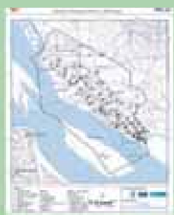
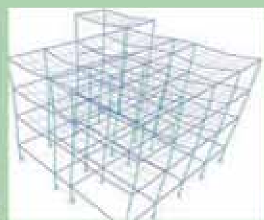
Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness

Main Report





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Report on
Cyclone Shelter Information for Management of Tsunami and Cyclone Preparedness

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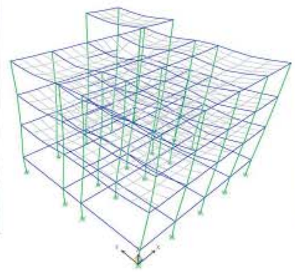






April 2009

CEGIS

Center for Environmental and Geographic Information Services

In Cooperation with Comprehensive Disaster Management Programme

CDMP DFID Department for International Development UNDP

Table of Contents

List of Tables

List of Figures

Abbreviations

ATWC	Alaska Tsunami Warning Center
BBS	Bangladesh Bureau of Statistics
BDRCS	Bangladesh Red Crescent Society
BIDS	Bangladesh Institute of Development Studies
BMD	Bangladesh Meteorological Department
BNBC	Bangladesh National Building Code
BUET	Bangladesh University of Engineering and Technology
CDMP	Comprehensive Disaster Management Programme
CEGIS	Center for Environmental and Geographic Information Services
CPP	Cyclone Preparedness Programme
CSMMC	Cyclone Shelter Management and Maintenance Committee
CYSMIS	Cyclone Shelter Management Information System
DDMC	District Disaster Management Committee
DEM	Digital Elevation Model
DFID-B	Department for International Development – Bangladesh
DMB	Disaster Management Bureau
DMC	Disaster Management Committee
DRRO	District Rehabilitation & Relief Officer
EC	European Commission
FCDI	Flood Control, Drainage and Irrigation
FEM	Finite Element Method
GIS	Geographic Information System
GO	Government Organization
GoB	Government of Bangladesh
GPS	Global Positioning System
HIL	High Inundation Level
HRA	High Risk Area
ICZMP	Integrated Coastal Zone Management Plan
ITIC	International Tsunami Information Centre
IWM	Institute of Water Modelling
LGED	Local Government Engineering Department
MCSP	Multipurpose Cyclone Shelter Programme
MoFDM	Ministry of Food and Disaster Management

NGO	Non Government Organization
NOAA	National Oceanic and Atmospheric Administration
NWRD	National Water Resources Database
PRISM	Projects in Agriculture, Rural Industry, Science and Medicine
PTWS	Pacific Tsunami Warning Center
RA	Risk Area
RS	Remote Sensing
SMC	Shelter Management Committee
ToR	Terms of Reference
UDMC	Union Disaster Management Committee
UNDP	United Nations Development Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
UNO	Upazila Nirbahi Officer
UzDMC	Upazila Disaster Management Committee
WARPO	Water Resources Planning Organisation

Study Team

The CEGIS Study team is coordinated by Mr. Ahmadul Hassan as Project Manager, while Mr. Mohammad Ragib Ahsan served as Project Leader and Database Manager. The study team comprises three components, Survey and data entry team, Structural analysis team and Field testing team.

The Survey team is lead by Mr. Mohammad Ragib Ahsan. The survey works are coordinated by Mr. Md. Monirul Islam Manik and Mr. Syed Ahsanul Haque. Field supervisors Mr. A. K. Mahbub-Ur-Razzak, Mr. Md. Shafiqul Islam, Mr. Syed Sohel Ali and Mr. Md. Abu Obaida managed the field survey. Data entry and database quality management has been done by Qazi Imroj Jahan and Farjana Akhter.

The structural analysis team is lead by Dr. Raquib Ahsan, Associate Professor, BUET. The team comprises Bhuiya Md. Tamim Al Hossain, Sadia Rahman and Farjana Akhter who assisted Dr. Raquib Ahsan in conducting the structural strength analysis using 3D modeling techniques.

The field tests of cyclone shelters have been done by Bureau of Research, Testing and Consultation (BRTC), BUET. Dr. Md. Shamsul Hoque, Professor and Director, BRTC coordinated the field study. The field team includes Dr. Md. Mizanur Rahman, Associate Professor, BUET; Mr. Md. Hadiuzzaman, Assistant Professor, BUET; Mr. Rupak Mutsuddy and Mr. M. Neaz Murshed, Lecturer, BUET and two technicians from BUET.

Besides these teams Mr. Ahmadul Hassan, Dr. Raquib Ahsan, Mr. Mohammed Mukteruzzaman, Mr. S. M. Shafi-ul-alam, Anushila Mazumder, Bhuiya Md. Tamim Al Hossain, Farjana Akhter and Md. Saidur Rahman are involved in preparing the reports, attribute database and maps.

Acknowledgements

The Comprehensive Disaster Management Programme (CDMP) of the Government of Bangladesh (GoB) is a strategic institutional and programming approach that is designed to optimise the reduction of long-term risk and to strengthen the operational capacities for responding to emergencies and disaster situations including actions to improve recovery from these events. The programme is being implemented by the Ministry of Food and Disaster Management (MoFDM) and is supported by the United Nations Development Programme (UNDP), UK Department for International Development – Bangladesh (DFID-B) and the European Commission (EC). Component 4a (Tsunami and Earthquake Preparedness) of CDMP is EC funded component that recognizes growing vulnerability to earthquakes caused by increasing population densities and unplanned development. Under this component, CEGIS has been assigned to conduct the study on “Update available information on cyclone shelter management for tsunami and storm surge preparedness”.

The study team expresses their utter gratitude to Mr. Md. Farhad Uddin, Director General of the Disaster Management Bureau and Dr. Aminul Islam (Assistant Country Director) of UNDP for their continuous support and encouragement to complete this assignment.

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Executive Summary

The Comprehensive Disaster Management Programme (CDMP) of the Government of Bangladesh (GoB) has assigned CEGIS to conduct study on “Update available information on cyclone shelter management for tsunami and storm surge preparedness” under “Component 4a: Earthquake and Tsunami Preparedness”. The assignment includes four tasks such as (a) Spatial distribution of cyclone shelters and their attributes, (b) Structural Strength Analysis of Cyclone Shelters, (c) Catchment Area Delineation of cyclone shelters, and (d) Cyclone shelter management against tsunami hazards. This report presents the results of the study. This report focuses mainly on what should be the guideline for construction, management and maintenance of new shelters and management and maintenance of the existing shelters. Based on the study tasks a conceptual guideline is prepared. The guideline has been finalized with suggestions from community consultation and shelter management related literatures.

The study has been conducted in the coastal area of Bangladesh comprising 16 districts which are exposed to cyclone and tsunami hazards. The coast of Bangladesh is approximately 710 km long, as estimated by measuring the distance around the Bay of Bengal between the borders of India and Myanmar. The coastal zone is mainly low-lying with 62% of land having an elevation of less than 3 metres and 86% less than 5 metres. The coastal zone comprises the Sundarbans, the world’s largest uninterrupted stretch of mangrove ecosystem. The estimated population (2009) of the coastal 16 districts is about 38.2 million, of which 49% are female. Major livelihood groups are farmer, fishermen and wage labourer. After the devastating cyclone of 1970, which caused a death toll of about 470,000 people, the government, donors, NGOs and various humanitarian organizations started building cyclone shelters for providing safe haven facilities for the coastal population.

In order to assess cyclone shelter management issues, it is very important to identify the spatial locations of the cyclone shelters. For updating the spatial location information of cyclone shelters, a survey has been conducted. In the survey GPS locations and various information regarding cyclone shelters has been collected. From survey it is found that, there are a total of 2,917 cyclone shelters. Among these 2,583 (88.5%) shelters are in usable condition, 246 (8.4%) are not usable and 88 (3%) are washed away/destroyed/dismantled. In addition to this, survey also covered 924 open ground floor structures/schools constructed under PEDP-II. Although people take shelter in PEDP-II structures in worst cases, but these structures are not suitable as shelters.

