SPATIAL PLANNING OF CYCLONE SHELTERS IN BARGUNA DISTRICT BASED ON VULNERABILITY ANALYSIS

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The author wishes to dedicate this Master's thesis to her sister, parents and beloved husband.

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Abstract

This study was conducted from the realization of the need for identification of the areas that are vulnerable to disaster and provide some guidelines for effective emergency planning during post-disaster phase. Disasters have much more severe impacts in a developing country than in a developed country. For instance, the damage caused by the last catastrophic cyclone SIDR was extensive in Bangladesh. This is why; developing an effective strategy for disaster management for cyclone zones is a challenging issue to emergency planners. This study examines spatial variability in evacuation assistance needs during cyclone hazard in Barguna district and identifies the optimum locations and non-engineered structural design of cyclone shelters. For this, composite vulnerability map of unions in Barguna district is developed based on the community demographics, resources, structures and geophysical risk indicators. Four evacuation dimensions are: population character and building structures, differential access to resources, special evacuation needs, and a combination of three dimensions. Moreover, the difference between the cyclone shelters demand and existing shelters in the highest vulnerable areas are analyzed. Results indicate that relative majority of the unions are characterized by high evacuation assistance need and similar scenario exists in the spatial distributions of geophysical risk and socio-economic vulnerability. Nevertheless, spatial disparity of socio-economic vulnerability is also observed among the unions within the geophysical risk zone. Barabagi union of Amtali upazila was identified as the most vulnerable union in terms of both geophysical risk and socio-economic factors. Towards this, methodology was developed for determination of number of new shelters required and their tentative locations in the same union. Moreover, this study also provides some guidelines for construction of low cost housing, which can withstand during tropical storm. Thus, in an environment where financial and human resources are limited, spatial analyses should be incorporated in disaster-management procedures of both the government and development agencies to decrease the vulnerability of the country's population, especially in rural and remote regions. In order to integrate spatial analyses it is essential that the government and its agencies and others, keep up, or better, increase the compilation of spatially referenced data sets and share them as well.

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INTRODUCTION

Chapter 1
Introduction

1.1 Background and General statement of the problem

Developing an effective strategy for disaster management for cyclone zones presents challenge to emergency planners because of spatial differences in geophysical risk and social vulnerability. Although the approaches differ and definition vary, there has been increasing emphasis on the importance of the intersection of geophysical condition and the social systems (Liverman 1990; Dow 1992; Montz and Tobin 2003). Hazards and social vulnerability are inextricably intertwined by their very nature. The study of hazards and social vulnerability each have a voluminous body of work that spans many disciplines and is utilized for many different kinds of research including: emergency planning, risk exposure, and many other purposes.

In terms of definition, there is a difference between natural hazard and disaster. A hazard is a potentially damaging event and the measure of hazard is its probability of occurrence at a certain level of severity within a specified period of time in a given area (Office if the United Nations Disaster Relief Coordination, 1991). On the other hand, natural disaster is defined as a consequence of the occurrence of a natural phenomenon affecting a vulnerable social system (Appel, 2001). Thus natural hazards represent the potential events whereas natural disasters result from actual events (Tobin and Montz, 1997). Developing countries are more vulnerable to natural hazards than the developed countries (United Nations Environmetual Program, 1992). It is very rare that natural hazards caused a large number of deaths in developed countries. The main reason of higher number of death in developing countries is their economic situation (Ono, 2001). High population density is another reason for the higher death toll in developing countries. As population increase and more land is utilized, more people are forced to live in coastal areas. In a recent study, the Center for Climate System Research (CCSR) at Colombia University has predicted that the World's coastal population will increase by 35 percent from 1995 to 2025 and will put more people at risk from natural hazards such as tsunamis or tropical cyclone (CCSR, 2006).

Bangladesh is the most densely populated country (1045 person/sq.km) in the world and cyclone disaster is the most frequently occurred disaster and which has a significant deadly impact on the coastal areas in Bangladesh (Wikipedia, 2009). The coastal areas of Bangladesh are highly vulnerable to disaster as the population exposure is high. According to the study of Water Resource Planning Organization in 2004, around 35.1 million people live in coastal areas in Bangladesh, which is 23 percent of the total Nation's population. The study will contribute to the disaster management effort in a particular district in Bangladesh in the response phase not only for reducing damage but also for allocating evacuation sites in the appropriate location.

1.2 Specific problem

Bangladesh is subject to a variety of natural hazards, which has the potential to threat both its population and environment. Over 8900 square kilometers of the country's coastal area is identified as the high- risk zone that is prone to cyclones and inundation by storm surges (CEGIS, 2004). Nevertheless, the coastal districts of Bangladesh are mainly susceptible to cyclones and storm surge. For example, the extent of damage caused by the last super cyclone SIDR that swept through Bangladesh coast on 15 November 2007 was about $450 million and the entire Patuakhali, Barguna and Jhalokati districts were hit hard by the storm surge of over 5 meters (16 ft). In Barguna district, 1335 people were died (44.5 percent of total casualties), 1119.89 sq. km. area was annihilated (61.15 percent of total area) and 60-70 percent of crop was lost and 95,412 houses were fully and partially damaged (36.89 percent of total) (Mustaafa, 1998). Like this, Barguna was also affected by cyclones during 1935 and 1965. According to BUET-BIDS study on 1993, around 70 percent of total area in Barguna district falls under the high-risk area (BUET-BIDS, 1993).

Nevertheless, the spatial coverage of geophysical risk and vulnerability assessment is comparatively problematic than estimation of total damage. Vulnerable groups are those who are likely to suffer a disproportionate share of the effects of hazardous events (Clarke *et al*, 1998). Recent hazard research focused on the vulnerability that exacerbates the effect of disaster. Literatures have also identified many components of vulnerability (Blaikie *et al*., 1994; Clarke *et al.*, 1998; Cutter, 1996; Hewitt, 1997; Kasperson *et al.*, 1995; Montz, 1994; Susman, 1983; Tobin, 1997 and United Nations International Strategy for Disaster Reduction, 2001) but few clear measures of vulnerability have been established. A more recent challenge has been to address the interaction of vulnerability components in the context of multiple hazard and risk. Bangladesh University of Engineering and Technology and Bangladesh Institute of Development Studies conducted a study entitled "Multipurpose Cyclone Shelter Programme", which assessed the vulnerability based on geophysical risk (BUET-BIDS, 1993). However, this research will approach these issues by evaluating spatial variations in both geophysical risk and social vulnerability at union level of Barguna district in order to identify and distribute the required cyclone shelters.

1.3 Objectives with specific aims and possible outcome

The aim of the research is to facilitate effective spatial planning for the evacuation of populations in Barguna district.

Objectives:

The objectives of the research are:

1. To assess geophysical and socio-economic vulnerability of different unions of Barguna district
2. To create a composite vulnerability map based on the community demographics, damage and geophysical risk provided.
3. To identify optimum locations for cyclone shelters in highly vulnerable unions based on the evacuation needs.

1.4 Rationale of the study

Delineation of areas based on vulnerability assessment (geophysical risk and social vulnerability) of cyclone is important for spatial planning and disaster management planning. This study will provide a detail picture of a coastal district (Barguna) in terms of vulnerability that will help policy makers to identify the regions of maximum risk and prioritize the regions according to both resource allocations along with spatial planning.

1.5 Overview and cyclone disasters in Bangladesh

Tropical cyclones generally occur over some parts of tropical oceans in latitudes between10° and 30° both sides of the equator, and they became severe when they are located between 20° and 30° latitude (Holmes, 2001). Bangladesh lies between 20°34′ N and 26°38′ N latitude, and with 440-mile long coastline is highly vulnerable to tropical cyclone and associated storm surge. The Bay of Bengal is an ideal breeding ground of tropical cyclones and others natural disasters. Cyclone is an atmospheric circulation system in which the sense of rotation of the wind about the local vertical is the same as that of earth's rotation. Thus a cyclone rotates clockwise in the southern hemisphere and the counter clockwise in the northern hemisphere. In meteorologically the term cyclone is reserved for circulation systems with horizontal dimension of hundreds (tropical cyclones) or thousands (extra tropical cyclones) of Kms (Parkers, 1980).

Table 1.1 Classification of tropical storms

Disturbances	Wind speed	
	(km/hr)	(m/s)
Depression	32-50	9-13
Deep depression	51-60	14-16
Cyclonic storm	61-89	17-23
Severe cyclonic storm	90-119	24-31
Severe cyclonic storm with a Hurricane wind	>120	>32

Source: Bangladesh Metreorological Department (2008).

The highest frequency of cyclone in Bay of Bengal occurred during May and October. The depression first originates in small anti clockwise motion and rapidly changes its direction, which at last becomes circular in shape. The wind velocity varies from 24 to 240 Km/hr. The average duration of tropical cyclone averages between couple of hours to a week. The average rate of travel is about 400 kilometers a day. Table 1.2 lists the number if deaths in different countries associated cyclone disasters where the death tolls were in excess of 5000 lives. It can be easily discerned from the table that most of these deadly disasters occurred in Bangladesh from tropical cyclone.

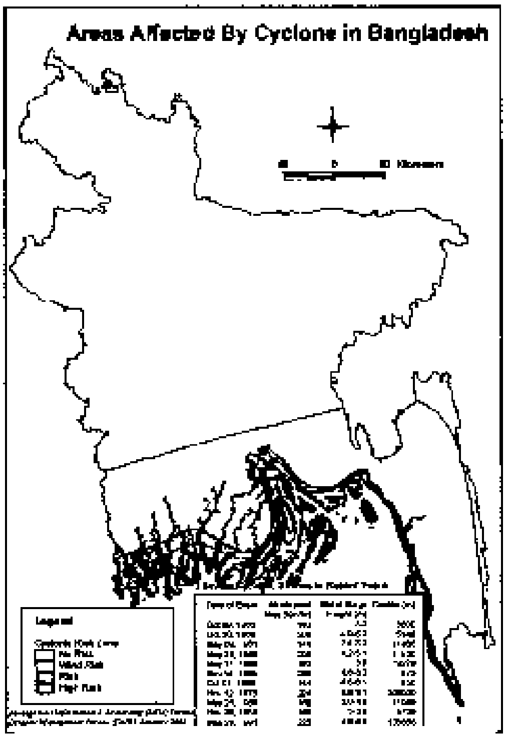
Table 1.2 Deaths in tropical cyclones in Bangladesh

Year	Countries	Deaths	Year	Countries	Deaths
1970	Bangladesh	300,000	1965	Bangladesh	19,279
1737	India	300,000	1963	Bangladesh	11,520
1886	China	300,000	1961	Bangladesh	11,466
1923	Japan	250,000	1985	Bangladesh	11,069

1876	Bangladesh	200,000	1971	India	10.000
1897	Bangladesh	175,000	1977	India	10,000
1991	Bangladesh	140,000	1963	Cuba	7,196
1833	India	50,000	1900	USA	6,000
1864	India	50,000	1960	Bangladesh	5,149
1822	Bangladesh	40,000	1960	Japan	5,000
1780	Antilles (W. Indies)	22.000	1973	India	5,000

Source: Dube et.al., 1997

Bangladesh has experienced major cyclones during 1970, 1991 and 2007. The severe cyclone of 12 November 1970 took a toll of 0.3 million human lives in Bangladesh and put property damages to billions of $US dollars. Yet another worst cyclone which hit Bangladesh coast on April 1991 killed 0.14 million people and property damages were more than two billion US dollars. Cyclone SIDR was the most powerful cyclone to impact Bangladesh since 1991 when a reported 140,000 people perished and billions of dollars damage was reported. In this instance the death toll is significantly less (approximately 3,406) however the damage to crop and infrastructure is significant across 30 districts, 200 upazila and 1,950 unions. Over 55.000 people were injured, while over 1,000remain missing.



Source: The daily star, 2007

1.6 Cyclone SIDR, 2007

Cyclone SIDR (also known as Very Severe Cyclonic Storm SIDR) is Category-4 equivalent tropical cyclone of the 2007 formed in Bay of Bengal having wind speed 215 km/hr made landfall near Bangladesh on November 15. So far, 3,113 deaths have been blamed on the storm. Tidal waves reaching up to a height of 4 metres (12-15ft) and the damage were extensive, including tin shacks flattened. houses and schools blown away and enormous tree damage. Some local officials have described the damage as being even worse than that from the 1991 cyclone. The entire cities of Patuakhali, Barguna and Jhalokati District were hit hard by the storm surge of over 5 meters (16 ft). The hardest-hit area was Barguna, where the number of causalities was 1335 according to local officials. As it intensified to a Category 4-equivalent cyclone on November15, thousands of emergency officials were put on standby in Bangladesh in advance of the storm's arrival. Newspaper reported that massive evacuations of low-lying coastal areas also took place, although sheltering was only available for about 500,000 of the over 10 million residents of coastal areas. A total of 650,000 people in Bangladesh evacuated to emergency shelters. Another problem was that the mechanism to resist disaster was not systematic. A lacking of efficiency was observed after the disaster for relief operation. It is inevitable that a spatial planning to withstand disaster is a major concern.

Bangladesh had established 2,400 cyclone shelters in high-risk areas. Over 1.5 million people were moved to shelters in the lead up to Cyclone Sidr *(Ministry of Food and Disaster Management)*. Some did not seek shelter because there were no facilities for the cattle and other livestock. A survey conducted in 2004 by the Centre for Environmental and Geographic Information (CEGIS) on 1,705 shelters that identified some deficiencies in the shelters:

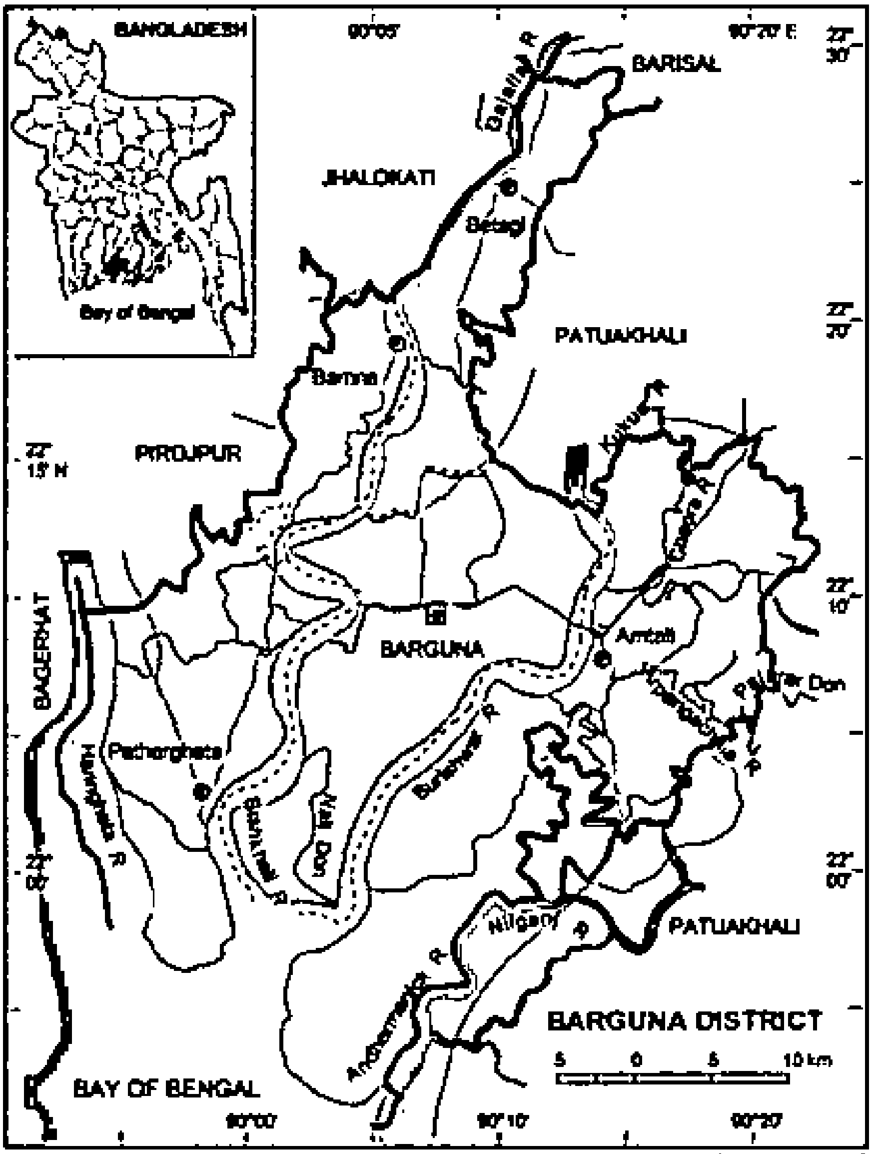
- The total number of shelters was not enough to hold the evacuated population.
- More than 65 percent of all shelters had no provision for the special needs of women.
- Almost 100 percent had no facilities for people with disabilities.
- 75 percent of shelters surveyed had no provision for storage of water.
- 80 percent made no provision for the shelter of livestock
- 87 percent of all shelters surveyed had some structural vulnerability.
- Little or no effects were made to preserve drinking water
- Preparedness measures for protection and restoration of power and telecommunication were inadequate.

Disaster management in terms of cyclone disaster is very reactive now a day in Bangladesh. The evidence is observed from the lowest number of death tolls in super cyclone SIDR although the severity of SIDR is higher than the cyclone of the past two decades 1970 and 1991. In spite of reactive approach of disaster management in

Bangladesh there are some lacking in response phase of disaster management and a gap in spatial planning is however significant. Therefore there is a real need for spatial planning for the vulnerable population in cyclone-affected areas. The study aims to identify the vulnerable location in Barguna district of Bangladesh and finally move forward for a solution through spatial planning specially for cyclone shelter location considering the vulnerability analysis.

1.7 Study area

Barguna District (Barishal division) is a coastal district of Bangladesh, with an area of 1831.31 sq km and bounded by Burirshwr, Bishkali and Baleshwar (Fig 1.2). The district consists of 5 upazilas, 38 union parishads, 238 mouzas, 560 villages, 4 municipalities, 44 wards and 49 mahallas. The upazilas are Barguna Sadar, Amtali, Patharghata, Betagi and Bamna (Banglapedia, 2006). Number of population is 837955 and the percentage of male population is 49.88 and female 50.12 (BBS, 2006).



Source: Banglapedia (2006)

Fig 1.2 Barguna district in Bangladesh.

The district is hazard-prone and has been directly threatened numerous times by cyclones and tropical storms. Since 1887 approximately 35 such storms along with depression hit this district. The most recent events include Severe Cyclone SIDR during 2007 and Severe Cyclone 1970. Islam (2008) shows the frequency of cyclone track and the tropical depression of Bay of Bengal. From the study of Islam and data of Bangladesh Meteorological Department the frequency analysis of cyclone for Barguna district is analyzed (Table 1).

Table 1.3: Frequency distribution f cyclone in Barguna district.

Type	Wind speed (Knots)	Frequency
Tropical depression (TD)	17-33	19
Tropical Storm (TS)	34-47	9
Severe Cyclonic storm	48-63	3
Very Severe Cyclonic storm	64-119	3
Super Cyclone Storm	>120	1
Total		**35**

Source: Islam (2008), BMD (2007)

1.8 Outline of the Chapters

The second and third chapter provide a literature review covering the methods used for hazard research as it pertains to the hazards selected for this research, methods used to determine social vulnerability, and the utilization of GIS as an analytical tool for this process.

The fourth chapter outlines the details of the method used to identify the degree of geophysical vulnerability of Barguna district. The frequency data of cyclone for the previous years was collected from secondary sources. This chapter also identifies the high-risk zones and risk areas in the study areas and shows the storm surge inundation level in pervious catastrophic cyclones and the forecasted cyclone by using hydrodynamic model.

The fifth chapter considers the socio-economic vulnerability due to cyclone based on socio-economic parameters. The social vulnerability pattern was also validated by damage information in catastrophic cyclone SIDR. Finally a composite vulnerability maps was created by using GIS.

Chapter six reveals the methods of cyclone shelter planning and introduction of house building loan at low interest rate as a solution for disaster management. This chapter also provides some strategies to improve the low cost housing in order to withstand disaster.

Chapter seven summarizes the results and provides an overview of the usefulness of the various methods described. Suggestions for improving this research and other considerations are described in this chapter.

Chapter 2

THEORETICAL FRAMEWORK

Chapter 2

Theoretical framework

2.1 Definition of Hazards and disaster

The literature on hazard, risk, exposure, and social vulnerability is voluminous and a multitude of disciplines have contributed to this research. Hazard research is often complicated because of the variety of different disciplines that have contributed to the field. Each discipline has a slightly different perspective of the subject (Crozier 1988). It is important to examine the different definitions that have been applied to words like hazard, risk, and disaster.

Hazard is a naturally occurring or human-induced process or event with the potential to create loss (Smith, 1996). Natural hazard is defined by Burton at al. (1993) as 'those elements of the physical environment harmful to Man and caused by forces extraneous to him'. Natural hazard means the probability of occurrence within a specific period of time in a give area, of a potentially damaging natural phenomenon (Crozier, 1988). Tobin and Montz (1997) define natural hazard as the potential interaction between humans and extreme natural events. It represents the potential or likelihood of an event. The hazard exists because humans or their activities are constantly exposed to natural forces. Natural hazards are those triggered by climatic and geological variability, which is at least partly beyond the control of human activity (Palm, 1990). Mitchell (1990) defined hazard as the sum of risk, exposure, vulnerability, and response. Tobin and Montz (1997) describe risk as the product of the probability of occurrence and social vulnerability.

Ball (1979) expands on the idea that "natural" disasters are not in fact natural but that they rely on an interaction between the natural world and the human society that inhabits it. When large numbers of people exposed to a hazard are killed, injured, or structural damage occurs, the event is termed a disaster, although the threshold, which must be surpassed, to qualify as a disaster is often debated and therefore unclearly defined (Smith, 1996). Disasters are characterized by the scope of an emergency and an emergency becomes a disaster when it exceeds the capability of the local resources to manage it. Disasters often result in great damage, loss, or destruction. Disasters are defined as a hazardous event that has had a large impact on society. Unfortunately, there are no definitive boundaries to determine exactly when a threshold has been reached such that we can categorically say, "this constitutes a disaster" (Tobin and Montz, 1997).

2.2 Definition of vulnerability

Recent hazard research has focused on vulnerability and the role it can play in exacerbating or ameliorating the effect of disaster. The combination of geophysical risk and vulnerability reflect the degree to which societies or individuals are threatened by, or alternatively, protected from, the effects, of natural hazards (UNISDR 2001). Vulnerability is therefore is a complex term and difficult to define. Timmerman (1981) define vulnerability as the degree to which a system acts adversely to the occurrence of hazardous events. The degree and quality of the adverse reaction are conditioned by a system's resilience (a measure of the systems capacity to absorb and recover from the disaster). Cutter (1996) defined vulnerability as the likelihood that an individual or a group will be exposed to an adversely affected by a hazard. It is the interaction of the hazard of the place (risk and mitigation) with the social profile of the communities. Clarke et al. (1998) defined vulnerability as a function of two attributes:1) exposure (the risk of experiencing a hazardous event); and 2) coping ability, subdivided into resistance (the ability to absorb impact and continue functioning), and resilience (the ability to recover from losses after an impact) (Islam, 2006).

Vulnerability is a human-induced situation that results from public policy and resource availability or distribution, and it is the root cause of many disaster impacts. Indeed, research demonstrates that marginalized groups invariably suffer most in disasters. Higher levels of vulnerability are correlated with higher levels of poverty and with those excluded from the mainstream of society.

The hazards literature has identified many of the components that comprise vulnerability (e.g., Susman et al. 1983; Blaikie et al. 1994; Monte 1994; Kasperson et al. 1995; Cutter 1996a; Hewitt 1997; Tobin and Montz 1997; Mustaafa 1998). An index of vulnerability would help to account for the dynamic characteristics of the human system. A more recent challenge has been to address the interaction of vulnerability components in the context of multiple hazards and risk. So far, however, no predictive, scientifically based model that correlates measures of vulnerability with the degree of hazard impact has been developed. Some of these studies incorporate a multitude of geophysical threats to an area (Cutter et al. 2000; Flax et al. 2002), encompassing measures of geophysical risk probabilities and recurrence intervals (Montz 1994), whereas others explore the spatial extent of areas at risk for different events (Montz and Tobin 1998; Odeh 2002). Cutter et al. (2000) develops quantitative indicators to represent social vulnerability and incorporates them into maps that depict areas at risk for multiple hazards. Frequently, the objective has been to produce indices of social vulnerability and geophysical risk and ultimately provide a model of community vulnerability. Odeh (2002) used measures of exposure (assets, population, and resources) within a given region to determine social vulnerability; again, one might argue with the selection of variables and actual measurements, but the attempt is laudable.

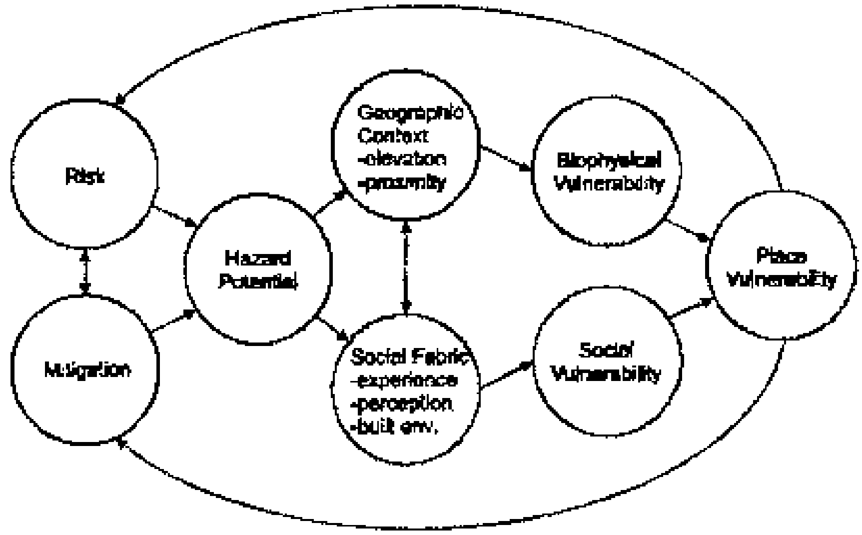
Many different variables have been identified as possibly affecting vulnerability (Blaikie et al. 1994), but determining, which of them are most significant under different conditions has proved elusive. Clark et al. (1998) used factor analysis, whereas others have advocated the use of "expert opinion." Integrating geophysical risk and social vulnerability compounds the methodological problems. Odeh (2002) combines the two scores (hazard and exposure) by multiplying the two indices, whereas Montz and Evans (2001) summed the two indices. Finally Chakraborti *et al* (2005) addresses this research gap by focusing on a coastal county in the state of Florida by adding the two major indices i.e; geophysical risk and social vulnerability of community by using the GIS tool. My study also considered the approach followed by Chakraborty *et al*. A considerable change was undertaken from the study of Chakaborti *et al* (2005) in terms of selecting the variables of geophysical and social vulnerability. Like previous literature of vulnerability of natural hazard, this study also focused on expert opinion for selecting the variable of social vulnerability.

In undertaking such research, extensive use has been made of GIS. This technology is particularly well suited for such research because it allows for (1) the integration of multiple data sources, including hazardous locations and vulnerable populations; (2) the geographic representation of complex data in map form; and (3) the application of spatial analytic and overlay. To analyze social context, variables that represent various socioeconomic characteristics are combined, either as absolute numbers, relative numbers, or quantitative indicators of vulnerability. Similarly, data layers that represent various aspects of the geophysical environment, including hydrologic and topographic factors. are combined. The integration of these two sets in a GIS environment provides a composite view of community vulnerability to hazards.

2.3 Social Vulnerability

Although considerable research attention has examined components of biophysical vulnerability and the vulnerability of the built environment (Mileti, 1999), social aspects of vulnerability are known the least. Socially created vulnerabilities are largely ignored, mainly due to the difficulty in quantifying them. Instead social vulnerability is most often described using the individual characteristics of people (age, race, health, income, type of dwelling unit, employment). Social vulnerability is partially the product of social inequalities—those social factors that influence or shape the susceptibility of various groups to harm and that also govern their ability to respond. However, it also includes place inequalities—those characteristics of communities and the built environment. such as the level of urbanization, growth rates, and economic vitality that contribute to the social vulnerability of places.

This article utilizes the hazards-of-place model of vulnerability (Cutter, 1996; Cutter, Mitchell, and Scott, 2000; Heinz Center for Science, Economics, and the Environment, 2002) to examine the components of social vulnerability. The hazard potential interacts with the underlying social fabric of the place to create the social vulnerability. The social fabric includes socio-demographic characteristics, perception and experience with risks and hazards, and overall capacity to respond to hazards. The social and biophysical vulnerability elements mutually relate and produce the overall vulnerability of the place. The fundamental causes of human vulnerability include a lack of access to resources, information, and knowledge (Cutter et al 2000).



Source: Cutter *et al* (2003)

Fig. 2.1: The Hazards-of-Place Model of Vulnerability

Hazard exposure is primarily a factor of location, whereas, social vulnerability is dependant on the social characteristics of the community and is less dependant on location. Total population is an important factor for vulnerability analysis because the more people located in a hazardous area results in greater potential exposure and more people to recover post disaster. Mileti (1999) states, "as areas become more densely populated, they also become more exposed to hazards." The greater population density and the more difficult it is to respond to hazardous events in terms of evacuation planning and disaster recovery.

Extremes of age can affect social vulnerability. The elderly may have mobility constraints or mobility concerns increasing the burden of care and lack of resilience (Cutter et al. 2000 and Hewitt 1997). The elderly are more likely to suffer from illness and be dependent on the uninterrupted supply of medicine and direct medical care. They may suffer from a generally lack of mobility due to age or disease and therefore be dependent on caretakers to aid in their evacuation and recovery from hazardous events. The every young are dependant on family or other caretakers for food, shelter, and health issues. Therefore they may be disproportionately vulnerable to hazards.

However, many researchers have attempted to quantify social vulnerability based on information available through the United States Census Bureau. Clark et al. (1998) used factor analysis to simplify the multivariate data to examine social vulnerability in River Valley, MA to flooding hazards. The methed of developing a social vulnerability score and standardization methods were developed by Cutter et al. (2000) and the same methods were used by Emrich (2000) for vulnerability analysis in Hillsborough County.

2.4 Spatial Planning of cyclone shelters in coastal areas in Bangladesh

A master plan, prepared at the request of the Government of Bangladesh, estimated that 2,500 new cyclone shelters are needed to provide adequate protection for the projected population in the year 2002. Since this will require an investment of 300 million USD (12 billion Bangladeshi Taka), which may not be possible in the near future, a means of identifying priority areas is needed (Chowdhury, 1998). In the early 1990s there was only 449 shelters, in 1996 it was 1816 (CSPS, 1998), and in October 2001 the total number of shelters stood at 2033 (DMB). CEGIS conducted the survey (January – May 2004) only in the HRA and found 1705 shelters and killas. According to the study of CEGIS in 2004, 49 construction agencies had built these shelters and killas funded by 72 different funding agencies.

