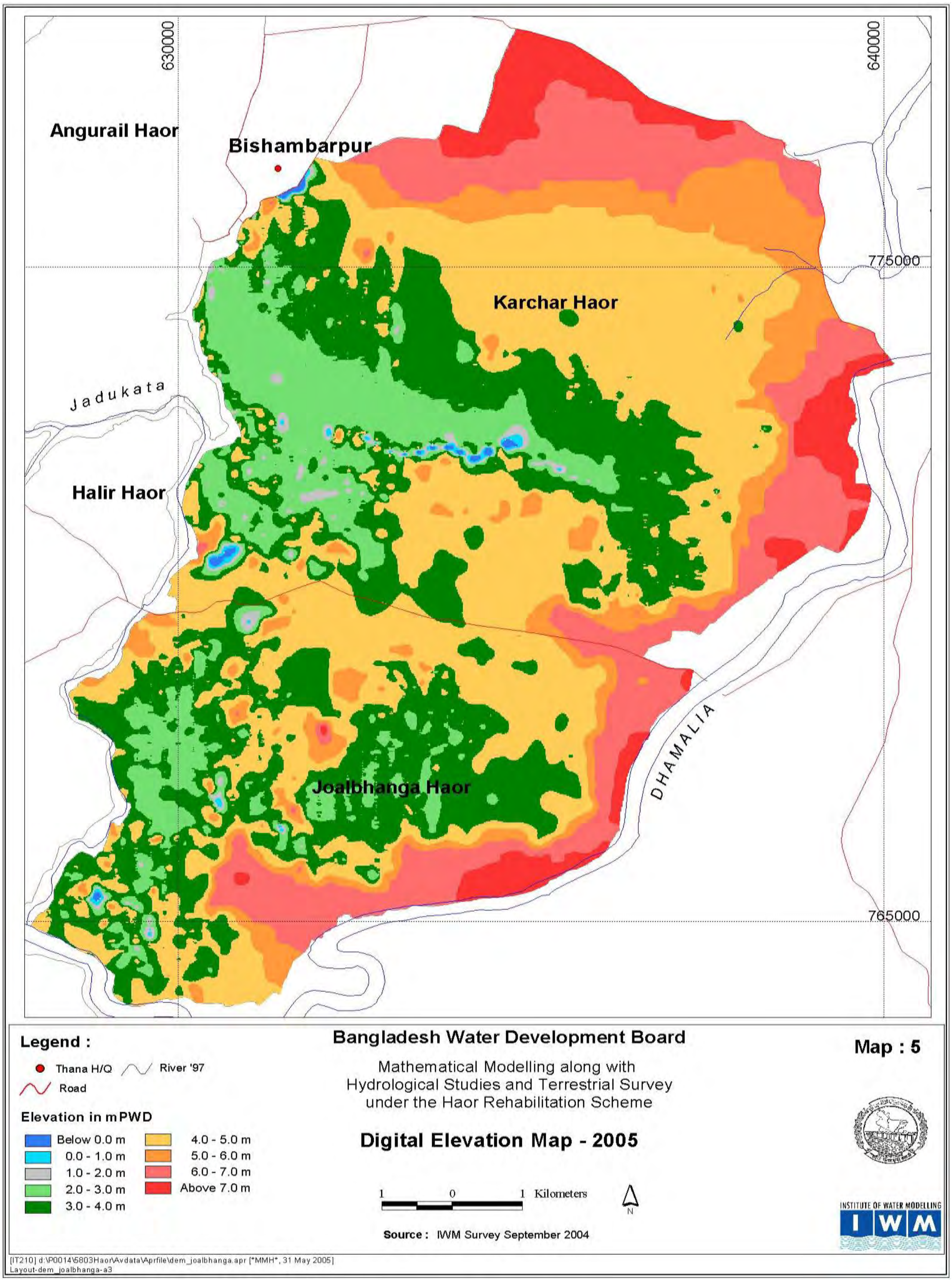


Figure 4.2 Topographic Map of Karchar Haor along with Adjacent Haor

4.3 Water Resources System

Water resources system of the Karchar haor sub-project is composed of rivers, khals, Haors and Beels located in and around the project area. The Jhalukhali (Chalti) River flows along the east periphery, the Surma flows along the southern and eastern boundary of this project and the Rakti River flows along the western side (IWM, 2006). There are a number of Beels within the Karchar haor sub-project area (Figure 4.3), which are connected to the bounding rivers through various khal. Also there are charas which flow from hilly area into Beels.

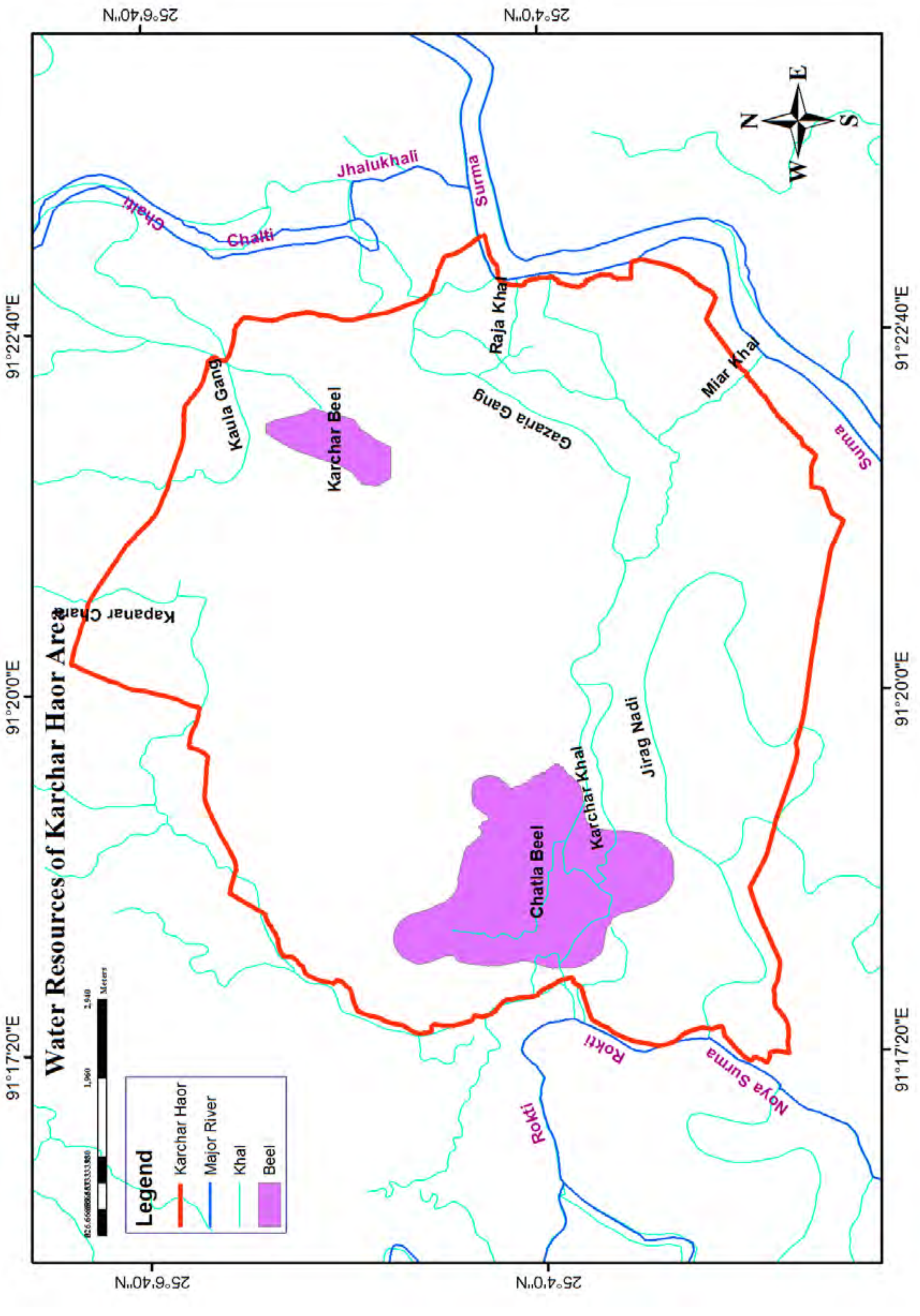


Figure 4.3 Water Resources of Karchar Haor Area (Source IWM)

4.4 Flooding Condition

The project area faces pre-monsoon flash flood almost every year due to huge volume of water coming in from the Surma River through different connected rivers surrounding the project area. In the early monsoon when excessive flood water accumulates in the Surma River, it creates backwater in the Chalti, Jhalukhali and Rokti Rivers. This backwater as well as water coming from upstream jointly raises the water level above the embankment resulting in overtopping and breaching of the embankment at several location through which water easily enter into the Haor. Flood water normally entered into the haor area within the time range from 15^{th} April to 20^{th} April (SSSIP, 1990).

Water starts overtopping the submersible embankment into this haor area from north-east and north-west part of the project area when flash flood occurs. Local rainfall also creates flood in the haor, but it does not exceed inundating one-forth of the haor area. The entire haor inundates within few days when heavy rainfall occurred in the neighboring hilly area. The rivers which are responsible for the flash flood and their distribution are Chalti River (Control 45%), Surma River (20%) and Rokti River (20%). During monsoon Karchar haor is flooded to depth ranging from 1.5 to 6.00 m (William Halcrow & Partners et al., 1993).

4.5 Drainage Condition

Drainage network of the study area comprises of a number of khal, beels and rivers in and around the project area. Land level slopes down from north to south which favors drainage to the Surma River through Jhalukhali and Rokti River. Water from low lying beels is mainly drained out by Ghatia khal through Ghatia regulator and Gazaria khal through Gazaria breach point. In addition to above mentioned location water also drains out through a number of locations where embankment is cut by the public and breach by flood water.

In the lowest part and the beels of the study area water normally drains out within the first week of December. But there is a tendency of delay in water drain out due to drainage congestion. If the area drain out within first week of December it will be good for farmers to transplant Boro in the field. About 25% area of haor suffer drainage congestion problem.

The rivers those controls drainage are Rokti River, Gazaria khal, Chalti River, Surma River and various canals. All internal and external canals are silted up to an extent. Water logging is becoming a challenging issue in the study area.

4.6 Irrigation

At present most of the cultivable land is under irrigation facilities. Surface water is the only source of irrigation in the project area and like other Haor area groundwater is not used at all due to high cost. Mostly LLPs are used to withdraw surface water from rivers and Beels for irrigation purposes. In some cases indigenous technology Kun is used for irrigation purpose from Beel areas. Local people reported that over the year the water storage capacity of the beel areas had decreased due to silting up of bed level of Beels. They also suggested that irrigation facilities from Beel area could be improved if the re-excavation of Beel is done.

From Union Chairman and Block Supervisors it has been found that the number of LLP and their corresponding command area for the 2011 season was as shown in the table below:

Table 4.1: Number of LLP and command area

Union	Number of LLP	Irrigated Area (ha)
Palash	82	1250
Dakshin Badaghat	47	715
Fatehpur	33	500
Gourarang	68	1035
Total	230	3500

4.7 Land Resources

The Karchar haor falls under Agro-ecological region 7 of Sylhet basin. The landform of the project comprises very lowland. The periphery of the project is moderately to deeply flood. The area comprises two major soils Fagu and Sallu. The Fagu soil occurs on the upper part of the basin. They are gray mottled brown firm clays. The Sulla soil occupies the basin bottoms. These soils are highly acidic to neutral and average organic matter content is 3.5%. Most of the soil nutrients are high to medium except phosphorous arid boron. The land is inundated periodically by pre-monsoon flash flood and every year by monsoon flood (Shawinigan Lavalin Inc and Others, 1992). It is found that 90% of the total area is agricultural land (Table 4.2).

Table 4.2 Land use distribution of Karchar Haor project area

SL No	Type of Land use	Percentage of Total Land	Remarks
1	Settlement	2%	
2	Homestead garden	1%	
3	Vegetable garden/ Seed bed	2%	
4	Cattle grazing	1%	Fallow land
5	Road/ Infrastructure	1%	
6	Agriculture	90%	
7	Water body	3%	
	Total	**100%**	

4.8 Structural Component of Karchar Haor Sub-project

The major physical elements of the SEP include submersible embankment, compartmental embankment, regulator, pipe sluice and closure. The cross sectional parameters of the submersible embankment are shown in Table 4.3.

Table 4.3 Embankment cross section parameters

Parameter	Dimension
Crest Width	3.00 m
River Side Slope	1:3
Country Side Slope	1:3
Free Board	0.30 m
Crest Elevation	

The height of embankment is designed for 10 year frequency level pre-monsoon flood expected to occur before May 15. Since the embankment is designed to be overtopped, the free board is provided mainly to accommodate the expected rise in pre-monsoon water levels after the project implementation. The CEGIS findings of present operation status of the interventions are given in Table 4.4 (CEGIS, 2002).

Table 4.4 CEGIS findings of present operation status of the interventions

	Location/structures	Existing conditions	Proposed solutions
1	Submersible embankment from Hossainpur to Minajuri village (eastern side of Karchar Haor)	Four major breaches and six other minor breaches. The height and width of the submersible embankment have reduced.	Construct a regulator at Gozaria in one location with provision of boat passage. Otherwise, construct a cross dam at Badurpur, Gazaria and Shonapur. All other public cuts and submersible embankment need strong repair work/ re-sectioning (both height-wise and width- wise).
2	Submersible embankment from Minajuri village to Biswambarpur Bazer (Northern side of the Karchar haor)	No major breach on the embankment. Embankment is used as a type-B road. 7 bridges and 2 box culverts on the embankment are in good condition. Out of these 7 bridges 3 are located near Biswambharpur, Muktikola and Rasulpur village. However, the early flash flood (mostly from the upland hills) often intrude the cross dam (locally constructed) and enter through these 3 openings and cause boro damage in the haor.	Transform/ construct permanent water control structures at 3 locations near Bishambarpur, Muktikola and Rasulpur village.
3	Submersible embankment from Biswambarpur Bazaar to Zirag-Taherpur (western side of Karchar Haor)	Two major breaches near Badurpur village. Poor condition (low height and width) of the submersible embankment	Rehabilitate the embankment (height and width) with concrete blocks to strengthen its slope. Use the soil (collected from the riverbed instead from near the embankment) for repairing/ rehabilitating the embankment
4	Submersible embankment from Zirag-Taherpur to Hossainpur village (southern side of Karchar Haor)	The condition of the embankment is satisfactory. The Zirag regulator (under Joalbhanga Haor) helps in providing support to this part of the embankment. Some settlements are located near this part of the embankment	No solutions are required frorn Karchar Haor but people of Joalbhanga Haor have suggested raising the embankment height to prevent flash floods from entering from Karchar Haor to Joalbhanga Haor.
5	4-vent regulator at Ghatta (Ghatta regulator)	The physical condition of the regulator is good. However, due to siltation in the Rupsha and Rakti riverbeds drainage in Karchar Haor remains a problem during the boro crop planting season.	Re-excavate the Rupsha and Rakti rivers. Control the regulator on the basis of agricultural requirements and timings.
8	Other suggestions	- Re-excavate Chalti river - Construct an embankment from Minajuri –Badhertek – southern side of Sonapur- Bazargaon – Surma River. This will creat a better hydrological situiation for alternative drainage of upland flow and reduce pressure into Karchar Haor. Pander khal cross-dam had wider effect. - Construct rubber dam (or water pump) for irrigation at Bomardala over Chalti river.	

4.9 Agriculture practice

This Haor is deeply to moderately flooded during the monsoon season. The soils are clayey and less porous and less permeable. About 90 percent of the total project area is used for the agricultural crops. Boro is the main crop grown in these areas. Both HYV and local variety are grown in this Haor (Table 4.5).

Table 4.5 Boro land type and area of Karchar Haor

Land type	Crop	Area (ha)	Percent Of NCA
Low land	Boro (HYV)	1650	46
Very low land	Boro (Local)	1850	54
	Total	**3500**	**100**

HYV Boro includes BRRI dhan-28, BRRI dhan-29 and BRRI dhan-26. Shail is the most local variety practices in these places. But the crops grown in these areas are frequently damaged by flash flood in the month of April and May. The River Rokti in the west and Chalti in the north-east and Surma in the east are mainly responsible for damaging the corps due to inadequate height of submersible embankment to prevent early flash flood water. In the devastating flood of 2010, more than 85% of the Boro crops areas were damaged. Other crops which grown in the Karchar haor area includes T-Aman, Aus, potato, corn, lintel etc. Annual average production of various crops is shown in table (Table 4.6).

Table 4.6 Annual average productions of various crops

Serial No	Name of Crop	Cultivated Area (Ha)	Annual Average Production (Ton)
1	T-aman	1200	2620
2	Boro	3500	11400
3	Aus	300	600
4	Wheat	80	120
5	Corn	9	31
6	Potato	80	204
7	Lintel	10	9
8	Mustard	70	67

4.10 Fisheries and other ecological resources

Karchar Haor is moderately rich in fisheries resources. This Haor is under various threats due to population pressure and indiscriminate resource use. According to the local people, the main causes of degradation are over- harvesting, siltation, conversion of wetlands into rice fields, unwise falling of aquatic trees, erection of embankment and other anthropogenic interventions. According to the local Fishery Officer, the average current fish production is around 1416 metric ton from the study area. Major fisheries issues so far identified by the local people are as follows-

- Fish production is decreasing due to habitat loss, change of existing aquatic ecological condition and poor fisheries management.
- Fisheries biodiversity is declining due to in discriminate fishing e.g. use of harmful fishing gears, catching of post larva and brood fish, completely dewatering of leased water bodies for fishing etc.
- Loss of fish habitats (both area and depth of perennial beels, Khals and adjacent rivers) due to rapid siltation and illegal encroachment.

There has been mass extinction of the native flora and fauna of the Haor basin of Northeastern Bangladesh. In its original form, the basin would have consisted of a rich mosaic of permanent and seasonal lakes and ponds with abundant aquatic vegetation, surrounded by vast areas of swampy ground with tall reeds and seasonally flooded grasslands. Swamp forest, dominated by *Barringtonia, Pongamia* and other flood-tolerant tree species, would have covered the river levees and provided a secure refuge for terrestrial wildlife during the monsoon floods. On higher ground this would have given way to scrub jungle and dense stands of bamboo.