Cyclone shelters provide safe haven facilities to the coastal population. So, it is very important to ensure that, the structures of the shelters are capable to withstand forces induced by various hazards. Based on the structural dimensions, construction and funding agencies the cyclone shelters were grouped into thirteen major design types. These major design types were assessed for structural vulnerability. The Schmidt Hammer Test and James Windsor Pin Test were conducted for assessing the concrete strength of the structures. The test results show that the concrete strength of the structures varies from 1,240 pound/sq. inch (psi) to 5,970 psi. Structural Analyses were conducted using linear 3D Finite Element Method (FEM) based ETABS software. Loading on the structures like, dead load, live load, wind load, earthquake load and storm surge load are calculated based on the Bangladesh National Building Code (BNBC, 1993), FEMA CCM (2000) and other guidelines for tsunami related loading.

From the structural vulnerability analysis it is found that, 81 shelters are vulnerable to tsunami and 208 are vulnerable to cyclone, while a large portion of shelters (1,881 nos.) are vulnerable to earthquake. The analysis showed that the most vulnerable districts to hazards like tsunami or cyclone are Bhola, Patuakhali, Barguna, Chittagong and Cox’s Bazar.

For cyclone shelter management and emergency evacuation it is necessary to know where people are living and where they should go during disaster. In this regard, the catchment area for each shelter has been identified and using GIS network analysis methods, evacuation routes from settlements to shelters have been identified. Based on distance and capacity of shelters, settlement population has been allocated to the shelters. Finally upazila wise maps are prepared showing shelter vulnerability information and evacuation routes from settlements to shelters.

Using all information collected through survey, structural vulnerability and evacuation route mapping, a conceptual guideline has been prepared for cyclone shelter management. Based on literature review a criteria based matrix has been developed to assess the cyclone shelter management issues. Issue based management options in pre, during and post disaster situations have been synthesized from the criteria based matrix. Based on the matrix, consultations were held with local people, union disaster management committees, school committees and shelter management committees (CPP, Red Crescent etc.) for assessing the cyclone shelter management issues and criteria. All the information collected at the local level consultation meetings were compiled and used to develop the management framework. The compiled information of the local consultation meetings were verified and incorporated in the final management framework. Finally, a guideline was developed for the construction, management and maintenance of cyclone shelters to ensure efficient management and structural safety of the shelters.

For new shelter construction site selection should be coordinated at national and local level. The planning for construction of new shelters should be done nationally, on the basis of long and short-term requirements. This planning should allocate resources for Upazila level based on efficiency and equitability. At the local level, planning should be targeted to identify specific locations of new shelters based on equity, suitability and usability.

Over the time period various government and non-government organizations have been constructing cyclone shelters in the coastal areas. But no specific design guideline has been followed in design and construction of new shelters. In this regard, some design criteria have been proposed in the guideline for new shelter construction, using BNBC specifications and other relevant literatures.

Maintenance and management of cyclone shelter is essential for ensuring safe haven facilities to the affected population. In this regard, the guideline proposes management guidelines for formation and activation of shelter management committees and activities of the committee before, during and after disaster.

Chapter 1
Introduction

1.1 Background

The Comprehensive Disaster Management Programme (CDMP) of the Government of Bangladesh (GoB) is being implemented by the Ministry of Food and Disaster Management (MoFDM) and is supported by the United Nations Development Programme (UNDP), UK Department for International Development, Bangladesh (DFID-B) and the European Commission (EC).

In August, 2006 EC and UNDP signed a cooperation agreement related to the funding of three new components within the CDMP framework. “Component 4a: Earthquake and Tsunami Preparedness” is one of them. This component has been divided into several clusters. Among these clusters CEGIS has been assigned the corresponding tasks of the assignment entitled “*Update available information on cyclone shelter management for tsunami and storm surge preparedness*”. The ultimate goal of this assignment is identification of shelter management issues for tsunami and cyclone.

The coastal area of Bangladesh as defined by the Integrated Coastal Zone Management Plan (ICZMP) of the Water Resources Planning Organisation (WARPO), comprises 19 districts, located in the southern part of Bangladesh and influenced by the Bay of Bengal (PDO-ICZMP, 2005). The coast of Bangladesh is approximately 710 km long, as estimated by measuring the distance around the Bay of Bengal between the borders of India and Myanmar. The coastal zone is mainly low-lying with 62% of land having an elevation of less than 3 metres and 86% less than 5 metres. The coastal zone comprises the Sundarbans, the world’s largest uninterrupted stretch of mangrove ecosystem.

According to the population census 2001, the population of the coastal area is about 28 million, which is about 22% of the total population of Bangladesh. According to ICZM (2006) the sex ratio in coast5al area is 105 female per 100 male while the average literacy rate is 51% and the average household size is 5.4 (IWM & CEGIS, 2007). The average population density considering the total land area is about 792 people per sq.km (IWM & CEGIS, 2007). The estimated population (2009) of the 16 coastal districts is about 38.2 million of which 48.8% is women.

The livelihood activities of the coastal population are multidimensional (IWM & CEGIS, 2007). Major livelihood groups consist of farmers, fishermen and wage labourers. Farmer households are the largest group, constituting 25% of the coastal households. The percentage of farmer is higher in fresh water zones, mainly in Pirojpur, Barisal, Shariatpur, Narail, Jessore, Patuakhali and Barguna, being about 30% and above. The number of fishermen households in the coastal region is about 0.20 million, which is about 3% percent of the total households. The Wage labourer group constitutes 0.15 million households, which is about 24% of the total households in the coastal zone. Women constitute about 50% of the total population in coastal region (IWM & CEGIS, 2007).

Bangladesh is one of the most disaster prone countries in the world. Natural hazards like floods, cyclones, droughts, earthquakes, tornadoes, etc. frequently affect the country almost every year. Out of all these, the tropical cyclone causes huge damage to the coastal infrastructure, wealth and social livelihood. Historically, major cyclones struck the coastal areas of the country in 1970, 1991, and 2007. Table 1.1 shows a summary of the major historic cyclones and their impacts over the country. The high number of casualties is due to the fact that cyclones are always accompanied by storm surges. Lack of adequate shelters and preparedness facilities increased the number of casualties during past cyclone events.

Table 1.1: Previous Cyclones and their impacts

Cyclone events	1970	1991	2007
Storm Surge	6-9 m	6-7.5 m	Up to 10 m
Maximum Wind Speed	223 km/hr	225 km/hr	Up to 240 km/hr
Affected District	5	19	30
Affected People	1,100,000	13,798,275	6,851,147
No of Dead People	470,000	138,882	3,292

Source: DMB, 2008; GoB, 2008

Cyclone shelters are meant to provide shelter and reduce the number of casualties in the coastal area during cyclone and tsunami. However, due to the lack of adequate management these shelters have gradually become run down. As cyclone shelters are the only safe places for the coastal population during cyclone and tsunami, existing shelters should be managed properly to ensure life-time use.

1.2 Objective

As per the ToR provided by CDMP, the overall objective of the study was to update available information on cyclone shelter management for tsunami and storm surge preparedness.

Under this study, a major task was to identify the management issues of cyclone shelters in three stages, such as prior, during and post earthquake hazard (tsunami) periods. The objective of this report is to present the existing shelter management practices, bottlenecks of current management practices, and finally, to prepare a guideline for construction, management and maintenance of cyclone shelters.