Instead of the problems, Bangladesh has a world-renowned community based early warning system and has built cyclone shelters on stilts, so that the storm surge can flow underneath. In order to protect human lives and resources in the coastal areas various mitigation measures like formal cyclone shelters, coastal embankments, shelters, raised roads, killas etc., have been implemented over the years since 1960s by the Government of Bangladesh (GoB) and Non Governmental Organizations (NGOs). These shelters typically provide refuge to over 700 people and have separate spaces for women and men (MoEF, 2008). However, people are often reluctant to go to the shelters, leaving their livestock and other assets behind.

Nevertheless, cyclone shelters in the coastal areas are inadequate and their location allocation is not appropriate. According to the study of Gall (2004), the factors considered most important for establishing new accommodation centres are: their proximity to vulnerable population; their proximity to roads; their proximity to potential host infrastructure (schools, health posts); their proximity to farmland; and the availability of potable water. But no study takes into account the above-mentioned factors nor the factors related to the local context that has significant impact on location decision.

In 2007, cyclone shelters and the very effective early warning system helped limit the number of fatalities, to around 3,500. This is still too many but a small fraction of the loss incurred in 1991 when some 3,00,000 lives were lost due to the less effective early warning system and lack of shelters. The multi-purpose cyclone shelter is a concrete example of indigenous adaptation to extreme climatic events in Bangladesh. To reduce the sufferings of people due to natural disasters CARE Bangladesh accumulated information in an organized and accessible database and engaged CEGIS to identify relevant data to assess the problem and its spatial extent.

To this end social, economic and environmental factors are taken into account in producing a decision that is more conducive to determine geophysical and social vulnerability in selected study area. The factors can include demographics, health, education, employment etc.

Chapter 3

RESEARCH DESIGN

Chapter 3

Research design

Research design describes steps taken to achieve the goal and objectives of the study. It is the most imperative ingredient of any research work as the quality and the anticipated consequences of the research depend on it and a well-designed methodology persuade researcher to attain goal and objectives very straightforwardly. Thus, the study was carried out following the methods described below—

3.1 Research questions

The research questions related to the objectives were: How to assess geophysical and socio-economic vulnerability of different unions of Barguna district? What are the optimum locations for cyclone shelters in highly vulnerable union(s)?

3.2 Selection of the study area

The five Upazilas of Barguna districts e.g. Barguna Sadar, Pathargharta, Bamna, Betagi and Amtali were considered as the study area to get factual and vivid picture of disaster vulnerability in Barguna district.

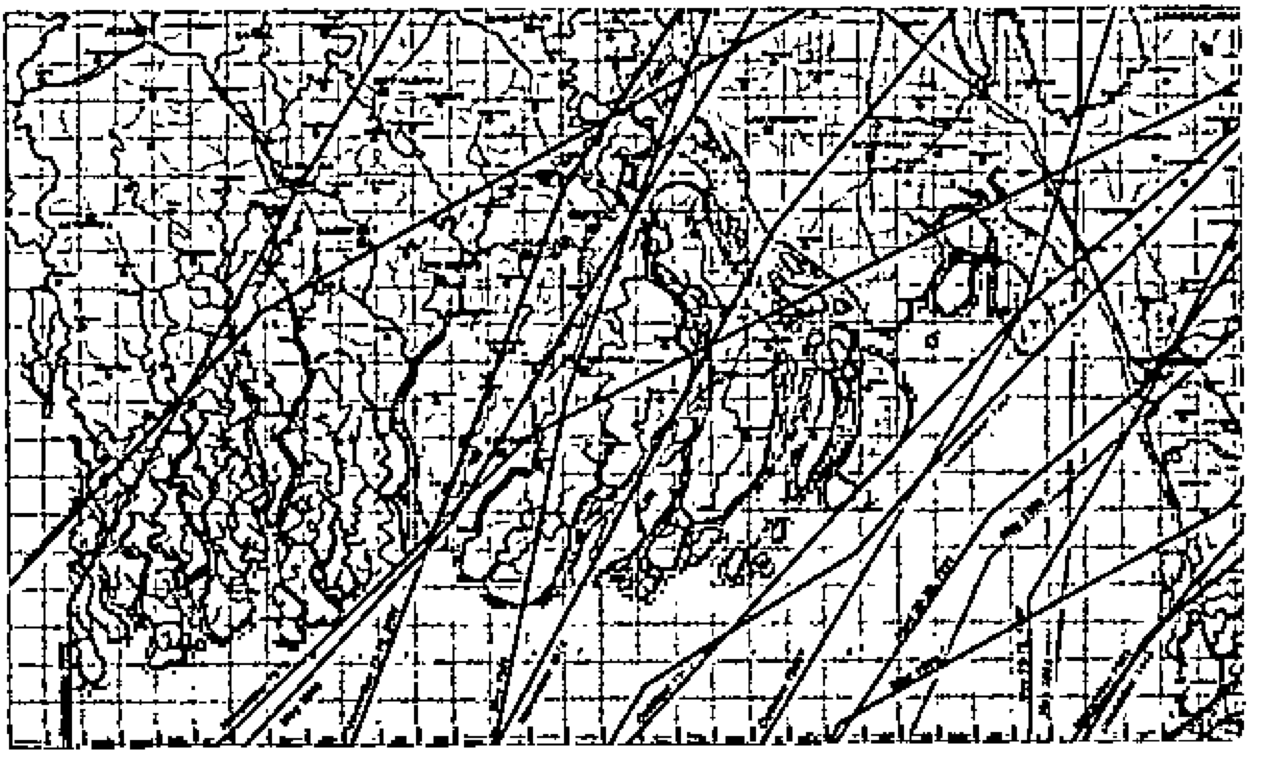
3.3 Literature review

Relevant information was reviewed extensively. Theses, journals, articles in newspapers and periodicals and the Internet contributed immense help to make the study well to do.

3.4 Variables Identification and data collection

Various methodologies can be deployed in order to identify the relevant parameters and variables of the geophysical risk and social vulnerability.

In this study, the storm surge height and wind speed are considered as the two indicators of geophysical risk and the Union level geophysical vulnerability analysis was carried out in 38 Unions of Barguna district based on storm surge height and wind speed. Probability occurrence of cyclone based on the severity of wind speed in Barguna district was identified from the historic data of previous 130 years (Fig. 3.1). The data was collected from Bangladesh Meteorological Department (BMD), Joint Typhoon Warning Centre (JTWC) and Literature survey. The latitude-longitude information of the cyclone track was put into GIS to show how many cyclones in the previous 130 years was passed over the study area. In order to classify the cyclone, the Saffir-Simpson scale was followed (Table 3.1).



Source: IWM, 2007

Fig. 3.1 Severe cyclonic tracks in Bangladesh coast from the year 1960.

Table 3.1: GTCCA classification

Type	Category	Wind speed (Knots)
Tropical Depression	TD	<34
Tropical Storm	TS	34-63
Hurricane		>64

Source: Islam, 2008

Later on, extensive literature review was conducted in order to determine the variables of the social vulnerability. Characteristics those influence social vulnerability most often found in the literature are listed in Table 3.3, along with the relevant research that identified them. Among them generally accepted are age, gender, and socioeconomic status. Other characteristics identify special needs populations or those that lack the normal social safety nets necessary in disaster recovery, such as the physically or mentally challenged, the homeless, transients, and seasonal tourists (Cutter *et al*, 2003). The quality of human settlements (housing type and construction, infrastructure, and lifelines) and the built environment are also important in understanding social vulnerability.

Table 3.3 Social Vulnerability Concepts and Matrix

Concept	Description	Increases (+) or Decreases (-) Social Vulnerability
Socio-economic status (income, political power, prestige)	The ability to absorb losses and enhance resilience to hazard impacts. Wealth enables communities to absorb and recover from losses more quickly due to insurance, social safety nets, and entitlement programs.	High status (+) Low income or status (-)
Gender	Women can have a more difficult time during recovery than men, often due to sector-specific employment, lower wages, and family care responsibilities.	Women (+), Men (-)
Age	Extremes of the age spectrum affect the movement out of harm's way. Elderly may	Elderly (+) Children (+)

	have mobility constraints or mobility concerns increasing the burden of care and lack of resilience.	
Commercial and industrial development	The value, quality, and density of commercial and industrial buildings provide an indicator of the state of economic health of a community, and potential losses in the business community, and longer-term issues with recovery after an event.	High density (+) High value (+/-)
Employment loss	The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster.	Employment loss (+)
Rural/urban	Rural residents may be more vulnerable due to lower incomes and more dependent on locally based resource extraction economies (e.g., farming, fishing). High-density areas (urban) complicate evacuation out of harm's way.	Rural (+) Urban (+)
Residential property	The value, quality, and density of residential construction affects potential losses and recovery. Expensive homes on the coast are costly to replace; mobile homes are easily destroyed and less resilient to hazards.	Residential property (-)
Infrastructure and lifelines	Loss of sewers, bridges, water, communications, and transportation infrastructure compounds potential disaster losses. The loss of infrastructure may place an insurmountable financial burden on smaller communities that lack the financial resources	Extensive infrastructure (+)

	to rebuild.	
Occupation	Some occupations, especially those involving resource extraction, may be severely impacted by a hazard event. Self-employed fisherman suffers when their means of production is lost and may not have the requisite capital to resume work in a timely fashion and thus will seek alternative employment. Those migrant workers engaged in agriculture and low-skilled service jobs may similarly suffer, as disposable income fades and the need for services declines.	Professional or managerial (-) Clerical or laborer (+) Service sector (+)
Family structure	Families with large numbers of dependents or single-parent households often have limited finances to outsource care for dependents, and thus must juggle work responsibilities and care for family members. All affect the resilience to and recovery from hazards.	High birth rates (+) Large families (+) Single-parent households (+)
Education	Education is linked to socioeconomic status, with higher educational attainment resulting in greater lifetime earnings. Lower education constrains the ability to understand warning information and access to recovery information.	Little education (+) Highly educated (-)
Population growth	Counties experiencing rapid growth lack available quality housing, and the social services network may not have had time to adjust to increased populations.	Rapid growth (+)
Medical services	Health care providers, including physicians, nursing homes, and hospitals, are important post-event sources of relief. The lack of	Higher density of medical (-)

	proximate medical services will lengthen immediate relief and longer-term recovery from disasters.	
Social dependence	Those people who are totally dependent on social services for survival are already economically and socially marginalized and require additional support in the post-disaster period.	High dependence (+) Low dependence (-)
Special needs populations	Special needs populations (infirm, institutionalized, transient, homeless), while difficult to identify and measure, are disproportionately affected during disasters and, because of their invisibility in communities, mostly ignored during recovery.	Large special needs population (+)

Source: Cutter, Boruff, and Shirley (2001); Heinz Center for Science, Economics, and the Environment (2002).

However, there is a general consensus within the social science community about some of the major factors that influence social vulnerability such as lack of access to resources (including information, knowledge, and technology); limited access to political power and representation; social capital, including social networks and connections; beliefs and customs; building stock and age; frail and physically limited individuals; and type and density of infrastructure and lifelines (Cutter, 2001a; Tierney, Lindell, and Perry, 2001; Putnam, 2000; Blaikie et al., 1994). In contrast, disagreements arise in the selection of specific variables to represent these broader concepts.

Based on the literature, correlation with disaster damage and expert opinion, sixteen variables of social vulnerability were identified under three parameters such as population and structure characteristics, access to resource, and population with special evacuation needs (Table 3.4). Population Census 2001 was the source in this regard.

Table 3.4. Variables Matrix used to determine social vulnerability

Characteristics (Weighted)	Variables (Weighted)	Source
Geo-physical risk	1. High risk area 2. Risk area	Report on Multipurpose cyclone shelter program (1993), National survey on current status on shelters and developing and operational CYSMIS (2004).
Socioeconomic variables		
Population and structures Index (PSI) (40)	1. Total population (20)	Bangladesh Bureau of Statistics: Community Series (2001)
	2. Total number of Jhupri house (5)	Do
	3. Total number of Katcha house (5)	Do
	4. Total number of semi-pucca house (5)	Do
	5. Population involved in agriculture (5)	Do
Differential access to resources Index (DARI) (30)	1. Total number of households with no safe drinking water (10)	Do
	2. Total number of households with no hygienic sanitation (3)	Do
	3. Total number of households with no electricity connection (2)	Do
	4. Unavailability of pucca road in Km (5)	Local Government Engineering Department (LGED)
	5. Unavailability of health care establishments (5)	Do

	6. Unavailability of Bank (5)	Do
	7. Unavailability of food Godown (1)	Do
	8. Unavailability growth centers (3)	Do
Population with special Evacuation needs Index (PSENI) (30)	1. Total number of people below 5 year age (10)	Do
	2. Total number of people above 60 years age (10)	Do
	3. Disable population (10)	National Forum of Organizations Working with the Disabled (NFOWD) (2006)

Later on, damage data of catastrophic SIDR 2007 were collected from the Amtali, Barguna Sadar, Bamna, Betagi and Patharghata Upazila Parishad Office under 24 variables (Table 3.5).

Table 3.5: Variables of Disaster Damage Index (DDI)

Disaster Damage Index (DDI) (20)	1. Affected area (sq. km.) (1)	Field survey (2008) from union parishad office.
	2. Total number of dead people (8)	Do
	3. Total number of affected people (1.5)	Do
	4. Total number of fully damaged house (1)	Do
	5. Total number of partially damaged house (1)	Do
	6. Monetary value of livestock damage (TK) (1)	Do
	7. Monetary value of poultry damage (TK) (1)	Do
	8. Monetary value of fully and partially damaged crops (TK) (2.5)	Do
	9. Monetary damage of fisheries (TK) (1.3)	Do
	10. Monetary damage of power line (TK) (0.1)	Do

11. Monetary damage of telecommunication (TK) (0.2)	Do
12. Total length of fully damaged pucca roads (km) (0.2)	Do
13. Total length of partially damaged pucca roads (km) (0.2)	Do
14. Total length of fully damaged katcha roads (km) (0.1)	Do
15. Total length of partially damaged katcha roads (km) (0.1)	Do
16. Total length of damaged embankment (km)	Do
17. Monetary value of damaged plants and trees (TK) (0.1)	Do
18. Total number of partially damaged educational institutions (0.1)	Do
19. Total number of fully damaged educational institutions	Do
20. Total number of damaged mosque (0.1)	Do
21. Total number of damaged deep tubewells (1.0)	Do
22. Total number of damaged shallow tubewells (0.2)	Do
22. Total number of ponds (0.3)	Do
23. Monetary value of damaged trawlers, boats and nets (0.3)	Do
24. Monetary value of damaged cottage industries (0.2)	Do

Finally, the existing location and structural condition of cyclone shelters, location of primary and high schools were collected from the Local Government Engineering Department of the Ministry of Local Government Rural Development and Cooperatives.

3.5 Data analysis

3.5.1 Measuring geophysical risk

Geophysical risk zones for cyclone and tropical storms were defined using the study of 'Multipurpose Cyclone Shelter Program (MCSP)' (BUET and BIDS, 1993) and 'National survey on Current Status on Shelters and Developing and Operational CYSMIS' (CEGIS, 2004). In addition, storm surge inundation data for the next fifty years were simulated by applying MIKE 21 with the assistance of Institute for Water Modeling. Later on, the outcomes of the storm surge inundation model were verified with the field level data collected from the local people by applying participatory approach of questionnaire survey.

3.5.2 Measuring Social Vulnerability for Evacuation Assistance

This study identified three specific characteristics of the social vulnerability such as population and structural attributes, access to resources, and special evacuation needs because of physical disability and age.

Several methods have been suggested to compute composite vulnerability measures on the basis of multiple variables. Some incorporate weighting systems (Lowry *et al.* 1995; Montz and Evans 2001) those reflect the relative contributions of the variables under study, while others are based on indices with differing elements that contribute to them (Cutter *et al.* 2000; Montz 2000). Chakraborty and others (2005) modified the procedure developed by Cutter *et al.* (2000) to formulate an index to measure the social vulnerability of the population for evacuation assessment needs at the block group level. This study has also applied the procedure adopted by Chakraborty and others (2005). However, the methodology used to compute the 'socio-economic vulnerability for evacuation assistance index' (SEVEAI) for each union in the study area can be summarized as follows (Appendix 1):

Step 1. Weights in the scale of 100 were assigned to each variables based on the local and expert opinions. The experts are the professionals who were involved in the previous work "Multipurpose Cyclone Program" in 1993 and the other experts are recently working in the revised study of the cyclone shelter planning in the coastal areas in Bangladesh in 2009. Moreover opinion of civil engineers, planners and water resource engineers were considered very vigilantly. Finally the opinion of the officials who are working on the Upazila parisad and Water Development Board in Barguna district were considered.

Step 2. For each variable *i*, ratio of the variable in each union to the total number of that variable in the union *R* was determined. In case of 'Direct Access to Resources', deprivation of resource in each union was first determined.

Step 3. Standardized social-economic vulnerability for evacuation index SVEAI for variable i using the maximum ratio value Rmax observed in the union was computed. SVEAIi =Ri/Rmax

Step 4. To combine multiple variables in the assessment of socio-economic vulnerability, weighted mean of the vulnerability indices was calculated by dividing the sum of weighted index values of all variables by the number of variables n considered. SVEAI = $\sum w_i * SVEAI_i / n$

The values of SVEAI range from 0 to 1 and are not influenced by the number of variables included in the computation. Higher scores for this index indicate greater vulnerability for the unions. Although each socioeconomic variable can be examined independently, the average of all measures provides a general overview of socio-economic vulnerability for any union within the district and is more useful for the emergency management community than individual factors are.

Four alternative approaches were derived for grouping the variables to calculate socio-economic vulnerability and for examining the spatial distribution of each approach within the study area. Each grouping approach represents a combination of socio-economic variables from Table 1. These characteristics are listed below, along with the number of variables associated with each approach:

- Approach 1: Population and structure (five variables),
- Approach 2: Differential access to resources (eight variables),
- Approach 3: Special evacuation needs (three variables), and
- Approach 4: All three characteristics (16 variables).

Later on, the damage data of catastrophic SIDR 2007 were collected from the Amtali, Barguna Sadar, Bamna, Betagi and Patharghata upazilas under 24 variables (Table 2). Like the socio-economic vulnerability index, Disaster Damage Index was calculated after giving the weight of 20. Before calculation of DDI, weight of each variable was assigned based on the expert opinions.

Finally, each approach of the socio-economic vulnerability analysis was combined with the Disaster Damage Index in order to compare the existing scenario of socio-economic vulnerability, the intensity of damage or loss in the unions of the Barguna district and the composite picture of vulnerability.

3.5.3 Spatial planning of cyclone shelter

Required number of shelters for highest vulnerable union was located optimally based on the weight of population and distance. The number of shelters depends on the existing stock of shelters and the number of population exposed to risk. The database that is required for the optimum location of cyclone shelters were collected from literature review, local peoples' opinion and secondary survey.

Table 3.6. Variables Matrix used to determine optimum location of cyclone shelters

Variables	Source
Present number of population in Barguna	Bangladesh Bureau of Statistics:
district, Parawise (community) population in	Community Series (2001).
Barabagi union	Do
Growth rate	
Primary School attendance	Bangladesh Bureau of Statistics:
Secondary school attendance	Community Series (2001)
Number of Pucca household	Do
Growth rate of pucca household	Do
Determination of the catchment area	Based on the opinion of the local population
Existing cyclone shelter location and capacity	Field survey, 2008
Space requirement/person for shelter	Report on Multipurpose cyclone shelter program (1993)
Map of Para (community)	Upazila Parisad office, Amtali

3.6 Recommendation and conclusion

Based on the finding of the data analysis, possible structural and non-structural recommendations were outlined as the pre-disaster mitigation measures in order to reduce the vulnerability and exposure to the risk, and help the emergency disaster management planners.

Chapter 4

GEOPHYSICAL VULNERABILITY OF CYCLONE IN BARGUNA DISTRICT

Chapter 4

Geophysical vulnerability of cyclone in Barguna district

From time to time, in designing or assessing the adequacy of facilities to withstand the damaging effects of natural hazards, it is appropriate to reexamine the topic of acceptable risk. In case of assessing the geophysical risk of cyclone in the study area, geophysical vulnerability analysis is conducted in this chapter by applying storm surge modeling.

Cyclones are synoptic scale events that are affected by and influence the environment over a large area in the scale of over 1000 km (Maniruzzaman, 1997). The satellite image in Fig. 4.1 and 4.2 showing the cloud covered cyclone with symmetrical circular shape. It revolves in a counter clockwise direction in the northern hemisphere and in the opposite direction in the southern hemisphere. The center of the storm is calm and high wind occurs at the distance from it.

Fig. 4.1 Super cyclone SIDR during 15th November, 2007

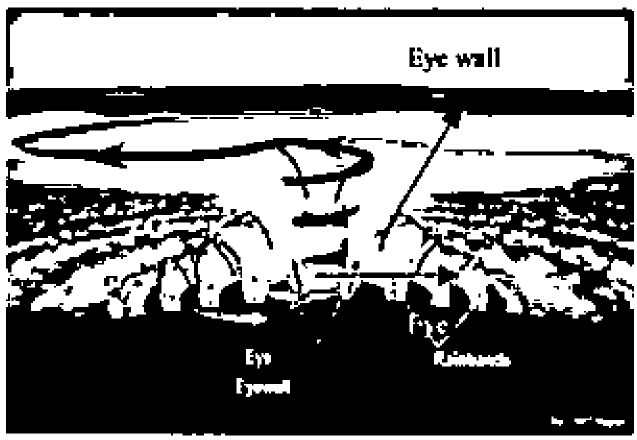


Fig. 4.2 Physical structure of a cyclone

Wind tends to flow from areas of high pressure to the areas where pressure is lower. Moreover, in the northern hemisphere, the highest wind speed is observed on the right of the track because of the effect of the cyclone itself. After landfall, the friction experienced over land slows the speed of cyclone. The cyclones in the GTCCA (Global Tropical Cyclone Climatic Atlas) database are classified into three categories such as tropical depression (wind speed less than 34 knots), tropical storm (wind speed 34-63 knots) and hurricane (wind speed greater than 64 knots). Furthermore, World Meteorological Organization classified the cyclones into seven categories for its panel countries such as low-pressure area, depression, cyclone storm, severe cyclonic storm, severe cyclonic storm with a core of hurricane wind, very severe cyclonic storm, and super cyclonic storm (Table 4.1).

Table 4.1: Classification of cyclones

Weather system	Maximum wind speed
1. Low pressure area	Wind speed less than 17 knots (31 km/hr)
2. Depression	Wind speed between 17-33 knots (31 km/hr and 61 km/hr)
3.Cyclone storm	Wind speed between 34 and 47 knots (62-88 km/hr)
4. Severe cyclonic storm	Wind speed between 48 and 63 knots (89-118 km/hr)
5.Severe cyclonic storm with a core of Hurricane wind	Wind speed 64 knots (119km/hr) or more
6. Very severe cyclonic storm	Wind speed between 64 and 119 knots (119 and 221 km/hr)
7. Super cyclonic storm	Wind speed 120 knots and above (222 km/hr)

Source Islam, 2008

According to the categories of cyclone by GTCCA, 39 tropical depressions, 52 tropical storms and 26 hurricanes hit the land of Bangladesh during the period of 1877 to 2003 (Islam, 2008). Based on this information, the cyclone track was developed for Barguna district. Moreover the track of super cyclone SIDR was identified from the information of Bangladesh Meteorological Department (BMD). It is revealed that during the period of 1877 to 2007, 35 storms have track in Barguna district (Table 4.2 and Fig. 4.3).

Table 4.2: List of historic storm track in Barguna District (1877-2007)

Year	Cyclone type	Year	Cyclone type	Year	Cyclone type
1887	TD	1928	TD	1961	TS (60 Knots)
1888	TS	1929	TD	1964	TD
1890 June	TD	1932	TD	1965	(34-47 Knots)
1890 October	TS	1937	TS	1967	TS
1895	34-47 Knots	1938 May	TD	1970	130 Knots
1913	TD	1938 August	TD	1974	75 Knots
1916	TS	1941 June	TD	1977	TS (60 Knots)
1917	TD	1941 July	TD	1988 Oct	TS (35 Knots)
1919	TD	1941 August	TS	1988 Nov	110 Knots
1920	TD	1950	TD	1997	65 Knots
1923	TD	1958	TD	2007	133 Knots
1924	TD	1959	TD		

Source: Islam, 2008

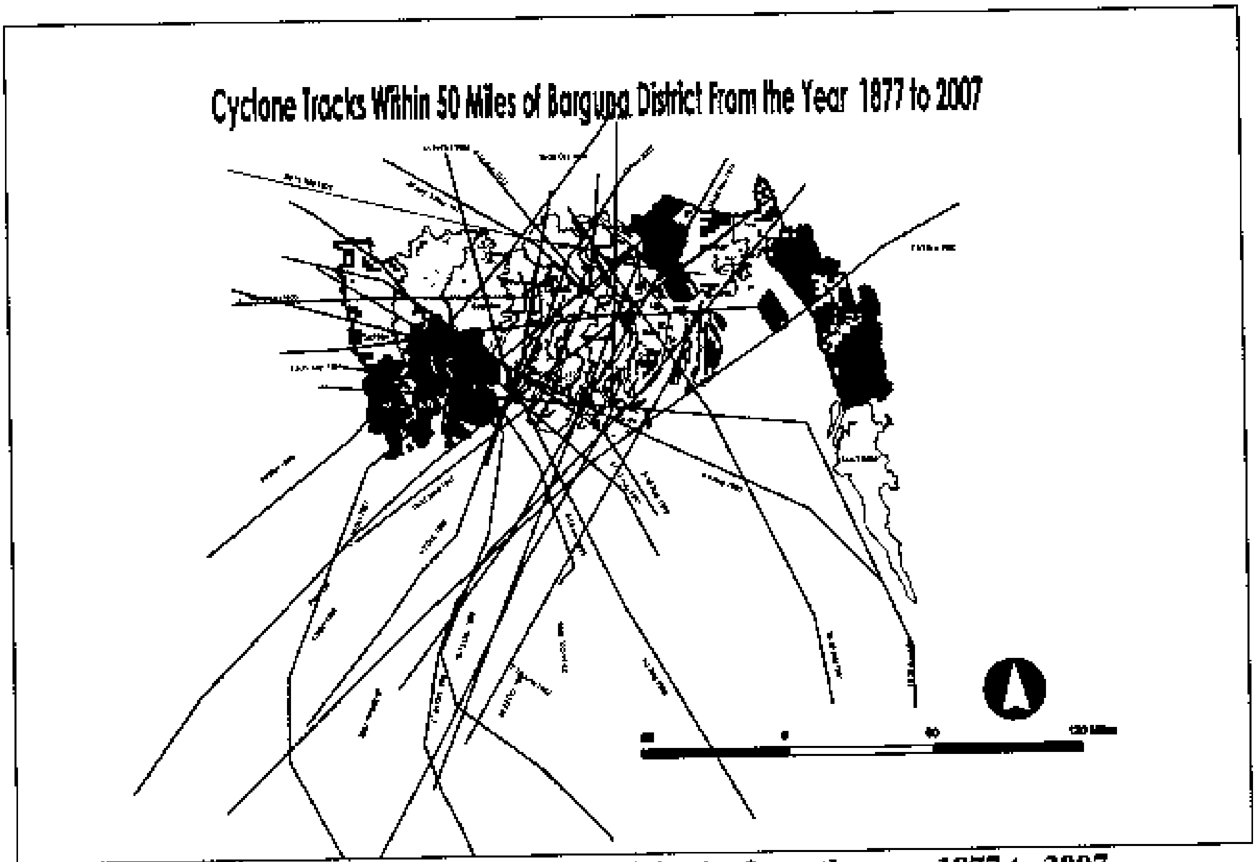


Fig 4.3: Cyclone track of Barguna District from the year 1877 to 2007

Later on, based on the frequency of cyclone, probability of cyclone occurrence in Barguna district was determined for the return period of 10, 20, 50 and 100 years (Table 4.3). The probability of cyclone occurrence revealed that the probability of super cyclone storm in Barguna district during the return period of 10 years, 20 years, 50 years and 100 years is 0.1339, 0.2290, 0.3599 and 0.3313 respectively (Table 4.3).

Table 4.3: Probability of Cyclone in Barguna District

Type	10_yrs	Percent	20_yrs	Percent	50_yrs	Percent	100_yrs	Percent
Severe Cyclonic storm	0.187	18.7	0.2963	29.63	0.3674	36.74	0.228	22.80
Very Severe Cyclonic storm	0.187	18.7	0.2963	29.63	0.3674	36.74	0.228	22.80
Super Cyclone Storm	0.1339	13.39	0.2290	22.90	0.3599	35.99	0.3313	33.13

Source: Calculated by the author, 2009

Thus the geophysical risk of cyclone is based on the two parameters such as wind speed and storm surge. The wind speed and storm surge parameters were calculated based on the wind fit model and storm surge model respectively.

4.1 Frequency analysis of annual maximum cyclonic wind speed in the Bay of Bengal

The description of a cyclone is based on few parameters related to the pressure field, which is imposed on the water surface and a wind field is acting as a drag force on the water body through a wind shear stress description. The pressure field creates a local level set up close to the eye up to one metre only. Whereas the wind shear contributes more to the surge giving a level set up on the right side of the eye and a level set down on the left side. A reasonable description of maximum wind and especially the extent of the high winds in the cyclone is important to obtain the right level set up and set down. Cyclone eye is almost circular and it coincides with the area of lowest pressure (maximum pressure drop) where the cyclonic wind speed is nearly zero. During the last two decades a considerable amount of researches has been carried out for modeling of cyclone wind field and the general conclusion is that the following parameters describe the wind fields quite well:

- Radius to maximum winds, *Rm*
- Maximum wind speed, *Vmax*
- Cyclone track, forward speed *Vf* and direction

The wind field consists of a rotational and a translational component. At a distance, *R*, from the center of the cyclone the rotational wind speed, *Vr*, is given as:

$$V_r = V\max.(R/Rm)^{.7}\exp 7(1-R/Rm) \qquad \text{for } R<Rm$$

$$Vr = V\max.\exp((0.0025Rm+0.05)(1-R/Rm) \qquad \text{for } R \geq Rm \qquad (4.1)$$

The translational component, *Vt*, is given as

$$Vt = -0.05.Vf.-\cos\phi \qquad (4.2)$$

Where ϕ is the angle between the radial arm and the line of maximum wind.

Thus, the total wind speed, *V*, is given as

$$V = Vr + Vt \qquad (4.3)$$

Considering the above concepts of wind speed, BUET-BIDS studies (1993) collected data of cyclonic wind speed from the year 1960 from Bangladesh Meteorological Department (BMD) and fitted the wind data to the Gumbel distribution employing the method of maximum likelihood. The fitted distribution of wind speed for the coast of Bangladesh at 90 percent confidence limit is given below:

$$V_T = 100.53 - 40.10[-\ln(1-1/T)] \pm 16.8C_T \quad (4.4)$$

Where V_T is the cyclonic wind speed (km/hr) in the Bay of Bengal that approaches Bangladesh coast corresponding to the return period T years, and C_T=1.4055, 1.7195, 2.1383 and 2.4574 for T=10, 20, 50 and 100 years respectively.