CHAPTER FIVE

DISCUSSION ON CAUSES OF FAILURE OF EMBANKMENT

5.1 Introduction

Flash floods cause massive damage to Boro crops in the Haor areas very frequently which are generated in the steep upland catchments in India adjacent to the Haor region. Just like previous other years also in 2010 flash flood causes failure of embankment before harvesting of Boro crops and ultimately caused colossal damage to lives, crops and properties of the Haor area. Flash flood approaches towards Karchar Haor from the northern side through small channels and from the Jhalukhali river. Major intrusion points are located near Gazaria where several breaches exist in the submersible embankment. These breaches have to be closed each year before the pre-monsoon. After harvesting the crop these portions are mostly cut by local people for shorter navigation route through the Haor (IWM, 2006). In most of the circumstances it is observed that the breach closing is not done in appropriate time and consequently damage to Boro crops occurs due to entering of flash flood water through breach. Moreover sometimes overtopping of embankment also occurred along with breaching.

5.2 Breach Closing in Gazaria

Gazaria breach point (Photo 5.1) is the most important and vulnerable breaching point from chainage km 1.51 to km 1.88 of Karchar haor submersible embankment which is needed to be closed by constructing Gazaria Closure across the Gazaria river every year. If the Gazaria Closure fails before harvesting the Boro crops then the whole Karchar haor area is submersed by flash floodwater and all the crops are damaged. It is revealed from the FGD that every three to four years the failure of Gazaria Closure is usually observed. According to local people there are several causes of failure of Gazaira Closure. Among them two major causes are; 1) poor quality of repair work; and 2) delay in construction. The causes of delay in construction and poor quality work and consequent failure phenomenon are discussed in the following section.

Photo 5.1 Gazaria breach point

5.2.1 Delay in Construction

Delay in construction is one of the important reasons for which failure of the closure in Gazaria breach point occurs. According to the local people the bed level of the Gazaria River is lower than that of the Chalti and Surma rivers and that is why the river side water pressure against the Gazaria Closure is very high due to combined effect of the water pressure of both the rivers. As a result of delay in construction the soil materials used for construction do not get enough time for natural compaction due to movement of people and small vehicles and for this reason the closure can not be strong enough to withstand against high pressure of water in the river side. Also seepage is another factor which occurs through the newly constructed closure due to less compaction, causing washing out soil materials from the base of the closure and suddenly the top level of closure become lower and ultimately fail. Sometimes due to delay in construction the flash floodwater comes during the period of construction and consequently failure of closure occurs.

There are different types of causes for which delay in construction occurs. Previously the construction of closure was done by the contractor through tendering, but now-a-days construction is done by PIC, formed by the resolution of Union Parishad meeting. PIC is supposed to be formed with the members who have land in concern Haor area. But practically it is found that there is political involvement in the formation of PIC. Local political workers want to become benefited from the process of formation of PIC. They maintain the communication with local MP for the purpose of formation of PIC. For this reason formation of PIC is delayed and ultimately construction of embankment is delayed. Another thing regarding delay in construction of closure is due to non availability of fund in due time. In case of construction by contractor the bill can be paid after finishing some portion of work. But in case of construction by PIC bill should be paid on day to day basis immediately after ending day work because local marginal day laborers are recruited as PIC member for construction work who can not work other than day to day basis payment. Also sometimes payment is required to be made in advance basis in case of construction of breach closing works through PIC. But fund for the construction is released in four installments and it is observed that the last installment is released in the month of June. In many cases fund is not adequate enough for the breach closing work. So, it is not possible to make day to day basis payment for PIC members and avail required number of labors in order to finish the construction work in due time.

From FGD it was also revealed that if the laborers, who have land in the Haor of interest are recruited as PIC member as per Union Parishad resolution then they have the interest to save their crop. So they work hard and try their best to close the breach point. But usually it is observed that due to political influence a significant number of PIC members are recruited who have no land in the Haor of interest violating the resolution of UP. As a result they don't have any interest to save the crop of the Haor area by hard work. This hinders the process of construction of closure in breach point in due time.

5.2.2 Poor Quality Work

Poor quality work is another reason for which failure of the closure in Gazaria breach point occurs. It was revealed from FGD that the soil used for construction is sandy soil in many cases and hence closure is not very good against seepage. Locally available soil for construction is not appropriate as per design and specification. In this regards carried earth may be used for construction but it is very much costly and not feasible in comparison to availability of fund. It was found that compaction is not done as per specification. Also it can be concluded from GD and FGD that the design crest level and side slope are not properly maintained in maximum cases during construction of closure which affect the stability of closure and reduce the capacity to withstand high river side water pressure.

5.3 Failure at Adang Village

From FGD it is found that more than 1 km of Karchar haor submersible embankment at Adang village from chainage km 3.25 to km 4.25 is washed out every year due to wave action of the Chalti River (Photo 5.2 and Figure 5.1 and 5.2). Eventually this damaged portion of embankment is repaired by resectioning every year. As a result of washing out of some portion of sandy embankment materials to the adjacent agricultural lands the fertility of the lands is reduced. In this area the embankment crest level is relatively high to protect from full flood and save the adjacent homestead area. It is revealed from the FGD that due to failure of embankment at Adang, 17 villages are inundated by flood which causes a lot of suffering to the people. Movement of people and transport of goods are obstructed. Also education is hampered due to inundation of schools. Flood causes a remarkable amount of economic damage in this area. In some cases there is evidence of entering river water to the haor area through elevated homestead area that causes damage to the crop. People of this area think that repair of the embankment every year is totally useless which is done only for the interest of local politician. According to them this repair work causes people suffering rather than benefit. This repaired portion can not protect the people of the area from flood and hence from suffering, where as the sandy soil of the damaged embankment causes the loss of fertility of the adjacent land. They rather think that normal damaged condition is better than repair of embankment every year in this way. Their opinion is that, if slope protection of embankment can be done, the area can be saved from flood.

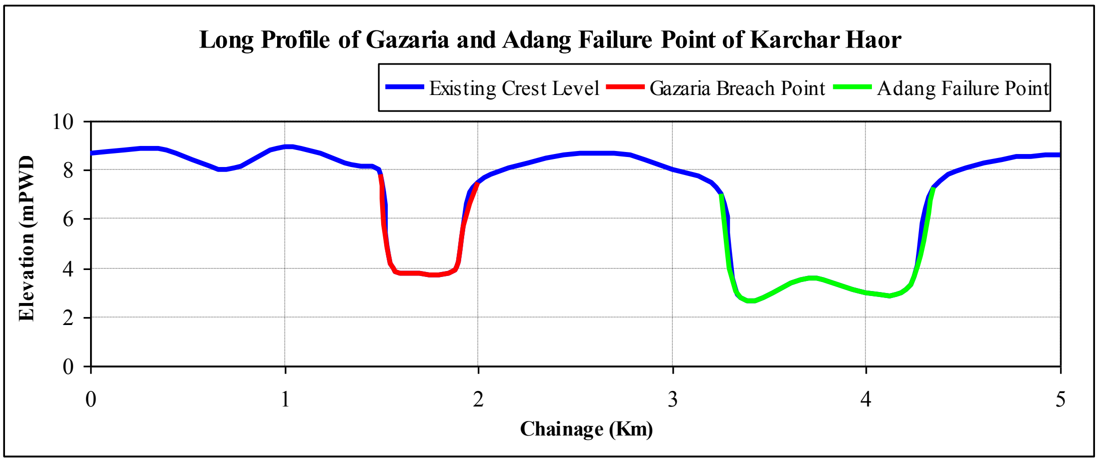


Figure 5.1 Long Profile of Gazaria and Adang failure point

Photo 5.2 Damaged embankment at Adang village

5.4 Overtopping at Zirak Tahirpoor

The Haor area adjacent to the Rokti river at Zirak Tahirpoor is comparatively lower in elevation (Figure 5.6) than other areas of the Karchar haor. Almost 2450 ha haor land in this area is protected by submersible embankment along the Rokti river. GD (Group Discussion) revealed that the submersible embankment of Karchar Haor from chainage

Km 15.00 to Km 20.00 (Figure 5.2) was overtopped in 2010 (28th of Bengali Choitro). After every flood the top level of embankment becomes lower than original level due to erosion of embankment soil resulting from submergence (Photo 5.3). As a result every year repair of embankment is done in this area.

From FGD and group discussion it was revealed that the repair and re-sectioning is not done properly. The people think that repaired crest level, what is done every year is not adequate to protect flash flood before harvesting the Boro crop. It was found from GD and FGD that after re-sectioning and repair the crest level come to an undulated long profile rather a uniform long profile. They think that the repaired top level should be another 1.50 m higher than what is actually done. Also after placing the earth for re-sectioning no finishing or turfing work is done and side slope is maintained properly.

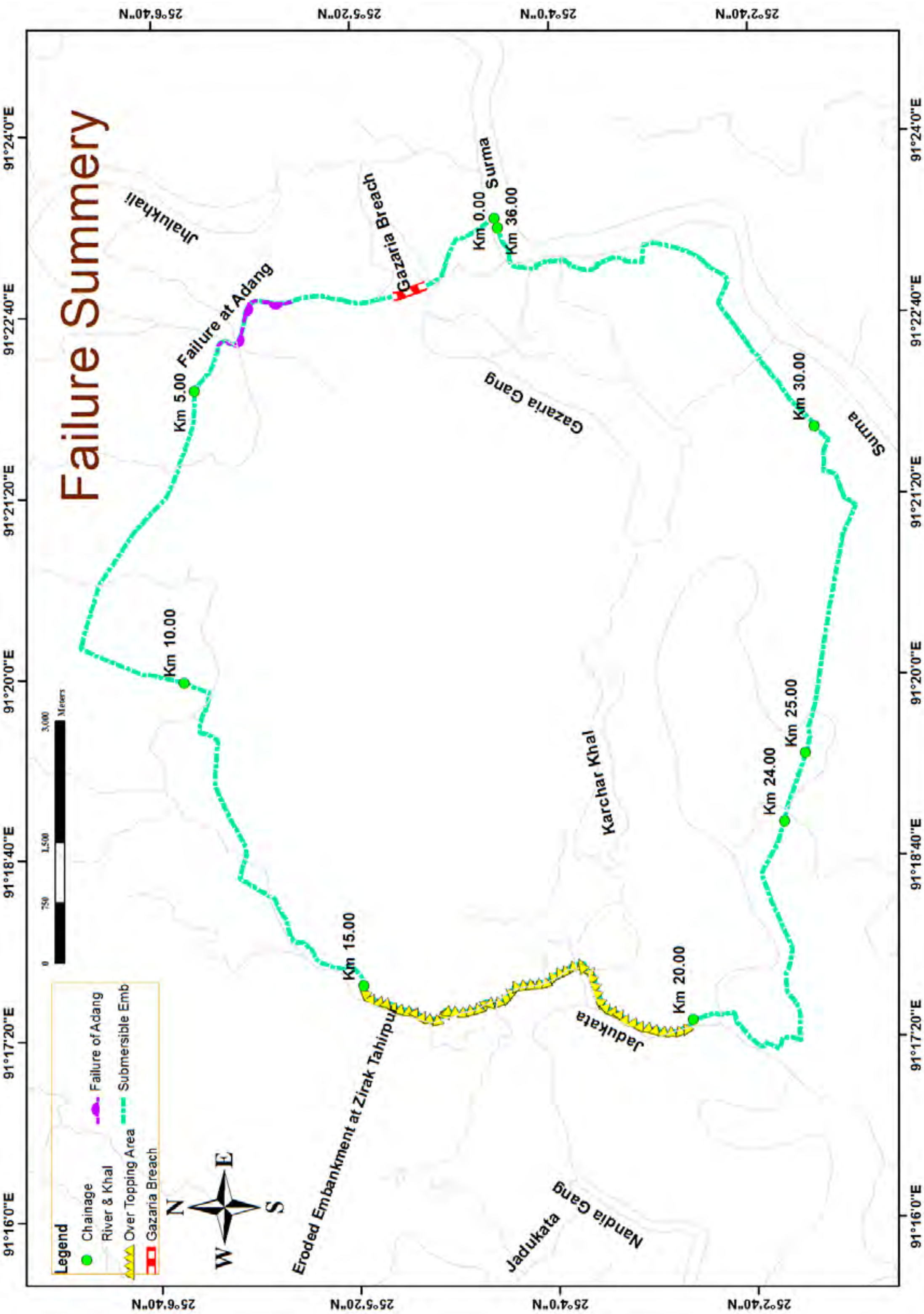
Photo 5.3 Condition of submersible embankment at Zirak Tahirpur after flood

5.5 Summery of Failure

Among the locations of failure of Karchar Haor submersible embankment the breaching at Gazaria, failure of embankment at Adang and damage of embankment at Zirak Tahirpur are the most significant in every year. Besides these failures, sometimes small breaching also occurs in other places. The location and quantity of damage of breach point at Gazaria, failure at Adang and eroded embankment at Zirak Tahirpur are presented in Table 5.1 and shown in Figure 5.2.

Table 5.1 Location and damaged quantity of major failure

Sr No	Failure Type	Location	Chainage (Km)	Damaged Length (Km)
1	Breaching	Gazaria	1.51-1.88	0.37 Km
2	Washed out of embankment	Adang	3.25-4.25	1.00 Km
3	Overtopping	Zirak-Tahirpur	15.00-20.00	5.00 Km



(Source IWM)

Figure 5.2 Location of Major Failure Points

5.6 Discussion on Adequacy of Design Crest Level of Embankment

In order to assess the adequacy of design crest level of submersible embankment and present condition of the embankment a comparison was made among the design crest level, existing crest level and calculated crest level in this study. For the purpose of calculation of required crest level to protect Boro crops from flash flood the historical water level data of differnt gauge stations in the surrounding rivers of the Karchar Haor was collected from BWDB. The water level data were analyzed and maximum water level up to 15 May in different years of various stations were fitted with an appropriate probability distribution function. It is found that the peak water level within 15 May of all the stations have reasonable fitness with the Extreme Value Type-I (EVI) distribution. The analysis of water level data of the Noya-Surma River at station Shukdevpur has been shown in Figure 5.3.

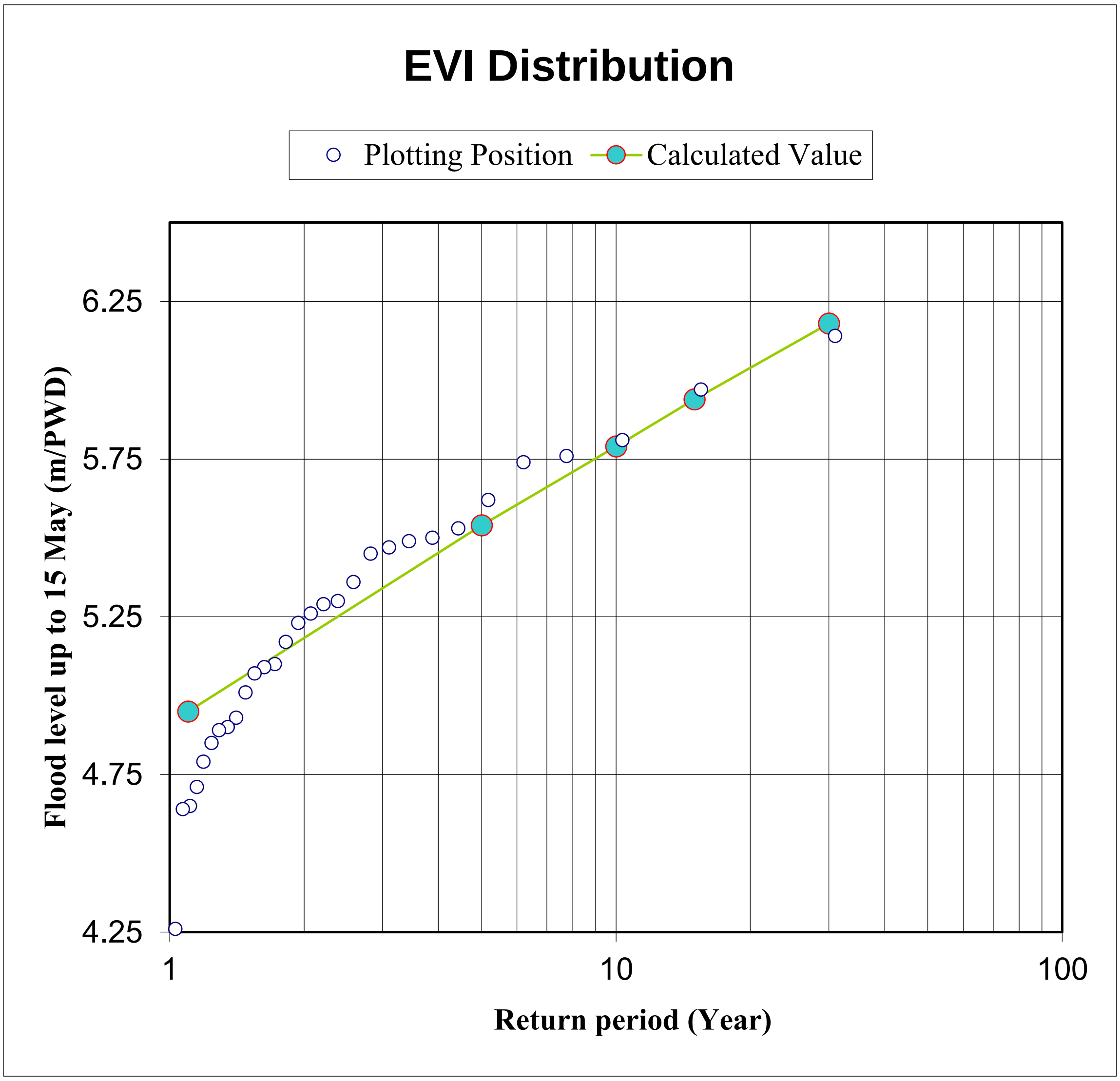


Figure 5.3: EVI distribution of peak WL up to 15 May of Noy-Surma river at Shukdevpur

The probable water levels within 15 May in various return periods has been shown in Table 5.2.