1.3 Study Area

ICZMP identifies 19 districts of Bangladesh as the coastal area. Out of these 19 districts, 16 were considered for updating cyclone shelter information. Three districts such as Jessore, Narail and Gopalganj were not included in this study as they are not exposed to cyclone and tsunami induced storm surge. The 16 districts under this study were Bagerhat, Barguna, Barisal, Bhola, Chandpur, Chittagong, Cox's Bazar, Feni, Jhalokati, Khulna, Lakshmipur, Noakhali, Patuakhali, Pirojpur, and Satkhira. These districts fall within the latitude of N- 21° to N- 23°30′ and the longitude of E- 90° to E-91°30′. Figure 1.1 shows the study area. These districts are not equally vulnerable to cyclone induced storm surge. The vulnerability of different districts has been defined by MCSP (Figure 1.2). CDMP is now updating the risk map with recent information and knowledge.

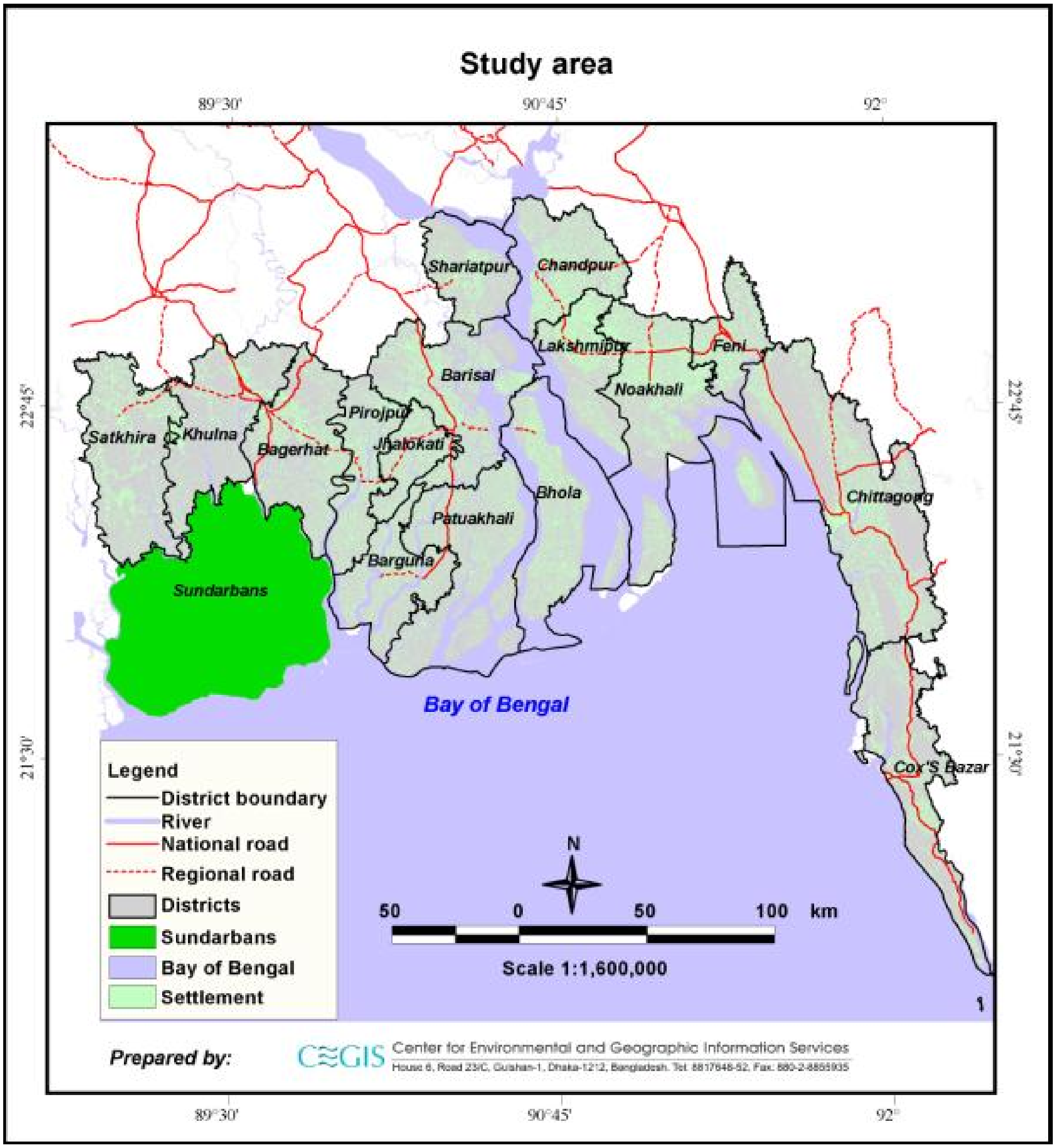


Figure 1.1: Study area

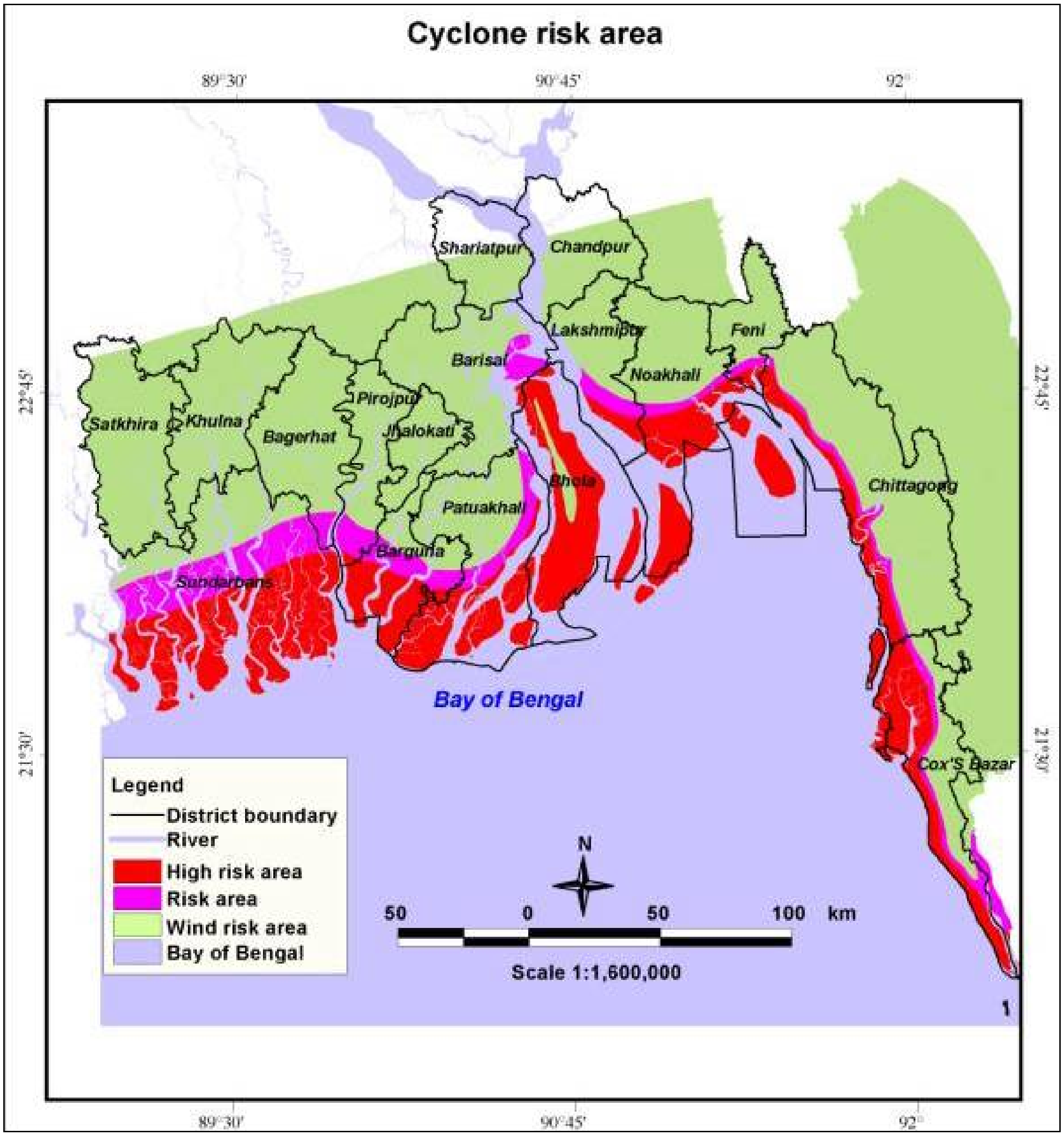


Figure 1.2: Cyclone risk area

Source: MCSP

1.4 Study Approach

The approach of this study includes needs assessment for cyclone shelter management and collection of available information to assess gaps. Proper management of existing cyclone shelters requires updated shelter information, structural strength analysis of shelters and information on evacuation routes i.e. how people will be taken to the shelter during hazard periods. The information on the existing management process including responsibilities and roles of involved institutions, and difficulties/bottlenecks in the current management process were investigated. Information was collected from the field through consultation with the local people. And finally, a guideline for shelter management was developed incorporating possible scopes and opportunities for improvement. All these were done through close interaction with CDMP and other relevant stakeholders, such as DMB, LGED, Red Crescent, etc. The overall approach is presented in figure 1.3.

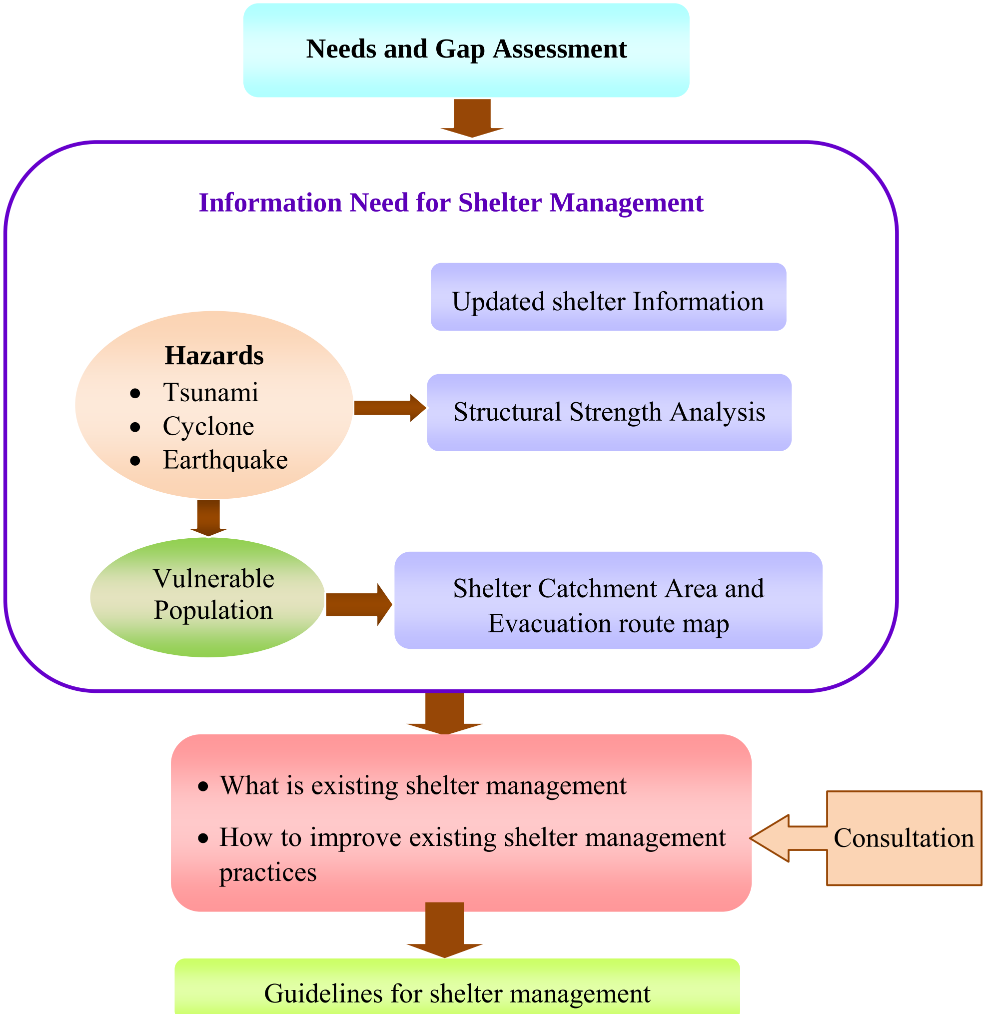


Figure 1.3: Flow diagram of overall approach

1.5 Major Hazards in Bangladesh

The coastal areas of Bangladesh are prone to various hazards. Among these major hazards are cyclone, tsunami and earthquake.

Cyclonic storms have two major impacts, storm surge and wind force. Due to storm surge, a depth of water with a velocity is imposed on the structures. Similarly, wind force applies very high wind pressure on the structures.