According to the study, the predicted wind speed for the Barguna district for 10, 20, 50 and 100 years return period were 165 km/hr, 195 km/hr, 223 km/hr, 261 km/hr and 289 km/hr respectively. Furthermore, the wind field model was run and validated by the Institute for Water Modeling (IWM) for the severe cyclones that affect the Bangladesh coast.

Among the severe cyclones, the cyclones during 1970 and 2007 having wind speed of 203 km/hr and 240 km/hr respectively hit Barguna district. On the other hand, BUET-BIDS studies (1993) predicted the wind speed of 261 km/hr for the 50 years return period that is the highest category (CAT5). This is why; the present study has been conducting based on the super cyclone SIDR. Later on, the wind field was generated by using MIKE 21 software for the wind speed 261 km/hr (Fig. 4.2, 4.3 and 4.4).

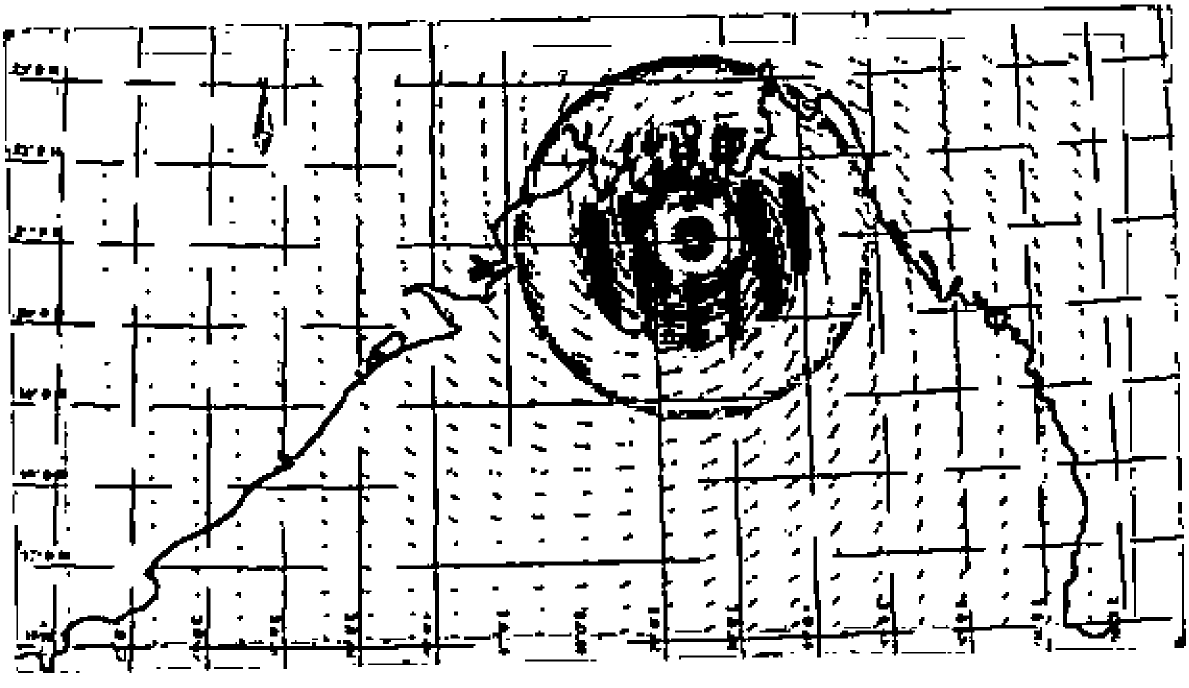


Fig. 4.2: Predicted wind field model for the coast of Bangladesh.

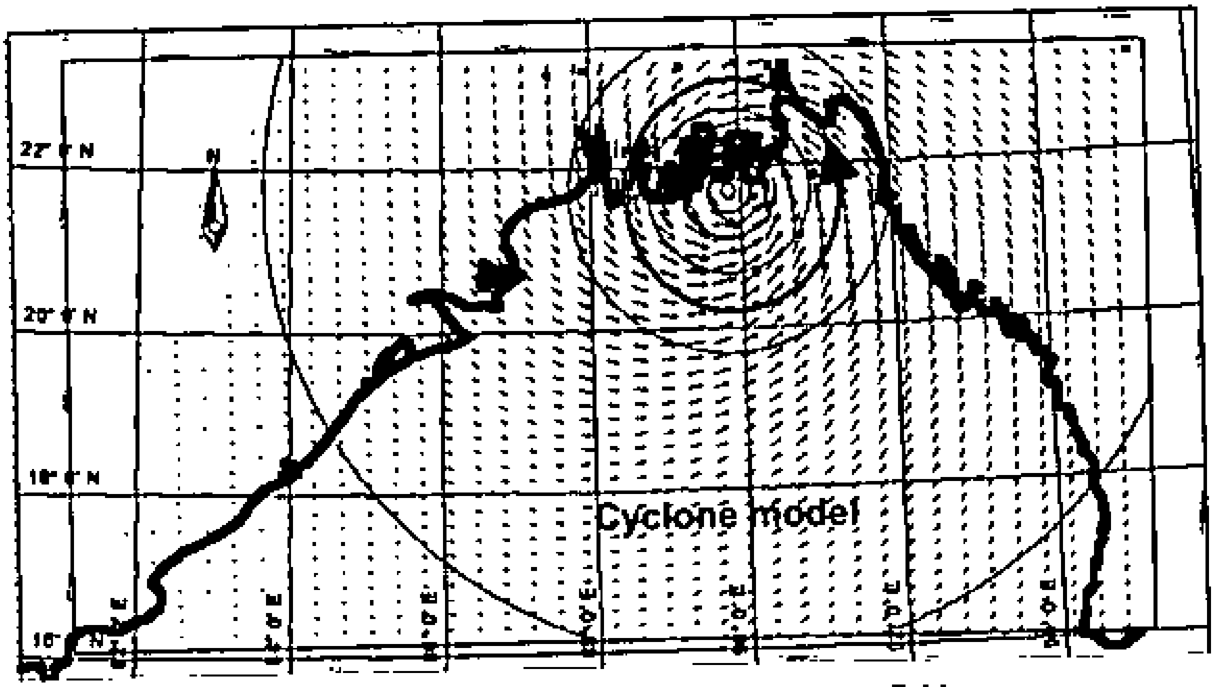
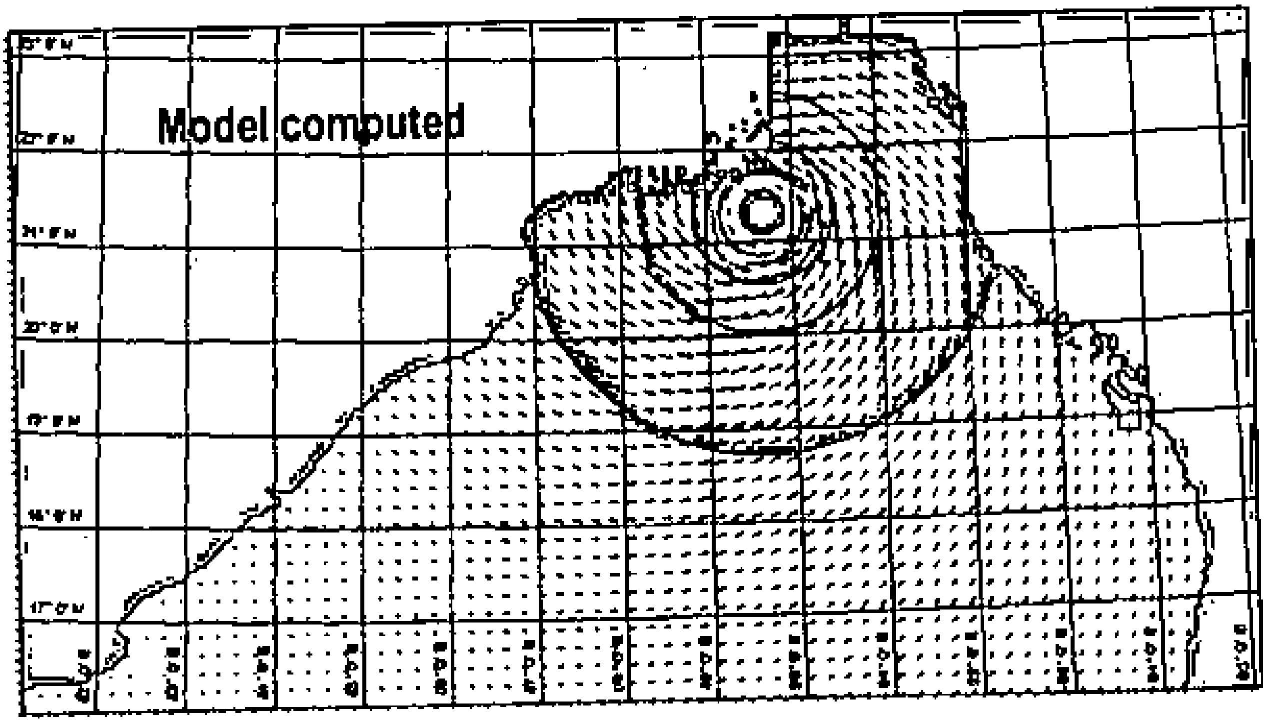


Fig. 4.3: Anti-clockwise wind and current field.

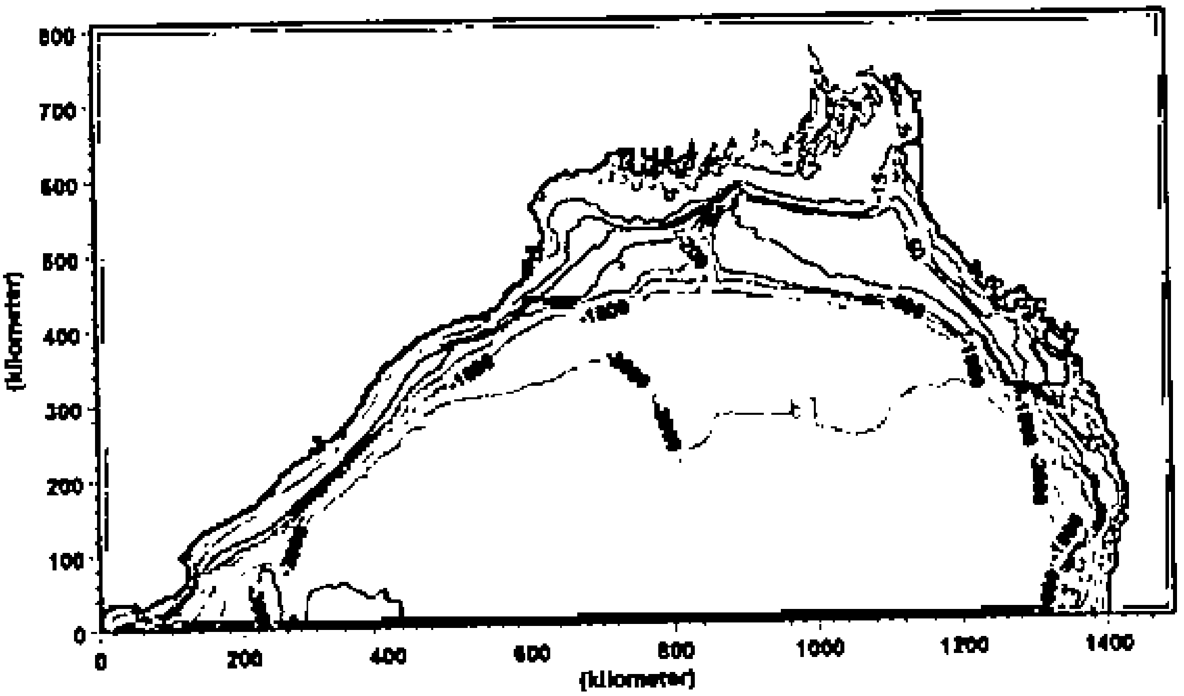


Source: IWM (2007)

Fig. 4.4: Wind field model for the coast of Bangladesh during SIDR 2007.

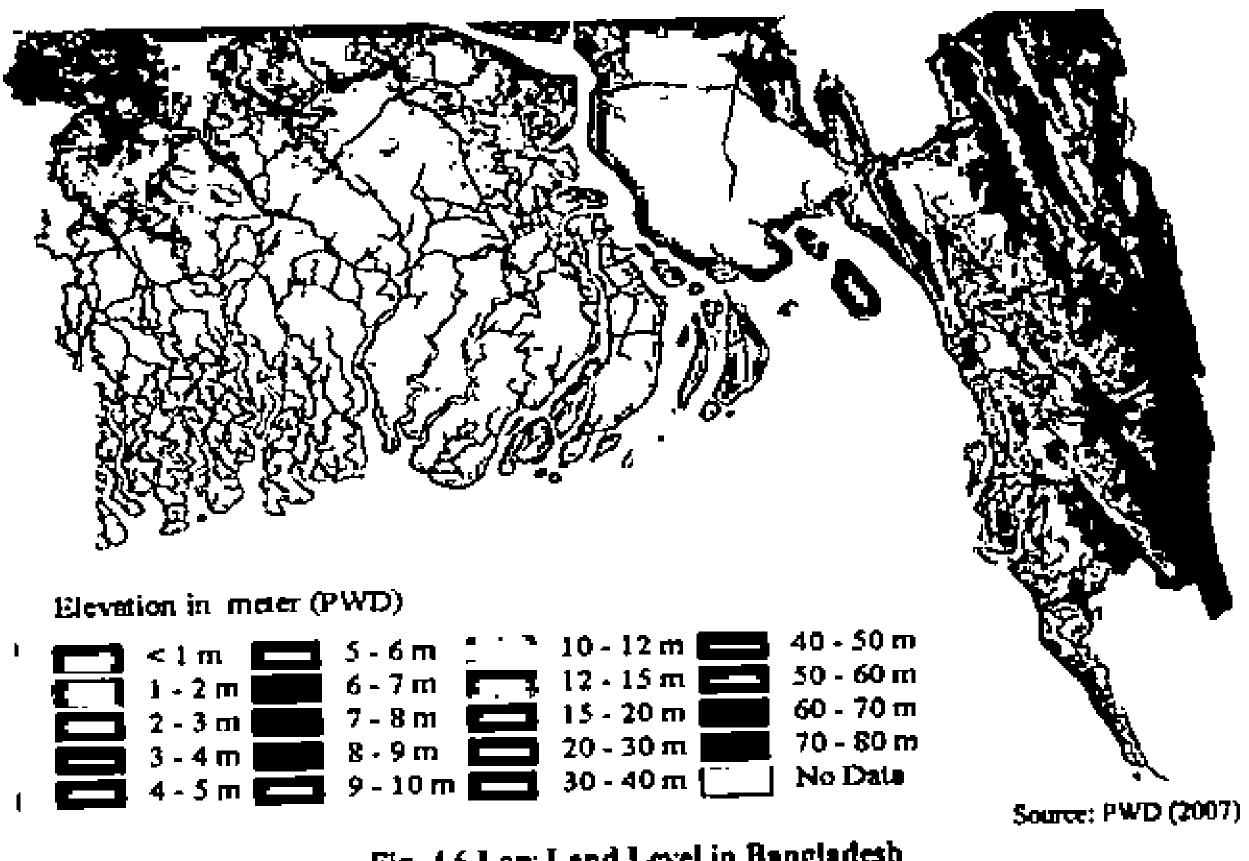
4.2 Storm surge vulnerability

Storm surges are rapid sea level variations induced by cyclone wind fields. Cyclonic storms affecting the coastal region of Bangladesh cause heavy loss of life and property. The coastal regions bordering the Bay of Bengal suffer the worst because most of the tropical cyclones have genesis over the Bay of Bengal and strike the coast of Bangladesh. About one-tenth of the global total cyclones forming in different regions of the tropics occur in the Bay of Bengal (IWM, 2007). About one-sixth of tropical storms generated in the Bay of Bengal usually hit the Bangladesh coast. In many cases the observed maximum water level was 4-12m and the death toll was 10,000 to 30,0000 (IWM, 2007). The main factors contributing to disastrous surges in the Bay of Bengal, especially in Bangladesh are (a) shallow and wide continental shelf (Fig 4.5 and 4.6) (b) convergence of the Bay, (c) high astronomical tides (d) thickly populated low lying island and (f) complex coastline and number of inlets including one of the worlds largest river system Ganga-Brahmaputra-Meghna.



Source: IWM (2007)

Fig. 4.5: Wide and Shallow continental shelf in the coast of Bay of Bengal.



Source: PWD (2007)

Fig. 4.6 Low Land Level in Bangladesh

However, tides and cyclonic storm surges are gradually varied unsteady flow and the water movement can be described by the long wave equations. The equations are based on the conversion of mass and momentum. These can be expressed as;

$$\frac{\partial H}{\partial t}+\frac{\partial P}{\partial x}+\frac{\partial q}{\partial y}=0 \qquad (3.6)$$

$$\frac{\partial p}{\partial t}+\frac{\partial}{\partial x}(\frac{p^2}{h})+\frac{\partial}{\partial y}(\frac{pq}{h})+gh\frac{\partial H}{\partial x}+g\frac{\sqrt{p^2+q^2}}{C^2h^2}p$$

$$-f_a\rho_a VV_x-\frac{h}{\rho w}\frac{\partial p_a}{\partial x}-\Omega q=0$$

$$\frac{\partial q}{\partial t}+\frac{\partial}{\partial y}(\frac{q^2}{h})+\frac{\partial}{\partial x}(\frac{pq}{h})+gh\frac{\partial H}{\partial y}+g\frac{\sqrt{p^2+q^2}}{C^2h^2}q$$

$$-f_a\rho_a VV_y-\frac{h}{\rho w}\frac{\partial p_a}{\partial y}+\Omega p=0$$

Where

H= Elevation of the water surface above datum (m);

p, q=Flux density (m^3/s/m) in the x and y direction respectively;

h=Depth of water (m);

C=Chezy roughness coefficient ($m^{1/2}$/s)

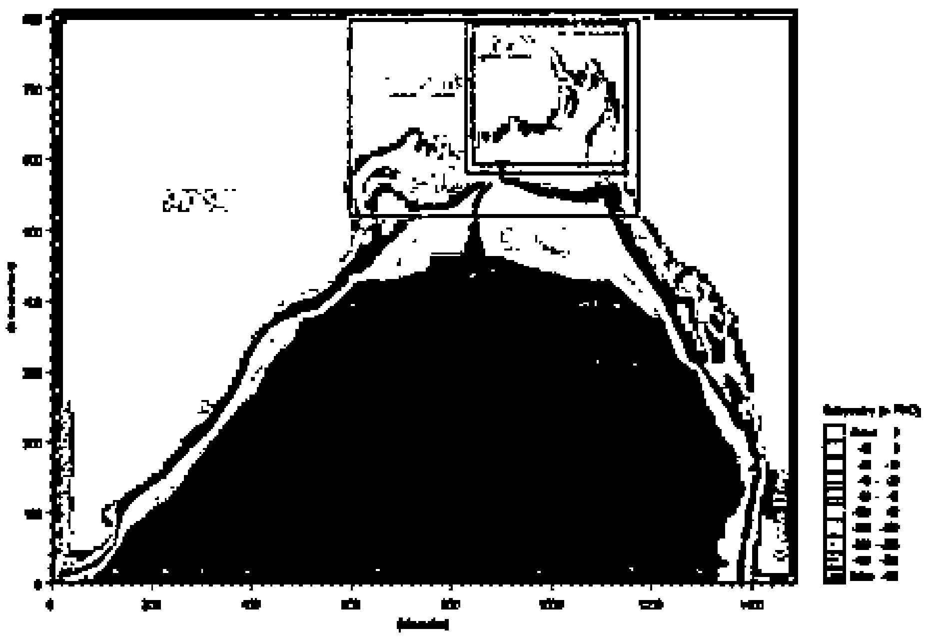
Ω =Coriolis coefficient (s^{-1})

V_x, V_y = Components of the wind velocity, V, in the x and y direction respectively;

f_a = Wind friction factor

For greater accuracy, effect of momentum dispersion (eddy), source of sinks, and evaporation can also be included in the above equations.

The equations are usually solved by expressing the partial derivatives as finite differences. For this purpose, the model area was divided into a number of grids using a suitable distance step. There are several variations in the numerical model depending on how the grid schematization is made (square grid, alternate grid, etc.) and how the finite differences are formulated at a grid point. This process results a system of simultaneous finite differences equations for a time step. The simultaneous equations can be solved with appropriate boundary conditions using suitable algorithm for matrix conversion. However, along the open water boundary, water level was specified at every grid point as a function of time. Depth of seabed was specified at every grid point in the model area using Bathymetric charts (Fig. 4.7). The friction coefficients were adjusted during calibration process where computed water levels were compared with the observed water levels.



Source: IWM (2007)

Fig. 4.7: Nested bathymetry of Bay of Bengal Model

The storm surge model is the combination of Cyclone and Hydrodynamic models. For simulating the storm surge and associated flooding, Bay of Bengal model based on MIKE21 hydrodynamic modeling system has been adopted. The MIKE 21 modeling system includes dynamical simulation of flooding and drying processes, which is very important for a realistic simulation of flooding in the coastal area and inundation. The model set-up comprises model grid, bathymetry, modelling parameters and calibration.

The model had been calibrated and validated by IWM for storm surge inundation for several severe cyclones in Bangladesh. In this study, the model was calibrated for the predicted cyclone after 50 years having the wind speed 261 km/hr. The extraction points were selected because of their locations in the three main rivers in Barguna district. These points are Point 1 at Harinkhola River, Point 2 at Baleshawr River, Point 3 at Bishkhali River and Point 4 at the confluences of the three rivers (Fig. 4.8). The surge levels of these four points were calculated for the year 1970 (Fig. 4.9), 2007 (Fig. 4.10) and wind speed of 261 km/hr (Fig. 4.11).

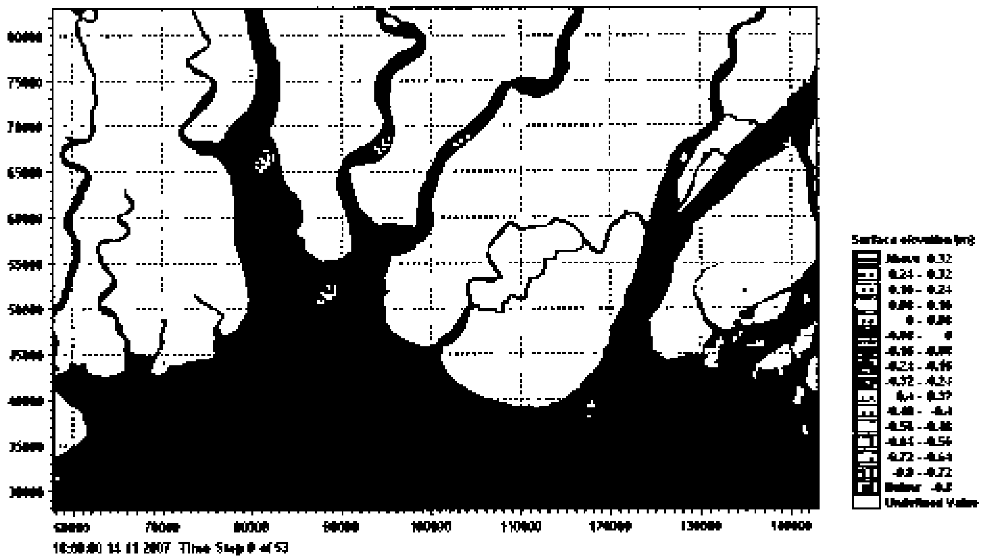


Fig.4.8: Extraction point for storm surge

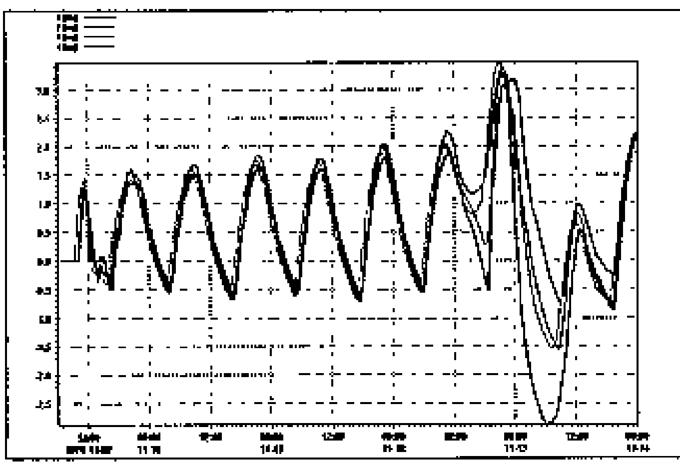


Fig. 4.9: Surge level at the four points for the cyclone 1970.

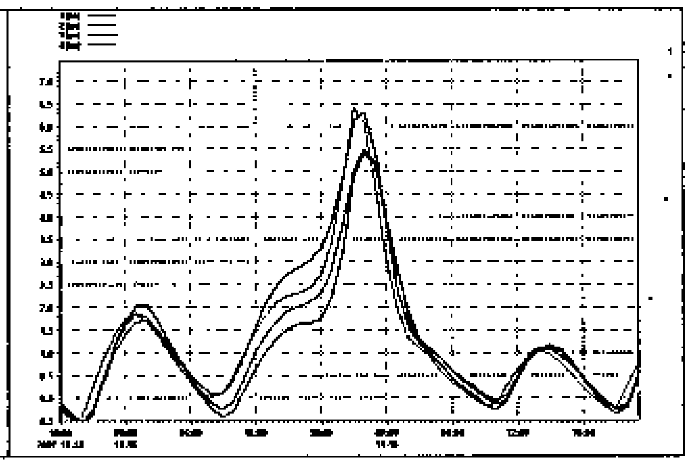


Fig. 4.10: Surge level at the four points for the cyclone 2007.

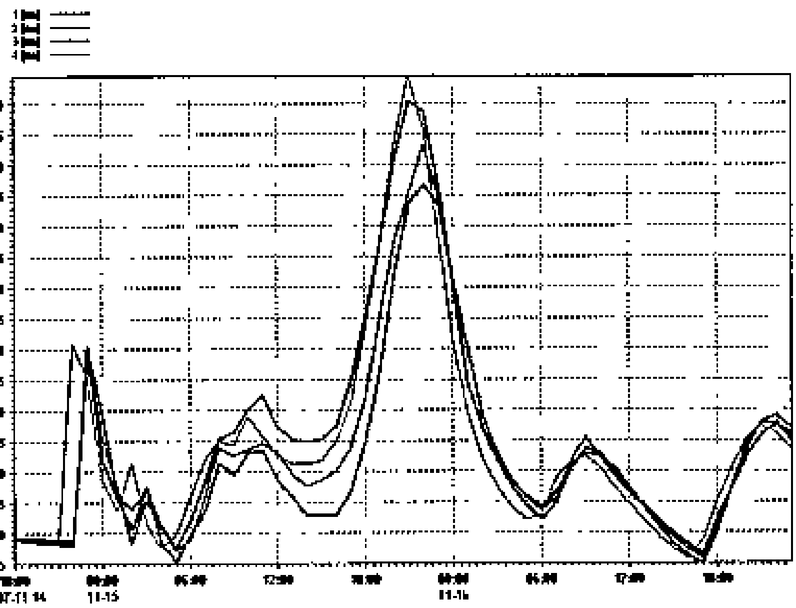


Fig. 4.11: Time series surge level at the four points for the predicted cyclone during high tide having wind speed 261 km/hr.

Along with the modeling of storm surge, a reconnaissance survey was conducted to collect the information of storm surge during SIDR at the union level of Barguna district. The survey was conducted by the recall of the memory of the local people of the unions. The surge depth was estimated at the field, with respect to the permanent objects such as, building, trees etc. The maximum distance of surge line from the coast i.e. the maximum distance up to which surge water reached was estimated at the field through the discussion with the local people (Table 4.4 and 4.5) and from the model study (Fig. 4.12, 4.13, and 4.14).

Table 4.4: Storm surge flooding of the fully inundated unions of Barguna district during SIDR 2007.

Upazila	Full inundated unions			Upazila	Full inundated unions		
	Union	Distance of the furthest boundary from the coast (km)	Approximate surge depth (m)		Union	Distance of the furthest boundary from the coast (km)	Approximate surge depth (m)
Amtali	Paurashava	11	3.66	Barguna Sadar	Ayla Patakata	43.79	2.13
	Amtali	11	3.66		Badarkhali	26.62	3.66
	Arpangashia	35	3.66		Burir Char	36.35	6.71
	Atharagashia	60	2.13		Dhalua	20.77	3.05
	Barabagi	17.66	6.71		Gaurichanna	14.21	2.13
	Chowra	37.41	6.10		Keorabunia	35.46	2.13
	Gulisakhali	46.92	6.10		M. Baliatali	30.07	7.62
	Haldia	36.62	2.44		Naltona	14.08	7.62
	Karaibaria	23.81	2.44	Patharg	Paurashava	13.32	6.10

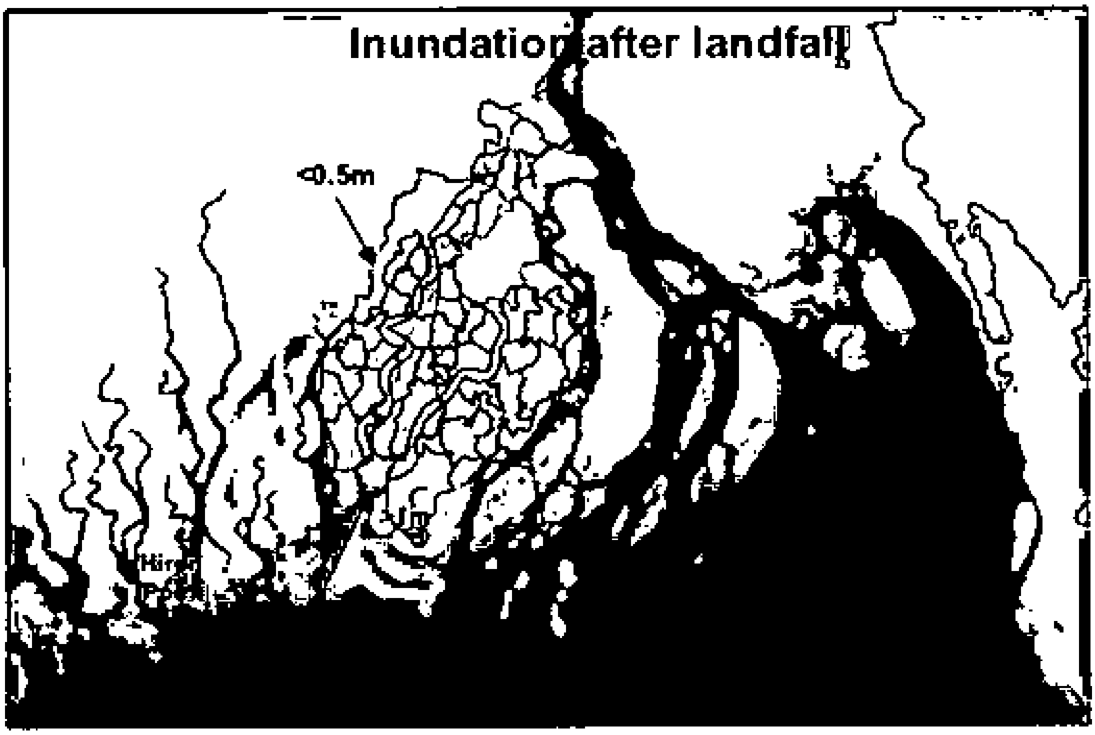
	Kukua	44.10	3.05	hata	Char Duanti	20.88	6.71
	Pancha Koralia	29.81	7.62		Kakchira	22.67	8.54
Pathargh ata	Nachna Para	25.85	4.57		Kalmegha	16.26	9.15
	Patharghata	13.32	9.15		Kanthaltali	24.80	6.10
	Raihanpur	29.71	4.57				

Source: Field survey, 2008

Table 4.5: Storm surge flooding of the partially inundated unions of Barguna district during SIDR 2007.