Table 5.2: The probable flood level of river Noya-Surma at Shukdevpur

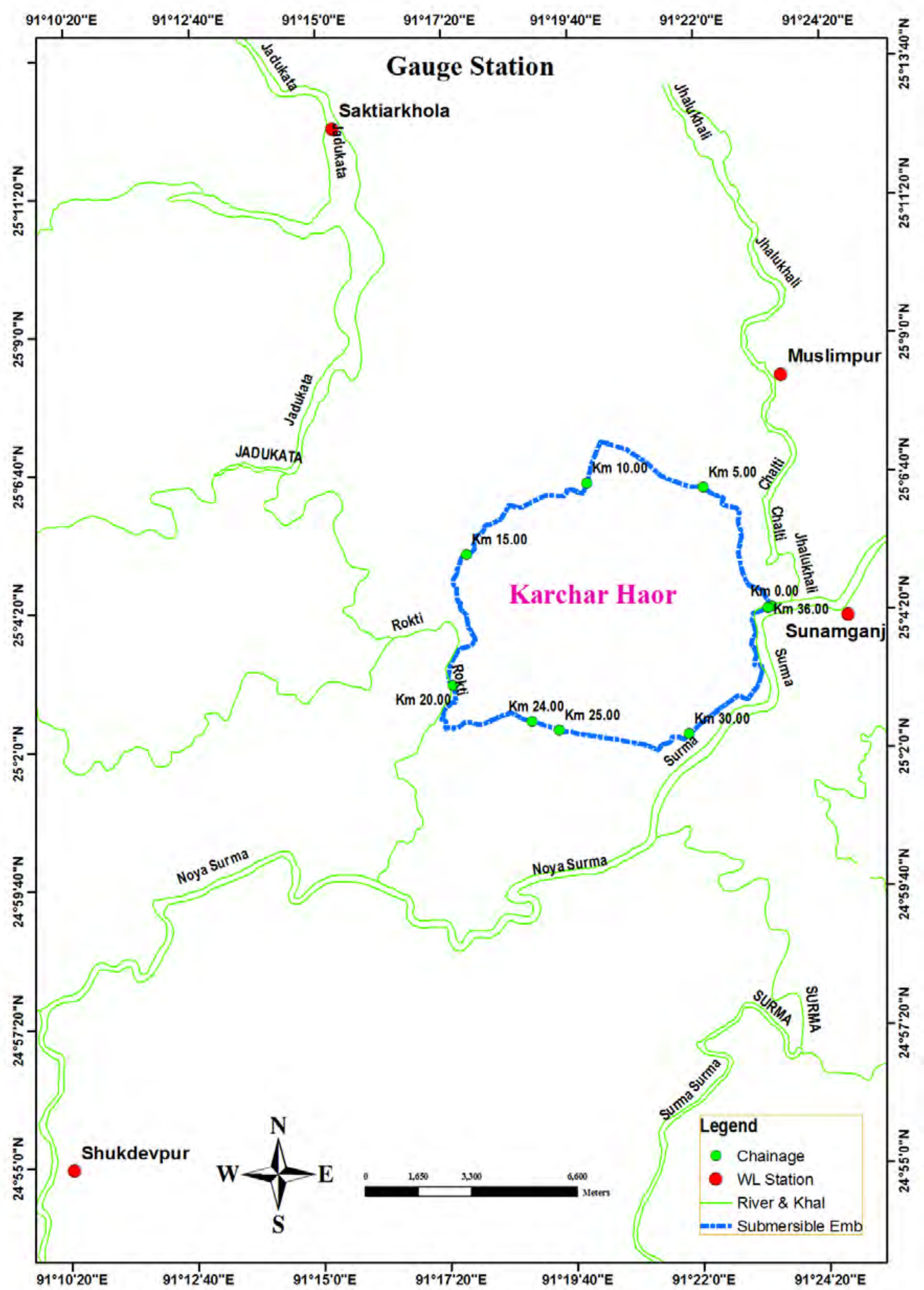
Serial No	Return Period (Years)	Probable Flood Level (m/PWD)
1	5	5.54
2	10	5.79
3	15	5.94
4	30	6.18

The analysis of water level data for other stations such as Saktiarkhola, Sunamgonj and Muslimpur are also done and the probable water levels found for 1 in 10 years frequency are represented in Table 5.3.

Table 5.3 One in ten years probable water level within 15 May

Sr No	Station Id	Station Name	River	1 in 10 Years Probable Water Level (mPWD)
1	SW72B	Shukdevpur	Noya-Surma	5.79
2	SW131	Saktiarkhola	Jadukata	8.67
3	SW269	Sunamgonj	Surma	7.90
4	SW333	Muslimpur	Jhalukhali (Chalti)	8.57

The water level in the river adjacent to the Karchar Haor submersible embankment is dependent on the distance of the station from the embankment and the gradient of the river. To obtain the 1 in 10 year probable water level in the river adjacent to submersible embankment for a certain length the process of interpolation/ extrapolation has been applied among the water levels of various stations considering the distance of the station from submersible embankment. As per design criteria of BWDB the analyzed crest levels are found by adding 0.30 m freeboard. The shortest distance of the stations are shown in Table 5.4 and the analyzed crest levels are represented in Table 5.5. Also the locations of the stations are represented in Figure 5.4.



(Source IWM)

Figure 5.4 Gauge Station around Karchar Haor Submersible Embankment

Table 5.4 Distances (shortest) of stations from submersible embankment

Sr No	Station Name	Distance from Submersible Embankment (Km)
1	Shukdevpur	18.50
2	Saktiarkhola	13.00
3	Sunamgonj	3.25
4	Muslimpur	4.25

(Source IWM)

Analyzed crest level for different chainage has been calculated by inter/extrapolation of the data of Table 5.3 and Table 5.4.

Table 5.5 Analyzed crest level for various locations of embankment

	Chainage (Km)	1 in 10 Years Probable Water Level (m.PWD)	Analyzed Crest Level (m.PWD)
1	0.00-5.00	8.20	8.50
2	5.00-13.00	8.10	8.40
3	13.00-23.00	7.50	7.80
4	23.00-29.00	7.80	8.10
5	29.00-36.00	7.90	8.20

The original design level shown in Table 5.6 was proposed in SRP at the time of implementation of the project during 1967-1968. In 2006 IWM suggested the design level described in the Table 5.6. The repair and maintenance of submersible embankment was done following the SRP design crest level.

Table 5.6 Design crest level of Karchar Haor submersible embankment

Sl. No.	Name of Haor	Chainage (km)	Design Crest Level (m.PWD) Suggested by IWM	Design Levels (m.PWD) as per original SRP Design	Remarks
1	Karchar Haor	0 – 10 10 – 29 29 – 36	8.1 7.1 8.1	0 – 5.3km: 10.05 rest : 7.56	0 to 5.3 km have been designed by SRP to provide full flood protection

The long profiles of the embankment regarding existing crest level, SRP design level, IWM suggested level and analyzed crest level in the study have been plotted in Figure 5.5. The existing crest level (Figure 5.5) in the actual field is drawn by using the data obtained from BWDB field office which was measured for the purpose of scheduled yearly repair and maintenance for the year 2011. The existing crest level is not measured physically. During social survey it was discussed about the adequacy of crest level with the local people.

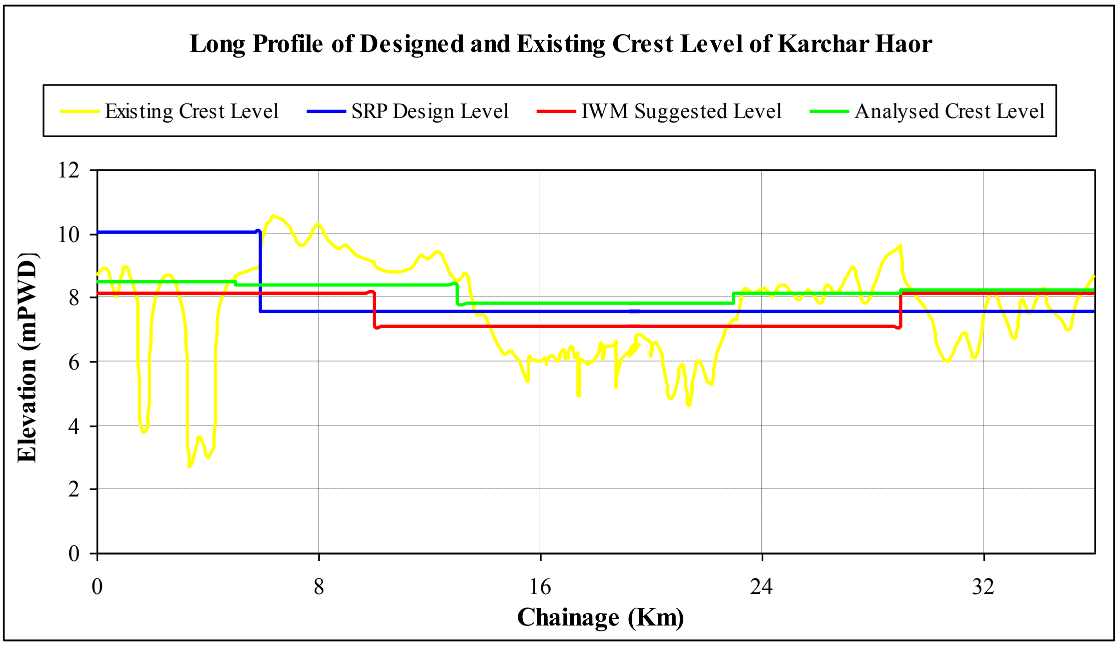


Figure 5.5 Long profile of Karchar Haor submersible embankment

It is observed from above findings that the calculated crest level is close to both the IWM suggested and SRP design crest level. Only small variation exists among different design level. Also it is found from the Figure 5.5 that the SRP design level is only 0.24 m lower than the analyzed crest level and greater than IWM suggested level between the chainage Km 15.00 and Km 20.00 where overtopping of embankment occurs as revealed in GD (Group discussion). Then the question is why overtopping of embankment occurs in maximum 1 in 4 year frequency as revealed in FGD. This may be due to poor O&M activity, unspecified soil used for repair work, violation of design in repair and maintenance. It is found from study that repair work is not done at required crest level and crest width. It is found from FGD that after finishing the repair work the long profile remain undulated. People think that 0.60 m to 0.90 m more embankment height than actually constructed during repair is required to stop the overtopping. The actual construction work is done at lower height than the design level and side slope is not sufficient for embankment stability. So it can be assumed that failure/ overtopping mainly occurs due to non maintenance of design and specification during rehabilitation of submersible embankment every year. So from PRA findings it can be said that the design crest level is adequate enough for protecting flash flood in 1 in 10 year frequency but failure occurs mainly due to improper O&M activity.

5.7 Rainfall-Flash flood Correlation

Flash flood in the Haor area mainly occurs due to heavy rainfall in hilly region. Almost all the rivers in this area are originated from nearby hilly area of India and have very steep in longitudinal slope. As a result these rivers are extremely flashy. When heavy rainfall occurs in the hilly region of India, water quickly moves towards the Haor area of Bangladesh through a number of rivers and khals due to steep slope. Heavy rainfall in pre-monsoon causes early flash flood.

Rainfall in the Haor area also causes some sort of inundation to the Haor. An assessment on which is more dominant to crop damage between in-Haor rainfall inundation and inundation by flash flood caused due to heavy rainfall in hilly area was made. Also correlation between rainfall in Haor area and water level of surrounding River of Karchar Haor is determined. Along with the daily rainfall of Sunamgonj station (Id CL-127), the Digital Elevation Model (900mX900m) obtained from CEGIS have been used for determining the inundation condition in the Haor and water level of various gauge station for finding the correlation between rainfall and water level.

It is found that out of the total 5513 ha of project area 3904 ha lies in the topographic range of 4.00m to 6.00 m with a depression of 411 ha with topographic range 1.50 m to 4.00m in southern part (Figure 5.6) of the project. The rest 1198 ha area has the topographic variation of ranges 6.00 m to 8.00 m. The decadal total rainfall is taken for the purpose of analysis the in-Hour rainfall inundation with a consideration that 70% of the total rainfall will be available for inundation after seepage, percolation, evapotranspiration etc. Using the amount of different area and its topographic variation the area-elevation curve is established in Figure 5.7.

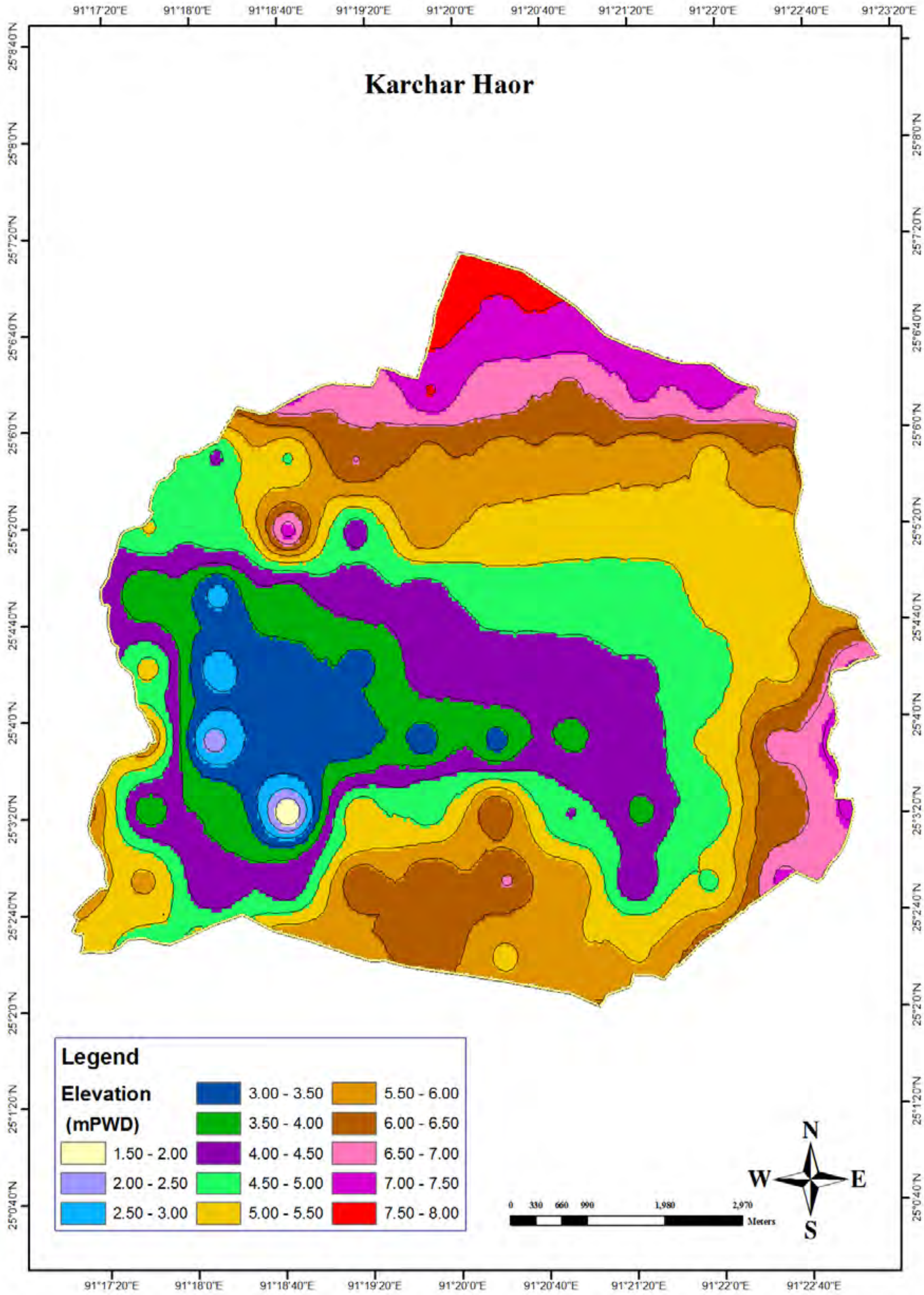


Figure 5.6 Digital elevation map of Karchar Haor (Source CEGIS)

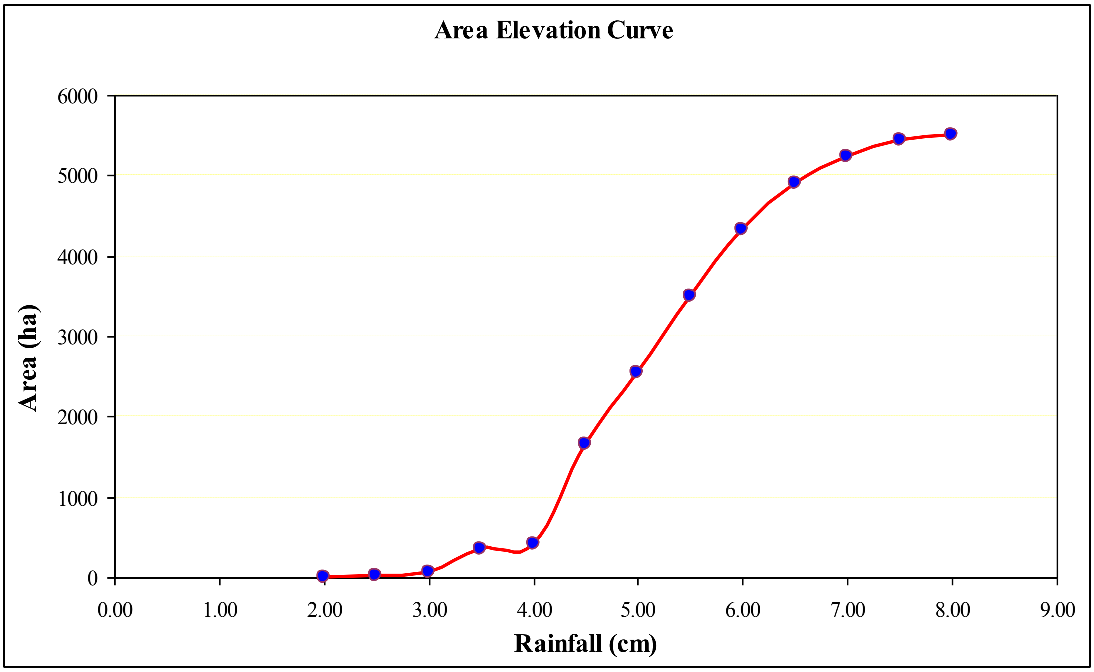


Figure 5.7 Area-elevation curve of Karchar Haor area

The corresponding reservoir volume of the Haor for a certain area has been determined and plotted against area and the Area-Volume curve (Figure 5.8) is obtained.