Under the "Component 4a: Earthquake and Tsunami Preparedness" of CDMP a study entitled "*Use existing data on available digital elevation models to prepare useable tsunami and storm surge inundation risk maps for the entire coastal region*" has been carried out by the Institute of Water Modelling (IWM) (IWM, 2008). In this study storm surge inundation risk maps have been generated for the entire coastal region. These risk maps are generated for both cyclone and tsunami induced storm surges. IWM generated the cyclone induced storm surge inundation risk map from the maximum inundation maps of 18 cyclones during 1960-2007 (shown in Figure 1.4). The map has been prepared considering land level of the digital elevation model and the existing polders in the coastal region of Bangladesh.

It shows that the highest inundation depth having range between 5 m and 7.5 m lies within the Meghna Estuary area. The eastern coast experiences maximum inundation between 4m and 6 m and western coast experiences inundation within the range of 3-5 m (IWM, 2008). Besides this, IWM has generated another risk map including the worst case scenario of 2007 cyclone. Figure 1.5 shows this map based on 18 real cyclones and one synthesized cyclone of 2007. In this map inundation increases at few locations around the Baleshar River mouth by maximum 1.5 m.

Tsunami causes very high surge with a higher water depth and velocity. However, this hazard does not pose a great threat to Bangladesh due to geographic location and coastal bathymetry. IWM has generated maximum inundation maps for 11 scenarios of tsunami based on the location of origin of tsunami (IWM, 2008). Combining these eleven inundation maps, a maximum inundation map has been generated which is presented in Figure 1.6. It shows that Sundarban area, Nijhum Dwip, south of Hatia (outside polder) and Cox's Bazaar coast are likely to be inundated during tsunami. Maximum inundation is seen at Nijhum Dwip in the range of 3-4 m, and at Sundarban area and Cox's Bazar coast in the range of 2-3 m. Small islands and part of the Manpura island in the Meghna Estuary get inundated by 2-3 m. Bauphal upazila of Patuakhali district is low lying area which may experience inundation of 1-2 m in Mean High Water Spring (MHWS) tide. According to IWM study, the influence of tsunami wave in this area is insignificant (IWM, 2008).

Earthquake is another major hazard. It causes horizontal forces on structures, making them very vulnerable. Bangladesh has a long history of massive earthquakes in the past. Figure 1.7 illustrates the seismic zoning map of Bangladesh. In this map, zone 1 is seen to be the least vulnerable while zone 2 has medium range vulnerability and zone 3 has high vulnerability. From this map, it is clear that, Chittagong coast is moderately prone while the Khulna and Barisal region is less prone to earthquakes.

Besides these, there are other hazards like coastal erosion, which were not considered in the analysis.