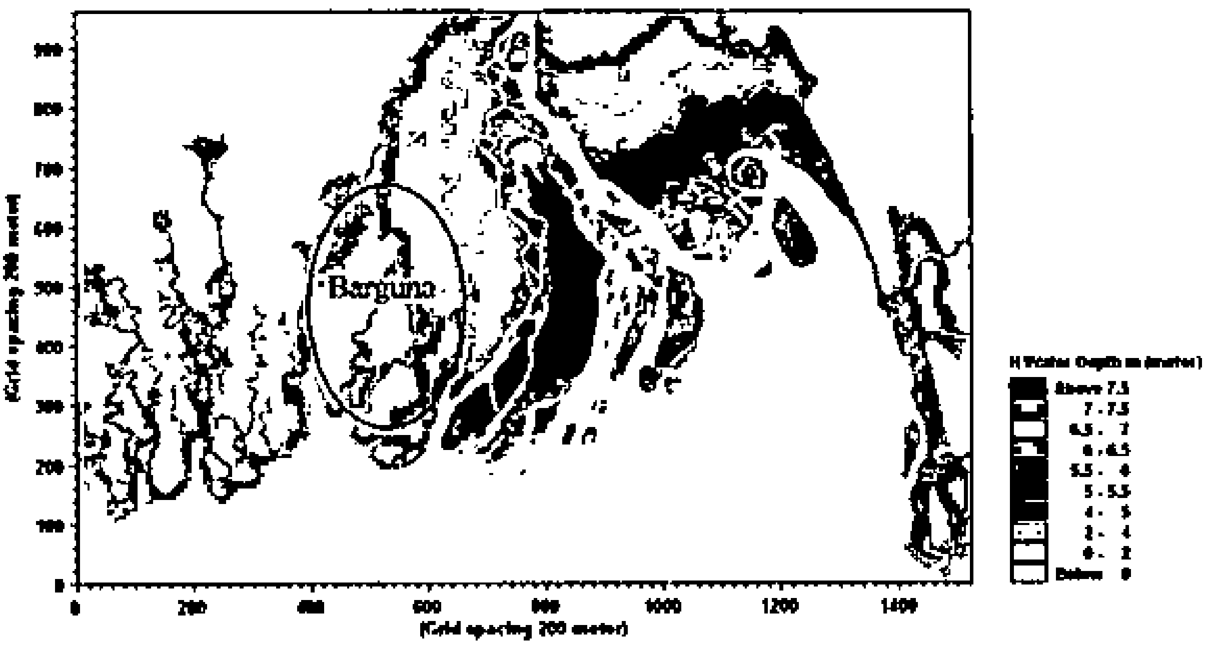
Upazila	Union	Distance of the furthest boundary from the coast (km)	Approximate surge depth (m)
Betagi	Paurashava	66.72	1.0
	Betagi	66.72	1.2
	Bibichini	72.81	1.2
	Bura Mazumdar	55.74	1.0
	Hosnabad	61.86	0.91
	Kazirabad	5.021	0.91
	Mokamia	61.03	1.22
	Sarishamuri	49.55	2.13
Bamna	Bamna	55.80	1.22
	Bukabunia	56.43	1.22
	Doutala	46.51	1.83
	Ramna	46.96	1.52
Barguna Sadar	Barguna	34.84	1.83
	Paurashava	34.84	1.83
	Phullhury	43.26	1.80

Source: Field survey, 2008



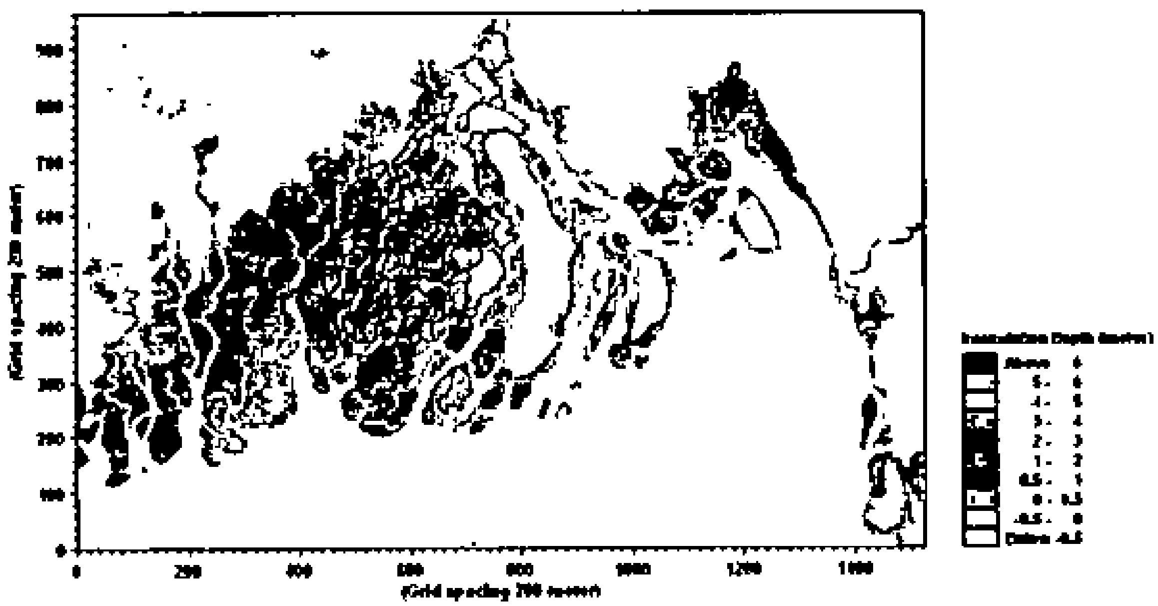
Source: IWM (2007)

Fig. 4.12: Inundation of Barguna district after landfall of SIDR during 2007.



Source: IWM (2007)

Fig. 4.13: Inundation of Barguna district after landfall of cyclone during 1970.



Source: Computed by the author, 2009

Fig. 4.14: Inundation of Barguna district after landfall of predicted cyclone.

Table 4.4 and 4.5 and Fig. 4.14 reveal that there is a relationship between the distance from the coast of the unions and the surge hight. Nevertheless there are some deviations. It is important to note that the reason of the deviation of the surge depth with the distance from the coast is due to the number of inlets in the Barguna district (Fig. 4.15). The unions beside river flooded highly during SIDR because of the overtooping and embankment failure (Fig. 4.16).

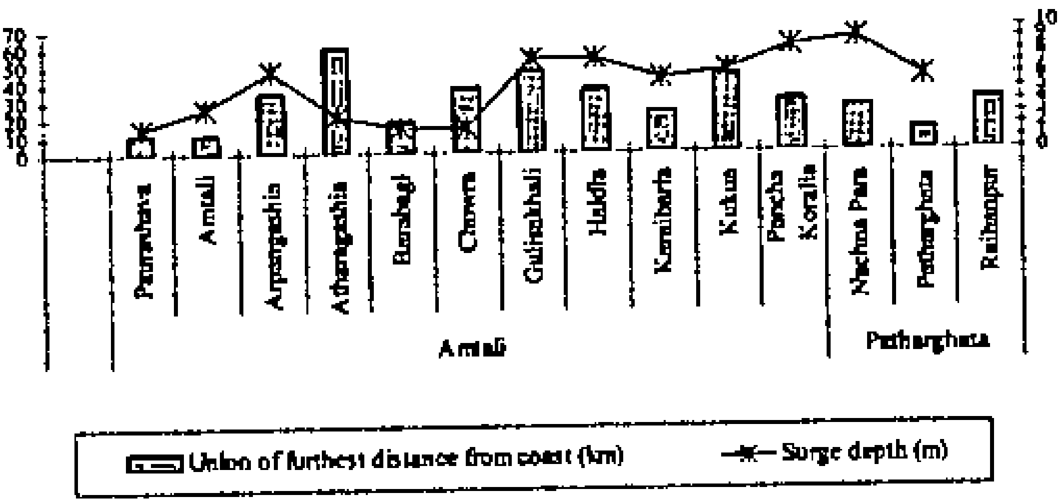
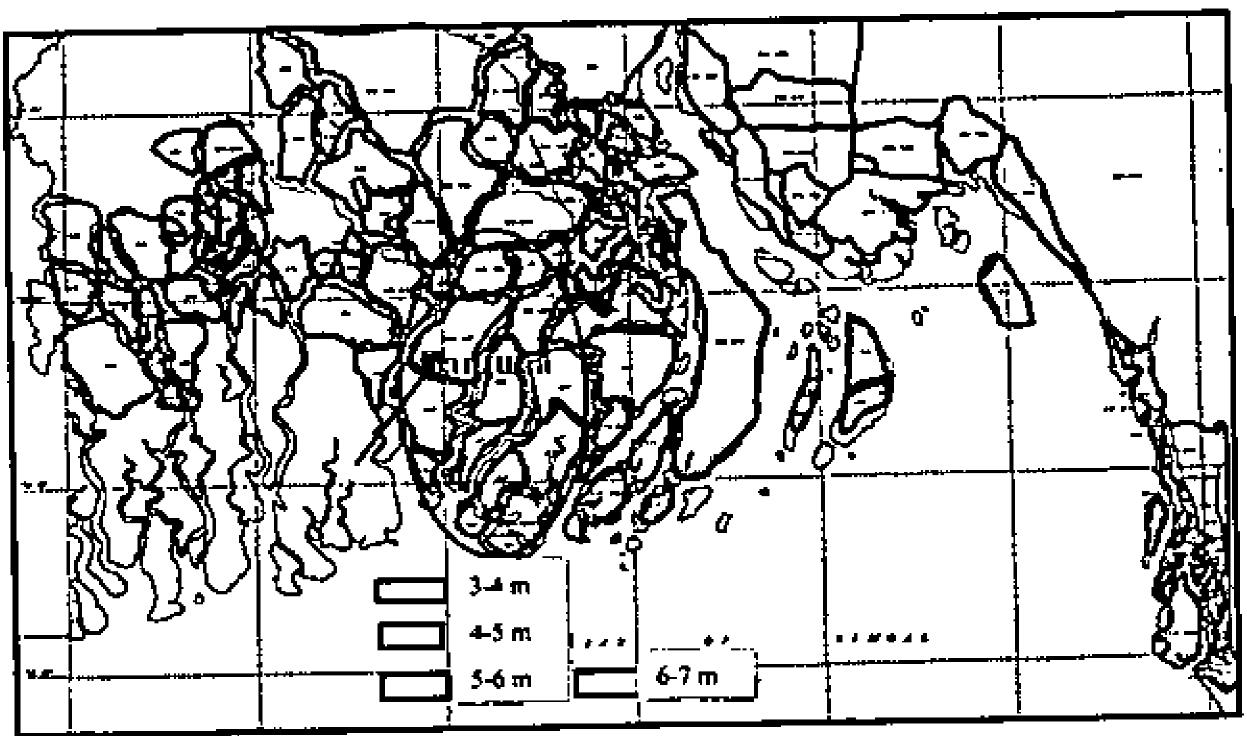


Fig. 4.15: Comparison with union distance from the coast and their surge height



Source: WARPO (2005)

Fig. 4.16: Embankment of the coastal districts in Bangladesh.

Thus, it can be said that there is a significant difference between the model study for the Super cyclone SIDR and the field data. According to the model study, the flood level for cyclone SIDR varies in between 0.5m-1.0m. But in case of real life scenario the range varies from approximately 1.00m to 9.00m. Moreover the surge level for the predicted cyclone is between 1m to above 6.0m. It is noted that the field data may be estimated because the data was collected based on the field level response of the local people of the study area.

In recapitulation, it can be said that in this chapter the geophysical risk of the study area was evaluated based on the storm surge attribute of the cyclone. By driving the model of storm surge, the study area was classified in various inundation levels. The succeeding chapter will focus on the socio-economic vulnerability analysis by deriving Population and Structure Index, Direct Access to Resource Index and Population Evacuation Needs Index.

Chapter 5

SOCIO-ECONOMIC VULNERABILITY ANALYSIS OF BARGUNA DISTRICT

Chapter 5

Socio-economic vulnerability analysis of Barguna district

The literature on assessment of social vulnerability has identified several characteristics that contribute to differential ability for coping with, and recovering from, natural hazards. Frequently mentioned traits include age, physical and mental disabilities, family structure and social networks, income and material resources, housing and built environment, and infrastructure and lifelines (Clark *et al.* 1998). Some of these attributes can also be used to understand and measure the mobility and evacuation assistance needs of a community.

For this research, social vulnerability was measured using four different approaches, as detailed previously. Substantial spatial variability exists in characteristics used to define socio-economic vulnerability. Based on the category of risk by BUET-BIDS (Fig 5.1), more than 65 percent of total population and 74 percent of total land area of Barguna district are exposed to risk zone (Table 5.1). Table 5.1 depicts that Amtali Upazila is highly vulnerable in which 19.50 percent population of Barguna district are living. Moreover, population vulnerability of Barguna Sadar and the Patharghata Upazila is also high (Table 5.3).

Table 5.1: Area and population exposure to risk in Barguna district

Variables		High Risk zone	Risk zone	Risk free zone
Population	Number	417599	141494	289461
	Percentage	49.21	16.67	34.11
Area	Total (Sq. Km)	940.37	212.55	354.49
	Percentage	62.38	14.10	23.52

Source: Calculated by author, 2009

Table 5.2: List of Unions in High-risk areas.

Upazila	Total Unions	Unions in High risk area	Area (%)	Unions in High risk area	Area (%)	Risk free area (%)
Amtali	10	Barabagi, Karaibaria, Pancha Karalia, Arpagashia, Amtali, Haldia- Total 6 nos.	73%	Chowra, Arthapargashia (part)-2 nos.	11.9%	16.31%
Barguna Sadar	11	M. Baliatali,Naltona,	60.35%	Ayla Patakata (part),	24.34%	15.31%

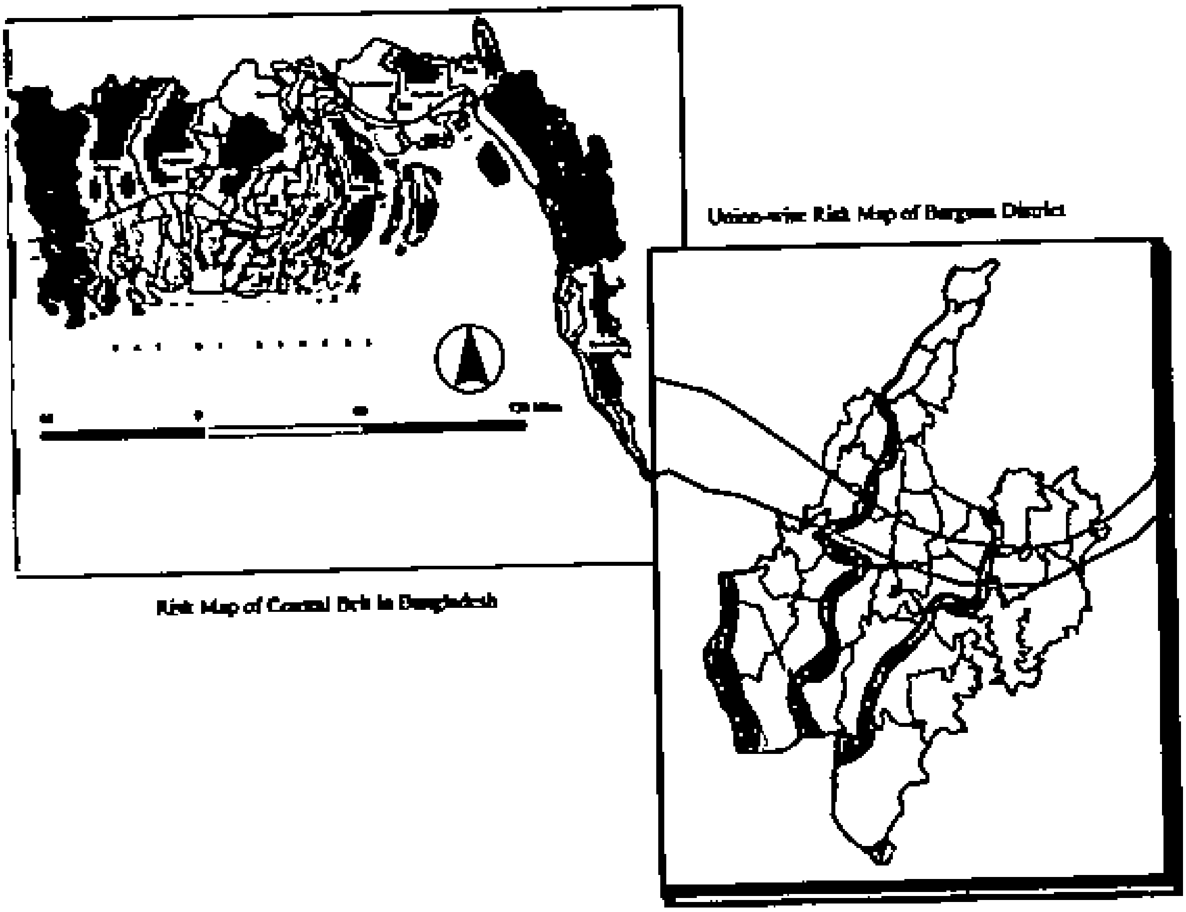
		Dhalua, Barguna, Burirchar (part), Keorabunia-6 nos.		Baradkhali, Gurirchamna-3 nos		
Bamna	4	Nil	Nil	Dauatala-1 Nos	29.15%	70.5%
Betagi	7	Nil	Nil	Sarisumari (part)-1 nos	16.67%	83.33%
Patharghata	7	Patharghata, Kalmegha, Char Duatni, Nachnapara, Kakchira, Raihanpur, Kantaltali-7 nos.	100%	Nil	Nil	Nil

Source: Calculated by author, 2009

Table 5.3: Population exposure in high-risk areas and risk zones.

Upazila	Total Unions	Unions in High risk area	Populat ion (%)	Unions in High risk area	Populat ion (%)	Risk free area Popn-(%)
Amtali	10	Barabagi, Karaibaria, Pancha Karalia, Arpagashia, Amtali, Haldia-Total 6 nos.	69.90%	Chowra, Arthapargashia (part)-2 nos.	9.18%	20.92%
Barguna Sadar	11	M. Baliatali,Naltona, Dhalua, Barguna, Burirchar (part), Keorabunia-6 nos.	49.54%	Ayla Patakata (part), Baradkhali, Gurirchamna-3 nos	28.30%	22.16%
Bamna	4	Nil	Nil	Dauatala-1 Nos	23.79%	76.321%
Betagi	7	Nil	Nil	Sarisumari (part)-1 nos	16.67%	83.33%
Patharghata	7	Patharghata, Kalmegha, Char Duatni, Nachnapara, Kakchira, Raihanpur, Kantaltali-7 nos.	100%	Nil	Nil	Nil

Source: Calculated by author, 2009



Source: BUET-BIDS, 1993

Fig. 5.1: High risk area and risk zone

The socio-economic vulnerability of different unions of Barguna district was examined by applying the Population and Structural Index (PSI), Direct Access to Resource Index (DARI), Population Evacuation Need Index (PENI) and Composite Index (CI) (Appendix A).

5.1 Social vulnerability based on population and structure

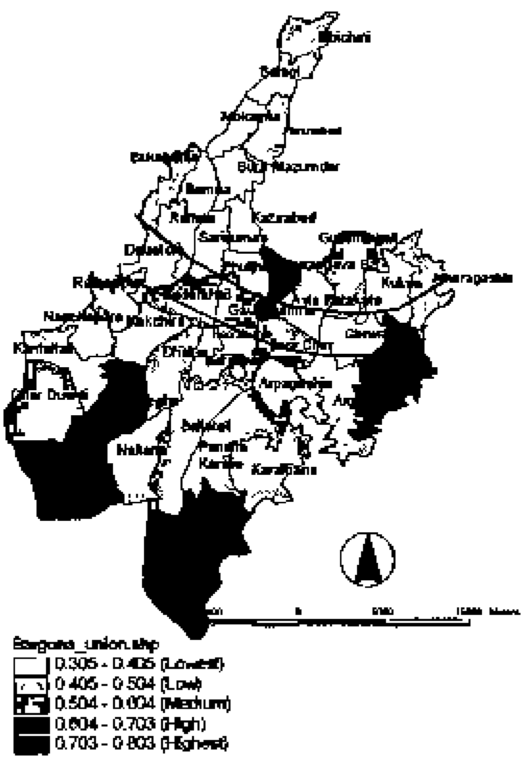
The Population and Structural Index (PSI) of social vulnerability indicate the potential zones of cyclone disaster in reverence of population, house structures (jhupri, katcha and semi –pucca) and dependence on agricultural activity. PSI in Fig. 5.2 shows that Barabagi union of Amtali upazila is the highest vulnerable area within the geo-physical riskness zone. While Patharghata, Kalmegha, Haldia and Gaurichanna unions are within the high vulnerable zone as well as high geo-physical riskness zone. In addition, Baliatali, Pancha Karalia, Char Duanti, Dhalua, Burir Char are in the medium vulnerable zone (Fig. 5.2).

Table 5.4: Percentage distribution of population, house structure and households in agriculture

Vulnerability class	Population	Percent	Structural condition of houses						HH in agriculture	Percent
			Jhupri	Percent	Katcha	Percent	Semi Pucca	Percent		
Low	60431	7.12	2452	7.30	9881	7.11	152	2.86	11431	7.90
Medium	402414	47.42	16719	49.79	67372	48.48	1034	19.48	71816	49.61
High	84909	10.01	3501	10.43	14110	10.15	216	4.08	15257	10.54
Highest	65426	7.71	2044	6.09	9803	7.05	1511	28.48	8557	5.91

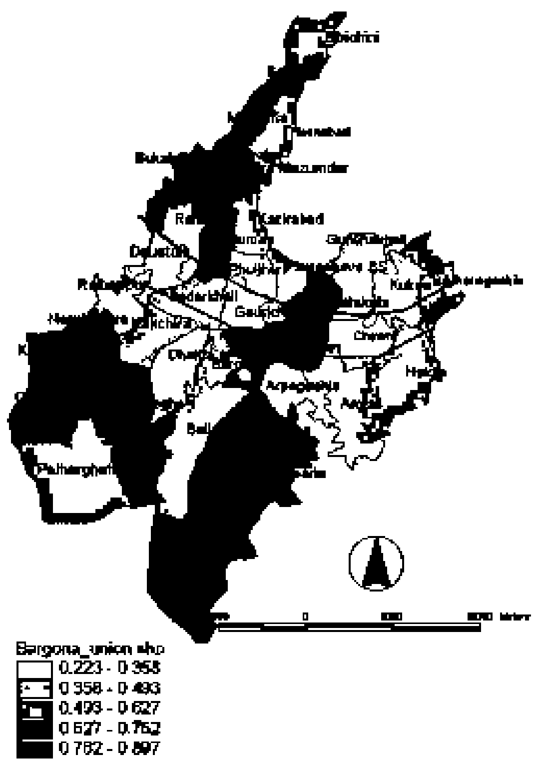
Source: Calculated by author, 2009

A significant portion (72.26 percent) of population is living within the delineated geo-physical high risk and risk zones indicated as red marks and blue marks respectively (Fig. 5.2). Among them 7.71 percent, 10.01 percent and 47.42 percent population are living in the highest (Barabagi union), high (Patharghata, Kalmegha, Haldia and Gaurichamna unions) and medium vulnerable regions (Baliatali, Pancha Karalia, Char Duanti, Dhalua, Burir Char) in respect of PSI. On the other hand, 6.09 percent, 7.05 percent 28.48 percent of jhupri, katcha and semi-pucca houses are within the highest vulnerable region (Table 5.4 and Fig. 5.2).



Source: Prepared by author, 2009

Fig 5.2 Social vulnerability of Barguna district based on population and structure (PSI).



Source: Prepared by author, 2009

Fig 5.3: Social vulnerability of Barguna district based on differential access to resource (DARI).

5.2 Social vulnerability based on Direct Access to Resource

Direct Access to Resource Index (DARI) indicates that Naltona, Kalmegha, Kataltali, Burir Char, Ayla Patakata, Pancha karalia and Bamna unions are highest vulnerable zone and fall within the geo-physical risk zone (Fig. 5.3). Even the provision of basic services and facilities such as safe drinking water, hygienic sanitation, electricity and pucca road are not adequate enough in this zone. About 73.05 percent, 69.74 percent and 95.25 percent households in this zone are deprived of safe drinking water, hygienic sanitation facility and electricity supply respectively. While only 39.34 km pucca road is available in this zone (BBS, 2006).

On the other hand, Barabagi, Karaibaria and Char Duanti are within high vulnerable zone based on DARI (Fig. 5.3). Like the highest vulnerable, majority of the households in this zone are deprived of basic services and facilities such as 61.42 percent, 69.62 percent and 95.18 percent households are deprived of safe drinking water, hygienic sanitation facility and electricity supply respectively. In addition, 49.86 km pucca road is available in this zone (Table 5.5).

Table 5.5: Percentage distribution of deprivation of services and facilities

Vulnerability class	Safe drinking water	Hygienic Sanitation	Electricity supply
Lowest	14.29	41.87	96.51
Low	10.26	46.48	91.94
Medium	30.31	61.05	93.30
High	61.42	69.62	95.18
Highest	73.05	69.74	95.25

Source: Calculated by author, 2009

5.3 Social vulnerability based on Special Evacuation Needs

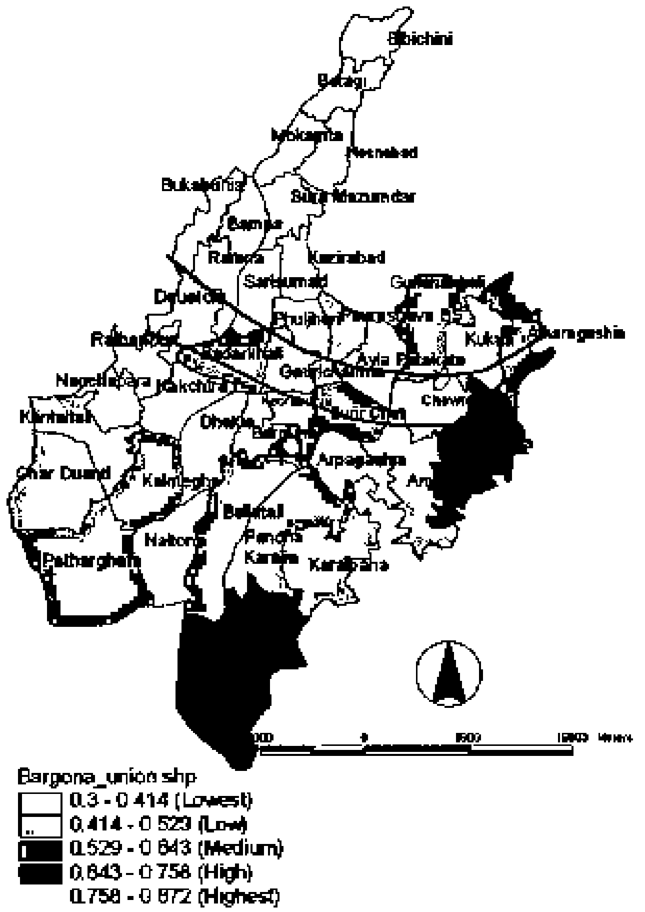
Based on the people needs evacuation support within the geo-physical risk zone is further categorized into five vulnerable zones i.e. highest, high, medium, low and lowest. Among the unions, Barabagi and Haldia unions are within the highest and high vulnerable zone respectively (Fig 5.4). While Patharghata, Baliatali, Pancha Karalia, Kalmegha, Burir Char, Barguna and Badarkhali unions are within the medium vulnerable zone (Fig 5.4). Later on, the evacuation assistance requiring population (age less than 5 years and greater than 60 years; and disabled people) is analyzed in order to determine their probable exposure to geo-physical and social vulnerability. About 5.09 percent, 4.21 percent, 4.62

percent people of age less than 5 years, age greater than 60 years and disable respectively are categorized as highest vulnerable. While 3.47 percent, 3.66 percent and 3.67 percent of age less than 5 years, age greater than 60 years and disable people respectively are categorized as high vulnerable. In addition, 26.82 percent, 26.57 percent and 27.38 percent of age less than 5 years, less than 60 years and disable people respectively are categorized as medium vulnerable (Table 5.6).

Table 5.6: Percentage distribution of people need evacuation assistance

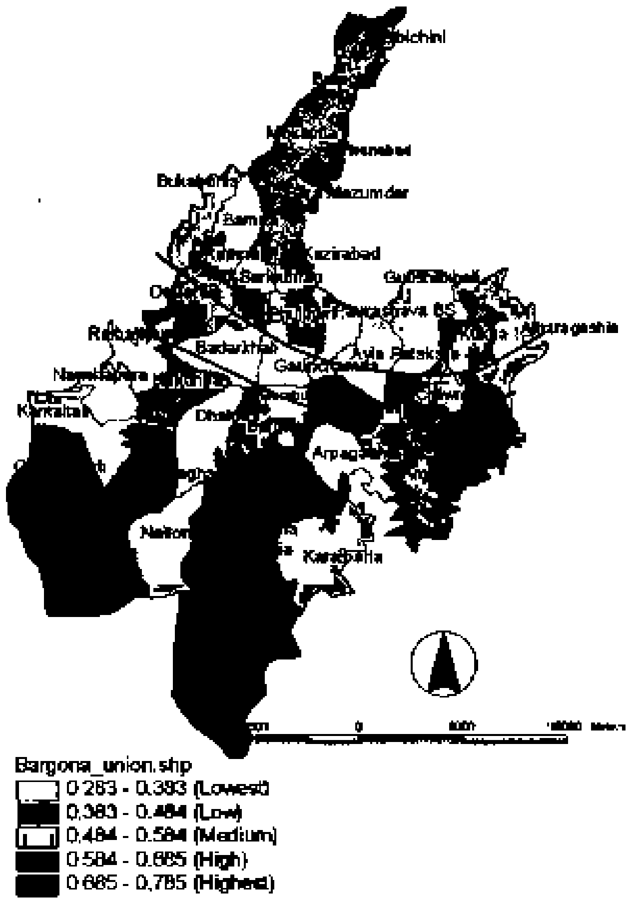
Vulnerable class	Age <5 years	Percent	Age 60+ years	Percent	Disabled	Percent
Lowest	19200	18.79	13192	19.10	10630.272	19.94
Low	15281	14.96	10489	15.19	8611.008	16.15
Medium	27401	26.82	18352	26.57	14596.544	27.38
High	3543	3.47	2526	3.66	1954.88	3.67
Highest	5198	5.09	2907	4.21	2462.208	4.62

Source: Calculated by author, 2009.