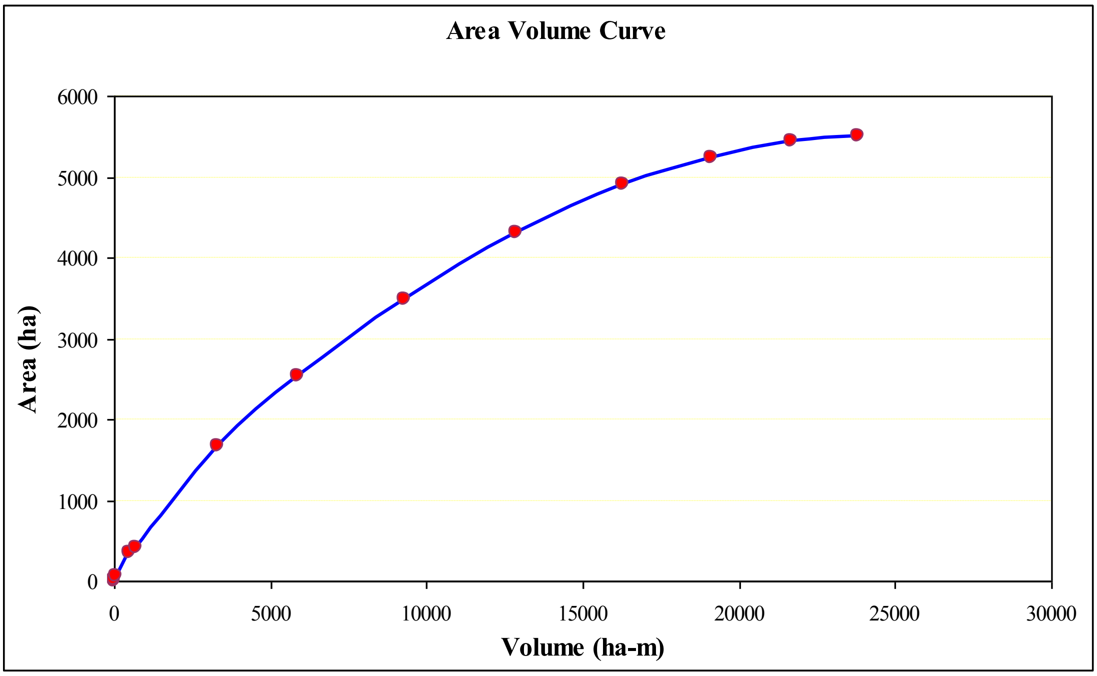


Figure 5.8 Area-volume curve of Karchar Haor area

In order to find out the inundated area for any depth of rainfall (70% effective) the volume of water which is precipitated in the whole Haor area is computed for various rainfall depths. From the Area-volume curve (Figure 5.8) the inundated area corresponding to the computed volume is obtained and represented in Table 5.7. The inundated area is plotted against depth of rainfall and rainfall-inundated-area curve (Figure 5.9) is found.

Table 5.7 Volume and inundated area with respect to rainfall

Depth of Rainfall (mm)	Volume of Water within the Haor (m^3)	Inundated Area (m^2))
40	154	130
80	309	241
120	463	349
160	617	393
200	772	455
240	926	528
280	1081	602
320	1235	676
360	1389	749
400	1544	823
440	1698	897
480	1852	970
520	2007	1044
560	2161	1118
600	2315	1191

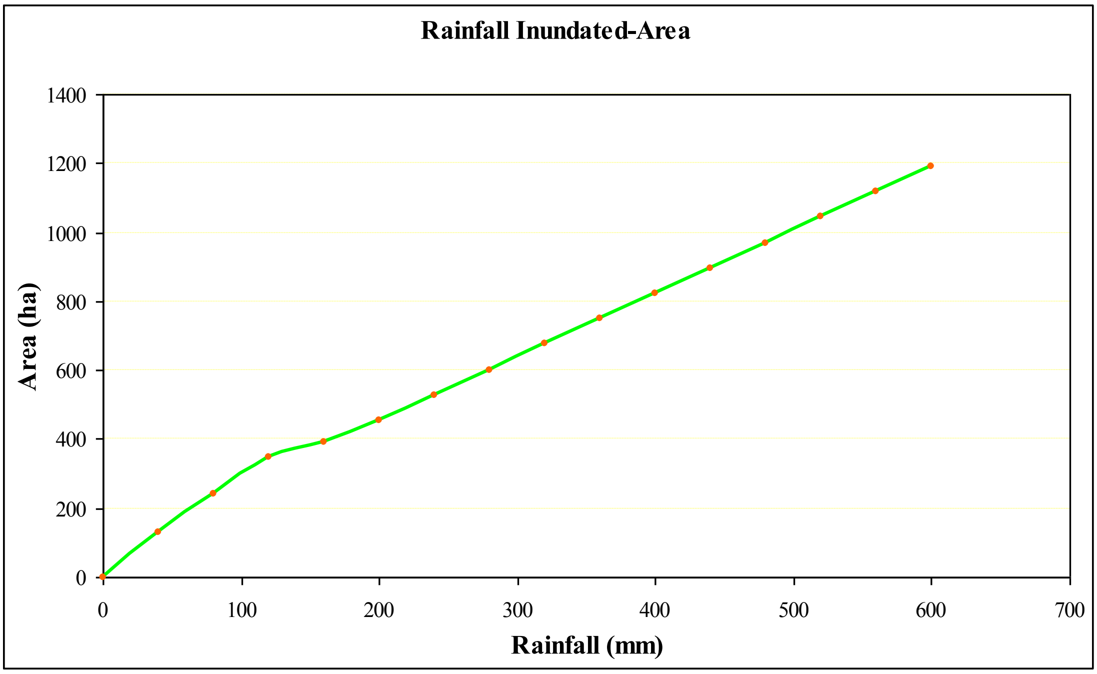


Figure 5.9 Rainfall inundated-area curve of Karchar Haor area

Table 5.8 shows the amount of decadal rainfall of different decade against various return periods. From the inundated-area rainfall curve it is found that the decadal rainfall in the first decade of May (which is maximum within 15 May) with 1 in 10 year frequency cause only 854 ha inundation of the Karchar Haor area. Also it is found that the May-I decadal rainfall of 2010 caused 690 ha of inundation. So it shows that inundation due to in-Haor rainfall is not very much significant

Table 5.8 Decadal rainfall (mm) at Sunamgonj station for various return periods

Month	Mar			Apr			May		
Decade	I	II	III	I	II	III	I	II	III
Return Period	1	2	3	4	5	6	7	8	9
1 in 2	23.59	47.74	134.29	156.71	201.70	226.20	268.83	249.24	415.90
1 in 5	37.77	74.03	202.66	229.37	287.93	319.43	370.23	349.40	578.12
1 in 10	47.16	91.43	247.93	277.48	345.02	381.15	437.36	415.71	685.53
1 in 20	56.16	108.12	291.35	323.63	399.79	440.36	501.76	479.32	788.55
1 in 50	67.82	129.73	347.55	383.36	470.67	517.00	585.12	561.66	921.91

(Source BWDB)

Table 5.9 Decadal peak water level (mPWD) at Sunamgonj station of the Surma

Month	Mar			Apr			May		
Decade	I	II	III	I	II	III	I	II	III
Return Period	1	2	3	4	5	6	7	8	9
1 in 2	2.51	3.10	4.58	5.18	6.18	6.30	6.82	7.09	7.64
1 in 5	3.03	3.97	5.99	6.48	7.55	7.51	7.96	8.25	8.57
1 in 10	3.37	4.55	6.93	7.34	8.46	8.32	8.71	9.01	9.18
1 in 20	3.70	5.11	7.83	8.17	9.34	9.09	9.43	9.75	9.77
1 in 50	4.13	5.83	9.00	9.24	10.47	10.08	10.36	10.70	10.54

(Source BWDB)

Now the decadal average rainfall, decadal rainfall in 2010 and decadal rainfall with 1 in 5/ 1 in 10 year return period of Sunamgonj station have been plotted in Figure 5.10. It is observed that in 2010 the decadal maximum rainfall of 355 mm occurs in first decade of May. It is almost twice greater than the decadal average rainfall and very little less than 1 in 5 year return period rainfall of May-I decade. Again the decadal average peak water level, decadal peak water level in 2010 and decadal water level with 1 in 5/ 1 in 10 year return period of station Sunamgonj in the river Surma have

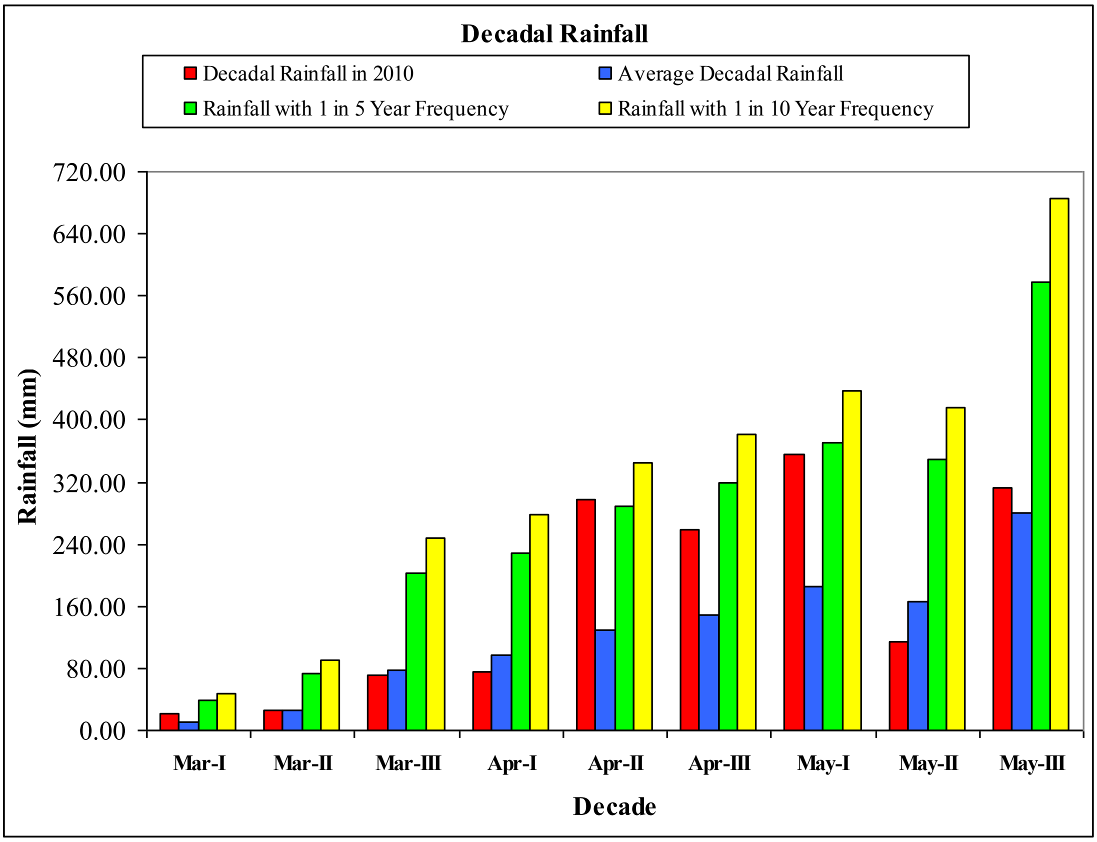


Figure 5.10 Diagram of decadal rainfall

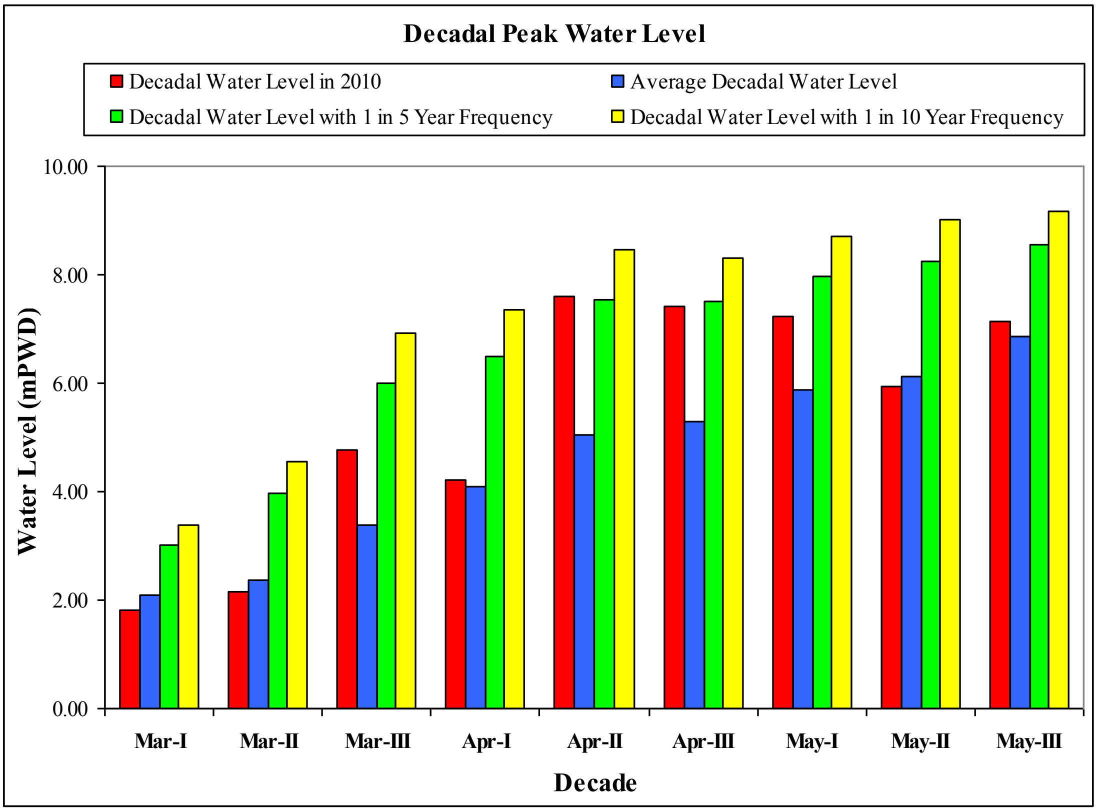


Figure 5.11 Diagram of decadal peak water level

been plotted in Figure 5.11. It shows that the May-I peak water level in 2010 is little greater than the average peak water level and little less than 1 in 5 year return period water level. On the other hand comparison between May-II rainfall and water level shows that the decadal rainfall in 2010 is little less than average decadal rainfall and less than one-third of 1 in 5 year decadal rainfall. At the same time the decadal water level in 2010 is very close to the average decadal water level and two-third of 1 in 5 year decadal water level. This means that the rainfall in the Haor area and water level in the surrounding Rivers are weakly correlated.

Table 5.10 Rainfall and water level correlation (value of correlation coefficient)

			Decadal Rainfall of Sunamgonj (Station Id CL-127)								
	Month		Mar			Apr			May		
		Decade	I	II	III	I	II	III	I	II	III
Decadal Peak Water Level of Sungonj	Mar	I	-0.05	0.05	0.16	-0.25	-0.06	-0.02	0.24	0.45	-0.19
		II	0.23	0.20	0.39	-0.12	-0.12	-0.13	0.33	0.24	-0.07
		III	0.04	0.59	0.64	-0.11	0.00	-0.21	0.31	0.37	-0.12
	Apr	I	0.26	0.58	0.43	0.28	-0.11	-0.05	0.25	0.26	-0.09
		II	0.20	0.27	0.01	0.43	0.51	0.09	0.02	-0.03	0.00
		III	0.16	0.20	-0.04	0.19	0.53	0.45	-0.12	-0.02	-0.02
	May	I	0.08	0.02	-0.13	0.16	0.15	0.52	0.42	0.26	0.03
		II	-0.04	0.18	-0.07	-0.10	0.10	0.31	0.44	0.68	0.18
		III	0.08	0.18	-0.03	-0.11	0.07	0.09	0.21	0.40	0.57

Again the head to head coefficient of correlation between decadal rainfall and decadal peak water level have been determined and represented in Table 5.10. It is observed that there is weak correlation between rainfall of a decade and water level of the same decade. Also rainfall of a decade shows better correlation with water level of next decade than that of same decade. The maximum value of correlation coefficient observed is 0.68 between may-II rainfall and May-II water level of Sunamgonj station. The May-II decadal rainfall and decadal peak water level of station Sunamgonj have been plotted in Figure 5.12 and observed that no distinct correlation exist between rainfall and water level.

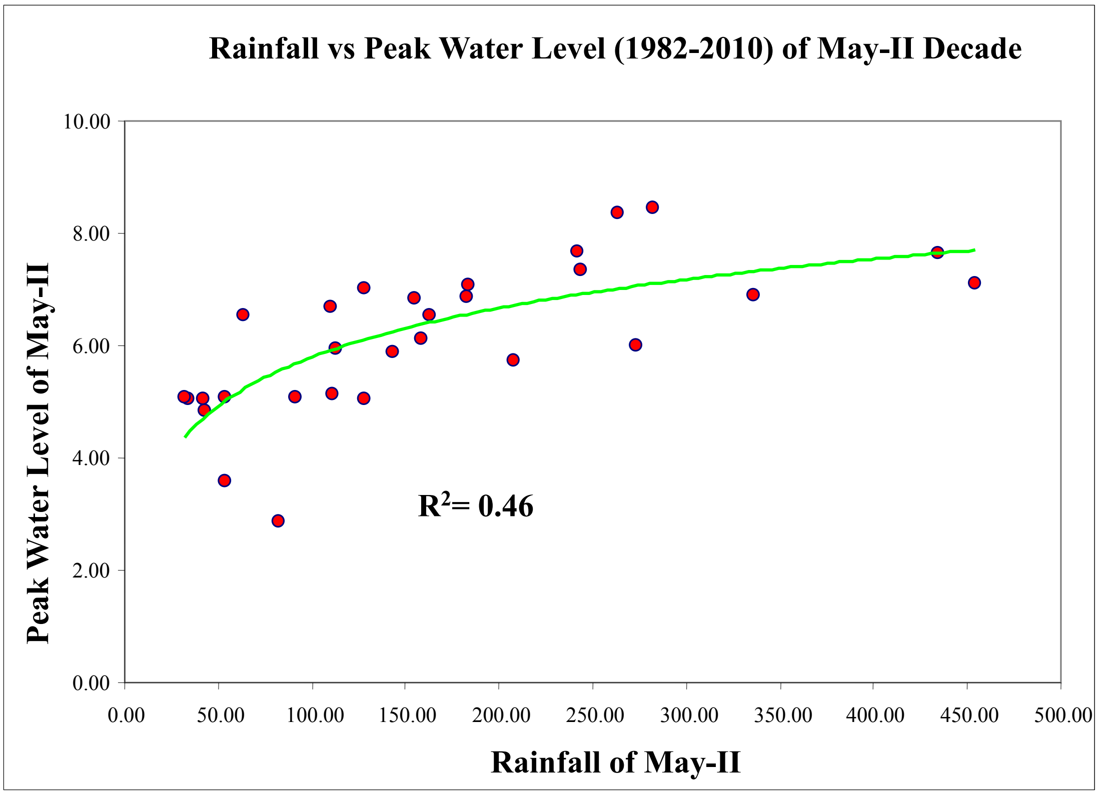


Figure 5.12 May-II rainfall Vs peak water level of Sunamgonj station

The mathematical formula for computing coefficient of correlation is

$$R = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n(\sum x^2) - (\sum x)^2} \times \sqrt{n(\sum y^2) - (\sum y)^2}}$$

From the above findings it may be concluded that the rainfall in the Haor area is the minor cause of inundation of Haor area. Rather the runoff generated upstream of Haor bounded River in the hilly area of India is major cause of causing flash flood.