1.6 Structure of the report

This report on cyclone shelter information for management of tsunami and cyclone preparedness comprises eight chapters. Chapter 1 includes the background, objective, study approach and structure of the report. Chapter 2 describes the tsunami phenomena, major tsunamis in the Indian Ocean, overall management and shelter management for tsunami. Chapter 3 describes the spatial location of cyclone shelters. Chapter 4 describes the structural vulnerability of cyclone shelters. Chapter 5 comprises a detailed description of analysis process regarding vulnerability analysis, accessibility analysis, cyclone shelter analysis and finally, the catchment area delineation for evacuation. Chapter 6 describes the overall approach for shelter management. Chapter 7 comprises cyclone shelter management information including existing management practices, Problems of current management practices and Suggestions to overcome those problems. Chapter 8 covers the guidelines and recommendations for new shelter construction and shelter management for existing and new shelters. This Report also includes three appendices. Appendix-1 describes the community level consultation outcomes, Appendix-2 presents a description of the Cyclone Preparedness Programme while Appendix-3 presents sample maps and attributes of cyclone shelter prepared under the study. Apart from the main report, this report has five annexes. Annex-A is on spatial distribution maps and attributes, Annex-B illustrates the structural strength analysis of cyclone shelters, Annex-C describes catchment area and evacuation route mapping, Annex-D presents the Upazila wise maps of shelter location, structural vulnerability and evacuation routes and Annex-E comprises the shelter attributes.