Source: Prepared by author, 2009

Fig 5.4: Social vulnerability of Barguna district based on population with special evacuation needs index (PENI).



Source: Prepared by author, 2009

Fig 5.5: Social vulnerability based on population and structures, access to resource and population with special assistance needs.

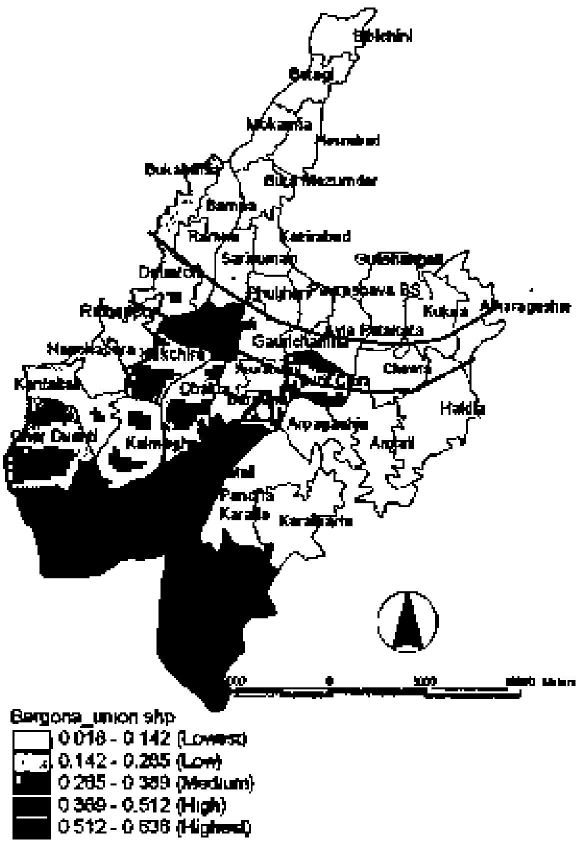
5.4 Social vulnerability based on Composite Index

Composite Index of socio-economic vulnerability was determined based on the overlay of three weighted indices i.e. Population and Structure Index, Direct Access to Resource Index and Population Evacuation Need Index. The weights of PSI, DARI and PENI were assigned as 0.40, 0.30 and 0.30 in the scale of 0-1 based on their significance in socio-economic vulnerability.

Composite Index indicates that within the geo-physical risk zone Barabagi union is the highest socio-economic vulnerable area, while Pancha Karalia, Baliatali, Patharghata, Char Duanti, Kalmegha, Haldia and Burir Char are in high vulnerable zone. On the other hand, Naltona, Karaibaria, Dhalua, Kanthaltali, Badarkhali, Gaurichamna, Nachnapara, Ayla Patakata, Artharagasia and Keorabunia unions are within the medium vulnerable zone (Fig 5.5).

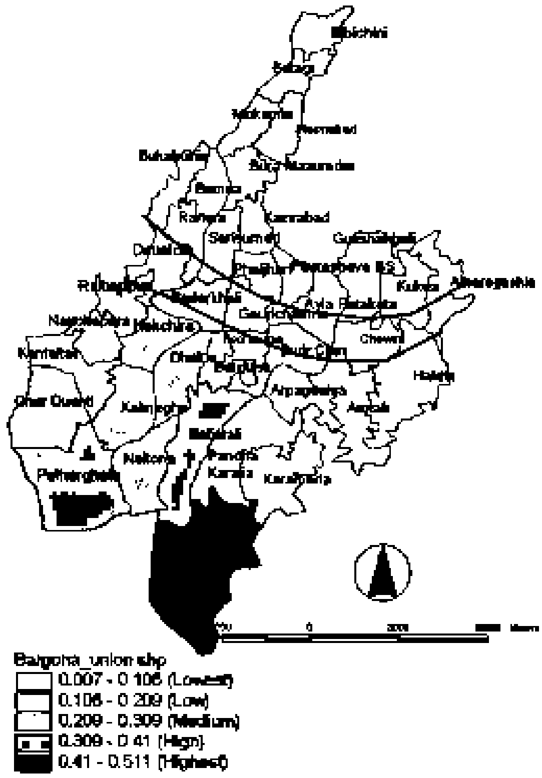
5.5 Disaster damage and socio-economic vulnerability

Disaster Damage Index (DDI) was developed based on the loss of lives and injury of people; and fully and partially financial loss of livelihoods, houses livestock, property, resources, infrastructures, services and facilities during catastrophic disaster of cyclone SIDR 2007 in Barguna district. Later on, weights were assigned to each indicator of the Disaster Damage Index based on the expert opinions.



Source: Prepared by author, 2009

Fig 5.6: Damage vulnerability of Barguna district (DDI).



Source: Prepared by author, 2009

Fig 5.7: Vulnerability of Barguna district based on population and damage (PSIxDDI).

DDI indicates that Barabagi union was the highest affected area in the Barguna district within the geo-physical risk zone while Patharghata, Naltona, Baliatali, Badarkhali are highly affected zone. The medium affected zone consists of Char Duanti, Dhalua, Kakchira, Barguna and Burir Char unions (Fig 5.6). On the other hand, Kantaltali, Kalmegha, Dauatola, Ramna and Sharishumari unions are lowly affected zone during SIDR 2007 (Fig 5.6).

Table 5.7: Degree of damage during SIDR 2007 dased on Disaster Damage Index (DDI)

Type of damage	Unit	Lowest	Low	Medium	High	Highest	Total
Affected area	Sq.km	450.65	99.4	146.88	272.35	160	1119.89
	%	40.24	8.88	13.12	24.32	14.29	
Death of people	No.	89	110	220	553	238	1321
	%	6.74	8.33	16.65	41.86	18.02	
Affected Population	No.	199370	45418	84845	108805	48985	770913
	%	25.86	5.89	11.01	14.11	6.35	

Fully damaged houses	No.	13266	6452	8858	14493	4177	70891
	%	18.71	9.10	12.50	20.44	5.89	
Partially damaged houses	No.	26649	2803	10882	14835	11462	118531
	%	22.48	2.36	9.18	12.52	9.67	
Loss of cattle and goats	TK	30930000	76848781	96626833	45283660	47340000	460893274
	%	6.71	16.67	20.97	9.83	10.27	
Loss of poultry	TK	8023000	4000000	16798800	23500000	485000	69077800
	%	11.61	5.79	24.32	34.02	0.70	
Destruction of crops	TK	169780000	176031063	452556684	120266411	34437000	1714786501
	%	9.90	10.27	26.39	7.01	2.01	
Destruction to fisheries farm	TK	6500000	105752366	57116576	12053839	22000	351137999
	%	1.85	30.12	16.27	3.43	0.01	
Destruction of powerline	TK	29261000	10896902	30732764	43697156	748000	133625030
	%	21.90	8.15	23.00	32.70	0.56	
Fully damaged pucca roads	Km	5.3	9	16.5	4.5	1.5	86.3
	%	6.14	10.43	19.12	5.21	1.74	
Partially damaged pucca roads	Km	41.54	23	27.5	21	14.79	302.02
	%	13.75	7.62	9.11	6.95	4.90	
Fully damaged earthen roads	Km	37.4	26	63.5	120	2.9	398.43
	%	12.89	6.53	15.94	30.12	0.73	
Partially damaged earthen roads	Km	196	85	90.5	148	80	894.5
	%	21.91	9.50	10.12	16.55	8.94	
Fully damaged embankments	TK	24.39	13.5	25.5	38	2.54	343.78
	%	7.09	3.93	7.42	11.05	0.74	
Partially damaged embankments	Km	93	23	38	74	29.58	472.63
	%	19.68	4.87	8.04	15.6	6.26	
Loss of trollers	TK	7106000	24558800	129671908	216080000	2422000	451124708
	%	1.58	5.44	28.74	47.90	0.54	

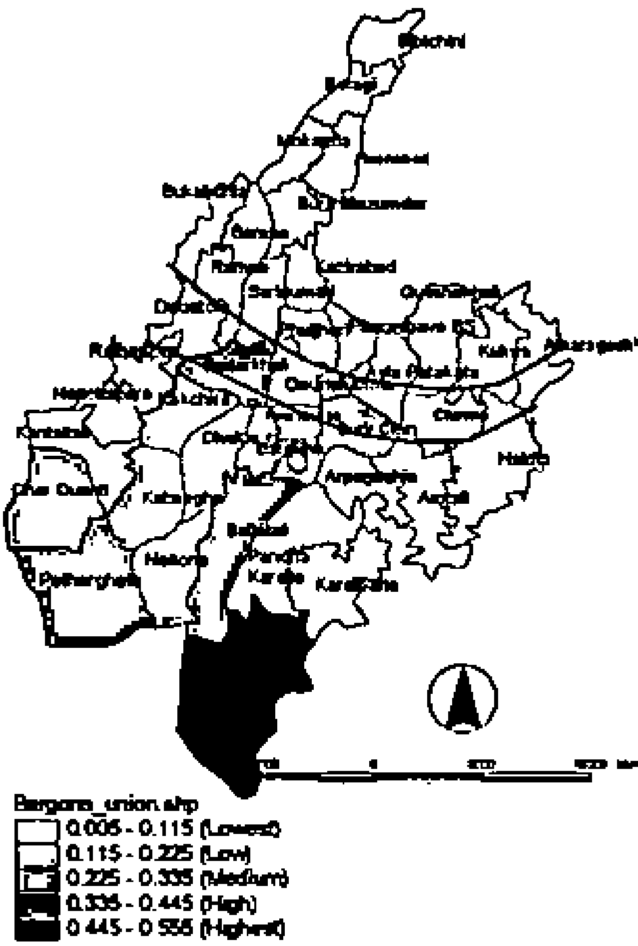
Source: Field survey of Barguna Sadar, Bamna, Betagi, Amtail and Patharghata Upazila Parishad, 2008.

Barabagi union was completely destroyed during the catastrophic SIDR 2007 such as 160 Sq.km area was completely destroyed, 238 people were died, 15639 houses were fully and partially damaged, loss of TK 47825000 worth livestock, destruction of TK 34437000 worth crops, 16.29 km of pucca road was fully and partially damaged, loss of TK 2422000 worth trollers and so on (Table 5.7). On the other hand, 24.32 percent of affected area, 41.86 percent of death toll, 20.44 percent of fully damaged houses, 9.83 percent of livestock, 34.02 percent of poultry, 7.01 percent destruction of crops, 3.43 percent of fisheries, 32.70 percent destruction of powerline, 5.21 percent of fully damaged pucca road, 11.05 percent of fully damaged embankment and 47.90 percent loss of trollers were taken place in highly affected zone (Table 5.7).

Later on Disaster Damage Index was overlaid with the four approaches of the socio-economic vulnerability analysis in order to relate the existing socio-economic vulnerability and the intensity of damage. Barabagi union is considered as the highest damage affected and vulnerable zone within the geophysical risk area in the context of both Population and Structure Index and Disaster Damage Index. While Patharghata, Baliatali, and Badarkhali unions were within the medium zone. In both the cases of PSI and DDI, Barabagi union was in highest vulnerable/affected zone. The scenario is similar in the context of medium vulnerable zone that represents the high zone of both PSI and DDI such as Patharghata, Baliatali and Badarkhali unions (Fig 5.7).

Source: Prepered by author, 2009

Fig 5.8: Vulnerability of Barguna district based on access to resource and damage (DARIxDDI).



Source: Prepered by author, 2009

Fig 5.9: Vulnerability based on population with special assistance needs and damage (PENIxDDI).

The overlaid map of two layers i.e. DARI and DDI represents again the highest vulnerable/affected zone as Barabagi union (Fig 5.8) While Baliatali and Naltona unions were within the highly vulnerable/affected zone of geophysical risk area. On the other hand, Patharghata, Char Duanti, Kalmegha, Badarkhali and Burir Char are within the medium vulnerable or affected zone. The comparative evaluation between the Fig 5.8, Fig 5.6 and Fig 5.3 reveals that the scenario of damage intensity is similar to the DARI and DDI overlaid map. Nevertheless, dissimilarity is observed in DARI map. Here deprivation of direct access to resources is highest in Naltona, Kantaltali, Kalmegha, Pancha Karolia, Barguna Sadar, Burir Char, Ayla Patakata unions. That means availability of resources required during the post-disaster period is lowest in these unions, which may cause serious post-disaster effect. The statement was obvious in Pancha Karalia, Burir Char and Ayla Patakata unions that were highly suffered during the post-disaster period in SIDR 2007 because of lack of adequate access to resources. Even the relief work was delayed due to the lack of available communication network in these unions.

The overlaid map of Population in Evacuation Needs Index and Disaster Damage Index reveals that Barabagi union is within the highest vulnerable or affected zone (Fig 5.9). This is factual in the respect of both DDI and PENI because the death toll was highest (238) in this union. Similarly the high (Patharghata, Baraibagi and Badarkhali) and medium (Char Duanti, Kalmegha, Naltona, Dhalua, and Burir Char) zone of overlaid map represents both the result of DDI and PENI (Fig 5.9).

Source: Prepared by author, 2009

Fig 5.10: Vulnerability of Barguna district based composite index and damage index (CIxDDI).

Fig 5.10 represents the overlaid map of Composite Index and Disaster Damage Index. Figure shows that Barabagi union is the highest vulnerable or affected zone. While Patharghata, Naltona, Baliatali, Badarkhali unions are in highly affected or vulnerable zone. On the other hand, Char Duanti, Kalmegha, Dhalua, Kakchira, Kantaltali and Burir Char unions are in the medium vulnerable or affected zone. Comparing the Composite Index and DDI with this overlaid map it can be remarked that Fig 5.10 represent the vivid picture of the Composite Index and DDI such as Patharghata, Naltona, Baliatalia and Badarkhali unions are in highly vulnerable or affected zone in Fig 5.10, 5.9 and 5.8 also identified them as the highly affected and vulnerable zone respectively.

5.6 Quantitative Comparison of Results

Although the four maps in Fig 5.2-5.10 provide a visual assessment of evacuation assistance need patterns within the study area, the analytical capabilities of GIS software can be used to estimate the total population in each evacuation assistance need zone, as well as their socio-economic and structural characteristics. These numerical estimations interpret the variability of results obtained from the four different approaches to measure social vulnerability in conjunction with geophysical risk. Four approaches are compared quantitatively by focusing on two specific aspects that are important for risk management and evacuation planning: (1) the number of people living in each evacuation assistance need zone; and (2) the characteristics of the population and structures in areas with the highest evacuation assistance need.

Table 5.8: Percent of Population within Evacuation Assistance Need Zones

Evacuation needs	Approach 1 (%)	Approach 2 (%)	Approach 3 (%)	Approach 4 (%)
Lowest	8.39	6.34	15.41	3.54
Low	7.12	4.74	18.15	14.41
Medium	47.42	22.99	18.46	22.15
High	10.01	9.78	3.60	22.28
Highest	7.71	17.82	8.53	8.53

Source: Calculated by author, 2009

Regardless of the approaches adopted, the percentage of the population appears to be declined with an increase in the magnitude of evacuation assistance need (from lowest to highest). Approach 1 indicates that almost 17 percent of the district population can be found in areas where evacuation assistance need is high or highest; this figure is about 27 percent for Approach 2, about 11 percent for Approach 3 and 31 percent for Approach 4. The numerical differences among the estimates obtained from the four approaches are reasonably consistent with the variation in patterns observed in visual assessment of the four maps except in case of Approach 4. If people, structure, deprivation of resource and people with special needs are being taken under consideration, the aggregate number of people increased whereas the number of people needs high or highest evacuation needs is reduced by taking the factors individually.

In a nutshell. it can be said that each approach has its significance for the emergency management purpose. It will be un complicated to take an area specific decision for the disaster management planners like prioritizing the unions in terms of structural solution, relief disbursement, policy fixation for the people with special needs and so on.

This chapter analyzed spatial variability of social vulnerability of different unions, which will help the emergency planners to take initiatives considering the population and structural, deprivation of resource and population who need special assistance. Planner can take initiatives in disaster period based on the vulnerability mapping whereas each characteristic can be considered individually. Moreover the combination of the characteristics is applicable for vulnerability mapping. However, the result of the vulnerability maps depicts that the Barabagi union of the Amtali upazila is most vulnerable. The next chapter will address the possible solution of disaster management for the most vulnerable union of Barguna district.

Chapter 6

SPATIAL PLANNING OF CYCLONE SHELTER IN BARABAGI UNION OF BARGUNA DISTRICT

Chapter 6

Spatial Planning of Cyclone Shelter in Barabagi union of Barguna district

One of the main objectives of this study was to prepare an outline for planning the locarion and space of multipurpose cyclone shelters in most vulnerable unions in Barguna district. A large number of people in the Barguna district live in thatched houses, which cannot withstand the high velocity of wind and storm surges resulting in extensive damages of such houses and deaths and injuries of a large number of poor people. The high rates of casualties in cyclone SIDR are primarily due to unsafe buildings in the study areas. The poor economic conditions of the people may not permit them to rebuild their houses as per the cyclone resistant designs and specifications. Therefore, community cyclone shelters constructed at appropriate places within the easy access of the habitations of the vulnerable communities can provide an immediate protection from deaths and injuries due to the collapse of houses. Such shelters are usually built on pillars above the danger level of storm surges/inundation, are specious enough to accommodate a few hundred people of the neighboring hamlets and provide provisions of drinking water, sanitation, kitchen, etc. During the normal season such shelters can be utilized as schools, dispensaries or other community purposes.

From the analysis of the previous chapter, Barabagi union of Amtali upazila was identified as the most vulnerable union in terms of both geophysical risk and socio-economic vulnerability. Towards this, methodology was developed for determination of number of new shelters required and their tentative locations in the same union. Moreover this chapter also provides some guidelines for construction of low cost housing, which can withstand during tropical storm.

6.1 The methodology for locating shelters

The areas susceptible to inundation due to storm surge were delineated and categorized into low risk area to high risk area (details given in chapter 4) based on damage potential, population structure and housing type, accessibility to resource and population with special evacuation needs.

Information and data about existing and under construction cyclone shelters with their potential capacity to serve as shelters during storm surge has been compiled. The data of existing cyclone shelter with their capacity were collected from LGED and field survey. Assumptions were made about the new pucca buildings that may be constructed in future.

Demographic characteristics of the study area were studied to anticipate the total population those need to be accommodated in shelters during a cyclone.

In determining the capacity of buildings as shelters, areas of 0.37 sq.m. per person were assumed for shelters and other public/private buildings (MCSP, 1993).

Provision of shelters has been made for estimated population in the year 2015. The rationale for taking up year 2015 was: it is expected that the construction programme of the shelters proposed by this study would commence in one year later after the completion of detailed engineering design and procurement procedure. The complete implementation of the programme would take about not more than 15 years time from 2001. Therefore the programme should satisfy the total requirements at the time of project completion and not the population of 2001. Thus the planning horizon for the first phase of the study was set at year 2015 and all projections and planning was made for the requirements at that year.

In order to plan the location of proposed cyclone shelter the first task is to study the existing stock of cyclone shelters that serve the communities of the Barabagi union. Moreover, the following tasks have been conducted to site the proposed cyclone shelters.

- Population projection for the year 2015 for Barabagi union
- Pucca structure projection for the same year
- Projection of school going children for the year 5-9 and 10-14.
- If the number of MCSs proposed was less than the MCSs required, then the required number of additional primary schools needed in 2015, was chosen as MCSs which would be located as a new primary schools. In areas where primary schools did not exist, but based on the school going children (i.e. around 470 children in 5-10 year age group) such a school was required, location of a new MCS would satisfy the need of both school and shelters.

- If the number of MCSs proposed was so-far was still less than the number of required MCSs, then the existing secondary schools, if they are not too close to the primary schools already proposed as MCSs, were given next preference.
- If still shelter capacity was needed, then MCSs were proposed as new secondary schools.

In actual placement of the MCSs the following aspects were considered in order of priority.

- -The MCSs were not too close to each other, to existing or under construction or proposed shelters, and interference with their catchments;
- -The distribution of cyclone shelters follows the pattern of distribution of population among the paras (communities);
- The distribution of MCSs were as close as possible to the existing communication network;
- The MCSs would be located within the radins of 1 km (1000 meters) from the center of a para;
- The travel time from the locality to the shelters would not be more than the 12.5 minute[1] (the average standard walking speed of a person is 4.75 km/hr) (Unterman, 1984);
- The MCSs were as far away as possible from the coastline;
- The MCSs were inside the embankment, where such embankment existed;

6.1.1 Projection of population and structures

- **Population projection**

According to the MCSP the total population of Amtali Upazila during 2002, 2007, 2012 and 2017 will be 98993, 109811, 118,857 and 126048 respectively. Whereas the population census (2001) showed that the population of Amtali Upazila was only 54404 having the decadal growth rate 18.78 and annual growth rate 1.74. Considering the base year population of 2001 and growth rate 1.59 percent of rural areas in Amtali upazila (BBS, 2001), population projection has been conducted for the year 2015 for Barabagi union of Amtali upazila. The projected population for the year 2015 is 47980. Due to

[1] Travel time (min.) = Travel distance (km)/ walking speed (km/min)

avoid the complexities in computation of population, it was estimated that the population growth rate is equal in all communities.

➢ **School attendance**

The number of school going population by age category was computed due to the planning consideration of cyclone shelters. The school attendance for the age group 5-9 and 10-14 years have been projected based on growth rate of school attendee in Amtali upazila, which is 3.27 percent. The literacy rate is collected from the data of Population Census (2001) of Bangladesh Bureau of Statistics. Similarly, the secondary school attendance was computed for the year 2015 (Table 5.1).

Table 6.1: Population by school attendance

Age category	Pop_5-9 yrs	Pop_10-14 yrs
Base year population	2688	4369
Projected population	4218	6855

Source: BBS, 2001

➢ **Pucca household projection**

The natural tendency of the people during the storm is to take shelter to the nearby pucca house rather than go to the cyclone shelter. Regarding this viewpoint, the major consideration was the estimation of pucca house in Barabagi union. Construction of private building in rural areas is a function of many economic and non-economic factors, such as level and structure of income, change of income, asset holding, social prestige, security considerations, physical condition of the locality etc. To avoid the complexity of the determination of pucca structure, projection was made based on the percentage of pucca house in Amtali upazila for the year 2001.

According to the Population Census 2001, the percentage of pucca house in Amtali upazila was 0.42. Considering the growth trend of pucca house it is predicted that the pucca structure of the locality will be 37 in 2015. The predicted pucca structure will be able to reside 13875 of the population, which is 33 percent of the total population of the union. Usually the two or more storied public and private buildings can be considered as the cyclone shelters. Due to the unavailability of data of economic and non-economic factors, the growth rate prediction of pucca structure is difficult. In order to simplify the difficulty of the pucca structure prediction, the growth rate is considered as zero.

- **Determination of the catchment area**

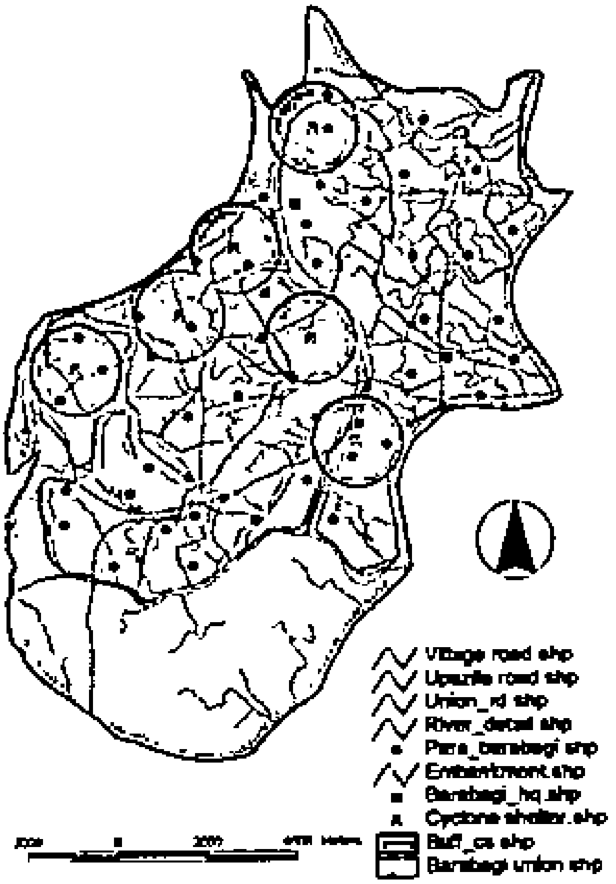
The catchment area of a cyclone shelter is the area from which people come to take shelter during cyclonic storms and surge. If there are few shelters this area may be quite extensive, bnt if there are several shelters within close proximity there may be considerable overlaps in their catchment areas. According to the MCSP study (1993), the size and shape of a catchment area was determined based on the following factors:

- The distance which most families were willing to move when winds peak up gale speed
- The density of habitations, settlement pattern and the number of people the shelter were designed to serve and
- Communication to the shelter.

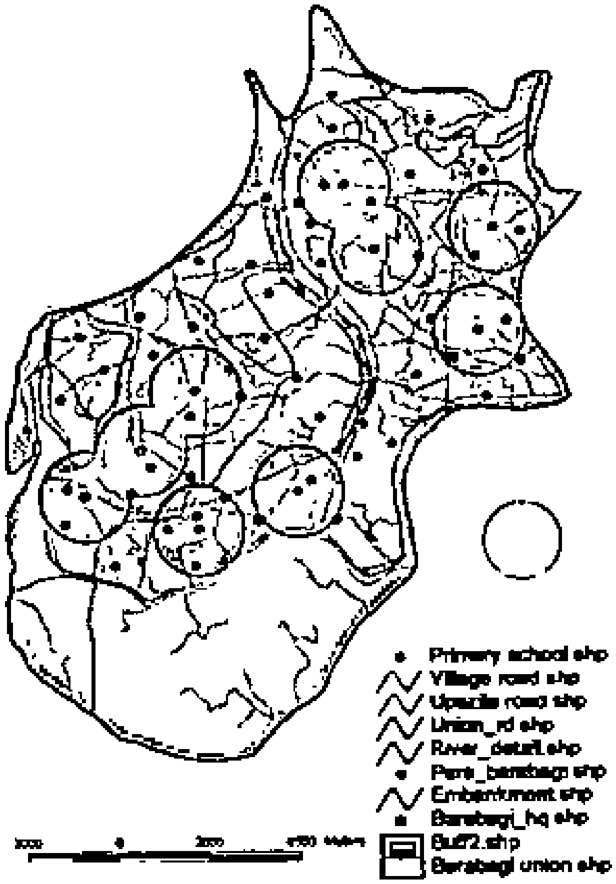
This study also considers the above-mentioned three factors. The field survey reveals that people are willing to travel not more than 1000 meter during the cyclone period. Based on the average walking speed (4.75 km/hr) and the travel distance, the average walking time required to evacuate is 12 minutes. In order to determine the distance from the para (community), the middle point of the para is considered.

6.1.2 Existing cyclone shelter location and capacity

Barabagi union has the area of 117.79 sq.km and fifty para (communities). Barguna district has 71 cyclone shelters and 2 killas. Only six cyclone shelters are located in Barabagi union covering only 3600 people, which is 7.5 percent (41891 nos) of the total population. The cyclone shelters cover only nineteen communities out of fifty (Fig. 6.1 and Table 5.2). The total population of these nineteen communities is 16141 bnt the total capacity of the six cyclone shelters is 3600. That means 22.60 percent of the total population (16141) those who resides within the catchment areas of the cyclone shelters can be accommodated during the cyclone. Additional 12541 population within the buffer zone of the cyclone shelters needs shelter.



Source: LGED (2008)



Source: LGED (2008)

Fig. 6.1 Catchment area of existing cyclone shelters in Barabagi union of Amtali upazila.

Fig. 6.2 Catchment area of proposed primary school cum cyclone shelters.

6.1.3 Primary school cum cyclone shelter

The school attendance during 2001 in Barabagi union for the year 5-9 years is 2396 and the projected school attendance will be 2609. If the existing location of nine selected primary schools could upgrade as a cyclone shelter, it would cover another twenty-two communities having the population coverage of 22832 (47.59 percent) (Fig. 6.2). The size and the capacity of the primary school is a matter of great concern, which will be varied in different para according to the population. A rough estimation has been conducted based on the following assumption:

- The existing location of the primary schools that indicate in the map of LGED will be same for the proposed primary school cum cyclone shelters (Fig. 6.2);
- The floor area for each primary school will be on an average 1500 sq.ft;
- The primary school should be three storied including the ground floor open;

- The distance from the settlement point to the cyclone shelter should not be more than 1 km.
- The coverage of built up area is 0.37 sq.m (4 sq. ft) for one person in primary school cum cyclone shelter.

Considering the above assumptions, the nine proposed primary school cum cyclone shelters would cover only 5400 populations within their catchment areas of para Momishapara, Champopara, Manipara, Baraitala, Lalupara, Joyalbhanga, Malipara, Tutatuli, Karamgapara, Nidraghorapara, Morati Agataluldarpara, Shikaripara, Chorpara, Harinkhola, Sakina, Sadagarpara, Chota Amkhola, Lalupara, Bora Amkhola, Lawpara and Idupara. As a result, 28996 populations in the year 2015 will be deprived of shelters during the occurrence of cyclone. Moreover, 6250 populations will be sheltered by the adjacent high schools, which are proposed in this study (Table 5.2). Finally, adequate space of shelters will be required for rest 22746 people, which is 55532 sq. ft.

6.1.4 High schools cum cyclone shelters

The school attendance during 2001 in Barabagi union for the year 10-14 years is 2484 and the projected school attendance will be 5820 in 2015. That means additional four high schools will be required along with the existing high school in the year 2015. Later on, proposed high schools along with the existing one will be upgraded as cyclone shelters. The location of proposed high schools (cyclone shelters) will be determined based on the Alternating Heuristic Algorithm model.