CHAPTER SIX
IMPACT OF FAILURE

6.1 Impact on Agriculture

FGD with the farmers and KII with the agriculture officers have been conducted and also secondary agricultural data from Upazilla Agricultural Office have been used for agricultural impact assessment. The main crop of the Karchar is Boro, produced annually in the area. Among other crops T Aman is produced in some upland area and Aush is produced in very limited area. Thus the current economic activity offers very limited potentials in terms of poverty alleviation unless a sustainable improvement can be achieved. It has been seen that the Boro crops are lost or damaged in every three to four years due to embankment failure/overtopping during the pre-monsoon season. This was resulted from lack of proper embankment maintenance. There are presently as many as 4.8 million people (likely to increase to 6.10 million by 2020) dependent on the deeply flooded Haors in the northeast region to earn their livelihood. The Haor agricultural system is coming under increasing pressure mainly due to a combination of increased population and reduced drainage effectiveness. The former has resulted in increased demand for food and other basic needs, while the latter has constrained the production.

About 80% of the total cultivable area of Karchar haor grows boro crops. Both HYV and Local variety Boro are grown in this area (Table 4.5)

The yield of HYV Boro is much greater than the local varieties practiced in this area. HYV Boro remains more in the vulnerable condition against flash flood, as it is harvested one month later than the local variety. The farmers go for HYV Boro with the expectation of more food grain to accommodate the food demand of his increasing number of family member. But as result of several severe damage to HYV Boro specially in 2010, day by day people are showing more inclination for Local variety for its early harvesting characteristics and hence sustenance from damage due to flash flood. The yield of different variety of boro is shown in Table 6.1. It shows that the yield of HYV BRRI Dhan-29 is more than twice of that of local Boro.

Table 6.1 Variety of Boro R\rice and their yield

Serial	Name	Ton/ha
1	BRRI Dhan-29	5.10
2	BRRI Dhan -28	3.8
3	BRRI Dhan -26	2.7
4	Local Boro	2.1

(Source FGD/GD)

Although yield of BRRI dhan-29 is high, presently people are showing more interest in growing other varieties in the table because those can be harvested earlier saving damage by flash flood. So production of Boro is reducing. Another problem is lower portion of Haors requires more time for draining out water. Again landowner in the upper portion wants slower draining out of water to avoid application of additional water for land preparation which ultimately force the landowner of low land portion to cultivate local variety and hence cause reduction in production.

The failure of submersible embankment resulting from early flash flood in 2010 causes major damage to both HYV and Local Boro crops. The comparison of crop production among the financial year 2008-2009, 2008-2010 and 2010-2011 has been shown in Table 6.2.

Table 6.2 Year wise comparison of crop production

Sr No	Name of Crop	2008-2009		2009-2010		2010-2011	
		Area (Ha)	Production (Ton)	Area (Ha)	Production (Ton)	Area (Ha)	Production (Ton)
1	T-aman	1200	2620	1200	2610	1260	2625
2	Boro	**3500**	**11400**	**3500**	**1080**	**3450**	**11200**
3	Aus	300	650	300	600	300	680
4	Wheat	80	120	75	108	80	125
5	Corn	9	31	7	24	8	28
6	Potato	80	204	80	210	80	205
7	Lintel	10	9	5	4.8	4	5
8	Mustard	70	67	70	65	120	118

(Source Upazilla Agricultural Office, Bishomvorpur)

6.2 Impact on Fisheries

Fisheries activities are another major earning source of the people of the haor area after agriculture. Karchar haor has considerable area of fish habitat and open migration route. A wide range of open water fishery is done in Karchar haor when water is present. After draining out water, the lowest portion of haor with area of 109 ha is leased through government body. As per leasing of Haor the records of fish production are shown in Table 6.3

Table 6.3 Fish production as per leasing record

Serial No	Year	Fish Production (Metric Ton)
1	2009	51
2	2010	46.55
3	2011	50.98

(Source Upazilla Fisheries Office, Bishomvorpur)

From group discussion it is found that the fish production in leasing may be 55-60% of the total free open water fishery by general fisherman.

The group discussion with some fishermen in Bahadurpur Gastola Bazar (ch. Km 15.00 approx of Karchar haor submersible embankment) and KII with Upazila Fisheries Officer revealed that if water enters earlier in the haor area then breeding of fish is hampered because the environment then is not suitable for breeding. Also many fish with egg is captured as a result of free open water fishery. For this reason if failure of embankment occurs due to early flash flood the reduction in fish production occurs due to obstruction to fish breeding. It is found from the Table 6.3 that fish production in 2010 is lesser than that in 2009 and 2011.

6.3 Impact on Livelihood

The livelihood impact assessment has been made based on HDDI in pre and post damage condition as calculated in appendix B. In case of agriculture and fisherman groups, which are the occupations of 80% of the population of Karchar haor are, the declination of HDDI is observed in post damage condition. The value of HDDI for boatman and aquatic plant based groups are slightly higher in post damage condition. For agriculture and fisherman groups lowering of HDDI value indicates that the livelihood of majority of households has declined rather than improved.

6.3.1 Indicator and Livelihood group wise result

Table 6.4 HHDI value of different livelihood groups

Livelihood Group	Indicator	Value of indicator	
		Pre Damage	Post Damage
Agricultural	Income	0.36	0.14
	Food security	0.54	0.38
	Working opportunity in main occupation	0.76	0.48
	Working opportunity in other occupation	0.19	0.28
	Protein intake	0.68	0.42
	Access to natural resources	0.49	0.51
	HHDI	**0.50**	**0.37**
Fisherman	Income	0.26	0.21
	Food security	0.38	0.33
	Working opportunity in main occupation	0.69	0.62
	Working opportunity in other occupation	0.16	0.14
	Protein intake	0.59	0.51
	Access to natural resources	0.45	0.46
	HHDI	**0.42**	**0.38**
Boatman	Income	0.23	0.24
	Food security	0.41	0.38
	Working opportunity in main occupation	0.39	0.42
	Working opportunity in other occupation	0.15	0.12
	Protein intake	0.56	0.55
	Access to natural resources	0.44	0.48
	HHDI	**0.36**	**0.37**
Aquatic Plant dependent	Income	0.18	0.19
	Food security	0.46	0.48
	Working opportunity in main occupation	0.61	0.62
	Working opportunity in other occupation	0.23	0.21
	Protein intake	0.52	0.51
	Access to natural resources	0.42	0.49
	HHDI	**0.40**	**0.42**

Income:

In comparison to the HHDI for income of different livelihood groups from pre-damaged to post-damaged condition it is observed that the HHDI value of agricultural and fisherman group has decreased (Figure 6.1). On the other hand it has slightly increased for boatman and aquatic plant based livelihood groups. The most declination (0.22) occurs for the agricultural livelihood group. This can be explained that the only crop Boro is grown mostly in the Haor area and damage to this crop due to failure of submersible embankment by early flash flood causes severe reduction in income of agricultural people. As a result of damage to agriculture the farmer find their job in other occupation such as fishing, stone picking etc. This may result in declination of income of fisherman group. At the same time due to inundation of the area for more duration the boatman get more opportunity for income and this may result in slight increase the income of boatman. The increment in aquatic plant based group may result from development of more aquatic plant because of greater duration of inundation of the area.

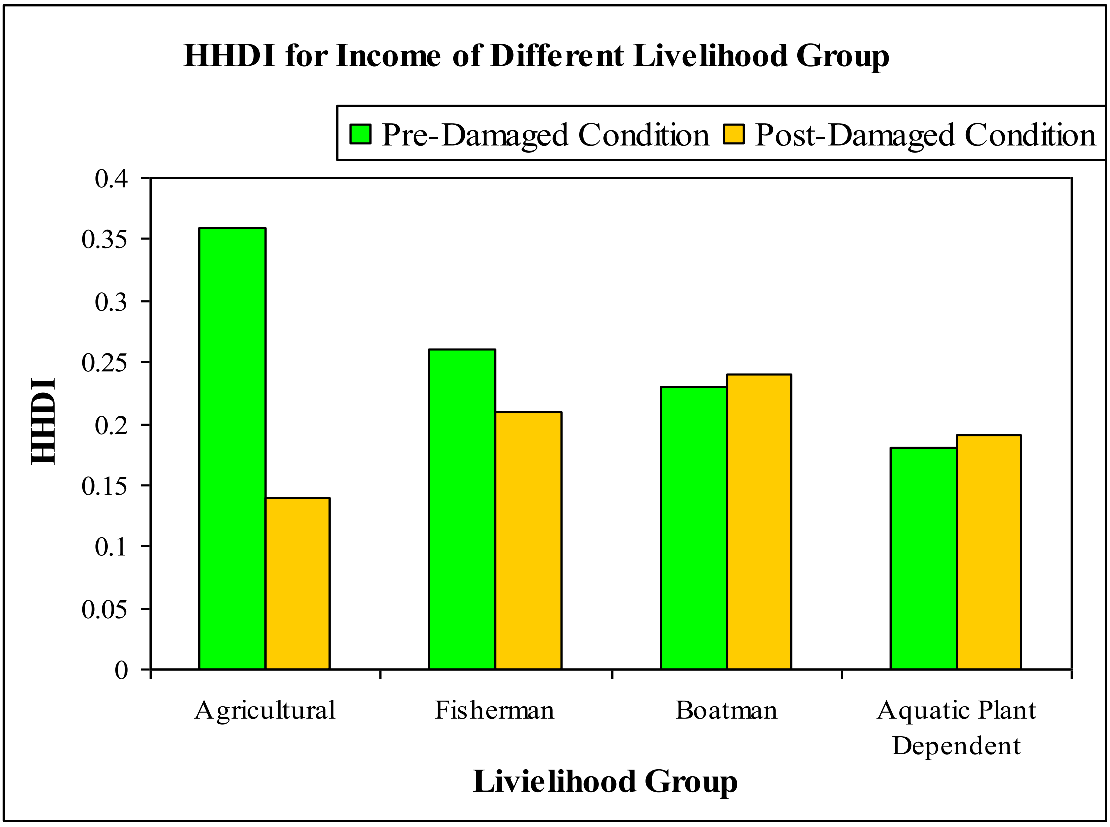


Figure 6.1 HHDI value for income of different livelihood group

Working opportunity in main occupation :

The working opportunity of main occupation for agricultural and fisherman group has decreased and for the boatman and aquatic plant based group has slightly increased (Figure 6.2). As a result of agricultural damage the scope of work in agriculture has reduced and the people engaged in agricultural activity has scattered in other occupation for their livelihood. The working opportunity of fisherman in fishing has reduced because of agricultural people engaged in fishing for their livelihood and also reduction in fish production due to obstruction to fish breading by early flash flood. The slight increment in working opportunity of aquatic plant based group result from higher ecological resources.

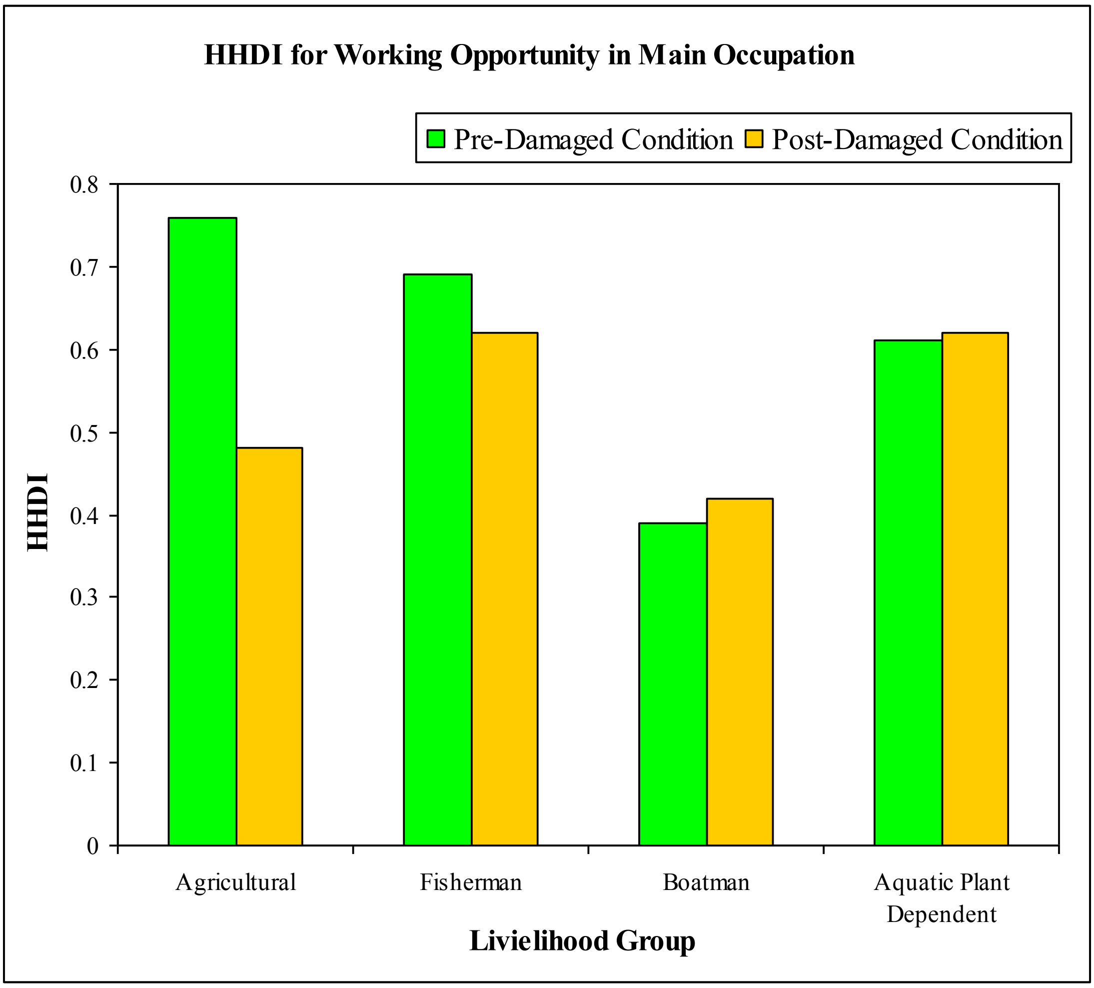


Figure 6.2 HHDI value for main occupation of different livelihood group

Working opportunity in other occupation :

In post-damaged condition the HHDI values of working opportunity in other occupations have decreased in all livelihood groups except the agricultural group (Figure 6.3). It is because of the increased coverage of Boro production due to submersible embankment promoted the increase opportunity in main occupation of agricultural group and failure lead more people to find out other occupation. Accordingly the decrease in other livelihood group can be due to survival of resources in the main occupation and destruction of scope in the agricultural occupation.

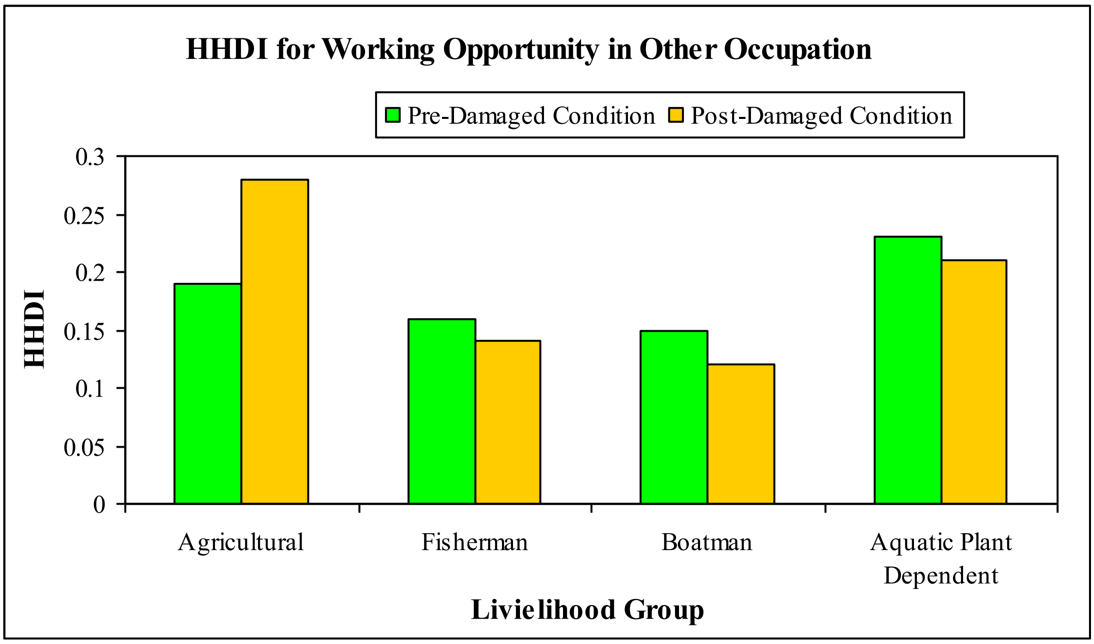


Figure 6.3 HHDI value for other occupation of different livelihood group

Food security:

HHDI value for food security of all livelihood groups have declined from pre-damaged to post-damaged condition except for aquatic plant based livelihood group (Figure 6.4). The most declination occurs for agricultural group. The increase in HHDI of aquatic plant based group may result from more food access. On the other hand declination in HHDI of other livelihood groups results from less availability of food.