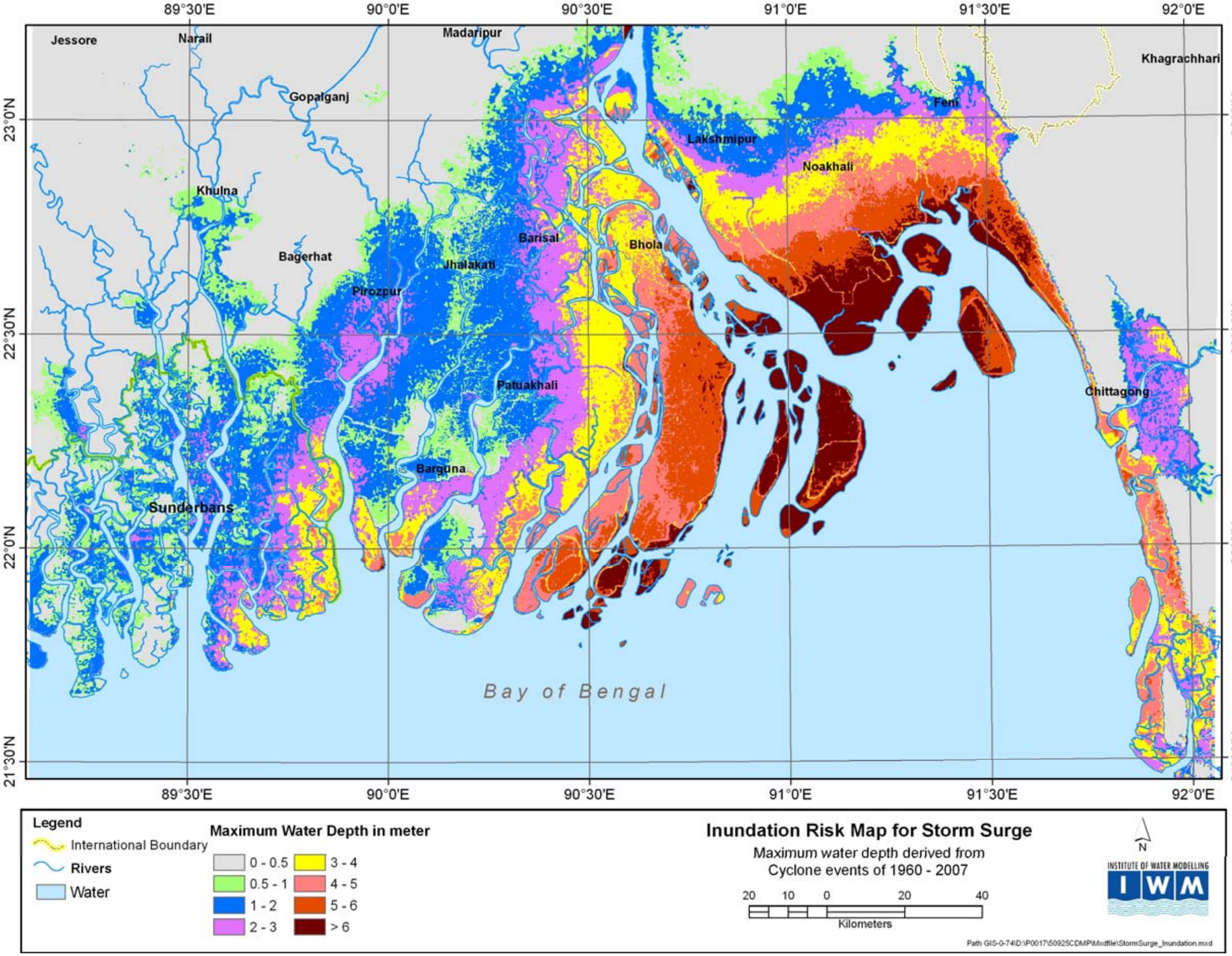


Figure 1.4: Inundation risk map based on 18 cyclones from 1960-2007

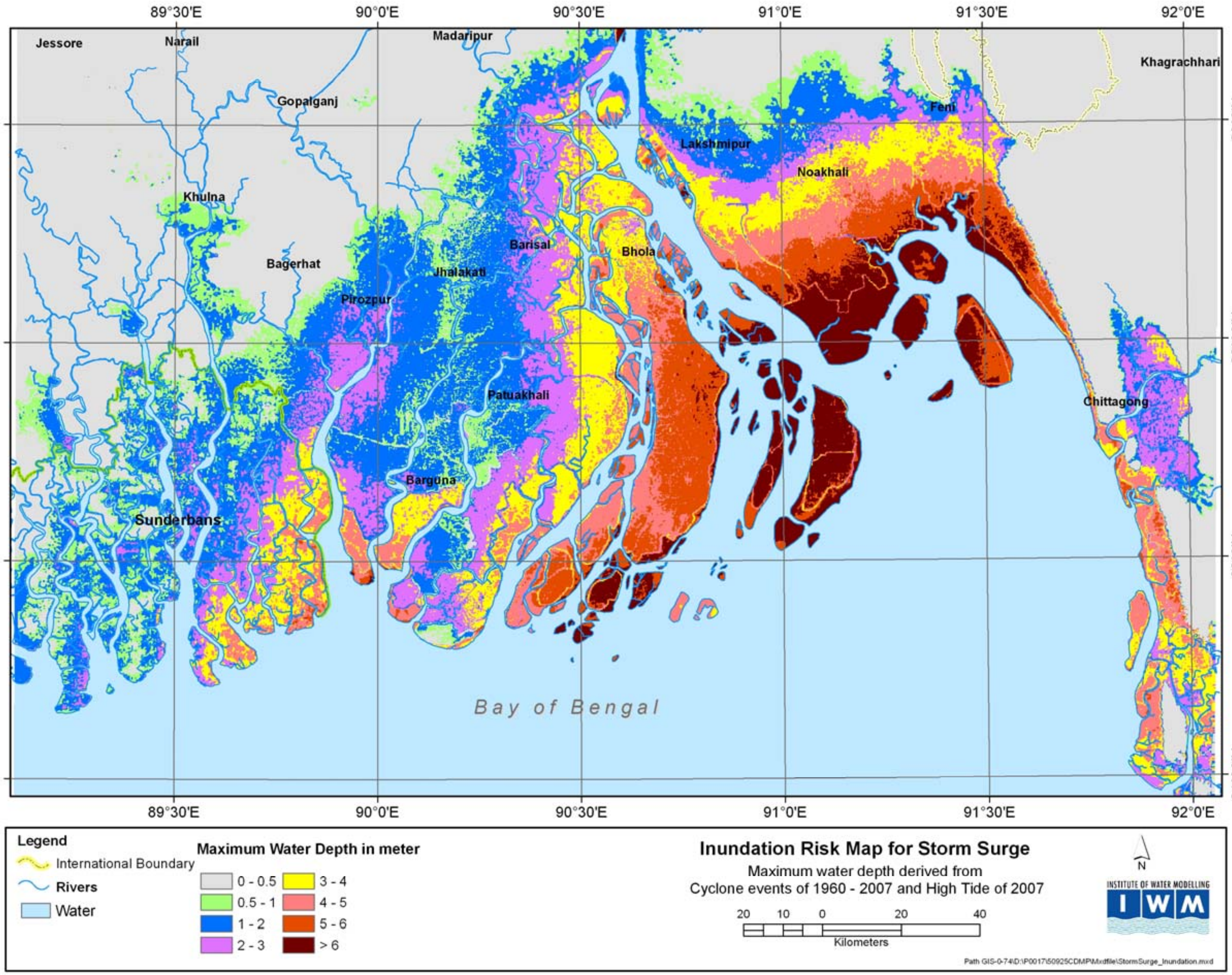


Figure 1.5: Inundation risk map based on 18 cyclones from 1960-2007 and one synthesized cyclone