Alternating Henristic Algorithm model concerned with assignment of n schools to m population where $n<m$. It is assumed that any movement between two points (x_i, y_i) and (x_j, y_j) is continuous and able to take place freely and is defined as

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3.1)$$

However, four major steps of this algorithm are –

Step 1: Selection of demand points as starting locations for the supply centers;

Calculation of proposed location of cyclone shelter (x_j^*, y_j^*) by solving the single-facility location problem for group of demand points (communities);

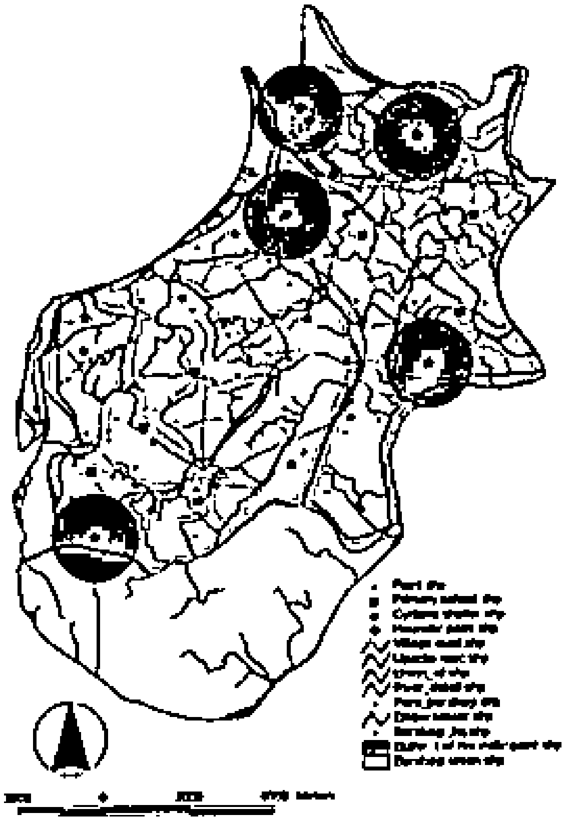
$$x_j^* = \frac{\sum_{i=1}^{n} \frac{w_i x_i}{d_{ij}}}{\sum_{i=1}^{n} \frac{w_i}{d_{ij}}} \quad \text{and} \quad y_j^* = \frac{\sum_{i=1}^{n} \frac{w_i y_i}{d_{ij}}}{\sum_{i=1}^{n} \frac{w_i}{d_{ij}}} \qquad (3.2)$$

Where w_i is the population of each para i.

Thus, the calculated location of the proposed four high schools along with the existing one will cover eight communities (Fig. 6.3). The eight communities (Angerpara, Bulipara, Momapara, Nayapara, Naya Bhaijora, Bora Bhaijora, Taltalipara, Chatanpara, Taltalipara and Manukhapara) have the projected population 8594 (17.91 percent of the total population). In addition, 1311 people who live within the catchment areas of primary schools, will also be accommodated in the proposed high school cum cyclone shelter. A rough estimation has been conducted based on the following assumption:

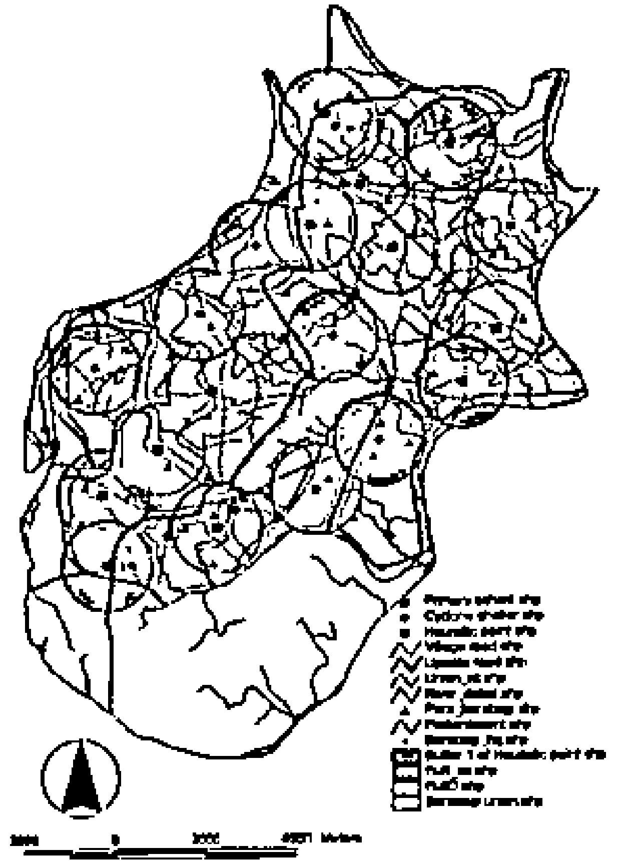
- The existing location of the high school, which is shown in the map of LGED will be same;
- The built up area for each high school will be on an average 2500 sq.ft;
- The high school should be three storied including the ground floor open;
- The distance from the settlement point to the cyclone shelter should not be more than 1 km.
- The coverage of built up area is 0.37 sq.m (4 sq. ft) for one person in high school cum cyclone shelter.

Therefore, a total of 28450 people (67.91 percent of the total population in the union) will be sheltered in the existing and proposed cyclone shelters (Table 5.2 and Fig. 6.4).



Source: LGED (2008)

Fig.6.3 Catchment area of high school cum cyclone shelter in Barabagi union.



Source: LGED (2008)

Fig. 6.4 Catchment area of cyclone shelters. primary school cum cyclone shelters and high school cum cyclone shelters.

Table 6.2: Existing and Proposed cyclone shelters

Cyclone shelter type	Existing capacity	Floor area (sq.ft)	No. of Floors	Proposed cyclone shelters	Total Capacity (population)
Cyclone shelter (without school)	No. 6 2400/shelter=3600 (population)	2400	2	1 storied addition	7200
Primary school (convert CS)	Nil	2500	1	PS cum CS =9 (3 stories each)	11250
High school	Nil	4000	1	HS cum CS=5 (3 stories each)	10000
Total	6			14	28450

PS= Primary school,
CS= Cyclone shelters,
HS= High school.

Source: Calculated by author, 2009

6.1.5 Alternative solutions for people out of coverage of existing and proposed shelters

Considering the existing and proposed shelters, it is stated that the total population coverage will be able to take shelters during cyclone is 66.86 percent (Population numbers is 28450) and rest of 32.09 percent (total number is 13443) of population have no shelters. This group of population reside in Naobhanga, Nameshpara, Tetulpara, Tantipara, Adapara, Sobahanpara, Bora Ankuja para, Choto Ankuja para, Choto Bhaijora, Sakina, Sadarpara, Choto Amkhola, Lalupara, Bora Amkhola, Lawpara, Idupara and Angerpara.

- **Option 1**

In order to provide shelters to these 32.09 percent population of Barabagi union, different initiatives can be taken into account. For instance, additional space of 53767 sq. ft. can be provided in six locations by providing multipurpose cyclone shelters (Table 5.3 and Map 5.5). But we should keep in mind that this would require either renovation of public/private buildings into more than one-storied buildings or construction of new buildings. This will indeed require huge financial assistance, which is not so economically feasible in the context of the existing socio-economic condition of the Barabagi. Even the government or donor agencies will not be interested to provide additional six cyclone shelters along with already proposed fourteen multipurpose cyclone shelters. For clarification, it can be said that these fourteen proposed cyclone shelters will also be used as the primary schools and high schools and they will fulfill the required space for the anticipated primary school and high school going students.

Table 6.3: Proposed additional cyclone shelters in catchment areas

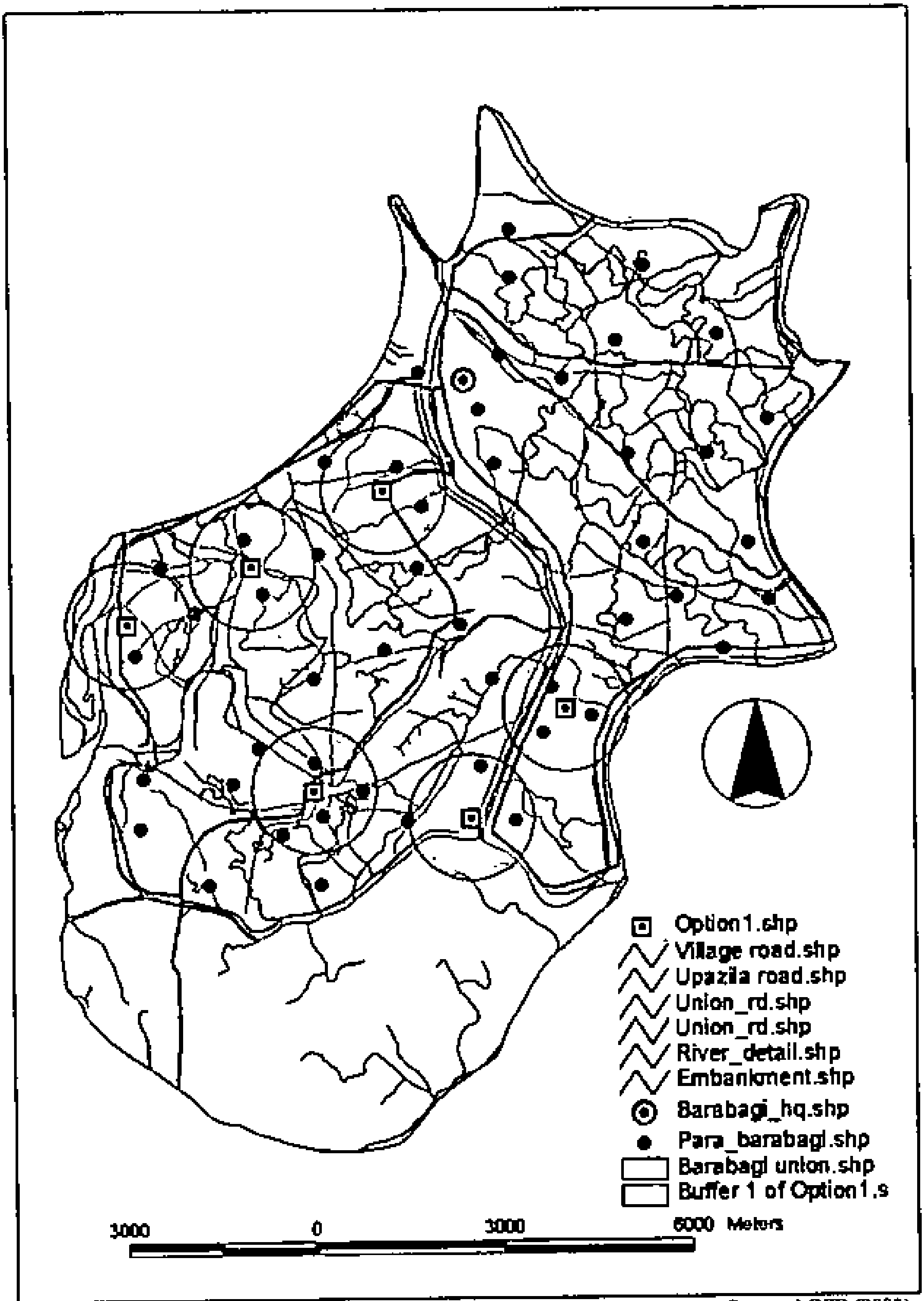
Catchment area	No. of population who requires shelters	Total space required	Type of shelters
1 (bottom left)	1255	5020	Multipurpose cyclone shelter
2 (bottom middle)	2186	8742	Multipurpose cyclone shelter
3 (up left)	3259	13034	Multipurpose cyclone shelter

6 (up right)	1252	5006	Multipurpose cyclone shelter
7 (right middle)	3042	12168	Multipurpose cyclone shelter
8 (bottom right)	2450	9797	Multipurpose cyclone shelter
Total	13444	53767 (sq.ft)	

Source: Calculated by author, 2009

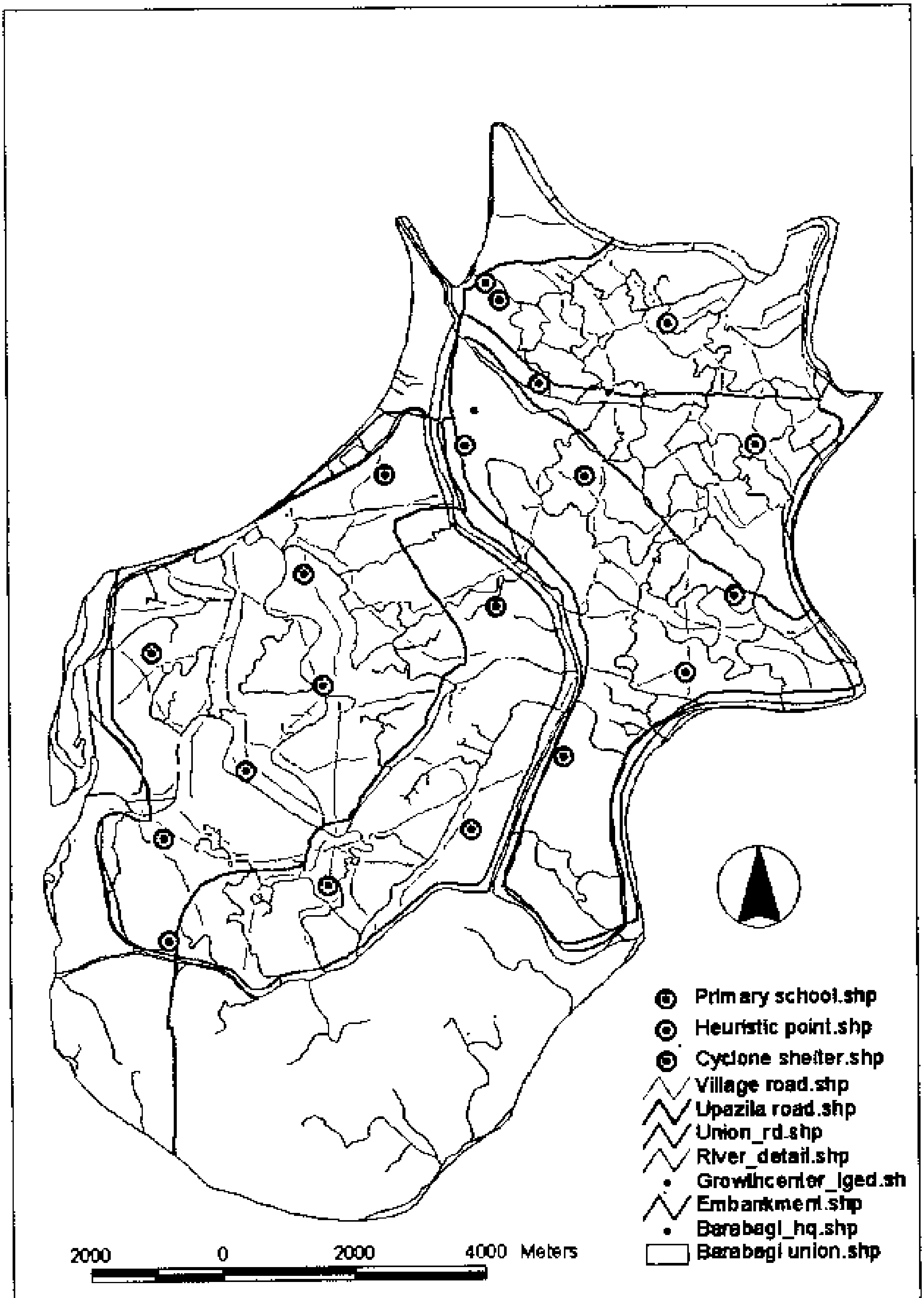
- **Option 2**

Taking into account the above circumstances, this study proposes another alternative i.e. provision of loan to the well-off people in those communities (Naobhanga, Nameshpara, Tetulpara, Tantipara, Adapara, Sobahanpara, Bora Ankuja para, Choto Ankuja para, Choto Bhaijora, Sakina, Sadarpara, Choto Amkhola, Lalupara, Bora Amkhola, Lawpara, Idupara and Angerpara), which are deprived of adequate space for shelter during cyclone. In this case thirty-six well-off people of the selected communities can be given loan at marginal interest rate for constructing two-storied houses having floor space 1500 sq.ft. Consequently, these two-storied houses will ensure adequate space (53767 sq. ft.) for shelter of 13444 people during cyclone.



Source: LGED (2008)

Fig. 6.5 Catchment area of cyclone shelters in Barabagi union that cannot fulfill the space demand of shelters.



Source: LGED (2008)

Fig. 6.5 Existing and proposed cyclone shelters in Barabagi union

In recapitulation, spatial planning of cyclone shelters is not only depends on the people's choice and demand but also the location is dependent on geography, soil condition, land use and other characteristics. Moreover, at union level the cyclone shelter planning depends on rural development as a whole. The option 2 in this research can be a realistic solution as most of the peoples' tendency during disaster is to take shelter to their neighbour's house. The possibility of using local construction material and human resource mobilization is more if responsibility of construction of cyclone shelters cum dwelling unit is vested upon the owners of the houses themselves. By implementing the soft loan approach to the inhabitants of Barabagi union, efficient disaster management planning as well as community development can be achieved.

Chapter 7

RECOMMENDATION AND CONCLUSION

Chapter 7

Recommendation and conclusion

7.1 Recommendation

Different actions and initiatives can be taken into consideration during the pre-disaster period in order to reduce the vulnerability of cyclone along with determination of geophysical risk, social vulnerability and spatial planning of cyclone shelters. Among them, IT augmented forecasting and warning system can be a significant one.

The findings of the study focus on geophysical vulnerability of the study area. The study area is mostly vulnerable to storm surge and the earthen embankment are not strong enough to prevent the high-energy wave. Attention should be given to the embankment approach. As embankment stabilization is related to financial constraints of the country, the focus should be elsewhere. Moreover, embankment stabilization specially by using concrete material will be strong enough for resisting surge. The recent research work of Integrated Coastal Zone Management (ICZM) highlighted on sustainable management of coastal areas. Embankment stabilization by using locally available material can be useful one. As most of the unions located of Barguna district located beside the estuaries or coast, priority should be given in those areas. Some indigenous trees like chample or coconut trees can be used as slope stabilization of the vulnerable areas.

Along with the stated measures, some other preventive measures can be taken into account. For instance, the houses cannot withstand in high wind like 60 km/hr as most of the houses are poorly made. Therefore, some modifications, mostly adopted by the neighbour countries, are recommended in the structural design of kutcha or semi-pucca houses of the study area so that the houses can withstand in high wind.

The study reveals that there is a shortage of cyclone shelters in the highest vulnerable area (Barabagi union). But it is not possible to construct all the cyclone shelters at a time. So priority should be preset in construction of the cyclone shelters. The study recommends that house building loan for sixteen well off people of the Barabagi union should be given for constructing 1500 sq.ft houses so that the vulnerable neighbours can take shelter to these houses. However, a detail study is necessary for the feasibility of loan distribution.

The emergency planner should take into consideration all the aspects that are depicted in the study like vulnerability of population and structure, deprivation of resources and population with special evacuation needs. A detail emergency plan should be provided in near future considering all the aspects individually. A detail land use plan and income survey is necessary for the study area. As the transport and economic condition of the study area are not good enough; attention should be given on the transport sector and the establishment of growth centers for accelerating the local economy. Transport specially the road sector development is urgent due to the post disaster response like relief and rehabilitation.

As four Abashan project are located in Barabagi union, the Abashan houses can be imperative locations as shelters during cyclone. Therefore government of Bangladesh can implement the projects with little modification of the existing design. The houses can be developed in such a way so that the houses can accommodate safely the people who are residing in the Abashan housing.

7.2 Conclusion

The social and geophysical vulnerability maps and quantitative analyses provide an empirical basis upon which the objectives of the study can be addressed. First, the coastal unions of Barguna district are identified as geophysical risk zone such as Raihanpur, Bardarkhali, Keorabunia, Burir Char, Amtali, Haldia, Arpagashia, Barguna, Dhalua, Kakchira, Nachnapara, Kantaltali, Char Duanti, Kalmegha, Patharghata, Barabagi, Karaibaria, Pancha Karalia, Naltona, and Baliatali unions are within the high geophysical risk zone. On the other hand, socio-economic vulnerability is highest in the Barabagi union. In fact, relatively majority of the unions are characterized by high evacuation assistance need. Because it is known that socio-economically vulnerable populations are at risk and that many live in high geophysical risk region.

In the quantitative analysis, similar scenario exists in the spatial distributions of geophysical risk and vulnerability i.e. those unions, who are in high risk zone, are socio-economically vulnerable and those who are less geophysical risk zone are less socio-economically vulnerable such as Bibichini, Betagi, Mokamia, Hosnabad, and Buro Mazumdar unions. Nevertheless, spatial disparity of socio-economic vulnerability was observed among the unions within the geophysical risk zone such as Raihanpur and Arpagashia unions are lowly socio-economic vulnerable region but fall within the high geophysical risk zone. The results also indicate the important fact that the variables that are used for vulnerability analysis make a difference. Depending on which the measures that are used, 70.64 percent people are living in the geophysical risk zone, while 17.72 percent and 47.42 percent people are living in the high and medium socio-economic vulnerable regions respectively. Thus 70.64 percent people of the study area require evacuation assistance need.

The results of the socio-economic vulnerability analysis have important implications for emergency management and especially for evacuation planning. Evacuation planners cannot ignore the high-risk areas, because no matter who lives in these areas, appropriate measures need to be in place before an event. However, because of the scarcity of resources special needs for evacuation assistance in the form of early warning, mobility assistance, or both should be given highest priority in those areas which are highly socio-economically vulnerable and high geophysical risky. For example, Barabagi, Patharghata, Baliatali, Haldia, Pancha Karalia and Kalmegha unions require highest priority.

Furthermore, the quantitative analysis of recent past damage scenario of the catastrophic cyclone SIDR and the socio-economically vulnerability reveals the exact scenario, which is previously anticipated. In the socio-economic vulnerability and geophysical risk analysis, the study found out that the Barabagi, Patharghata, Pancha Karalia, Baliatali, Char Duanti, Kalmegha, Haldia and Burir char unions would be highly affected because they are in high geophysical risk zone and are in highest priority for evacuation needs. The analysis of SIDR damage data indicates that Badarkhali, Patharghata, Naltona, Baliatali, Badarkhali unions are within highly affected region. Integration of existing socio-economic vulnerability analysis with the damage caused by the SIDR reveals that Barabagi, Patharghata, Naltona, Baliatali, and Badarkhali unions are within the highest region which reveals the exact scenario derived from the analysis. Therefore, the priority determination for evacuation needs is factual and vivid in the respect of the real occurrence.

Moreover, it can be said that the results of this research demonstrate the importance of evaluating both risk and vulnerability from several perspectives of emergency management purposes. Yet, much more considerations to be done to develop dynamic, effective, and efficient evacuation plans. For example, the location and capacity of evacuation routes will greatly influence the success (or lack of success) of any evacuation process. Within the spatial analysis, transportation networks can be incorporated in order to identify optimal evacuation routes. Moreover, the focus should be given to the cyclone shelter outside the study area.

Furthermore, it is argued that a bottom-up process, namely improving the situation locally by creating a reliable network of (multi-purpose) shelters, triggers improved performances at a higher level (e.g. speed-up relief operations, effective and efficient humanitarian assistance). Of course, it is recognized that capacity-building projects on the national level are as important as local measures, although the delay in generating tangible benefits at the local level is tremendous. Thus, in an environment where financial and human resources are limited, spatial analyses should be incorporated in disaster-management procedures of both the government and development agencies to decrease the vulnerability of the country's population, especially in rural and remote regions. In order to integrate spatial analyses it is essential that the government and its agencies and others, keep up, or better, increase the compilation of spatially referenced data sets and share them as well. Future project planning and evaluation could significantly benefit from detailed, accurate and complete data sets that allow for comprehensive vulnerability assessments and cross-checks of existing findings at the national and sub-national level.

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APPENDICES

Table A.1. Calculation of Population and structure Index

Upazila	Union	Total popn	Ri_pop	Popn Index	House unit	Ri_h_u	HU Index
Amtali	Paurashava	13305	0.0157	0.3484	2712	0.0151	0.3277
	Amtali	23850	0.0281	0.6246	5072	0.0282	0.6129
	Arpangashia	14533	0.0171	0.3806	3154	0.0175	0.3811
	Atharagashia (RZ)	22628	0.0267	0.5926	4896	0.0272	0.5916
	Barabagi	38472	0.0453	1.0075	8205	0.0456	0.9915
	Chowra (RZ)	20146	0.0237	0.5276	4227	0.0235	0.5108
	Gulisakhali	28183	0.0332	0.7381	5841	0.0325	0.7058
	Haldia	30545	0.0360	0.7999	6293	0.0350	0.7604
	Karaibaria	20472	0.0241	0.5361	4128	0.0229	0.4988
	Kukua (RZ)	23359	0.0275	0.6117	4850	0.0270	0.5861
	Pancha Koralia	24264	0.0286	0.6354	5026	0.0279	0.6073
Bamna	Bamna	18683	0.0220	0.4893	3974	0.0221	0.4802
	Bukabunia	17972	0.0212	0.4707	3985	0.0222	0.4815
	Dauatala (RZ)	16603	0.0196	0.4348	3599	0.0200	0.4349
	Ramna	16545	0.0195	0.4333	3643	0.0202	0.4402
Barguna Sadar	Paurashava	26954	0.0318	0.7059	5809	0.0323	0.7020
	Ayla Patakata (RZ)	18806	0.0222	0.4925	3904	0.0217	0.4718
	Badarkhali (RZ)	25840	0.0305	0.6767	5633	0.0313	0.6807
	Barguna	18744	0.0221	0.4909	3959	0.0220	0.4784
	Burir Char (RZ)	25690	0.0303	0.6728	5419	0.0301	0.6548
	Dhalua	23683	0.0279	0.6202	5077	0.0282	0.6135
	Phullhury	13768	0.0162	0.3606	2878	0.0160	0.3478
	Gaurichanna (RZ)	22610	0.0266	0.5921	5089	0.0283	0.6149
	Keorabunia	16812	0.0198	0.4403	3578	0.0199	0.4324
	M. Baliatali	26526	0.0313	0.6947	5666	0.0315	0.6847
	Naltona	18180	0.0214	0.4761	3753	0.0209	0.4535
Betagi	Paurashava	8368	0.0099	0.2191	1840	0.0102	0.2223
	Betagi	16702	0.0197	0.4374	3653	0.0203	0.4414
	Bibichini	17531	0.0207	0.4591	3648	0.0203	0.4408
	Bura Mazumdar	14573	0.0172	0.3816	2898	0.0161	0.3502
	Hosnabad	17740	0.0209	0.4646	3587	0.0199	0.4334
	Kazirabad	14964	0.0176	0.3919	3090	0.0172	0.3734
	Mokamia	14617	0.0172	0.3828	3118	0.0173	0.3768
	Sarishamuri (RZ)	14861	0.0175	0.3892	3221	0.0179	0.3892
Patharghata	Paurashava	14275	0.0168	0.3738	3193	0.0177	0.3858
	Char Duanti	24049	0.0283	0.6298	5076	0.0282	0.6134
	Kakchira	19888	0.0234	0.5208	4295	0.0239	0.5190
	Kalmegha	26080	0.0307	0.6830	5840	0.0325	0.7057
	Kanthaltali	19519	0.0230	0.5112	4236	0.0235	0.5119
	Nachna Para	14434	0.0170	0.3780	2556	0.0142	0.3089
	Patharghata	28284	0.0333	0.7407	5759	0.0320	0.6959
	Raihanpur	15496	0.0183	0.4058	3522	0.0196	0.4256
Total		848554			179902		

Source: Calculated by author 2008.

Table A.1. Calculation of Population and structure Index (contd.)

Jhupri house	Ri_jhupri	Jhupri_H_Index	Katcha	Ri_katcha	katcha_H_Index	Semi-Pucca	Ri_semi	Semi_H_Index
204	0.0061	0.12688	1556	0.0112	0.2382	659	0.1242	0.4670
993	0.0296	0.61588	4000	0.0288	0.6124	61	0.0116	0.0435
617	0.0184	0.38298	2487	0.0179	0.3808	38	0.0072	0.0270
958	0.0285	0.59451	3861	0.0278	0.5912	59	0.0112	0.0420
1606	0.0478	0.99631	6470	0.0466	0.9907	99	0.0187	0.0703
827	0.0246	0.51327	3333	0.0240	0.5104	51	0.0096	0.0362
1143	0.0340	0.70926	4606	0.0331	0.7053	71	0.0133	0.0501
1232	0.0367	0.76414	4963	0.0357	0.7599	76	0.0143	0.0539
808	0.0241	0.50125	3255	0.0234	0.4984	50	0.0094	0.0354
949	0.0283	0.58892	3825	0.0275	0.5856	59	0.0111	0.0416
984	0.0293	0.61029	3964	0.0285	0.6069	61	0.0115	0.0431
778	0.0232	0.48255	3134	0.0226	0.4798	48	0.0091	0.0341
780	0.0232	0.48389	3143	0.0226	0.4812	48	0.0091	0.0342
704	0.0210	0.43702	2838	0.0204	0.4346	44	0.0082	0.0308
713	0.0212	0.44236	2873	0.0207	0.4399	44	0.0083	0.0312
438	0.0130	0.27177	3333	0.0240	0.5103	1412	0.2661	1.0002
764	0.0228	0.47405	3079	0.0222	0.4714	47	0.0089	0.0335
1102	0.0328	0.68400	4442	0.0320	0.6802	68	0.0128	0.0483
775	0.0231	0.48073	3122	0.0225	0.4780	48	0.0090	0.0339
1060	0.0316	0.65802	4273	0.0308	0.6543	66	0.0124	0.0464
994	0.0296	0.61649	4004	0.0288	0.6130	61	0.0116	0.0435
563	0.0168	0.34947	2270	0.0163	0.3475	35	0.0066	0.0247
996	0.0297	0.61794	4013	0.0289	0.6145	62	0.0116	0.0436
700	0.0209	0.43447	2822	0.0203	0.4320	43	0.0082	0.0307
1109	0.0330	0.68801	4468	0.0322	0.6842	69	0.0129	0.0486
734	0.0219	0.45572	2960	0.0213	0.4532	45	0.0086	0.0322
139	0.0041	0.08608	1056	0.0076	0.1616	447	0.0843	0.3168
715	0.0213	0.44357	2881	0.0207	0.4411	44	0.0083	0.0313
714	0.0213	0.44297	2877	0.0207	0.4405	44	0.0083	0.0313
567	0.0169	0.35190	2285	0.0164	0.3499	35	0.0066	0.0248
702	0.0209	0.43556	2829	0.0204	0.4331	43	0.0082	0.0307
605	0.0180	0.37521	2437	0.0175	0.3731	37	0.0070	0.0265
610	0.0182	0.37861	2459	0.0177	0.3765	38	0.0071	0.0267
630	0.0188	0.39112	2540	0.0183	0.3889	39	0.0073	0.0276
241	0.0072	0.14938	1832	0.0132	0.2805	776	0.1462	0.5498
993	0.0296	0.61637	4003	0.0288	0.6129	61	0.0116	0.0435
841	0.0250	0.52153	3387	0.0244	0.5186	52	0.0098	0.0368
1143	0.0340	0.70914	4605	0.0331	0.7052	71	0.0133	0.0500
829	0.0247	0.51437	3341	0.0240	0.5115	51	0.0097	0.0363
500	0.0149	0.31037	2016	0.0145	0.3086	31	0.0058	0.0219
1127	0.0336	0.69930	4542	0.0327	0.6954	70	0.0131	0.0494
689	0.0205	0.42767	2777	0.0200	0.4253	43	0.0080	0.0302
33576			138958			5308		

Source: Calculated by author 2008.

Table A.1. Calculation of Population and structure Index (contd.)