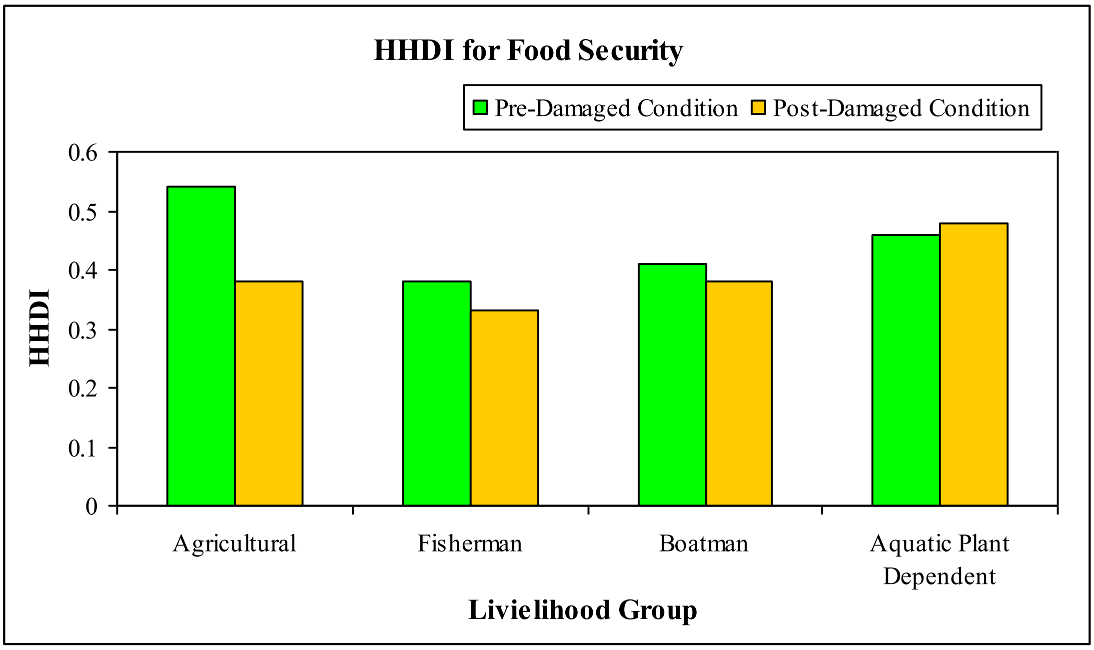


Figure 6.4 HHDI Value for food security of different livelihood group

Protein intake:

The HHDI value of this indicator has declined for all livelihood groups. The most declination occurs for agricultural livelihood group and the next for fisherman group (Figure 6.5). This may result from reduction in fish production due to obstruction to fish breading by early flash flood in the Haor area.

Survey result shows in post-damaged situation many people have to almost starve more than quarter of the year and 75% of the HH of all livelihood groups do not have three times meal in a day more than half of the year.

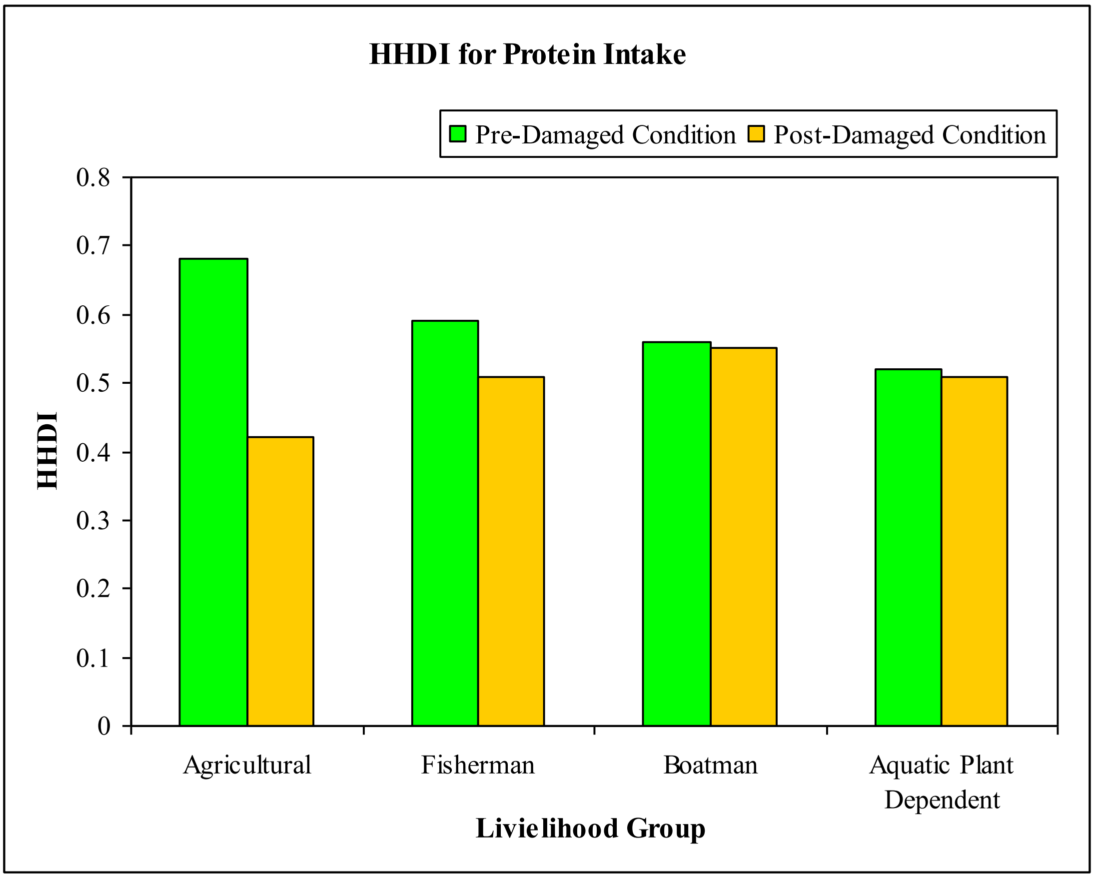


Figure 6.5 HHDI Value for protein intake of different livelihood group

Access to natural resources

The HHDI value for access to natural resources indicator has increased in all livelihood groups (Figure 6.6). This may result because of the environmental and ecological refreshment due to early dilution of fertilizers, pesticides etc. used for increased coverage of HYV Boro.

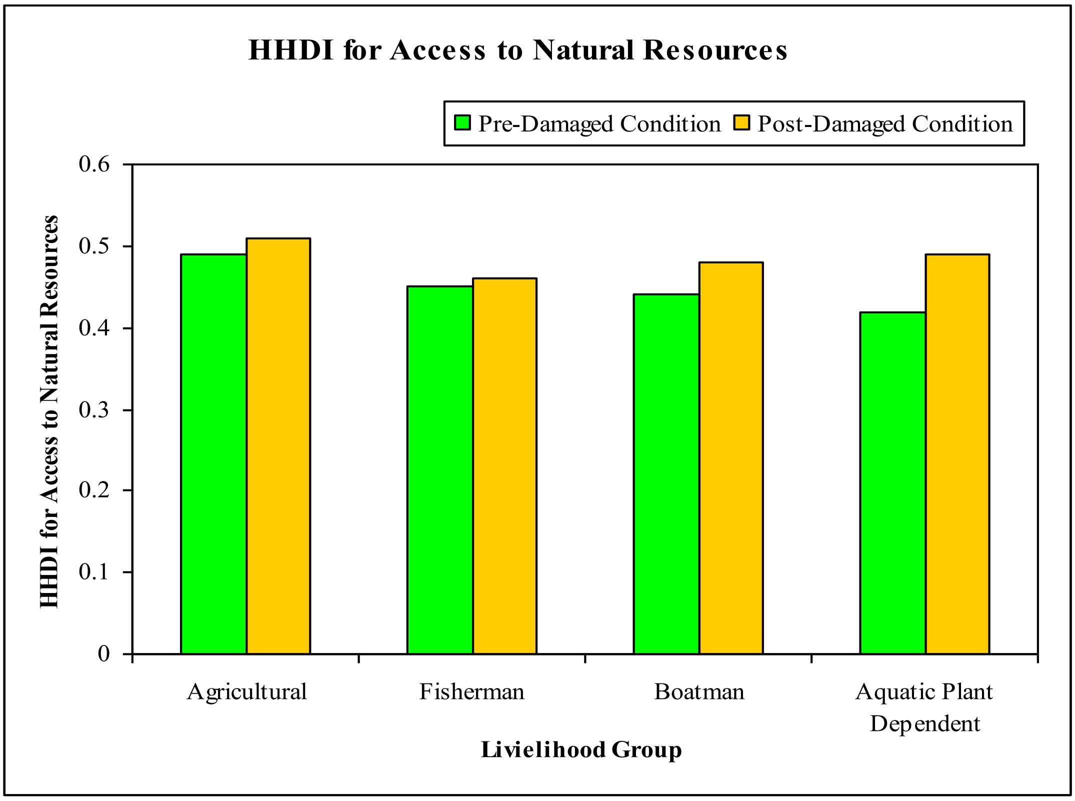


Figure 6.6 HHDI Value for Access to Natural Resources

Livelihood GroupWise HHDI and Overall HHDI:

The HHDI value of each livelihood group has been calculated by taking the average of all HHDI for different indicator of that group. The overall value of household development index (Table 6.7) for the study area has been calculated with taking weighted average of HHDI of four Haor based livelihood groups.

Table 6.7: Overall Household livelihood development index in the study area

Livelihood group	Weight age factor	Pre-Damaged HHDI	Post-Damaged HHDI
Agriculture	0.75	0.50	0.37
Fisherman	0.19	0.42	0.38
Boatman	0.04	0.36	0.37
Aquatic plant dependent	0.02	0.40	0.42
Weighted Average HHID	1.00	0.48	0.37

The number of households of livelihood group agriculture, fisherman, boatman and aquatic plant based is considered to calculate the weighted average of HHDI. The HHDI value of agricultural livelihood groups has declined the most. The overall value has declined from 0.54 in pre-damaged condition to 0.43 in post- damaged condition shown in Figure 6.7.

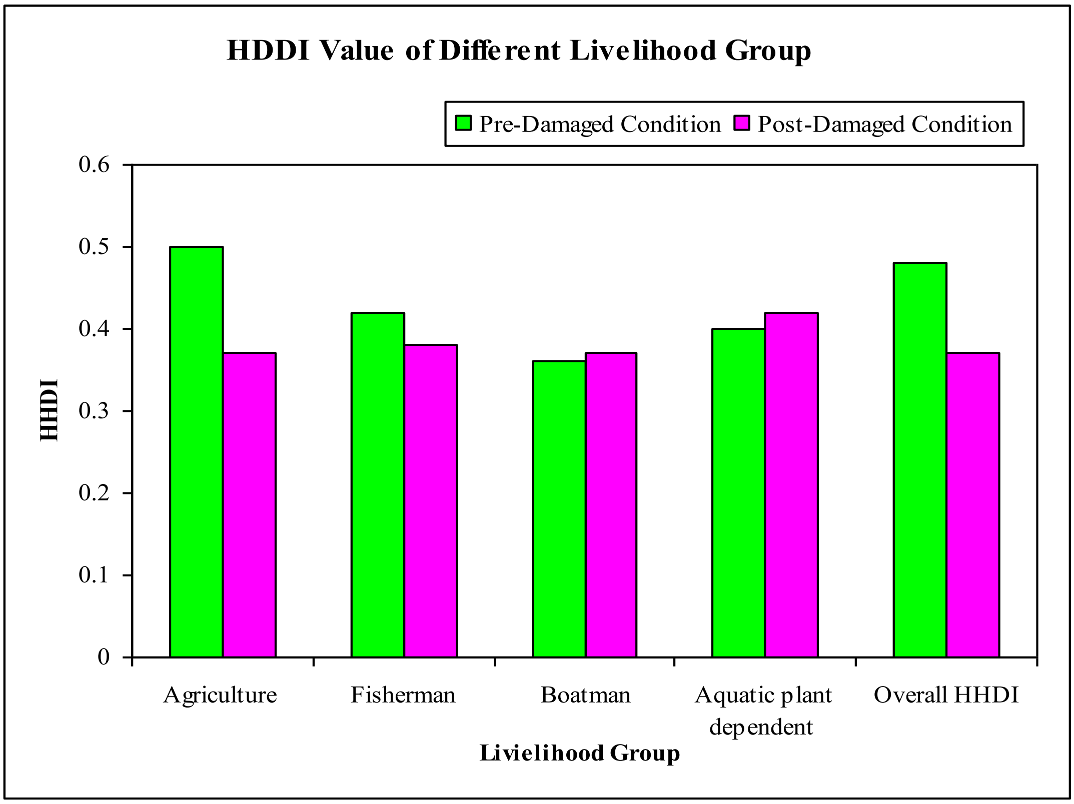


Figure 6.7 HHDI Value for Different Livelihood Group

Above findings indicates that the majority of people in the study area is farmer and agriculture is their main occupation. So, damage to agriculture cause drastically reduction in HDDI value.

6.4 Impact on Livestock

Livestock is very less in the study area. This may be due to inundation of a wide range of land in the Haor area during flood and eventually less area for rearing livestock. Lack of availability of fodder for livestock is another cause of less livestock. During transect walk and discussion with the villagers it is observed that some villagers rear only few poultry or duck some have no livestock at all and very few rear cattle, goats or sheep. Failure of embankment due to early flash flood in 2010 caused a severe damage to Boro crops. In case of crop damage in a year they do not have sufficient food grain to meet the food demand for whole year. For this reason they have to sell livestock at reduced price to buy additional food. In 2010 more than 20% of livestock was reduced in this way.

It is known from the villagers that livestock is naturally reducing day by day. If crop damage occurs very frequently in such way the reduction of livestock will increase much more in future

CHAPTER SEVEN
RESILIENCE AND COPING STRATEGY

7.1 Introduction

This resilience is the capacity to cope with stress or catastrophe and return to its original form or function. Resilience (or resiliency) is the ability to manage and learn from difficulties and to bounce back after adversity. Resilient people have personal strengths, skills and abilities which help to buffer them against stress. Resilience skills can be learned from a young age, and are important keys to positive mental health.

When challenged or distressed, resilient people expect to find a way to make things work well. They feel capable and self-reliant and have a learning/coping reaction rather than the victim/blaming reaction.

Highly resilient people show many similar qualities: playful, child-like curiosity; they constantly learn from experience; they adapt quickly; they have solid self-esteem; possess self-confidence; have good friendships, loving relationships; express feelings honestly; expect things to work out well; read others with empathy; use intuition, creative hunches; defend themselves well; have a talent for serendipity; and get better and better as time goes on.

The people of haor area have to learn a certain degree of resilience. The economic activity of haor basin is frequently affected by natural calamity. Every three to four years the people of the haor area is affected by a serious damage to the main Boro crop due to flash flood. More than 80% of the Boro crops in the area are damaged and the economies of the people in the area are severely destroyed.

7.2 Resilience in People of Haor

The people of the Karchar haor area are very much resilient. When failure of embankment occurs, almost all the Boro crops are damaged. Boro production is the only source of income of many people in the haor area. Boro damage causes total collapse of their economy. But they have ability to withstand against the situation. They have the mental strength to fight for survival. They find out other income generating option for their livelihood.

When damage to Boro occurs, people previously involved in agriculture find out other occupation such as day labour, stone picking from river, fishing, cow rearing, poultry rearing etc. Some people (about 10%) migrate to other places to find out job. It takes two to three years to bounce back to the economic condition before damage.

7.3 Economic Activity to Cope with the Situation

Increasing numbers of people in Haor areas are sliding into poverty because of economic and social conditions resulting from damage to Boro crops due to failure of submersible embankment. The situation is often characterized by lack of competitiveness, unemployment, unstable financial systems, and sustainable use of natural resources. The economic significant of various economic activity, adapted by Karchar haor people are discussed below.

Duck rearing for sustainable livelihood: Duck rearing is one of the major income generation opportunities in the study area in case of agricultural damage. About 9% of the household's livelihood activity is duck rearing, which is depending on haor. From selling duck and eggs most of the households earn BDT1500 per month. But duck supply, diseases control, credit facilities, and markets are the barriers to sustainable development through duck rearing. Agricultural resources of which scavenging duck rearing is considered to have potential both for poverty alleviation and food production, especially for the rural poor women. Ducks eggs and meat produced from scavenging ducks are considered to be organic products and are completely free from hormones and antibiotics

Fishing for sustainable livelihood: Fishing related activities such as capturing fish, fish trading, fish drying and net weaving is the one of the major alternative livelihood activities in the haor areas in failure situation. The average annual income from this sector is about BDT 5400 but illegal harvesting, unsustainable collection of fish and illegal leasing system of water body is the barrier to sustainable livelihood development.

Sewing and Embroidery: Sewing and embroidery (including tilla work, Crochet, Weaving) is the alternative livelihood common activities of haor area especially for women in case of agricultural failure. This may be a very good source of earning through these multiple activities throughout the year but it requires training and credit facilities. The people have to be designed with the resources, skills, abilities and interests of the people concerned. Also lack of product marketing and social issue are obstacle to sustainable livelihood development for the rural poor and marginalized,.

Floating vegetable gardens: Lack of cultivatable space over the long flooding period is a vital concern in the Karchar haors and it restricts the livelihoods of the local communities. Floating garden cultivation in the area including consumption/ marketing of the products is another income generating activity in failure situation. Through appropriate capacity building and community organization this initiative will promote floating garden cultivation as a sustainable alternative livelihood in monsoon as well as in winter through seedling raising and vegetable gardening.

Jari Chumki for alternative sustainable livelihood: Jari chumki is a famous and potential profitable income generating activities of haor people especially women. It requires a certain level of skills training. Shari has been designed by embroidery machine and then it is being hand made stitched using different colorful and attractive thread, Jari and chumki. Local vender supplies the plain shari along with necessary materials to the selected women to complete the work. Local vendor collect raw materials from Benaroshi Palli in Mirpur and supply finished product to the same or Dhaka, Gulshan, Banani, Mirpur and Gaushia super market. Every people earn Tk. 200-250 per day from their house. It is the most important alternative livelihood in study area but some barrier to develop this sector such as lack of training, no forward and backward market linkage, no bargaining power.

Stone Picking: Stone picking from hilly river and sell them in the stone grinding factory is another important livelihood activity in case of failure of Boro crops. Many people involves in stone picking when economic damage occurs by crop failure. By stone picking one can earn Tk. 150-200 every day. In photo 7.1 people involved in stone picking are seen

Photo 7.1 Stone picking as alternative livelihood activity

7.4 Ranking of Resilient Option

From study various resilient options were found during failure situation which have been ranked in order in Table 7.1. The percentage of preference for different options has been represented in Figure 7.2.