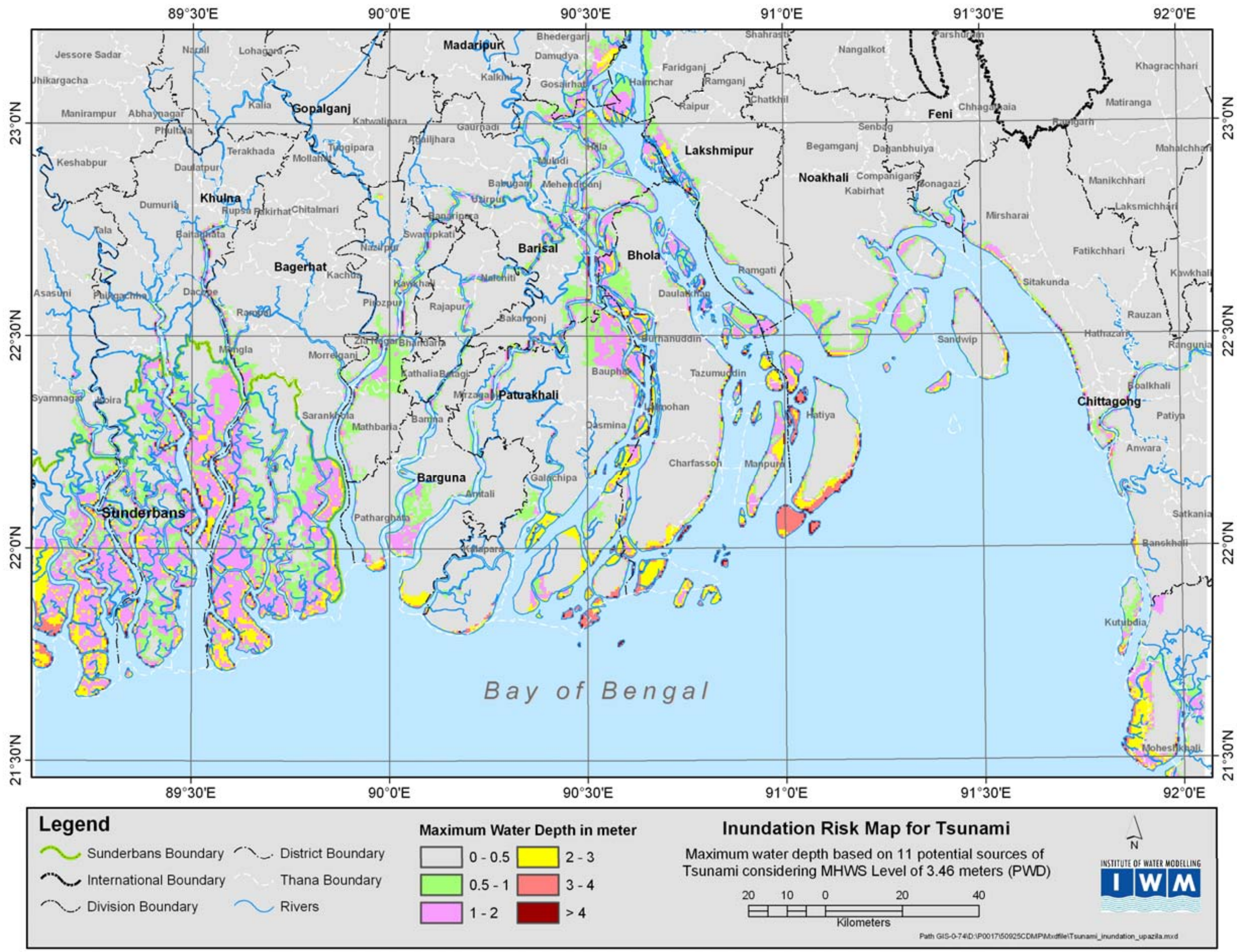


Figure 1.6: Inundation risk map of tsunami for coastal region of Bangladesh

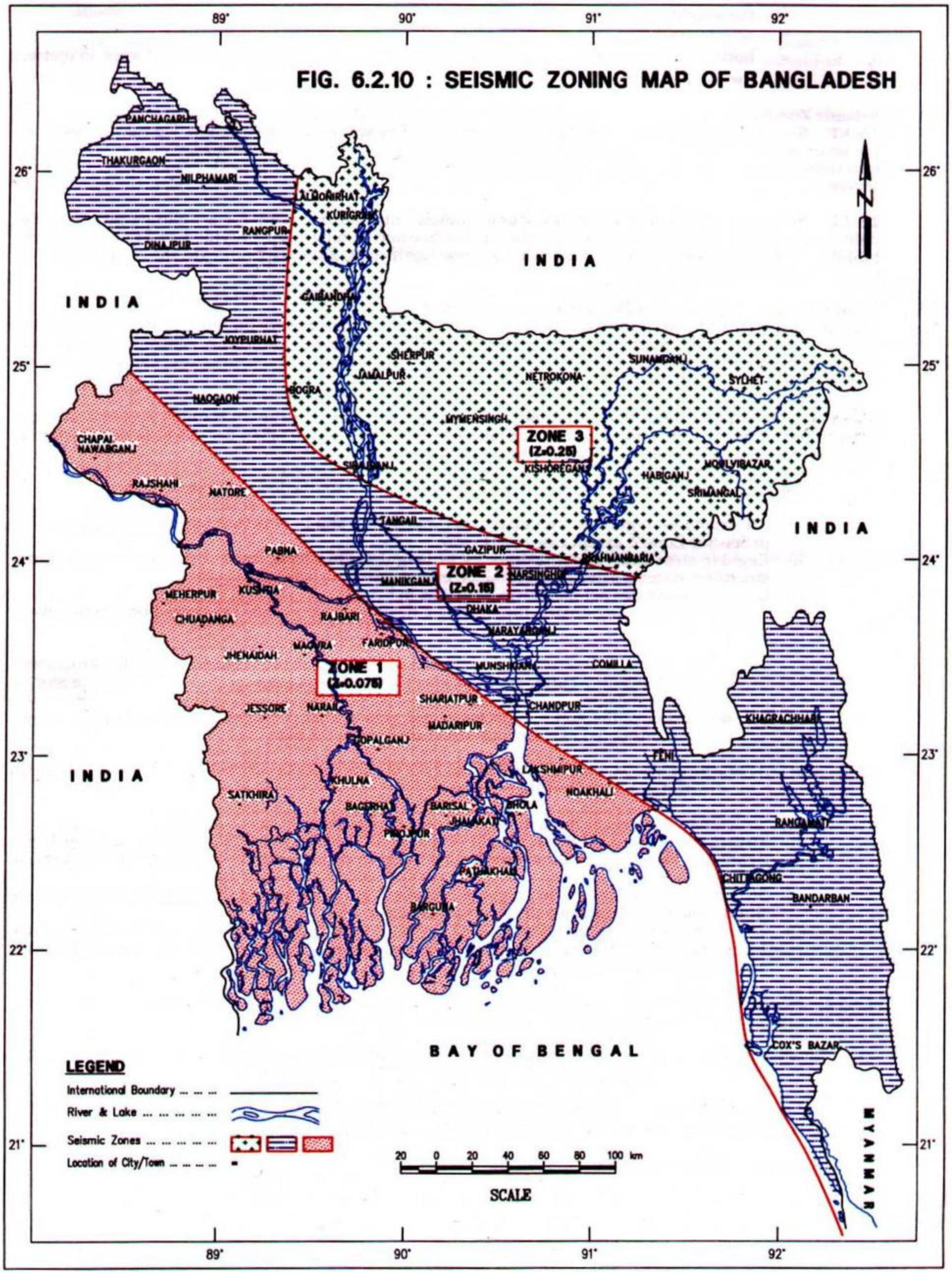


Figure 1.7: Seismic zoning map of Bangladesh

Source: Bangladesh National Building Code, 1993

Chapter 2

Shelter Management for Tsunami

2.1 Introduction

Bangladesh does not have recent memories of tsunami. The management of tsunami in Bangladesh is done mainly based on the experience gathered from tsunami prone countries of the world. The preparedness activities of other tsunami prone countries, how they warn their people, their evacuation strategies and their post tsunami management strategies are mainly reviewed in this chapter. The following is a description of how tsunami could be managed in Bangladesh based on the experiences and suggestions of such countries.

2.2 Tsunami

A tsunami is a series of powerful and destructive ocean waves of local or distant origin that result from large-scale seafloor displacements associated with large earthquakes, major underwater landslides, or exploding volcanic islands. Even the impact of cosmic bodies, such as meteorites, can generate tsunamis. A tsunami can travel at speeds in excess of 450 mph. As the waves enter shallow water they slow down and may rise several feet, or in rare cases, tens of feet. The first wave is almost never the largest and damaging waves may potentially arrive for hours. Tsunamis can occur at any season of the year and at any time, day or night.

Its speed and height depend upon the depth of the water. As the waves get closer to shore, they decrease in speed and increase in height. In the deep ocean, tsunami waves can travel at speeds of 500 to 1,000 kilometers (km) per hour. Near the shore, however, a tsunami slows down to just a few tens of kilometers per hour. A tsunami that is just a meter in height in the deep ocean can grow to tens of meters at the shoreline.

Tsunami waves can cause tremendous damage when they reach land. Damage and destruction from tsunamis is the direct result of three factors: inundation, wave impact on structures, and erosion.

Local tsunami

Local tsunami originates from a nearby source for which its destructive effects are confined to coasts within 100 km or less than 1 hour tsunami travel time from its source. A local tsunami is usually generated by an earthquake, but can also be caused by a landslide or a pyroclastic flow from a volcanic eruption.

Regional tsunami

A tsunami capable of destruction in a particular geographic region, generally within 1,000 km or 1-3 hours tsunami travel time from its source is termed as regional tsunami. Regional tsunamis also occasionally have very limited and localized effects outside the region.

Transoceanic Tsunami

Transoceanic tsunami originates from a far away source, generally more than 1,000 km or more than 3 hours tsunami travel time from its source. Less frequent, but more hazardous than regional tsunamis, are ocean-wide or distant tsunamis. Usually starting as a local tsunami that causes extensive destruction near the source, these waves continue to travel across an entire ocean basin with sufficient energy to cause additional casualties and destruction on shores more than 1,000 kilometers from the source.

2.3 Tsunami in Indian Ocean

Tsunamis are rarer in the Indian Ocean and the seismic activity is less than in the Pacific. Tsunamis are relatively rare despite earthquakes being relatively frequent in Indonesia. The last major tsunami in the Indian Ocean occurred on December 26, 2004, just off the coast of Indonesia. An earthquake of magnitude of 9.0 created a series of tsunamis that caused great destruction and loss of life throughout the Indian Ocean basin. Another remarkable one was caused by the Krakatau eruption of 1883. It should be noted, however, that not every earthquake produces large tsunamis. For example, on March 28, 2005, an earthquake of the magnitude of 8.7 hit roughly the same area of the Indian Ocean but did not result in a major tsunami. The causalities of major Indian ocean tsunami are given in the following table.

Table 2.1: Major Tsunamis in the Indian Ocean

Date	Source Location	Casualties
12 September, 2007	Southern coast of the island of Sumatra, Indonesia	9
17 July, 2006	Java Indonesia	664
28 March, 2005	Sumatra, Indonesia	10
26 December 2004	Banda Ache Indonesia	2,27,898
12 December, 1992	Flores Sea, Indonesia	2,500
19August, 1977	Sumbawa, Indonesia	189
1941	Andaman Island	5,000
26 and 27 August, 1883	Krakatau, Indonesia	36,000

Source: ITIC, 2009

2.4 Management Related to Tsunami

There is very little that can be done to prevent the occurrence of natural hazards. But while these natural disasters cannot be prevented, their results, such as, loss of life and property, can be reduced by proper planning. The Western Australian State Emergency Service identifies the following activities that can reduce the effects of tsunami (Western Australian State Emergency Service, 1999)

- Coastal land use planning
- Identification, design and construction of tsunami shelters
- Public education campaigns to increase community awareness in relation to Tsunami prevention strategies
- Improving warning and warning dissemination systems
- Development of efficient evacuation routes

Providing appropriate tsunami warning is a very important task. Many tsunami warning centers are functioning in different tsunami prone regions of the world. As part of an international cooperative effort to save lives and protect property, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service operates two regional tsunami warning centers. One is the Alaska Tsunami Warning Center (ATWC) operating in Palmer, Alaska, that serves as the regional Tsunami Warning Center for Alaska, British Columbia, Washington, Oregon, and California and another, the Pacific Tsunami Warning Center (PTWS) in Ewa Beach, Hawaii, that serves as the regional Tsunami Warning Center for Hawaii and as a national/international warning center for tsunamis that pose a Pacific-wide threat. The objective of the PTWS is to detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Pacific Basin or its immediate margins (Earth and Space Sciences, 2009). After the Indian Ocean tsunami in 2004, PTWC has extended its warning guidance to include the Indian Ocean, the Caribbean and adjacent regions until regional capability is in place for these areas. On June 2006, a tsunami warning system for the Indian Ocean was established under the leadership of the United Nations (UNESCO, 2009).

PTWC and ATWC perceive earthquake information by operating seismic stations. If the location and magnitude of an earthquake meet the known criteria for generation of a tsunami, a tsunami warning is issued to warn of an imminent tsunami hazard. The warning includes predicted tsunami arrival times at selected coastal communities within the geographic area defined by the maximum distance the tsunami could travel in a few hours. A tsunami watch with additional predicted tsunami arrival times is issued for a geographic area defined by the distance the tsunami could travel in a subsequent time period. As tsunami warning cannot be provided with long lead time tsunami watch, warning, and information bulletins are disseminated to appropriate emergency officials and the general public by a variety of communication methods, Police or Fire public announcements, the Emergency Alert System, NOAA Weather Radios or automated reverse call system. The overall process of the tsunami warning system is presented in the following figure.