Pucca	Ri_pucca	Pucca_H_Index	Popn_argi	Ri_agri	Agri_Index
292	0.1419	0.4668	2562	0.0145	0.091
18	0.0089	0.0292	5057	0.0286	0.112
11	0.0055	0.0181	3085	0.0175	0.128
18	0.0086	0.0281	4660	0.0264	0.218
30	0.0143	0.0472	8006	0.0453	0.339
15	0.0074	0.0243	4195	0.0237	0.341
21	0.0102	0.0336	5802	0.0328	0.355
23	0.0110	0.0362	6225	0.0352	0.360
15	0.0072	0.0237	4115	0.0233	0.363
17	0.0085	0.0279	4755	0.0269	0.368
18	0.0088	0.0289	4983	0.0282	0.372
14	0.0069	0.0228	3912	0.0221	0.378
14	0.0070	0.0229	3973	0.0225	0.383
13	0.0063	0.0207	3553	0.0201	0.401
13	0.0064	0.0209	3565	0.0202	0.404
626	0.3040	1.0000	5215	0.0295	0.410
14	0.0068	0.0224	3887	0.0220	0.427
20	0.0098	0.0324	5602	0.0317	0.431
14	0.0069	0.0228	3913	0.0222	0.436
20	0.0095	0.0312	5376	0.0304	0.447
18	0.0089	0.0292	5003	0.0283	0.454
10	0.0050	0.0165	2863	0.0162	0.456
18	0.0089	0.0293	5049	0.0286	0.462
13	0.0063	0.0206	3571	0.0202	0.498
20	0.0099	0.0326	5583	0.0316	0.501
14	0.0066	0.0216	3729	0.0211	0.504
198	0.0963	0.3167	1718	0.0097	0.511
13	0.0064	0.0210	3526	0.0200	0.558
13	0.0064	0.0210	3648	0.0207	0.559
10	0.0051	0.0167	2818	0.0160	0.598
13	0.0063	0.0206	3573	0.0202	0.606
11	0.0054	0.0178	2976	0.0168	0.617
11	0.0054	0.0179	3093	0.0175	0.623
12	0.0056	0.0185	3169	0.0179	0.630
344	0.1671	0.5496	2964	0.0168	0.641
18	0.0089	0.0292	5025	0.0284	0.641
15	0.0075	0.0247	4248	0.0240	0.663
21	0.0102	0.0336	5816	0.0329	0.755
15	0.0074	0.0244	4197	0.0238	0.759
9	0.0045	0.0147	2518	0.0143	0.840
21	0.0101	0.0331	5722	0.0324	0.983
13	0.0062	0.0202	3398	0.0192	1.000
2060			176648		

Source: Calculated by author 2008.

Table A.2. Calculation of Deprivation of Resource Index

Union	House unit	Drinking water	Deprived_dw	Percen_dep_dw	Ri_dw	SVEAI_Dw
Paurashava	2712	2386	326	12.02	0.3023	0.12689
Amtali	5072	4832	240	4.73	0.1190	0.04995
Arpangashia	3154	2809	345	10.94	0.2750	0.11547
Atharagashia	4896	4303	593	12.11	0.3045	0.12785
Barabagi	8205	821	7384	89.99	2.2628	0.94997
Chowra	4227	4156	71	1.68	0.0422	0.01773
Gulisakhali	5841	4951	890	15.24	0.3831	0.16084
Haldia	6293	5567	726	11.54	0.2901	0.12178
Karaibaria	4128	2479	1649	39.95	1.0044	0.42168
Kukua	4850	4325	525	10.82	0.2722	0.11427
Pancha Koralia	5026	349	4677	93.06	2.3398	0.98230
Bamna	3974	210	3764	94.72	2.3816	0.99982
Bukabunia	3985	827	3158	79.25	1.9926	0.83653
Dauatala	3599	2652	947	26.31	0.6616	0.27776
Ramna	3643	3420	223	6.12	0.1539	0.06462
Paurashava	5809	4368	1441	24.81	0.6237	0.26185
Ayla Patakata	3904	263	3641	93.26	2.3450	0.98448
Badarkhali	5633	5507	126	2.24	0.0562	0.02361
Barguna	3959	3821	138	3.49	0.0876	0.03680
Burir Char	5419	1661	3758	69.35	1.7437	0.73204
Dhalua	5077	4935	142	2.80	0.0703	0.02952
Phullhury	2878	1759	1119	38.88	0.9776	0.41043
Gaurichanna	5089	5016	73	1.43	0.0361	0.01514
Keorabunia	3578	1247	2331	65.15	1.6381	0.68770
M. Baliatali	5666	5106	560	9.88	0.2485	0.10433
Naltona	3753	1507	2246	59.85	1.5048	0.63173
Betagi	3653	3144	509	13.93	0.3504	0.14708
Bibichini	3648	2553	1095	30.02	0.7547	0.31685
Bura Mazumdar	2898	2562	336	11.59	0.2915	0.12239
Hosnabad	3587	2061	1526	42.54	1.0697	0.44908
Kazirabad	3090	1995	1095	35.44	0.8910	0.37407
Mokamia	3118	2929	189	6.06	0.1524	0.06399
Sarishamuri	3221	2528	693	21.52	0.5410	0.22711
Paurashava	3193	1373	1820	57.00	1.4332	0.60169
Char Duanti	5076	294	4782	94.21	2.3688	0.99446
Kakchira	4295	259	4036	93.97	2.3628	0.99194
Kalmegha	5840	3645	2195	37.59	0.9451	0.39675
Kanthaltali	4236	628	3608	85.17	2.1417	0.89910
Nachna Para	2556	838	1718	67.21	1.6901	0.70951
Patharghata	5759	596	5163	89.65	2.2542	0.94635
Raihanpur	3522	2564	958	27.20	0.6839	0.28713
Total	**178062**	**107246**	**70816**	**39.77**		

Source: Calculated by author 2008.

Table A.2. Calculation of Deprivation of Resource Index (contd.)

Sanitation	Depri_ Sani	%_dep_ sani	Ri_ sani	SVEAI_ sani	Electricity	elec_ dep	%_elec	Ri_elec	SVEAI_ elec
2291	421	15.52	0.2815	0.1782	1558	1154	42.5516	0.4760	0.4307
2154	2918	57.53	1.0432	0.6603	178	4894	96.4905	1.0794	0.9767
2473	681	21.59	0.3915	0.2478	176	2978	94.4198	1.0562	0.9558
2146	2750	56.17	1.0185	0.6447	316	4580	93.5458	1.0464	0.9469
1364	6841	83.38	1.5118	0.9570	522	7683	93.6380	1.0475	0.9478
2306	1921	45.45	0.8240	0.5216	439	3788	89.6144	1.0025	0.9071
3399	2442	41.81	0.7581	0.4799	360	5481	93.8367	1.0497	0.9499
1185	5108	81.17	1.4718	0.9316	158	6135	97.4893	1.0905	0.9868
1140	2988	72.38	1.3125	0.8308	135	3993	96.7297	1.0820	0.9791
1835	3015	62.16	1.1272	0.7135	811	4039	83.2784	0.9316	0.8430
647	4379	87.13	1.5798	1.0000	186	4840	96.2992	1.0772	0.9748
3092	882	22.19	0.4024	0.2547	523	3451	86.8395	0.9714	0.8790
2161	1824	45.77	0.8299	0.5254	277	3708	93.0489	1.0409	0.9419
2055	1544	42.90	0.7779	0.4924	143	3456	96.0267	1.0742	0.9720
1796	1847	50.70	0.9193	0.5819	44	3599	98.7922	1.1051	1.0000
4735	1074	18.49	0.3352	0.2122	2946	2863	49.2856	0.5513	0.4989
989	2915	74.67	1.3539	0.8570	411	3493	89.4723	1.0009	0.9057
2659	2974	52.80	0.9573	0.6060	700	4933	87.5732	0.9796	0.8865
1819	2140	54.05	0.9801	0.6204	373	3586	90.5784	1.0132	0.9169
1866	3553	65.57	1.1889	0.7525	505	4914	90.6809	1.0144	0.9179
2483	2594	51.09	0.9264	0.5864	498	4579	90.1911	1.0089	0.9130
1333	1545	53.68	0.9734	0.6162	561	2317	80.5073	0.9006	0.8149
2806	2283	44.86	0.8134	0.5149	880	4209	82.7078	0.9252	0.8372
1009	2569	71.80	1.3019	0.8241	542	3036	84.8519	0.9492	0.8589
1331	4335	76.51	1.3873	0.8781	115	5551	97.9703	1.0959	0.9917
952	2801	74.63	1.3533	0.8566	55	3698	98.5345	1.1022	0.9974
1045	2608	71.39	1.2945	0.8194	719	2934	80.3175	0.8985	0.8130
1989	1659	45.48	0.8246	0.5220	539	3109	85.2248	0.9533	0.8627
1489	1409	48.62	0.8816	0.5580	646	2252	77.7088	0.8693	0.7866
2261	1326	36.97	0.6703	0.4243	738	2849	79.4257	0.8885	0.8040
1527	1563	50.58	0.9172	0.5806	579	2511	81.2621	0.9090	0.8226
2126	992	31.82	0.5769	0.3652	163	2955	94.7723	1.0601	0.9593
1253	1968	61.10	1.1079	0.7013	246	2975	92.3626	1.0332	0.9349
2391	802	25.12	0.4554	0.2883	1277	1916	60.0063	0.6712	0.6074
1948	3128	61.62	1.1174	0.7073	102	4974	97.9905	1.0961	0.9919
2012	2283	53.15	0.9638	0.6101	85	4210	98.0210	1.0965	0.9922
2405	3435	58.82	1.0665	0.6751	106	5734	98.1849	1.0983	0.9939
1795	2441	57.63	1.0449	0.6614	72	4164	98.3003	1.0996	0.9950
1682	874	34.19	0.6200	0.3925	79	2477	96.9092	1.0841	0.9810
2027	3732	64.80	1.1750	0.7438	71	5688	98.7671	1.1048	0.9998
1885	1637	46.48	0.8428	0.5335	49	3473	98.6087	1.1031	0.9982
79861	**98201**	**55.15**			**18883**	**159179**	**89.3953**		

Source: Calculated by author, 2008

Table A.2. Calculation of Deprivation of Resource Index (contd.)

Pucca Road (km)	SVEAI_P-road	Health centre	SVEAI_health	Bank	SVEAI_bank	Food godown	SVEAI_godown	Growth centre	SVEAI_growth
28.23	0.8089	4	0.2	5	0.375	4	0	3	0.4
140.63	0.0480	3	0.4	4	0.5	3	0.25	3	0.4
117.526	0.2044	5	0	0	1	3	0.25	4	0.2
35.7	0.7583	2	0.6	1	0.875	0	1	3	0.4
42.03	0.7155	4	0.2	3	0.625	1	0.75	5	0
88.407	0.4015	1	0.8	0	1	0	1	2	0.6
0	1.0000	3	0.4	0	1	0	1	5	0
3.85	0.9739	2	0.6	0	1	1	0.75	5	0
76.43	0.4826	1	0.8	0	1	0	1	0	1
65.33	0.5577	4	0.2	1	0.875	1	0.75	4	0.2
26.95	0.8176	1	0.8	0	1	0	1	4	0.2
46.97	0.6820	1	0.8	0	1	1	0.75	2	0.6
0	1.0000	3	0.4	0	1	0	1	2	0.6
130.06	0.1196	0	1	0	1	1	0.75	4	0.2
145.92	0.0122	1	0.8	0	1	0	1	2	0.6
22.5	0.8477	1	0.8	8	0	1	0.75	0	1
29.69	0.7990	0	1	1	0.875	0	1	2	0.6
0	1.0000	1	0.8	1	0.875	1	0.75	1	0.8
6.28	0.9575	0	1	0	1	0	1	2	0.6
26.63	0.8197	0	1	0	1	0	1	0	1
71.05	0.5190	1	0.8	1	0.875	0	1	1	0.8
39.53	0.7324	1	0.8	0	1	0	1	3	0.4
70.86	0.5203	0	1	1	0.875	0	1	1	0.8
15.62	0.8943	1	0.8	1	0.875	1	0.75	2	0.6
0	1.0000	2	0.6	0	1	0	1	2	0.6
0	1.0000	1	0.8	0	1	0	1	2	0.6
147.72	0.0000	0	1	0	1	0	1	1	0.8
14.09	0.9046	1	0.8	0	1	0	1	1	0.8
52.49	0.6447	0	1	1	0.875	1	0.75	1	0.8
4.99	0.9662	1	0.8	1	0.875	0	1	1	0.8
82.31	0.4428	1	0.8	1	0.875	0	1	2	0.6
27.94	0.8109	0	1	0	1	0	1	1	0.8
0	1.0000	1	0.8	0	1	0	1	1	0.8
0	1.0000	1	0.8	1	0.875	1	0.75	0	1
80.975	0.4518	1	0.8	1	0.875	0	1	2	0.6
123.75	0.1623	1	0.8	0	1	0	1	3	0.4
122.88	0.1682	1	0.8	0	1	0	1	4	0.2
29.89	0.7977	1	0.8	0	1	0	1	1	0.8
0	1.0000	1	0.8	0	1	0	1	1	0.8
26.49	0.8207	0	1	0	1	0	1	4	0.2
12.37	0.9163	1	0.8	0	1	0	1	4	0.2
1956.08		**54**		**32**		**20**		**91**	

Source: Calculated by author, 2008

Table A.3. Calculation of Deprivation of Resource Index (contd.)

Upazila	Union	<5years	Ri <5	PENI <5	Above 60	Ri >60	PENI >60
Amtali	Paurashava	5898	0.0568	0.9958	3954	0.0562	1.0034
	Amtali	2703	0.0260	0.4564	1932	0.0275	0.4903
	Arpangashia	1670	0.0161	0.2820	1123	0.0160	0.2850
	Atharagashia	3181	0.0306	0.5371	1859	0.0264	0.4717
	Barabagi	5198	0.0500	0.8776	2907	0.0413	0.7377
	Chowra	2374	0.0228	0.4008	1562	0.0222	0.3964
	Gulisakhali	3489	0.0336	0.5891	2083	0.0296	0.5286
	Haldia	3543	0.0341	0.5982	2526	0.0359	0.6410
	Karaibaria	2580	0.0248	0.4356	1676	0.0238	0.4253
	Kukua	2881	0.0277	0.4864	1803	0.0256	0.4575
	Pancha Koralia	2924	0.0281	0.4937	2074	0.0295	0.5263
Bamna	Bamna	2245	0.0216	0.3790	1554	0.0221	0.3943
	Bukabunia	2261	0.0218	0.3817	1504	0.0214	0.3817
	Daustala	1864	0.0179	0.3147	1469	0.0209	0.3728
	Ramna	2109	0.0203	0.3561	1371	0.0195	0.3479
Barguna Sadar	Paurashava	2458	0.0237	0.4150	1555	0.0221	0.3946
	Ayla Pataknta	2202	0.0212	0.3718	1414	0.0201	0.3588
	Badarkhali	3023	0.0291	0.5104	2074	0.0295	0.5263
	Barguna	2134	0.0205	0.3603	1549	0.0220	0.3931
	Burir Char	2901	0.0279	0.4898	2099	0.0298	0.5326
	Dhalua	2851	0.0274	0.4814	1815	0.0258	0.4606
	Phullhury	1499	0.0144	0.2531	1134	0.0161	0.2878
	Gaurichanna	2578	0.0248	0.4353	1699	0.0241	0.4311
	Keorabunia	2008	0.0193	0.3390	1373	0.0195	0.3484
	M. Baliatali	3192	0.0307	0.5389	2199	0.0312	0.5580
	Naltona	2183	0.0210	0.3686	1425	0.0202	0.3616
Betagi	Paurashava	848	0.0082	0.1432	636	0.0090	0.1614
	Betagi	1944	0.0187	0.3282	1425	0.0202	0.3616
	Bibichini	2161	0.0208	0.3649	1578	0.0224	0.4004
	Bura Mazumdar	1507	0.0145	0.2544	1126	0.0160	0.2857
	Hosnabad	2080	0.0200	0.3512	1496	0.0213	0.3796
	Kazirabad	1741	0.0168	0.2940	1263	0.0179	0.3205
	Mokamia	1583	0.0152	0.2673	1300	0.0185	0.3299
	Sarishamuri	1924	0.0185	0.3248	1195	0.0170	0.3032
Patharghata	Paurashava	1325	0.0128	0.2237	908	0.0129	0.2304
	Char Duanti	2801	0.0270	0.4729	1829	0.0260	0.4641
	Kakchira	2296	0.0221	0.3877	1619	0.0230	0.4108
	Kalmegha	3023	0.0291	0.5104	2306	0.0328	0.5852
	Kanthaltali	2078	0.0200	0.3509	1576	0.0224	0.3999
	Nachna Para	1441	0.0139	0.2433	1107	0.0157	0.2809
	Patharghata	3478	0.0335	0.5872	1963	0.0279	0.4981
	Raihanpur	1729	0.0166	0.2919	1311	0.0186	0.3327
Total		103908			70371		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index

Union	Affect_area(skm)	Aff_ar_Ri	DDI_Aff_ar	Dead	Dead_Ri	DDI_dead
Paurashava	20	0.0179	0.0960	7	0.0053	0.0294
Amtali	66	0.0589	0.3169	5	0.0038	0.0210
Arpangashia	40	0.0357	0.1920	13	0.0098	0.0547
Atharagashia	54	0.0482	0.2592	2	0.0015	0.0084
Barabagi	160	0.1429	0.7681	238	0.1802	1.0009
Chowra	47	0.0420	0.2256	0	0.0000	0.0000
Gulisakhali	59	0.0527	0.2832	10	0.0076	0.0421
Haldia	86	0.0768	0.4129	0	0.0000	0.0000
Karaibaria	70	0.0625	0.3361	10	0.0076	0.0421
Kukua	50	0.0446	0.2400	0	0.0000	0.0000
Pancha Koralia	8	0.0071	0.0384	13	0.0098	0.0547
Bamna	24.43	0.0218	0.1173	9	0.0068	0.0379
Bukabunia	25.32	0.0226	0.1216	8	0.0061	0.0336
Dauatala	26.12	0.0233	0.1254	29	0.0220	0.1220
Ramna	23.68	0.0211	0.1137	1	0.0008	0.0042
Paurashava		0.0000	0.0000	8	0.0061	0.0336
Ayla Patakata	24.5	0.0219	0.1176	11	0.0083	0.0463
Badarkhali	72	0.0643	0.3457	149	0.1128	0.6266
Barguna	40	0.0357	0.1920	11	0.0083	0.0463
Burir Char	26	0.0232	0.1248	27	0.0204	0.1136
Dhalua	60	0.0536	0.2880	77	0.0583	0.3238
Phuljhury	28	0.0250	0.1344	2	0.0015	0.0084
Gaurichanna	26	0.0232	0.1248	21	0.0159	0.0883
Keorabunia	25	0.0223	0.1200	3	0.0023	0.0126
M. Baliatali	77.4	0.0691	0.3716	126	0.0954	0.5299
Naltona	72.6	0.0648	0.3485	150	0.1136	0.6308
Paurashava	6.9	0.0062	0.0331	0	0.0000	0.0000
Betagi	22.02	0.0197	0.1057	1	0.0008	0.0042
Bibichini	21.13	0.0189	0.1014	0	0.0000	0.0000
Bura Mazumdar	19.86	0.0177	0.0953	4	0.0030	0.0168
Hosnabad	22.95	0.0205	0.1102	2	0.0015	0.0084
Kazirabad	16.49	0.0147	0.0792	0	0.0000	0.0000
Mokamia	17.42	0.0156	0.0836	7	0.0053	0.0294
Sarishamuri	20.34	0.0182	0.0976	28	0.0212	0.1178
Paurashava	295.44	0.2638	1.4183	13	0.0098	0.0547
Char Duanti	34.67	0.0310	0.1664	39	0.0295	0.1640
Kakchira	26.21	0.0234	0.1258	77	0.0583	0.3238
Kalmegha	49.99	0.0446	0.2400	43	0.0326	0.1808
Kanthaltali	23.29	0.0208	0.1118	38	0.0288	0.1598
Nachna Para	18.15	0.0162	0.0871	2	0.0015	0.0084
Patharghata	50.35	0.0450	0.2417	128	0.0969	0.5383
Raihanpur	23.18	0.0207	0.1113	9	0.0068	0.0379
Total	1119.89			1321		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

Affected people	Aff_peo_Ri	DDI_Aff popn	House F	House_F Ri	DDI_House_f	House_F	House_F Ri	DDI_House_full_damage
9064	0.1117	0.1062	583	0.0082	0.0968	583	0.0082	0.0968
19950	0.2460	0.2338	997	0.0141	0.1655	997	0.0141	0.1655
17570	0.2166	0.2059	889	0.0125	0.1475	889	0.0125	0.1475
14160	0.1746	0.1659	659	0.0093	0.1094	659	0.0093	0.1094
48985	0.6039	0.5741	4177	0.0589	0.6932	4177	0.0589	0.6932
17746	0.2188	0.2080	885	0.0125	0.1469	885	0.0125	0.1469
23130	0.2852	0.2711	1355	0.0191	0.2249	1355	0.0191	0.2249
24144	0.2977	0.2829	1586	0.0224	0.2632	1586	0.0224	0.2632
24900	0.3070	0.2918	1206	0.0170	0.2001	1206	0.0170	0.2001
13780	0.1699	0.1615	594	0.0084	0.0986	594	0.0084	0.0986
32570	0.4015	0.3817	1798	0.0254	0.2984	1798	0.0254	0.2984
23844	0.2940	0.2794	2580	0.0364	0.4282	2580	0.0364	0.4282
22608	0.2787	0.2649	2574	0.0363	0.4272	2574	0.0363	0.4272
18998	0.2342	0.2226	3277	0.0462	0.5438	3277	0.0462	0.5438
18199	0.2244	0.2133	3318	0.0468	0.5506	3318	0.0468	0.5506
37000	0.4561	0.4336	1500	0.0212	0.2489	1500	0.0212	0.2489
19490	0.2403	0.2284	1159	0.0163	0.1923	1159	0.0163	0.1923
37500	0.4623	0.4395	3000	0.0423	0.4979	3000	0.0423	0.4979
14200	0.1751	0.1664	1800	0.0254	0.2987	1800	0.0254	0.2987
14230	0.1754	0.1668	3000	0.0423	0.4979	3000	0.0423	0.4979
29075	0.3584	0.3407	2500	0.0353	0.4149	2500	0.0353	0.4149
11400	0.1405	0.1336	1200	0.0169	0.1991	1200	0.0169	0.1991
11300	0.1393	0.1324	1300	0.0183	0.2157	1300	0.0183	0.2157
15000	0.1849	0.1758	939	0.0132	0.1558	939	0.0132	0.1558
35277	0.4349	0.4134	6000	0.0846	0.9957	6000	0.0846	0.9957
28528	0.3517	0.3343	3200	0.0451	0.5311	3200	0.0451	0.5311
7642	0.0942	0.0896	751	0.0106	0.1246	751	0.0106	0.1246
15677	0.1933	0.1837	819	0.0116	0.1359	819	0.0116	0.1359
15030	0.1853	0.1761	547	0.0077	0.0908	547	0.0077	0.0908
13063	0.1610	0.1531	1024	0.0144	0.1699	1024	0.0144	0.1699
15968	0.1969	0.1871	905	0.0128	0.1502	905	0.0128	0.1502
13476	0.1661	0.1579	683	0.0096	0.1133	683	0.0096	0.1133
12915	0.1592	0.1514	875	0.0123	0.1452	875	0.0123	0.1452
13380	0.1650	0.1568	1175	0.0166	0.1950	1175	0.0166	0.1950
1654	0.0204	0.0194	1357	0.0191	0.2252	1357	0.0191	0.2252
20000	0.2466	0.2344	1632	0.0230	0.2708	1632	0.0230	0.2708
21540	0.2656	0.2524	1726	0.0243	0.2864	1726	0.0243	0.2864
21000	0.2589	0.2461	1568	0.0221	0.2602	1568	0.0221	0.2602
5420	0.0668	0.0635	1607	0.0227	0.2667	1607	0.0227	0.2667
2500	0.0308	0.0293	707	0.0100	0.1173	707	0.0100	0.1173
7500	0.0925	0.0879	2293	0.0323	0.3805	2293	0.0323	0.3805
1500	0.0185	0.0176	1146	0.0162	0.1902	1146	0.0162	0.1902
81114			70891			70891		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

House_P	House_P_Ri	DDI_House_p	Cattle and Goat	Cattle_Ri	DDI_Cattle
1730	0.0146	0.0551	430000	0.0009	0.0060
2060	0.0174	0.0656	3200000	0.0069	0.0448
2334	0.0197	0.0743	7260000	0.0158	0.1016
1194	0.0101	0.0380	540000	0.0012	0.0076
11462	0.0967	0.3649	47340000	0.1027	0.6627
2587	0.0218	0.0824	1250000	0.0027	0.0175
3090	0.0261	0.0984	1100000	0.0024	0.0154
3026	0.0255	0.0963	1560000	0.0034	0.0218
1717	0.0145	0.0547	8140000	0.0177	0.1139
2000	0.0169	0.0637	840000	0.0018	0.0118
3800	0.0321	0.1210	8610000	0.0187	0.1205
1394	0.0118	0.0444	6000000	0.0130	0.0840
31411	0.2650	1.0000	2700000	0.0059	0.0378
853	0.0072	0.0272	3600000	0.0078	0.0504
625	0.0053	0.0199	1729000	0.0038	0.0242
2000	0.0169	0.0637	250000	0.0005	0.0035
3137	0.0265	0.0999	60000	0.0001	0.0008
4500	0.0380	0.1433	5000000	0.0108	0.0700
3200	0.0270	0.1019	200000	0.0004	0.0028
4053	0.0342	0.1290	30000000	0.0651	0.4199
4000	0.0337	0.1273	6750000	0.0146	0.0945
3113	0.0263	0.0991	75000	0.0002	0.0010
3000	0.0253	0.0955	150000	0.0003	0.0021
1100	0.0093	0.0350	500000	0.0011	0.0070
5150	0.0434	0.1640	20000000	0.0434	0.2800
3500	0.0295	0.1114	4000000	0.0087	0.0560
357	0.0030	0.0114	13200000	0.0286	0.1848
409	0.0035	0.0130	14400000	0.0312	0.2016
274	0.0023	0.0087	9600000	0.0208	0.1344
512	0.0043	0.0163	20000000	0.0434	0.2800
350	0.0030	0.0111	15600000	0.0338	0.2184
273	0.0023	0.0087	30000000	0.0651	0.4199
413	0.0035	0.0131	24000000	0.0521	0.3360
1580	0.0133	0.0503	23400000	0.0508	0.3276
221	0.0019	0.0070	0	0.0000	0.0000
1816	0.0153	0.0578	50878868	0.1104	0.7122
1013	0.0085	0.0323	8997965	0.0195	0.1260
1284	0.0108	0.0409	1858366	0.0040	0.0260
666	0.0056	0.0212	71390415	0.1549	0.9993
688	0.0058	0.0219	0	0.0000	0.0000
1685	0.0142	0.0536	16283660	0.0353	0.2279
954	0.0080	0.0304	0	0.0000	0.0000
118531			460893274		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

Poultry	Poultry_Ri	DDI_Poultry	Crop_failure	Crop_Ri	DDI_Crop	Fisheries farms	Ri_fish	DDI_Fisheries
1055000	0.0153	0.1512	565000	0.0003	0.0014	300000	0.0009	0.0036
277000	0.0040	0.0397	21699000	0.0127	0.0550	700000	0.0020	0.0084
420000	0.0061	0.0602	13601000	0.0079	0.0345	1300000	0.0037	0.0156
41000	0.0006	0.0059	20506000	0.0120	0.0520	300000	0.0009	0.0036
485000	0.0070	0.0695	34437000	0.0201	0.0873	22000	0.0001	0.0003
148000	0.0021	0.0212	18261000	0.0106	0.0463	300000	0.0009	0.0036
157000	0.0023	0.0225	25544000	0.0149	0.0648	100000	0.0003	0.0012
60000	0.0009	0.0086	27681000	0.0161	0.0702	500000	0.0014	0.0060
225000	0.0033	0.0322	18550000	0.0108	0.0470	1400000	0.0040	0.0168
78000	0.0011	0.0112	21170000	0.0123	0.0537	0	0.0000	0.0000
293000	0.0042	0.0420	21988000	0.0128	0.0558	700000	0.0020	0.0084
1047000	0.0152	0.1501	36300000	0.0212	0.0920	83600000	0.2381	1.0003
401000	0.0058	0.0575	40354000	0.0235	0.1023	3000000	0.0085	0.0359
2000000	0.0290	0.2867	46574000	0.0272	0.1181	70000000	0.1994	0.8376
382000	0.0055	0.0548	387812000	0.2262	0.9833	7800000	0.0222	0.0933
2000000	0.0290	0.2867	13000000	0.0076	0.0330	90000	0.0003	0.0011
3000000	0.0434	0.4300	11500000	0.0067	0.0292	250000	0.0007	0.0030
5000000	0.0724	0.7167	30000000	0.0175	0.0761	300000	0.0009	0.0036
2500000	0.0362	0.3583	19000000	0.0111	0.0482	100000	0.0003	0.0012
3500000	0.0507	0.5017	225000000	0.1312	0.5705	500000	0.0014	0.0060
4500000	0.0651	0.6450	24000000	0.0140	0.0609	400000	0.0011	0.0048
1500000	0.0217	0.2150	12500000	0.0073	0.0317	100000	0.0003	0.0012
1000000	0.0145	0.1433	10000000	0.0058	0.0254	1000000	0.0028	0.0120
100000	0.0014	0.0143	7500000	0.0044	0.0190	250000	0.0007	0.0030
6000000	0.0869	0.8600	25000000	0.0146	0.0634	1000000	0.0028	0.0120
5500000	0.0796	0.7883	28500000	0.0166	0.0723	600000	0.0017	0.0072
700000	0.0101	0.1003	21800000	0.0127	0.0553	9800000	0.0279	0.1173
3000000	0.0434	0.4300	24900000	0.0145	0.0631	10000000	0.0285	0.1197
280000	0.0041	0.0401	16778000	0.0098	0.0425	6720000	0.0191	0.0804
1200000	0.0174	0.1720	24000000	0.0140	0.0609	9000000	0.0256	0.1077
430000	0.0062	0.0616	26000000	0.0152	0.0659	10800000	0.0308	0.1292
1300000	0.0188	0.1863	26900000	0.0157	0.0682	3650000	0.0104	0.0437
1400000	0.0203	0.2007	27700000	0.0162	0.0702	11400000	0.0325	0.1364
1300000	0.0188	0.1863	27800000	0.0162	0.0705	10800000	0.0308	0.1292
0	0.0000	0.0000	8086343	0.0047	0.0205	2233218	0.0064	0.0267
6000000	0.0869	0.8600	98018570	0.0572	0.2485	27069946	0.0771	0.3239
2798800	0.0405	0.4012	105538114	0.0615	0.2676	29146630	0.0830	0.3488
500000	0.0072	0.0717	102893048	0.0600	0.2609	28416139	0.0809	0.3400
1500000	0.0217	0.2150	26564015	0.0155	0.0674	7336227	0.0209	0.0878
0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
7000000	0.1013	1.0033	36766411	0.0214	0.0932	10153839	0.0289	0.1215
0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
69077800			1714786501			351137999		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