Table 7.1 Ranking of resilient option

Sr No	Resilient Option	Percentage	Rank
1	Duck Rearing	9%	4
2	Cow Rearing	18%	2
3	Fishing	26%	1
4	Sewing and Embroidery	6%	7
5	Floating vegetable gardens	7%	6
6	Jari Chumki	4%	8
7	Stone Picking	12%	3
8	Handicraft	8%	5
9	Others	10%	

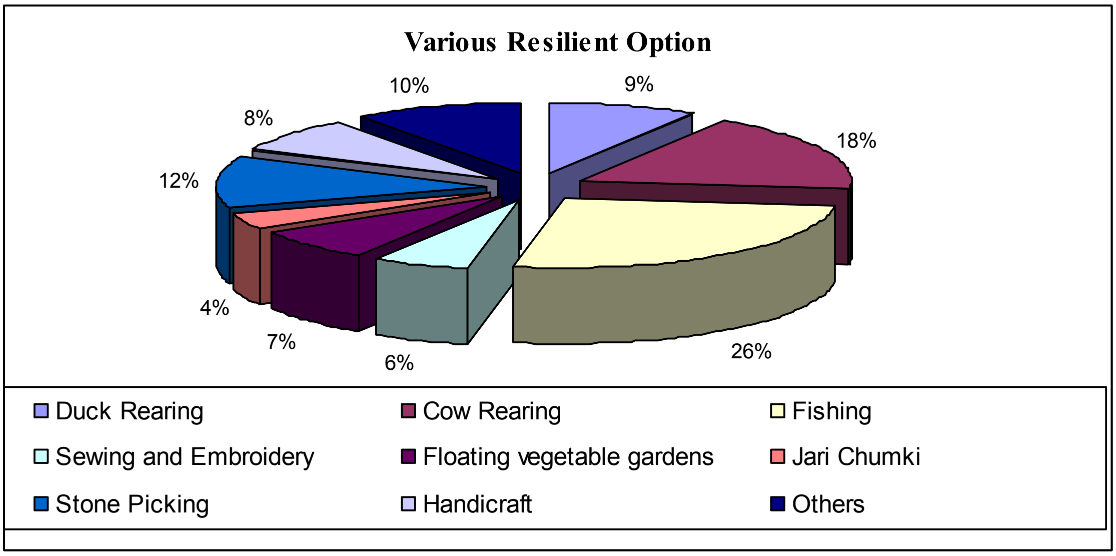


Figure 7.1 Various Resilient Options

CHAPTER EIGHT
STRATEGY FOR MANAGEMENT OF KARCHAR HAOR

8.1 Introduction

Past water resources management efforts in the haor region include a total of 66 water management projects implemented during the past two decades. Project types include full flood control, partial flood control, drainage improvement and irrigation. The estimated net benefited area is around 395,000 ha. A review of these projects reveals that most of the projects (80%) have had some positive impact, though not always in the intended manner, and some (45%) have had negative impacts including river confinement, loss of land to infrastructure and destruction of fisheries habitat and other environmental aspects.

Around 5.00 million people of Bangladesh are dependent on the deeply flooded Haors in the northeast region to earn their livelihoods. The Haor agricultural system is coming under increasing pressure mainly due to a combination of increased population and reduced drainage effectiveness. The only crop Boro is produced annually in the area. Thus the current economic activity offers very limited potentials in terms of poverty alleviation unless a sustainable improvement can be achieved. It has been seen that the Boro crop has been lost or damaged several times in the past decades due to embankment failure/overtopping during the premonsoon season. This is resulted from the lack of proper management strategy of Haor areas.

Thus in consideration of public demand triggered by the unprecedented damage to the Boro crops in almost maturity stage during early monsoon in 2010, the present study program has been formulated to suggest a proper management system regarding the following:

- Proper O&M activity
- Timely breach closing
- Proper drainage of flood water
- Requirement of interventions

8.2 Proper O&M Activity

It is observed that improper O&M activity is one of the major causes of failure of Haor.

Every year re-sectioning/reconstruction of embankment in different portion is done to achieve the crest level, crest width, side slopes and other parameters of embankment to its original design. From study it is found that the re-sectioning is done every year, but it is not necessarily adequate to prevent embankment overtopping/damage in case of early flash flood. Most of the time embankment crest level is not uniform along the longitudinal section after finishing repair work. The River side and country side slope are never made to its required design during repair. This is another reason for failure. The following important steps may be taken regarding repair of embankment.

- Repair and maintenance of submersible embankment should be done in proper time and with close monitoring
- Steps should be taken to maintain uniform longitudinal profile and crest width as per design.
- Since side slope is very important factor to prevent embankment failure due to early flash flood, necessary initiative should be taken to achieve proper side slope in country side and river side. For this purpose a model section may be constructed before commencing the re-sectioning work.
- A disaster management mechanism is required for the BWDB to take precautionary measure with maintenance materials as a part of flood defense considering the flood and condition of the dykes in reality.
- A central monitoring mechanism of BWDB may be established to monitor that during repair of embankment the uniform crest level and crest width and proper side slopes is maintaining or not.

8.3 Timely Breach Closing

There are several breach points in Karchar haor submersible embankment which needed to be closed every year. It is found that breach closing is not done in proper time. There are a lot of issues which causes delay in breach closing. Also no manual compaction is done during breach closing work. As no manual compaction is done it is required to allow sufficient time for natural compaction to prevent failure. Among the breach points in Karchar haor submersible Gazaria points is the most critical. If failure occurs in Gazaria breach points before harvesting the boro crops then the crops of whole Karchar haor area is damaged. As a result special attention is required in closing Gazaria breach point. During FGD it is observed that the people want a Rubber dam in Gazaria breach points. The following necessary steps may taken in closing the breach points

- Steps should be taken to ensure breach closing in proper time so that it can be allowed sufficient time for natural compaction of closure point.
- Closing earth should be such that embankment becomes adequately stable and withstand against seepage.
- Also designed side slope should be properly maintained to prevent failure by seepage or sliding of the slope.
- Construction of closure should be done by PIC which must be formed with the members who have land within the haor area.
- Steps should be taken for the adequacy and timely release of fund
- A central monitoring mechanism of BWDB may be established in order to monitor the system regarding formation of PIC, timely billing for PIC members, maintaining the quality of construction as per design.

8.4 Proper Drainage of Flood Water

One of the challenges regarding management of Karchar haor is the proper drainage of flood water in appropriate time. The Ghatia regulator (Photo 8.1) is the main important drainage structure for draining out water from Karchar haor. The structural condition of the regulator is good but the condition of gate is not good. People use wood log to operate the gates in order to control the drainage of water. The gates of this regulator require repairing. Almost whole water after draining out through breach point passes by this regulator to the Surma River through the Rakti and the Rupsha River. Drainage occurs in the upper portion very earlier due to draining through breach point in addition to draining through regulator and in lower portion very slower.

There exists a very low area of around 800 ha in the Karchar haor near Zirak Tahirpur

Photo 8.1 Drainage of water through Ghatia regulator

village. This low area cannot be drain out through Ghatia regulator. Draining of water from this 800 ha low area occurs through Chatla beel drainage pipe.

There is conflict among the people of Karchar haor specially Zirak Tahirpur area regarding the rate of drainage. Earlier drainage results in drying of land and requires application of additional water for land preparation before plantation of boro crops. At the same time delay in drainage results delay in achieving suitable soil-moisture condition for land preparation in order to transplantation of boro crops and ultimately results in compelling the farmer to choose low yielding local variety boro crops because of its early harvesting characteristic. The people who have land in the lower area want faster drainage so that draining out of water occurs earlier and they can choose high yielding variety crops. On the other hand the people who have land in the upper area want slower drainage in order to avoid application of additional water for land preparation.

As a result the rate of drainage depends on the influence and power of landowner who have land in what area. Usually drainage is allowed at slower rate by controlling the gate. It is observed from Figure 8.1 that only one gate is under operation and other three gates are closed. This means the landowner of upper area are more influential and powerful than that of lower area.

During study people opined that the gates of Ghatia regulator is required to be repaired. They think that construction of a pipe outlet at Chatla beel will be more efficient for drainage of water.

From above discussion it can be suggested that an optimum drainage rate through Ghatia regulator should be established considering the cost of application of additional water for land preparation in the upper land and economic value of loss of production due to choosing low yielding variety local Boro crops in lower area in order to obtain maximum benefit.

8.5 Requirement of Intervention

It is found in the study that the design crest level that means the design height of submersible embankment is adequate to protect the flash flood up to 15 May. Moreover, it is important to note that height of submersible embankments is a very crucial parameter. Flood protection with submersible embankments in the Haor area is a delicate issue, and associates noticeable negative consequence over benefit returns (IWM, 2006). Higher crest level increases implementation as well as maintenance cost radically. Besides, post-monsoon drainage is severely delayed with higher crest level. Therefore, any increase in the height of submersible embankments in the Haor area should be carried out only after careful assessment of requirements, and be avoided as much as possible.

The need for re-sectioning of embankment, repair of structures, construction of new structures are shown in the Table 8.1 and Table 8.2. Repair of regulators will be mainly concentrated to construction of approach embankment, repair of gate including hoists and gate grooves.

The gates and hoists of all the structures shall be modified in a way that operation is easy and maintenance is cheaper. The beneficiaries should be able to operate/lift the gate without going through much difficulty. Re-sectioning of embankment should be done to attain the crest level and slope to its original design with specified earth and proper compaction.

Table 8.1 Proposed structural interventions of Karchar Haor by IWM

Component	Quantity	Remarks
Embankment rehabilitation	Filling: 0.07 Mm^3	Resectioning of embankment i/c slope building and raising height and also closing breaches
Proposed causeway/Flood fuse	1 at Gazaria (w=30 m. sill= 5.0 m.PWD). 1 between embankment chainage km 14 & 15 (w=6m)	For navigation from Sunamganj to Tahirpur
New other structures	3 WCS at Biswambarpur, Muktikola & Rasulpur	
Rehabilitations of existing structures	Ghatta Regulator	
Other	Re-excavation of comnnecting khals to the drainage structures	

(Source IWM, 2006)

From study it is observed from public opinion that they think a Rubber dam at Gazaria is more suitable for effective operation and protecting failure. At Adang village rehabilitation of embankment of more than 1 Km from chainage km 3.25 to Km 4.25 with slope protection is required rather than normal repair and maintenance every year. The structural interventions that may be proposed are shown in Table-8.2 and Figure 8.1.

Table 8.2: Structural interventions that may be proposed as per study

Component	Quantity	Remarks
Embankment rehabilitation	5.00 Km	Resectioning of embankment i/c slope building and raising height and also closing breaches
Rubber Dam	1 at Gazaria (w=30 m. sill= 5.0 m.PWD).	For navigation from Sunamganj to Tahirpur

Component	Quantity	Remarks
Flood Fuse	1 between embankment chainage km 14 & 15 (w=6m)	
New other structures	3 Pipe Outlet at Chatla beel, Minajuri Khal & Miar Khal	
Rehabilitation of embankment with slope protection	1 Km chainage km 3.25 to 4.25	
Rehabilitations of existing structures	Ghatta Regulator	
Other	Re-excavation of connecting khals to the drainage structures	

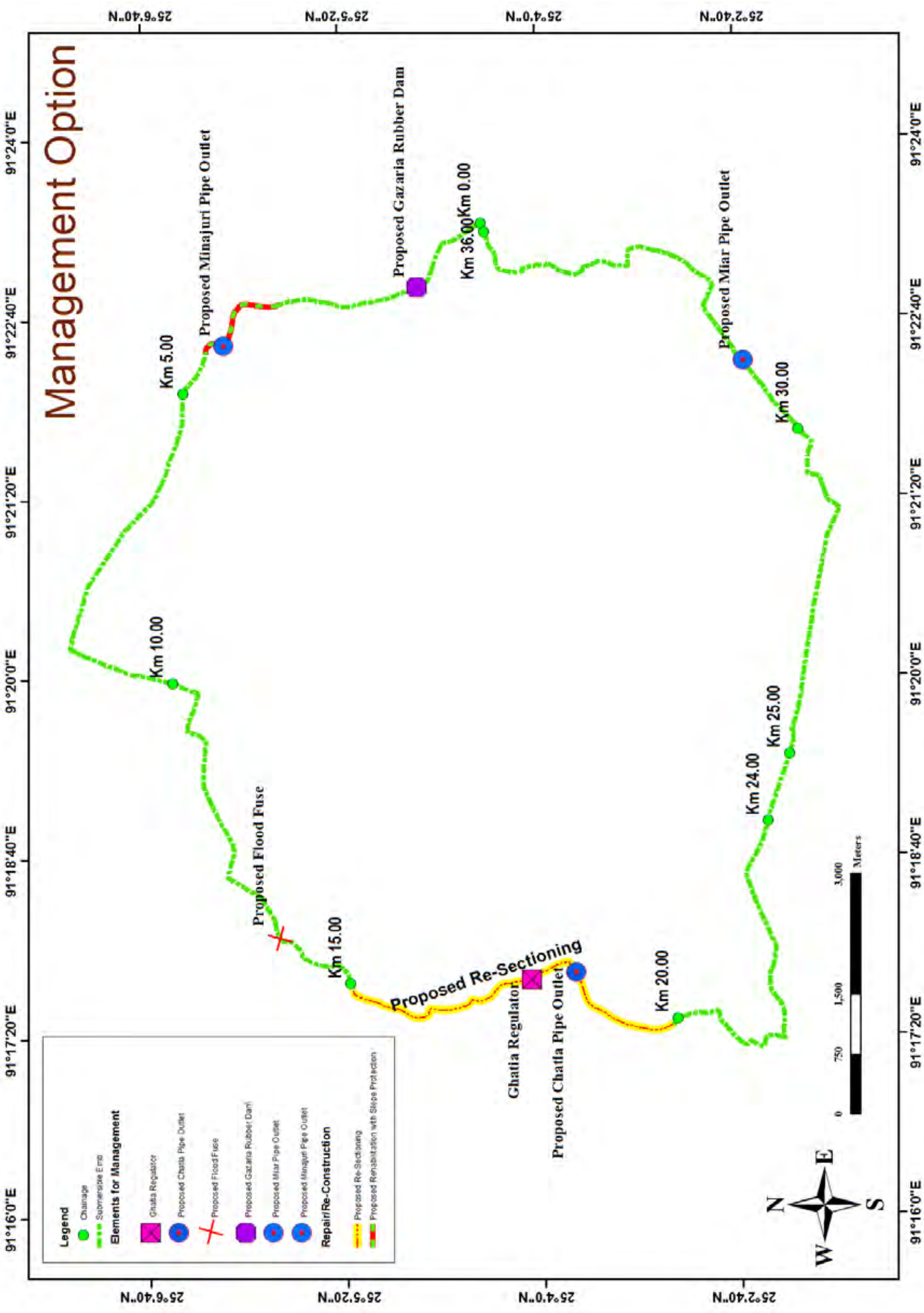


Figure 8.1: Proposed management option

8.6 Benefit Cost Analysis for Proposed Intervention

8.6.1 Management cost

The approximate construction cost for construction of proposed rubber dam was found from LGED. The obtained cost was for financial year 2003-2004. It is observed from the cost schedule of rate that present cost is around 70% higher than that in 2003-2004. So in order to obtain present cost the collected cost is increased 70%. Construction cost for other components are found from BWDB as per present schedule of rate. The total management cost for proposed intervention has been represented in Table 8.3.

Table 8.3 Management cost for proposed intervention

(In Lac Taka)

Sr No	Component	Estimated Cost	Percentage of Total cost	Source
1	Construction of Rubber Dam (30m)	1380.00	44.98%	LGED
2	Construction of Flood Fuse (6m)	360.00	11.73%	BWDB
3	Construction of Pipe Outlet	78.00	2.54%	BWDB
4	Rehabilitation of embankment with slope protection (1Km)	1050.00	34.22%	BWDB
5	Rehabilitation of Ghatta regulator	50.00	1.63%	BWDB
6	Re-sectioning of embankment every year (5Km)	150.00	4.89%	BWDB
	Total	3068.00	100.00%	BWDB

8.6.2 Benefit from Saved Properties

Study shows that every year breaching occurs in the Karchar Haor submersible embankment, which requires repairing after flood. It is found from discussion with BWDB official that every year sum of TK 1500.00 Lac is needed for breach closing.

More than 1.00 Km embankment is washed out near Adang village from chainage Km 3.25 to Km 4.25 every year. The re-construction of this portion of embankment requires

TK 210.00 Lac every year. Also failure causes loss of fertility to the adjacent agricultural land and suffering of people of adjacent 17 villages. As per public opinion if the proposed intervention of rehabilitation of embankment with slope protection is implemented than the suffering of people will be reduced and every year TK 210.00 Lac for re-construction of embankment will be saved. Properties that will be saved from implementation of the proposed intervention are shown in Table 8.4.

Table 8.4 Benefit from saved properties

(In Lac Taka)

Sl.No.	Name of Properties	Quantity	Financial Value	Conversion Factor (CF)	Economic Value
1	Crop Saved	LS.	4400.00	0.902	3968.80
2	Cost of Breach Closing	LS.	3300.00	0.902	2976.60
3	Cost of Re-construction of Embankment	1.00 Km	4600.00	0.902	4149.20
4	Loss of Fertility	100 ha.	700.00	0.902	631.40
5	Ponds/Fisheries	500 nos.	1100.00	0.902	992.20
6	Others (Infrastructure, Homestead etc)	LS.	2800.00	0.902	2525.60
	Total =		**16900.00**		**15243.80**
Source: BWDB/Assumption					
Average annual financial value (Total Value ÷ No. of Year) =				16900.00 ÷ 22 =	768.18
Average annual Economic value (Total Value ÷ No. of Year) =				15243.80 ÷ 22 =	692.90

The average annual O&M cost is TK 61.34 Lac (Table B.2 of Appendix B)

8.6.3 Benefit Cost Ratio (BCR) and Internal Rate of Return (IRR)

The economic and financial Benefit Cost Ratio (BCR) and Internal Rater of Return (IRR) have been calculated (Miah & Hardaker, 1988) and shown in Table 8.5 and Table 8.6. Calculations are based on the following assumptions:

1. The project life time has been considered to be 25 years including 3 years implementation period.
2. The discounting rate has been considered at 12% for this project.
3. The full benefit will accrue from 4th year of this project period.
4. Weighted Conversion Factor has been considered in calculating the investment cost of this project.

5. Standard Conversion Factor (SCF) 0.902 has been used in calculating all Non-traded Goods to maintain the consistency with the International Market.
6. Shadow Conversion Factor (SCF) 0.902 and 0.75 has been used in calculating the skilled and unskilled manpower respectively so that it can not create any harmful effect on the labor market through unemployment & inefficiency.