Powerline(km)	Ri_power	DDI_Power	DDI_Mosque	Road_F(km)	Road_P_F_Ri	DDI_Road
103000	0.0008	0.0041	0.1401	0.2	0.0023	0.0211
180000	0.0013	0.0072	0.2402	0.4	0.0046	0.0421
155000	0.0012	0.0062	0.2052	0.3	0.0035	0.0316
116000	0.0009	0.0046	0.1552	0.2	0.0023	0.0211
748000	0.0056	0.0299	1.0010	1.5	0.0174	0.1580
155000	0.0012	0.0062	0.2052	0.3	0.0035	0.0316
180000	0.0013	0.0072	0.2402	0.35	0.0041	0.0369
284000	0.0021	0.0114	0.3804	0.6	0.0070	0.0632
207000	0.0015	0.0083	0.2753	0.6	0.0070	0.0632
103000	0.0008	0.0041	0.1401	0.2	0.0023	0.0211
310000	0.0023	0.0124	0.4154	0.6	0.0070	0.0632
3854000	0.0288	0.1542	0.3003	7	0.0811	0.7374
3125000	0.0234	0.1251	0.2903	0	0.0000	0.0000
1400000	0.0105	0.0560	0.3504	2	0.0232	0.2107
2000000	0.0150	0.0800	0.2102	2.75	0.0319	0.2897
2000000	0.0150	0.0800	0.2503	0.5	0.0058	0.0527
16000000	0.1197	0.6403	0.1502	0.5	0.0058	0.0527
2000000	0.0150	0.0800	0.4505	1.5	0.0174	0.1580
5000000	0.0374	0.2001	0.3504	0.5	0.0058	0.0527
15000000	0.1123	0.6003	0.4505	1.5	0.0174	0.1580
800000	0.0060	0.0320	0.5005	1.5	0.0174	0.1580
600000	0.0045	0.0240	0.1502	0.5	0.0058	0.0527
1100000	0.0082	0.0440	0.1502	0.5	0.0058	0.0527
5870000	0.0439	0.2349	0.2002	1	0.0116	0.1053
25000000	0.1871	1.0005	0.4004	1.5	0.0174	0.1580
14000000	0.1048	0.5603	0.4004	1.5	0.0174	0.1580
1200000	0.0090	0.0480	0.5005	4	0.0463	0.4214
700000	0.0052	0.0280	0.6006	4	0.0463	0.4214
400000	0.0030	0.0160	0.4004	2.8	0.0324	0.2950
615000	0.0046	0.0246	0.5005	4	0.0463	0.4214
700000	0.0052	0.0280	0.6507	4	0.0463	0.4214
600000	0.0045	0.0240	0.8509	5	0.0579	0.5267
800000	0.0060	0.0320	0.7508	5	0.0579	0.5267
600000	0.0045	0.0240	0.7007	5	0.0579	0.5267
593208	0.0044	0.0237	0.0551	4	0.0463	0.4214
7190568	0.0538	0.2878	0.0601	4	0.0463	0.4214
7742196	0.0579	0.3098	0.0350	9.5	0.1101	1.0007
7548156	0.0565	0.3021	0.2252	2	0.0232	0.2107
1948746	0.0146	0.0780	0.1001	5	0.0579	0.5267
0	0.0000	0.0000	0.0000	0	0.0000	0.0000
2697156	0.0202	0.1079	0.0801	0	0.0000	0.0000
0	0.0000	0.0000	0.0000	0	0.0000	0.0000
133625030				**86.3**		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

Road_P(km)	Road_P P_Ri	DDI_Road_P_P	E road_F (km)	Road_E_F_Ri	DDI_Road_E_F	E road_P (km)	Ri earthen road	DDI_Road_E_P
2.04	0.0068	0.1023	0.4	0.0010	0.0067	5	0.0056	0.0628
3.57	0.0118	0.1791	0.7	0.0018	0.0117	25	0.0279	0.3140
3.06	0.0101	0.1535	0.6	0.0015	0.0100	25	0.0279	0.3140
2.3	0.0076	0.1154	0.45	0.0011	0.0075	12	0.0134	0.1507
14.79	0.0490	0.7420	2.9	0.0073	0.0485	80	0.0894	1.0049
3.06	0.0101	0.1535	0.6	0.0015	0.0100	10	0.0112	0.1256
3.57	0.0118	0.1791	0.7	0.0018	0.0117	14	0.0157	0.1759
5.61	0.0186	0.2814	1.1	0.0028	0.0184	13	0.0145	0.1633
6.12	0.0203	0.3070	1.2	0.0030	0.0201	25	0.0279	0.3140
2.04	0.0068	0.1023	0.4	0.0010	0.0067	10	0.0112	0.1256
6.12	0.0203	0.3070	1.2	0.0030	0.0201	25	0.0279	0.3140
15	0.0497	0.7525	13	0.0326	0.2175	20	0.0224	0.2512
10	0.0331	0.5017	15	0.0376	0.2510	22	0.0246	0.2763
3	0.0099	0.1505	10	0.0251	0.1673	20	0.0224	0.2512
5	0.0166	0.2508	14	0.0351	0.2343	20	0.0224	0.2512
4	0.0132	0.2007	5	0.0125	0.0837	10	0.0112	0.1256
2	0.0066	0.1003	10	0.0251	0.1673	20	0.0224	0.2512
5	0.0166	0.2508	20	0.0502	0.3346	50	0.0559	0.6281
4	0.0132	0.2007	8	0.0201	0.1339	18	0.0201	0.2261
1	0.0033	0.0502	14	0.0351	0.2343	20	0.0224	0.2512
7	0.0232	0.3512	15	0.0376	0.2510	20	0.0224	0.2512
2	0.0066	0.1003	15	0.0376	0.2510	18	0.0201	0.2261
3	0.0099	0.1505	10	0.0251	0.1673	20	0.0224	0.2512
5	0.0166	0.2508	4	0.0100	0.0669	15	0.0168	0.1884
8	0.0265	0.4013	15	0.0376	0.2510	30	0.0335	0.3768
8	0.0265	0.4013	25	0.0627	0.4183	30	0.0335	0.3768
14	0.0464	0.7023	8	0.0201	0.1339	22	0.0246	0.2763
16	0.0530	0.8027	21	0.0527	0.3514	7	0.0078	0.0879
10.24	0.0339	0.5137	5.68	0.0143	0.0950	15	0.0168	0.1884
14	0.0464	0.7023	7	0.0176	0.1171	21	0.0235	0.2638
16	0.0530	0.8027	9	0.0226	0.1506	24	0.0268	0.3015
20	0.0662	1.0033	11	0.0276	0.1841	25	0.0279	0.3140
18	0.0596	0.9030	10	0.0251	0.1673	24	0.0268	0.3015
16	0.0530	0.8027	10	0.0251	0.1673	24	0.0268	0.3015
4	0.0132	0.2007	3	0.0075	0.0502	2	0.0022	0.0251
10	0.0331	0.5017	8	0.0201	0.1339	20	0.0224	0.2512
9.5	0.0315	0.4766	26.5	0.0665	0.4434	30.5	0.0341	0.3831
15	0.0497	0.7525	6	0.0151	0.1004	15	0.0168	0.1884
5	0.0166	0.2508	10	0.0251	0.1673	50	0.0559	0.6281
0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
0	0.0000	0.0000	60	0.1506	1.0039	38	0.0425	0.4773
0	0.0000	0.0000	0	0.0000	0.0000	0	0.0000	0.0000
302.02			398.43			894.5		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

Embank_F(km)	Embank_F_Ri	DDI_Embank_F	Embank_P	Aff_Embank_P	DDI_Embank_P
0.35	0.0010	0.0086	4.08	0.0086	0.1233
0.61	0.0018	0.0149	7.14	0.0151	0.2158
0.53	0.0015	0.0130	6.12	0.0129	0.1850
0.4	0.0012	0.0098	4.6	0.0097	0.1390
2.54	0.0074	0.0621	29.58	0.0626	0.8941
0.53	0.0015	0.0130	6.12	0.0129	0.1850
0.61	0.0018	0.0149	7.14	0.0151	0.2158
0.97	0.0028	0.0237	11.22	0.0237	0.3391
0.7	0.0020	0.0171	8.16	0.0173	0.2466
0.35	0.0010	0.0086	4.08	0.0086	0.1233
1.05	0.0031	0.0257	12.24	0.0259	0.3700
9	0.0262	0.2200	2	0.0042	0.0605
0	0.0000	0.0000	15	0.0317	0.4534
7	0.0204	0.1711	3	0.0063	0.0907
5	0.0145	0.1222	1	0.0021	0.0302
2	0.0058	0.0489	5	0.0106	0.1511
5	0.0145	0.1222	14	0.0296	0.4232
10	0.0291	0.2444	34	0.0719	1.0277
8	0.0233	0.1956	15	0.0317	0.4534
5	0.0145	0.1222	9	0.0190	0.2720
5	0.0145	0.1222	25	0.0529	0.7556
2	0.0058	0.0489	5	0.0106	0.1511
2	0.0058	0.0489	5	0.0106	0.1511
5	0.0145	0.1222	8	0.0169	0.2418
13	0.0378	0.3178	20	0.0423	0.6045
15	0.0436	0.3667	20	0.0423	0.6045
27	0.0785	0.6600	21	0.0444	0.6347
41	0.1193	1.0022	21	0.0444	0.6347
0.64	0.0019	0.0156	0.15	0.0003	0.0045
24	0.0698	0.5867	25	0.0529	0.7556
28	0.0814	0.6844	22	0.0465	0.6650
34	0.0989	0.8311	26	0.0550	0.7859
33	0.0960	0.8067	25	0.0529	0.7556
32	0.0931	0.7822	25	0.0529	0.7556
0.5	0.0015	0.0122	2	0.0042	0.0605
6	0.0175	0.1467	3	0.0063	0.0907
9.5	0.0276	0.2322	1	0.0021	0.0302
1.5	0.0044	0.0367	10	0.0212	0.3023
5	0.0145	0.1222	10	0.0212	0.3023
0	0.0000	0.0000	0	0.0000	0.0000
0	0.0000	0.0000	0	0.0000	0.0000
0	0.0000	0.0000	0	0.0000	0.0000
343.78			472.63		

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

DDI_Forest	DDI_Edu_F	DDI_Edu_P	DDI_Tele	DDI_Deep_tube	DDI_Shallow
0	0	0	0.0043	0	0
0.0463	0.9968	0	0.0074	0.0801	0
0.0114	0.3426	0	0.0066	0.1002	0
0	0	0	0.0049	0.0801	0
0	0.3426	0	0.0309	0.4407	0
0	0	0	0.0066	0.0801	0
0	0.4672	0	0.0074	0.0801	0
0	0	0	0.0117	0.0601	0
0	0	0	0.0086	0.2003	0
0	0	0	0.0043	0.0601	0
0	0.3426	0	0.0129	0.1402	0
0.1424	0.1869	0.4724	0.0715	0.1402	0
0.1025	0.1557	0.2779	0.0000	0.2484	0
0.1510	0.0934	0.3890	0.0000	0.8013	0
0.1025	0.2492	0.1112	0.0000	0.1002	0
0.0057	0.1557	0.1389	1.0005	0	0.0812
0.0057	0.6541	0.1389	0.0100	0.0080	0.1624
0.0285	0.3115	0.6947	0.0154	0.0200	0.8122
0.0057	0.4672	0.5558	0.2544	0.0080	0.1354
0.0114	0.6541	0.4168	0.4288	0.0200	0.3520
0.0114	0.7787	0.8336	0.0040	0.0200	0.5144
0.0063	0.1869	0.2223	0.0169	0	0.0812
0.0085	0.2803	0.2779	0.3001	0	0.1354
0.0114	0.4672	0.1389	0.2638	0.0120	0.1354
0.0114	0.6541	0.6947	0.2487	0.0200	1.0017
0.0171	0.3426	0.2779	0.0071	0.0280	0.7039
0.0004	0.2180	0.2223	0.1386	0.0521	0
0.0004	0.2180	0.2501	0.0000	0.0521	0
0.0002	0.1557	0.6113	0.0915	0.0321	0
0.0004	0.1557	0.1945	0.0000	0.0401	0
0.0003	0.2492	0.2223	0.0000	0.0521	0
0.0004	0.2803	0.2779	0.0000	0.0561	0
0.0004	0.2492	0.2779	0.0000	0.0561	0
0.0004	0.2180	0.2501	0.0000	0.0561	0
0.0782	0.1869	0.2223	0.0008	0.1002	0
0.9478	0.2180	0.3335	0.0096	0.1002	0
1.0205	0.5607	0.4724	0.0104	0.2404	0
0.9949	0.0311	0.0556	0.0101	0.3405	0
0.2569	0.6230	0.2779	0.0026	0.2003	0
0.0057	0.0000	0.0000	0.0000	0	0
0.3555	0.0000	1.0004	0.0036	1.0016	0
0.0063	0.0000	0.0000	0.0000	0	0

Source: Calculated by author, 2008

Table A.4. Calculation of Disaster Damage Index (contd.)

DDI_Pond	DDI_Troller	DDI_Cottage
0.0007	0.0015	0
0.0012	0.0010	0
0.0010	0.0075	0
0.0009	0.0000	0
0.0044	0.0205	0.5560
0.0010	0.0009	0
0.0012	0.0050	0
0.0019	0.0000	0
0.0013	0.0018	0
0.0007	0.0000	0
0.0019	0.0151	0.1580
0.2615	0.1058	0
0.2324	0.0465	0
0.2324	0.0262	0
0.2295	0.0420	0
0	0.0000	0
0.1598	0.0127	0
0.1743	0.3384	3.1591
0	0.0212	0
0	0.2454	6.0023
0	0.0245	0
0	0.0000	0
0	0.0000	0
0.1743	0.0000	0
0.1743	0.2538	5.7496
0	0.2369	0
0.1871	0.0254	0
0.1743	0.0262	0
0.0119	0.0169	0
0.1598	0.0220	0
0.1888	0.0228	0
0.1888	0.0228	0
0.1888	0.0228	0
0.1888	0.0694	0
0.0767	0.1739	0
0.9290	0.1665	0
1.0002	0.6607	0
0.9752	0.1665	0
0.2517	0.0150	0
0.0872	0.0000	0
0.3486	0.9990	0
0.1453	0.0000	0

Source: Calculated by author, 2008

Table A.5. Calculation of Population Evacuation Assistance Need Index (contd.)

Union	Below five	Ri_<5	PENI_<5	Above 60	Ri_>60	PENI_>60	Disable
Paurashava	5898	0.0568	1.00	3954	0.0562	1.00	0.3458
Amtali	2703	0.0260	0.46	1932	0.0275	0.49	0.6199
Arpangashia	1670	0.0161	0.28	1123	0.0160	0.28	0.3778
Atharagashia	3181	0.0306	0.54	1859	0.0264	0.47	0.5882
Barabagi	5198	0.0500	0.88	2907	0.0413	0.74	1.0000
Chowra	2374	0.0228	0.40	1562	0.0222	0.40	0.5237
Gulisakhali	3489	0.0336	0.59	2083	0.0296	0.53	0.7326
Haldia	3543	0.0341	0.60	2526	0.0359	0.64	0.7940
Karaibaria	2580	0.0248	0.44	1676	0.0238	0.43	0.5321
Kukua	2881	0.0277	0.49	1803	0.0256	0.46	0.6072
Pancha Koralia	2924	0.0281	0.49	2074	0.0295	0.53	0.6307
Bamna	2245	0.0216	0.38	1554	0.0221	0.39	0.4856
Bukabunia	2261	0.0218	0.38	1504	0.0214	0.38	0.4671
Dauatala	1864	0.0179	0.31	1469	0.0209	0.37	0.4316
Ramna	2109	0.0203	0.36	1371	0.0195	0.35	0.4301
Paurashava	2458	0.0237	0.42	1555	0.0221	0.39	0.7006
Ayla Patakata	2202	0.0212	0.37	1414	0.0201	0.36	0.4888
Badarkhali	3023	0.0291	0.51	2074	0.0295	0.53	0.6717
Barguna	2134	0.0205	0.36	1549	0.0220	0.39	0.4872
Burir Char	2901	0.0279	0.49	2099	0.0298	0.53	0.6678
Dhalua	2851	0.0274	0.48	1815	0.0258	0.46	0.6156
Phulljhury	1499	0.0144	0.25	1134	0.0161	0.29	0.3579
Gaurichanna	2578	0.0248	0.44	1699	0.0241	0.43	0.5877
Keorabunia	2008	0.0193	0.34	1373	0.0195	0.35	0.4370
M. Baliatali	3192	0.0307	0.54	2199	0.0312	0.56	0.6895
Naltona	2183	0.0210	0.37	1425	0.0202	0.36	0.4726
Paurashava	848	0.0082	0.14	636	0.0090	0.16	0.2175
Betagi	1944	0.0187	0.33	1425	0.0202	0.36	0.4341
Bibichini	2161	0.0208	0.36	1578	0.0224	0.40	0.4557
Bura Mazumdar	1507	0.0145	0.25	1126	0.0160	0.29	0.3788
Hosnabad	2080	0.0200	0.35	1496	0.0213	0.38	0.4611
Kazirabad	1741	0.0168	0.29	1263	0.0179	0.32	0.3890
Mokamia	1583	0.0152	0.27	1300	0.0185	0.33	0.3799
Sarishamuri	1924	0.0185	0.32	1195	0.0170	0.30	0.3863
Paurashava	1325	0.0128	0.22	908	0.0129	0.23	0.3710
Char Duanti	2801	0.0270	0.47	1829	0.0260	0.46	0.6251
Kakchira	2296	0.0221	0.39	1619	0.0230	0.41	0.5169
Kalmegha	3023	0.0291	0.51	2306	0.0328	0.59	0.6779
Kanthaltali	2078	0.0200	0.35	1576	0.0224	0.40	0.5074
Nachna Para	1441	0.0139	0.24	1107	0.0157	0.28	0.3752
Patharghata	3478	0.0335	0.59	1963	0.0279	0.50	0.7352
Raihanpur	1729	0.0166	0.29	1311	0.0186	0.33	0.4028
	103908			70371			

Source: Calculated by author, 2008

Table A.6. Calculation of composite Index

Union	PSI	DARI	PENI	CI	DDI
Paurashava (A)	0.395	0.580	0.530	0.502	0.039
Amtali (A)	0.500	0.463	0.258	0.407	0.120
Arpangashia (A)	0.391	0.489	0.151	0.344	0.087
Atharagashia (A)	0.489	0.314	0.251	0.351	0.052
Barabagi (A)	0.676	0.414	0.394	0.495	0.368
Chowra (A)	0.454	0.278	0.210	0.314	0.060
Gulisakhali (A)	0.547	0.330	0.281	0.386	0.095
Haldia (A)	0.573	0.333	0.338	0.415	0.097
Karaibaria (A)	0.452	0.231	0.225	0.303	0.100
Kukua (A)	0.490	0.408	0.243	0.380	0.048
Pancha Koralia (A)	0.501	0.278	0.277	0.352	0.128
Bamna (Ba)	0.439	0.382	0.208	0.343	0.243
Bukabunia (Ba)	0.436	0.188	0.202	0.275	0.194
Dauatala (Ba)	0.416	0.310	0.195	0.307	0.211
Ramna (Ba)	0.417	0.257	0.184	0.286	0.168
Paurashava (BS)	0.594	0.380	0.209	0.395	0.134
Ayla Patakata (BS)	0.437	0.152	0.190	0.259	0.162
Badarkhali (BS)	0.529	0.329	0.278	0.379	0.448
Barguna (BS)	0.438	0.154	0.207	0.266	0.172
Burir Char (BS)	0.521	0.103	0.280	0.301	0.492
Dhalua (BS)	0.500	0.253	0.244	0.332	0.266
Phullhury (BS)	0.378	0.227	0.151	0.252	0.090
Gaurichanna (BS)	0.496	0.231	0.228	0.318	0.110
Keorabunia (BS)	0.416	0.191	0.184	0.264	0.121
M. Baliatali (BS)	0.533	0.182	0.294	0.337	0.616
Naltona (BS)	0.428	0.150	0.191	0.257	0.299
Paurashava (Be)	0.335		0.085	0.210	0.190
Betagi (Be)	0.418	0.249	0.190	0.286	0.227
Bibichini (Be)	0.422	0.185	0.211	0.273	0.120
Bura Mazumdar (Be)	0.382	0.206	0.150	0.246	0.193
Hosnabad (Be)	0.421	0.176	0.200	0.266	0.207
Kazirabad (Be)	0.391	0.241	0.169	0.267	0.247
Mokamia (Be)	0.390	0.167	0.173	0.243	0.239
Sarishamuri (Be)	0.395	0.137	0.161	0.231	0.237
Paurashava (P)	0.421	0.199	0.122	0.247	0.133
Char Duanti (P)	0.501	0.188	0.246	0.312	0.294
Kakchira (P)	0.455	0.242	0.216	0.305	0.348
Kalmegha (P)	0.538	0.288	0.307	0.377	0.245
Kanthaltali (P)	0.452	0.127	0.210	0.263	0.223
Nachna Para (P)	0.369	0.113	0.147	0.210	0.014
Patharghata (P)	0.544	0.189	0.266	0.333	0.313
Raihanpur (P)	0.409	0.202	0.175	0.262	0.021

Source: Calculated by author, 2008

Table A.6. Calculation of composite Index (contd.)

Union	(PSI*DDI)	(DARI*DDI)	(PENI*DDI)	(CI*DDI)	DDI
Paurashava (A)	0.016	0.023	0.021	0.020	0.039
Amtali (A)	0.060	0.055	0.031	0.049	0.120
Arpangashia (A)	0.034	0.043	0.013	0.030	0.087
Atharagashia (A)	0.025	0.016	0.013	0.018	0.052
Barabagi (A)	0.248	0.152	0.145	0.182	0.368
Chowra (A)	0.027	0.017	0.013	0.019	0.060
Gulisakhali (A)	0.052	0.031	0.027	0.037	0.095
Haldia (A)	0.055	0.032	0.033	0.040	0.097
Karaibaria (A)	0.045	0.023	0.022	0.030	0.100
Kukua (A)	0.023	0.019	0.012	0.018	0.048
Pancha Koralia (A)	0.064	0.035	0.035	0.045	0.128
Bamna (Ba)	0.106	0.093	0.050	0.083	0.243
Bukabunia (Ba)	0.085	0.037	0.039	0.053	0.194
Dauatala (Ba)	0.088	0.065	0.041	0.065	0.211
Ramna (Ba)	0.070	0.043	0.031	0.048	0.168
Paurashava (BS)	0.080	0.051	0.028	0.053	0.134
Ayla Patakata (BS)	0.071	0.025	0.031	0.042	0.162
Badarkhali (BS)	0.237	0.147	0.124	0.170	0.448
Barguna (BS)	0.075	0.027	0.036	0.046	0.172
Burir Char (BS)	0.256	0.051	0.138	0.148	0.492
Dhalua (BS)	0.133	0.067	0.065	0.088	0.266
Phullhury (BS)	0.034	0.020	0.014	0.023	0.090
Gaurichanna (BS)	0.054	0.025	0.025	0.035	0.110
Keorabunia (BS)	0.051	0.023	0.022	0.032	0.121
M. Baliatali (BS)	0.328	0.112	0.181	0.207	0.616
Naltona (BS)	0.128	0.045	0.057	0.077	0.299
Paurashava (Be)	0.064	0.000	0.016	0.040	0.190
Betagi (Be)	0.095	0.056	0.043	0.065	0.227
Bibichini (Be).	0.051	0.022	0.025	0.033	0.120
Bura Mazumdar (Be)	0.074	0.040	0.029	0.047	0.193
Hosnabad (Be)	0.067	0.037	0.041	0.055	0.207
Kazirabad (Be)	0.097	0.059	0.042	0.066	0.247
Mokamia (Be)	0.093	0.040	0.041	0.058	0.239
Sarishamuri (Be)	0.094	0.032	0.038	0.055	0.237
Paurashava (P)	0.056	0.027	0.016	0.033	0.133
Char Duanti (P)	0.147	0.055	0.072	0.092	0.294
Kakchira (P)	0.158	0.084	0.075	0.106	0.348
Kalmegha (P)	0.131	0.070	0.075	0.092	0.245
Kanthaltali (P)	0.101	0.028	0.047	0.059	0.223
Nachna Para (P)	0.005	0.002	0.002	0.003	0.014
Patharghata (P)	0.170	0.059	0.083	0.104	0.313
Raihanpur (P)	0.008	0.004	0.004	0.005	0.021

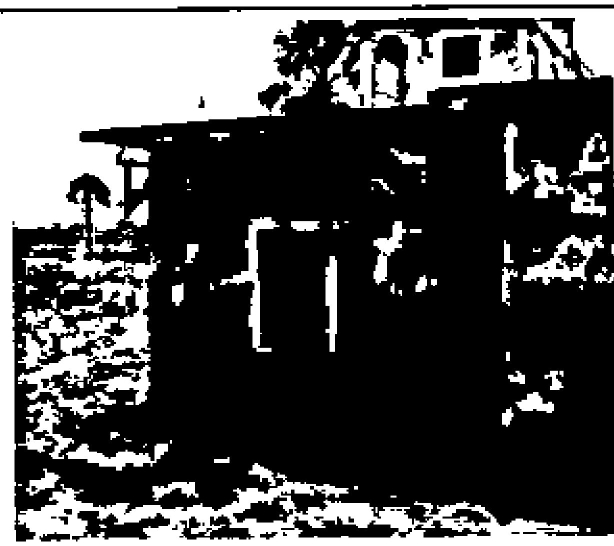
Source: Calculated by author, 2008

PHOTOGRAPHS

Photograph A.1. A ravaged structure after the Super Cyclone SIDR 2007. (Amtali Union)

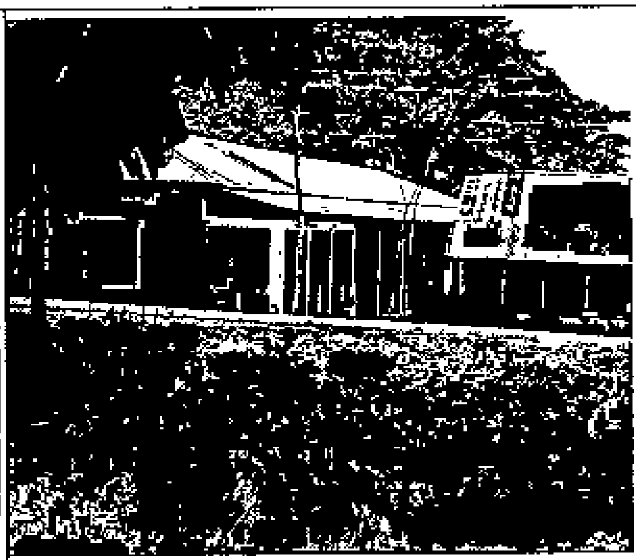
Photograph A.2. A ravaged cattle structure after the Super Cyclone SIDR 2007.

Photograph A.3. Cylone centre used as union parishad office_Arpangasia_Amtali.



Photograph A.4. Previous cyclone centre_Arpangasia_Amtali.

Photograph A.5. Kacha Road_Haladia_Amtali.

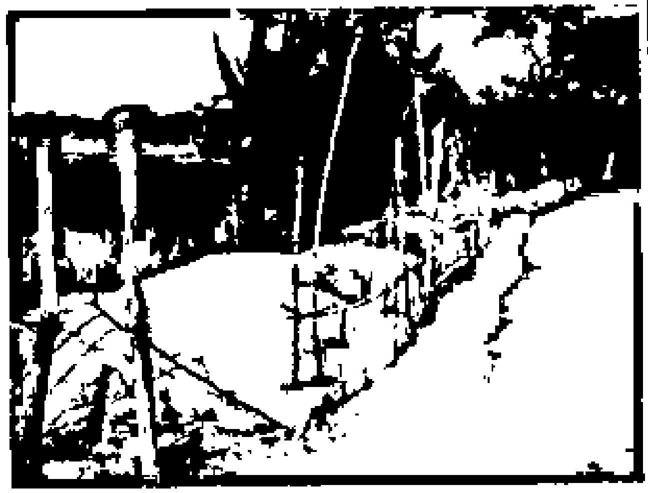


Photograph A.6. Madrasha located in Arpagashia union.

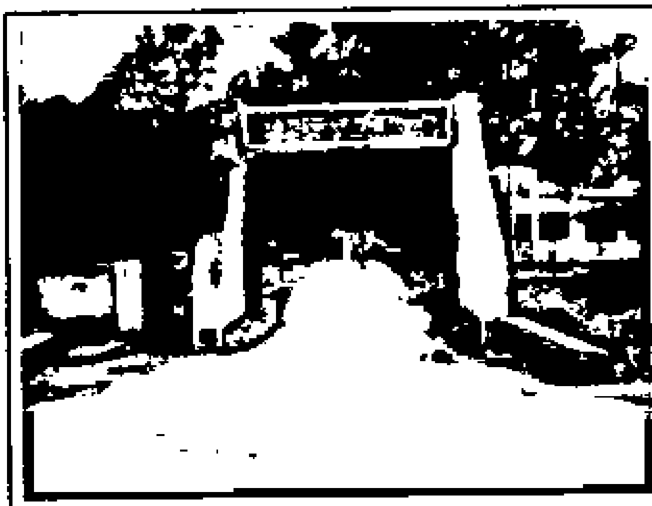
Photograph A.7. A cyclone affected house in Amtali Upazila.

Photograph A.8. Union Parishad cum cyclone shelter.

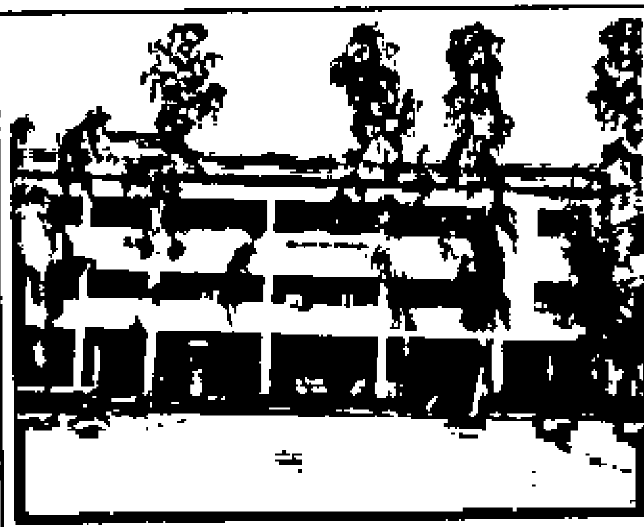
Photograph A.9. Road side plantation for preventing storm surge.



Photograph A.10. A Gono Kobor (graveyard) beside the road of Patharghata Union.



Photograph A.11. Upazila Parishad in Patharghata.



Photograph A.12. A cyclone shelter in Kamthaltali union.