8.6.4 Summary

From the analysis it is observed that the implementation of proposed intervention found in the study is beneficial to the Karchar Haor area. The financial Net Present Value (NPV) of saved properties in excess to investment cost is TK 1269.13 Lac over the project life. Also the economic NPV of saved properties in excess to investment cost is TK 1492.84 Lac over the project life. The financial Benefit Cost Ratio is 1.44: 1.00 (Appendix B). It indicates that the proposed intervention is very much feasible and viable. Following are the summary of analysis

1. Project Cost : Tk.3068.00 Lac
2. Implementation Period : 3 Years
3. Total Project Life : 25 Years
4. Total Benefit by Property saved : Tk.16900.00 Lac
5. Economic Analysis Result :

   (a)Net present value (NPV):

   (i) Financial : Tk.1269.13 Lac
   (ii) Economic : Tk.1492.84 Lac

   (b) Benefit-Cost Ratio (BCR):

   (i) Financial : 1.44: 1.00
   (ii) Economic : 1.66: 1.00

   c) Internal Rate of Return (IRR):

   (i) Financial : 17.80%
   (ii) Economic : 20.54%

CHAPTER NINE
CONCLUSION AND RECOMMENDATION

9.1 Conclusion

- The Boro production was reduced from 11300 metric ton in 2009 to 1080 metric ton in 2010. This means more than 90% boro was damaged by flash flood in 2010.
- It is observed that the design crest level suggested by IWM is adequate enough to protect the early flash flood up to 15 May. The main causes of failure are improper O&M activity, poor quality work during repair and maintenance, local conflict among political leaders and delay in PIC formation etc.
- Early flash flood causes obstruction to fish breading and ultimately a bit reduction to fish production. In some cases it is found that entrance of sandy soil of damaged embankment to the adjacent land causes reduction of fertility of that land.
- Damage has remarkable impact on agriculture and livelihood of that area. Now a day people prefer low yielding local variety boro rather than HYV boro.
- Livelihoods of agricultural people are more impacted than other. The value of HHDI of agricultural livelihood groups was declined from 0.50 in pre-damaged condition to 0.37 in post-damaged condition. The declination of HHDI for agricultural livelihood groups causes same kind of declination in overall HHDI for all livelihood groups because agriculture is the main occupation of the area and more than 80% people involved in this occupation.
- The people of haor area are resilient. They are able to bounce back to the previous situation in 2 to 3 years after one occurrence of economic loss. They always can find out different job to sustain their livelihood.
- The implementation of submersible embankment raises the Boro production in this area and improves the livelihood of people. But frequent damage obstructs the sustainability of this improvement.
- It is required a proper management strategy for appropriate utilization of the resources of haor area and sustainable improvement of the livelihood of the people of haor.

9.2 Recommendation

Based on this study, the following recommendations are made;

- Proper operation and maintenance of the submersible embankment is needed to reduce the vulnerability of the study area and it should be monitored by a central monitoring system.
- Study can be carried out for finding the optimal adaptation options to reduce the impact on economy and livelihood.
- Study can be carried out for introducing flash flood tolerable early harvesting type HYV boro for the haor area.

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APPENDIX A
CALCULATION FOR HOUSHOLD DEVELOPMENT INDEX

A.1 Defining Human Development

According to UNDP (1990), human development is a process of enlarging people's choices. In people this choice can be infinite and change over time. But at all levels of development, the three essential ones are for people to lead a long and healthy life, to acquire knowledge and to have access to resources needed for a decent standard of living. If these essential choices are not available, many other opportunities remain inaccessible. But human development does not end their additional choices, highly valued by many people, range from political, economic and social freedom to opportunities for being creative and productive, and enjoying personal self-respect and guaranteed human rights.

Human development has two sides: the formation of human capabilities such as improved heath knowledge and skills - and the use of their acquired capabilities - for leisure, productive purposes or being active in cultural, social and political affairs. If the scales of human development do not finely balance the two sides, considerable human frustration may result. According to this concept of human development, income is clearly only one option that people would like to have, albeit an important one. But it is not the sum total of their lives. Development must therefore, be more than just the expansion of income and wealth. Its focus must be people.

A.2 Considerations for Measuring Human Development

The measuring of human development should for the time being focus on the three essential elements of human life – longevity, knowledge and decent living standards.

For the first component-longevity life expectancy at birth is an indicator. The importance of life expectancy lies in the common belief that a long life is valuable in itself and in the fact that various indirect benefits (such as adequate nutrition and good health) are closely associated with higher life expectancy. This association makes life expectancy an important indicator of human development, especially in view of the present lack of comprehensive information about people's health and nutritional status.

For the second key component knowledge literacy figures are only a crude reflection of access to education, particularly to the good quality education so necessary for productive life in modern society. But literacy is a person's first step in learning and knowledge building, so literacy figures are essential in any measurement of human development. In a more varied set of indicators, importance would also have to be attached to the outputs of higher levels of education. But for basic human development, literacy deserves the clearest emphasis.

The third key component of human development - command over resources needed for a decent living - is perhaps the most difficult to measure simply. It requires data on access to land, credit, income and other resources. Income indicator is used in absence of the data on many of these variables, for the time being, making the best use of an income indicator. The most readily available income indicator - per capita income - has wide national coverage. But the presence of non tradable goods and services and the distortions form exchange rate anomalies, tariffs and taxes make per capita income data in nominal prices not very useful for international comparisons. Such data can, however be improved by using purchasing power - adjusted real GDP per capita figures, which provide better approximations of the relative power to buy commodities and to gain command over resources for a decent living standard.

A.3 The Human Development Index

People do not isolate the different aspects of their lives. Instead, they have an overall sense of well-being. Considering the various aspect of life it is difficult to construct a composite index of human development. Past efforts to devise such an index have not come up with a fully satisfactory measure. They have focused either on income or on social indicators, without bringing them together in a composite index. Since human beings are both the means and the end of development, a composite index must capture both these aspects. The Human development index (HDI) by UNDP (1990) captures the three essential components of human life – longevity, knowledge and basic income for a decent living standard. Longevity and knowledge refer to the formation of human capabilities, and income is a proxy measure for the choices people has in putting their capabilities to use.

The HDI is an indicator of the average achievements in the field of basic human capabilities (human development). One has to take into account its deficiencies as well, such as the incapacity to reflect the distributive effects of the development (the inequality) and to measure the deprivations aspects of the development. Moreover, according to Amartya Sen (Sen, 2000) it is important to distinguish between the use of HDI as an index and the overall concept of human development. Namely we should be clear about the fact that there are many relevant variables of the human development that are not included in the HDI.

Human development index is based on three components (the life expectancy. the achieved education and the living standard) and is not exclusively focused on the economic wealth – as the case may be with the GNP (Jahan, 2002).

The HDI is constructed as per UNDP (1990) in three steps. The first step is to define a measure of deprivation that a country suffers in each of the three basic variables -life expectancy (X1), literacy (X2), and real GDP per capita (X3). A maximum and a minimum value are determined for each of the three variables given the actual values. The deprivation measure then places a country in the range of zero to one as defined by the difference between the maximum and the minimum.

thus I_{ij} is the deprivation indicator for the j-th country with respect to the i-th variable and it is defined as:

$$I_{ij} = \frac{\left({}_{\max}X_{ij} - X_{ij} \right)}{\left({}_{\max}X_{ij} - {}_{\min}X_{ij} \right)} \ldots\ldots\ldots\ldots\ldots (1)$$

Where X_{ij} is the actual value of the *i-th* variable for the j-th country and ${}_{\min}X_{ij}$ and ${}_{\max}X_{ij}$ are the corresponding minimum and maximum values of the variables of that country.

The second step is to define and average deprivation indicator (I_{ij}). This is done by taking a simple average of the indicators.

$$I_i = \frac{\sum_{j=1}^{n} I_{ij}.}{n} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where, I_i is the value of average deprivation index of the i-th country and n is the number of variables.

The third step is to measure the human development index (HDI) as one minus the average deprivation index.

$$(HDI)_j = (I - I_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.3)$$

Where $(HDI)_j$ is the value of Human Development Index (HDI) of the j-th country

Dixon & Easter (1986) define integrated water shed management as a process of formulation and implementing a course of actions involving natural and human resources in a watershed, taking into account the social, political, economic and institutional factors operating within the watershed and surrounding river basin and other relevant regions to achieve social objectives. They emphasized that watershed management activities bring in many biophysical changes into the system. According to the water resources management report of World Bank (2003), watershed activities are intended to provide livelihood opportunity to the local community in developing countries. The success or failure of watershed management programmers in usually measured in terms of change in irrigated area, agriculture production, livestock etc. and the benefit of such programmes are only reaped by the bigger landlords, whilst the poor and landless are left behind. This situation compels us to have a proper quantitative mechanism in place for assessment of the contribution of such water management projects on livelihood taking relevant factors into account and eliminating the drawbacks of qualitative assessment.

The Human Development Report of UNDP (1990) uses three basic indicators; mainly income, health and literacy for measuring human development at national level. Lodha & Gosain (2005) proposed the use of two additional indicators of cattle holding and land holding along with the three HDI indicators, keeping in view the importance of these two factors in rural livelihood. They have used the technique to assess the impacts of development base programmers in the Dudhi micro watershed which is located in the Raisen district of Madhay Pradesh in India.

A.4 Formulation of Household development indicators and index

An approach similar to the UNDP's for capturing human development has been used to quantify the livelihood of the study Haor. A set of equation was formulated to measure the development of various livelihood groups.

According to Lodha & Gosain (2005) House Hold Development Index (HHDI) represents the position of a particular household within a given population.
Calculation of HHDI involves four steps in the first step Eq. (b.4) is used to measure development indicator D_{ij} as given below.

$$D_{ij} = \frac{(X_{ij} - {}_{\min}X_i)}{({}_{\max}X_i - {}_{\min}X_i)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (b.4)$$

Eq (4.4) is obtained by putting Eq (b.1) in Eq. (b.3) D_{ij} is the value of development indicator for the j th household with respect to the i th indicator and X_{ij} is the individual value of the i-th indicator for the j-th household and ${}_{\min}X_i$ and ${}_{\max}X_i$ are the corresponding minimum and maximum values of that indicator.

In the second step Eq. (b.5) is used to measure the Household Development Index (HHDI) for i-th indicator by taking a simple average of all the development indicator value of that indicator for each household of a certain livelihood group.

$$(HHDI)_i = \frac{\sum_{j=1}^{m} D_{ij}}{m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (b.5)$$

Where, *m* is the number of households of k-th livelihood group

In the third step Eq. (b.6) is used to measure the Household Development Index $(HHDI)_k$ of k-th livelihood group by taking average of HDDI for all indicator of that livelihood group.

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$$(HHDI)_k = \frac{\sum_{i=1}^{n} (HHDI)_i}{n} \quad \text{.......................................} (b.6)$$

Where, n is the number of indicator

In final step Eq. (b.7) is used to measure the Household Development Index of the project area $(HHDI)_p$ by taking average of the value of HHDI for all livelihood groups as shown in Eq. (4.3).

$$(HHDI)_p = \frac{\sum_{k=1}^{l} w_k \times (HHDI)_k}{l} \quad \text{.......................................} (b.7)$$

Where, l is the number of livelihood groups and w_k is the weight age factor of k-th livelihood groups of the project area

A.5 Selection of Indicators for Haor Based Household Development

Measurement of the household development of Haor based livelihood should not be based in terms of increase in production of crops or fish catch rather it is important to consider their increase in income, food security, opportunity to work, protein intake and access to natural resources. The indicators have been selected considering the major Haor based livelihood factors, which reflect the development of the households. Community opinion has also been taken into consideration in selection of indicators.

For measurement of the household development of Haor based livelihood, six indicators have been selected which are as follows:

- Income
- Food security
- Employment opportunity in main occupation
- Employment opportunity in other occupation
- Protein intake
- Access to ecological resources.

The indicators are discussed below:

Income: The annual income in terms of Taka per year is an important indicator for assessing HH development. Here the annual input cost for the livelihood options is deducted to get net come. This indicator reflects the economic outcome for the effort of the livelihood options. Income of individual households also indicate the well being status and resiliency to unwanted shocks.

Food Security: Food security is measured in terms of duration (months of a year) when a household have the ability to procure required food for their healthy life. It is observed that even after bumper production farmer has storage of food just for few months after the harvest or limited ability to procure food beyond few months. So, availability of food in number of months in a year is a reflector of the food security of a particular livelihood group.

Employment opportunity in main occupation: Employment opportunity for particular livelihood option in Haor area is dependent on seasonality. For example, farmers have their employment opportunity only in the dry season while fisherman has the employment opportunity in the wet season only. Rest of the period they are engaged in other occupations. For example, famers catch fish during the wet season and fisherman work in harvesting rice during the dry person. The HH development is strongly dependent on the length of employment opportunity in their man and other occupation. Here the total number of months of employment in a year is used as the indicator of the opportunity of employment. This employment opportunity reflects the HH development of a particular livelihood group.

Employment opportunity in other occupation: Employment opportunity in other than main occupation in terms of month in year reflect the opportunity for income in lean period, practically when there is no opportunity to work in main occupation. At the same time, it also reflects the tendency of change in main livelihood option, for which the households have the inherent skills and expertise.

Protein intake: In the Haor area fish in the main source of protein for HH because other protein source is quite scarce in the area. People in the Haor area meet their protein need through consuming fish. This protein intake is also related to the health status of the HH. The fish access and availability of fish is a good measurement of HH livelihood development. Protein stake is measured as a number of days in a week where HH have fish in their food menu.

Access and availability to ecological resources: Households in the Haor area are dependent on ecological resources in many ways especially on aquatic resources. Due to different unplanned development initiatives and gradual encroachment of land for cultivation these abundant resources are in stress. The access and availability to the ecological resources in becoming challenging for the button portion of the community. This indicator measures the availability and access for using aquatic plant as fire wood source, supplementary food and medicine.

Table A.1 Value of Indicators for various Livelihood Group

Livelihood Group	Indicator	Value of indicator			
		Pre Damage		Post Damage	
		Max	Min	Max	Min
Agricultural	Income (Tk per year)	350000.00	10000.00	300000.00	2000.00
	Food security (Months per year)	12	2	12	0
	Working opportunity in main occupation (Months per year)	6	3	3	0
	Working opportunity in other occupation (Months per year)	6	0	6	2
	Protein intake (days in week)	7	2	5	1
	Access to natural resources (%)	100.00	20	100	50
Fisherman	Income (Tk per year)	300000.00	8000.00	250000.00	5000.00
	Food security (Months per year)	12	0	12	0
	Working opportunity in main occupation (Months per year)	7	2	6	2
	Working opportunity in other occupation (Months per year)	8	2	5	1
	Protein intake (days in week)	7	2	6	1
	Access to natural resources (%)	100.00	10	100	20
Boatman	Income (Tk per year)	150000.00	15000.00	150000.00	18000.00
	Food security (Months per year)	12	0	12	0
	Working opportunity in main occupation (Months per year)	12	6	12	7
	Working opportunity in other occupation (Months per year)	6	0	3	0
	Protein intake (days in week)	6	2	7	2
	Access to natural resources (%)	100.00	15	100	30
Aquatic Plant dependent	Income (Tk per year)	80000.00	12000.00	60000.00	8000.00
	Food security (Months per year)	8	2	9	3
	Working opportunity in main occupation (Months per year)	12	1	12	2
	Working opportunity in other occupation (Months per year)	9	2	7	2
	Protein intake (days in week)	4	1	5	2
	Access to natural resources (%)	90.00	15.00	100	40

APPENDIX B
CALCULATION FOR BENEFIT COST RATIO

Table B.1 Computation of internal rate of return (Financial)

(In Lac Taka)

Year	Invest. Cost	O & M Cost	Total Cost	Benefits from saved Properties	Others Benefits	Total Benefits	Cashflow
1	1500.00	0.00	1500.00	0.00	0.00	0.00	-1500.00
2	1000.00	0.00	1000.00	0.00	0.00	0.00	-1000.00
3	568.00	0.00	568.00	0.00	0.00	0.00	-568.00
4		68.00	68.00	768.18	0.00	768.18	700.18
5		68.00	68.00	768.18	0.00	768.18	700.18
6		68.00	68.00	768.18	0.00	768.18	700.18
7		68.00	68.00	768.18	0.00	768.18	700.18
8		68.00	68.00	768.18	0.00	768.18	700.18
9		68.00	68.00	768.18	0.00	768.18	700.18
10		68.00	68.00	768.18	0.00	768.18	700.18
11		68.00	68.00	768.18	0.00	768.18	700.18
12		68.00	68.00	768.18	0.00	768.18	700.18
13		68.00	68.00	768.18	0.00	768.18	700.18
14		68.00	68.00	768.18	0.00	768.18	700.18
15		68.00	68.00	768.18	0.00	768.18	700.18
16		68.00	68.00	768.18	0.00	768.18	700.18
17		68.00	68.00	768.18	0.00	768.18	700.18
18		68.00	68.00	768.18	0.00	768.18	700.18
19		68.00	68.00	768.18	0.00	768.18	700.18
20		68.00	68.00	768.18	0.00	768.18	700.18
21		68.00	68.00	768.18	0.00	768.18	700.18
22		68.00	68.00	768.18	0.00	768.18	700.18
23		68.00	68.00	768.18	0.00	768.18	700.18
24		68.00	68.00	768.18	0.00	768.18	700.18
25		68.00	68.00	768.18	0.00	768.18	700.18
NPV @12%	2540.77	370.01	2910.78	4179.91	0.00	4179.91	1269.13

All calculations are based on project period of 25 years

FIRR base case	17.80%	
Benefit Cost Ratio	**1.44**	**: 1.00**
NPV(Lakh Taka)	1269.13	

Table B.2 Computation of internal rate of return (Economic)

(In Lac Taka)

Year	Invest. Cost	O & M Cost	Total Cost	Benefits from saved Properties	Others Benefits	Total Benefits	Cashflow
1	1147.50	0.00	1147.50	0.00	0.00	0.00	-1147.50
2	765.00	0.00	765.00	0.00	0.00	0.00	-765.00
3	434.52	0.00	434.52	0.00	0.00	0.00	-434.52
4		61.34	61.34	692.90	0.00	692.90	631.56
5		61.34	61.34	692.90	0.00	692.90	631.56
6		61.34	61.34	692.90	0.00	692.90	631.56
7		61.34	61.34	692.90	0.00	692.90	631.56
8		61.34	61.34	692.90	0.00	692.90	631.56
9		61.34	61.34	692.90	0.00	692.90	631.56
10		61.34	61.34	692.90	0.00	692.90	631.56
11		61.34	61.34	692.90	0.00	692.90	631.56
12		61.34	61.34	692.90	0.00	692.90	631.56
13		61.34	61.34	692.90	0.00	692.90	631.56
14		61.34	61.34	692.90	0.00	692.90	631.56
15		61.34	61.34	692.90	0.00	692.90	631.56
16		61.34	61.34	692.90	0.00	692.90	631.56
17		61.34	61.34	692.90	0.00	692.90	631.56
18		61.34	61.34	692.90	0.00	692.90	631.56
19		61.34	61.34	692.90	0.00	692.90	631.56
20		61.34	61.34	692.90	0.00	692.90	631.56
21		61.34	61.34	692.90	0.00	692.90	631.56
22		61.34	61.34	692.90	0.00	692.90	631.56
23		61.34	61.34	692.90	0.00	692.90	631.56
24		61.34	61.34	692.90	0.00	692.90	631.56
25		61.34	61.34	692.90	0.00	692.90	631.56
NPV @12%	1943.69	333.75	2277.44	3770.28	0.00	3770.28	1492.84

All calculations are based on project period of 25 years

EIRR base case	20.54%
Benefit Cost Ratio	**1.66 : 1.00**
NPV(Lakh Taka)	1492.84