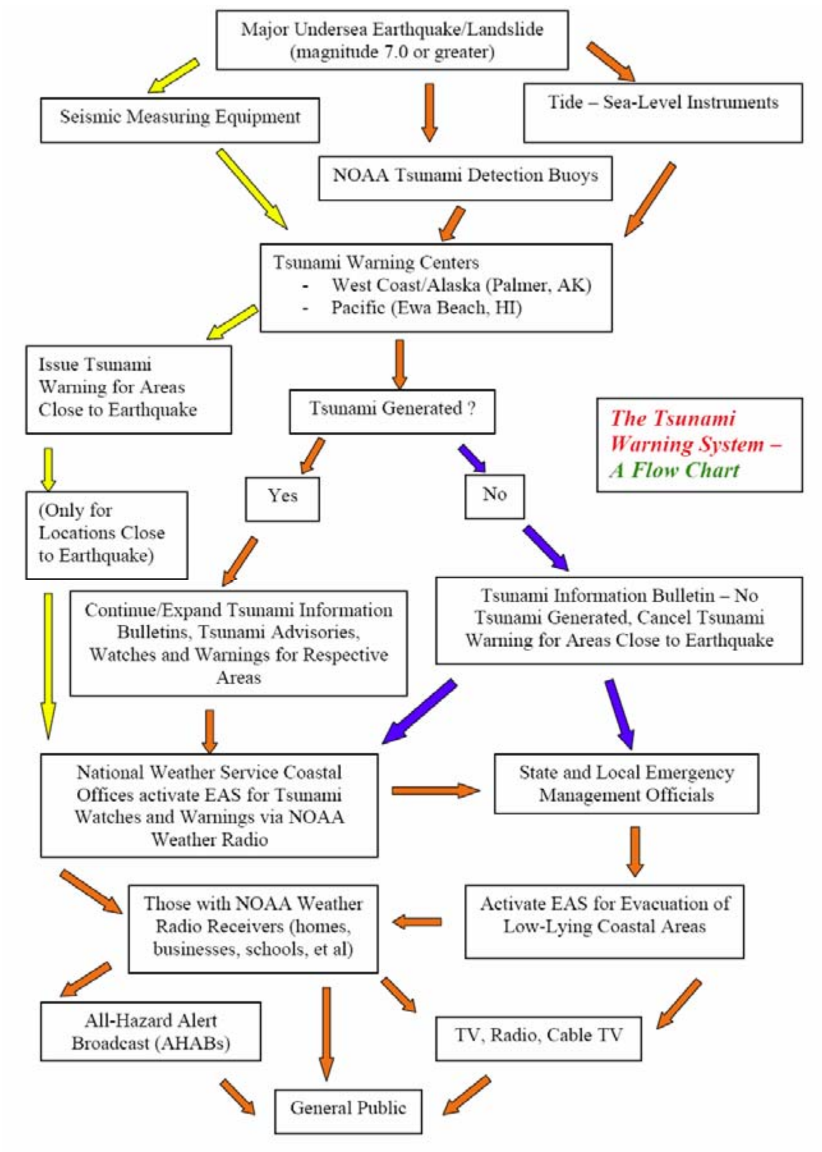


Figure 2.1: The Tsunami Warning System

Source: NOAA, 2009

Mitigation of loss of life and damage of property by tsunami can also be accomplished with proper and necessary evacuation strategy. In this regard tsunami hazard perception by the people of a coastal area is also very necessary. Hazard perception by the public is based on a technical understanding of the phenomenon, at least at the basic level, and a behavioral response stemming from that understanding and confidence of the public in the authorities responsible for warning.

In most of the tsunami prone regions there are many management strategies. The Provincial Emergency Programme of the Government of British Columbia suggests the following strategies to minimize the losses and damages from tsunami hazard.

- The best warning is the earthquake itself. If people of the tsunami prone zone feel the ground shakes severely for more than one minute, they should move to high ground immediately (at least 10-15 meters in elevation above the high tide line).
- If someone is near the shore and sees the water level rise or drop significantly, this is another sign a tsunami may be on the way. So he should move immediately to high ground.
- If possible traveling by vehicle should be avoided. Using footpaths are better. They are often the shortest and safest routes to high ground.
- If it is not possible to get to high ground, head inland, away from the coast. If this is also not possible, go to an upper story of a sturdy building or get on its roof. Concrete buildings are the safest.
- As a last resort, climb a strong tree.
- The upper floors of large concrete and steel buildings are frequently safe havens.
- People should stay at high ground until the official "All Clear" notification has been issued. Tsunami wave action can last 12 or more hours with the most dangerous waves arriving in the first 5-6 hours.
- If someone is in deep water (at least 200 fathoms or 400 metres) when a tsunami warning is issued, he/she should stay there. Tsunami waves are small in deep water and probably would not cause any damage. He/she should tune in to local radio station for updates.
- If someone is still in the harbor when a tsunami warning is issued, he/she may have time to get to deep water. But he/she should not motor the boat to open water if it is too close to the wave arrival time.
- If someone is in a floatplane in a harbour, he/she should take off as soon as possible. Land safely on a lake or another area not at risk.

In most cases tsunami warnings are issued with a very short lead time (less than 2 hours). So as a part of preparedness activity it is also important to activate the ground and air crews. This will assist in identifying areas of concern and a timely response. After the impact of a tsunami on a community, the main response tasks will be damage assessment, treatment of the injured and rescue of trapped persons. According to the Western Australian State Emergency Service the following post impact response activities should be considered by tsunami managers at all levels (Western Australian State Emergency Service, 1999):

- Identification, reporting and treatment of injured persons
- Location and rescue of trapped persons
- Survey and assessment of damage
- Clearance of debris from roads and ports
- Reopening of ports
- Return of evacuees
- Sheltering of the homeless

- Temporary repair of damaged buildings
- Reopening of roads
- Recovery, recording and storage of deceased persons
- Assessment of the need for post impact evacuations
- Re-establishment of communications systems
- Establishment of procedures to deal with media enquires

2.5 Management Considerations for Tsunami

Bangladesh is a country with a very flat topography. As most of the coastal area lies within a elevation of 3-4 meter, it is not possible for the coastal people to take shelter in 10-15 meter high lands. The only options left for coastal people to take shelter during tsunami are cyclone shelters or high rise buildings.

Tsunami warning is issued with a very short lead time. According to an IWM study on inundation risk map (IWM, 2008), the lead-time for tsunami is 50 minutes to 6 hours. So, in the worst case after getting the warning a maximum of 30 minutes may be available for people to take shelter in safe places. But within this very short time they might travel not more than half a kilometer. So, people should take shelter in nearby cyclone shelters or high rise buildings, which could withstand tsunami.

However, for being prepared for tsunami, people must be aware about the event. The managers should conduct public education/awareness campaigns to make the people of the coastal areas aware about tsunami and its symptoms, the tsunami warning system and the precautionary measures that they should take. The managers should also take all necessary preparations to be prepared for hazard, such as establishment of a tsunami warning dissemination network. Tsunami warning might be disseminated to the community through miking or megaphone or by using sirens. civil defense should also be prepared in tsunami prone areas.

Chapter 3
Spatial Location of Cyclone Shelters

3.1 Introduction

Cyclone shelters are being constructed for over the last 30 years in the coastal area of Bangladesh. Spatial location of these shelters is very important for assessing the future needs of shelters and also for shelter management issues.

3.2 Approach

Based on initial literature review and the methodology developed for spatial location information collection and preparation of spatial distribution maps (figure 3.1), secondary data were first collected from relevant sources like MoFDM, DMB, MCSP, DRRO, UNO, LGED, CYSMIS study etc. These data were used for developing a list of existing cyclone shelters and their related information. A questionnaire was then developed in consultation with experts and local stakeholders for collecting information of existing cyclone shelters. The questionnaire was synchronized based on available secondary information and additional data needed for shelter management. The questionnaire combined a wide range of information, such as, location, coordinates, description of the shelter, shelter type, construction agency and period, funding, details of structural elements, capacity and number of people taking shelter, various facilities present in the shelters etc. Primary data of cyclone shelters were collected through field survey using the questionnaire. During primary data collection the spatial location of each shelter was recorded by GPS and pictures of shelters were taken. After data collection through the field survey data entry was carried out and all collected information were then stored in an MS Access database.

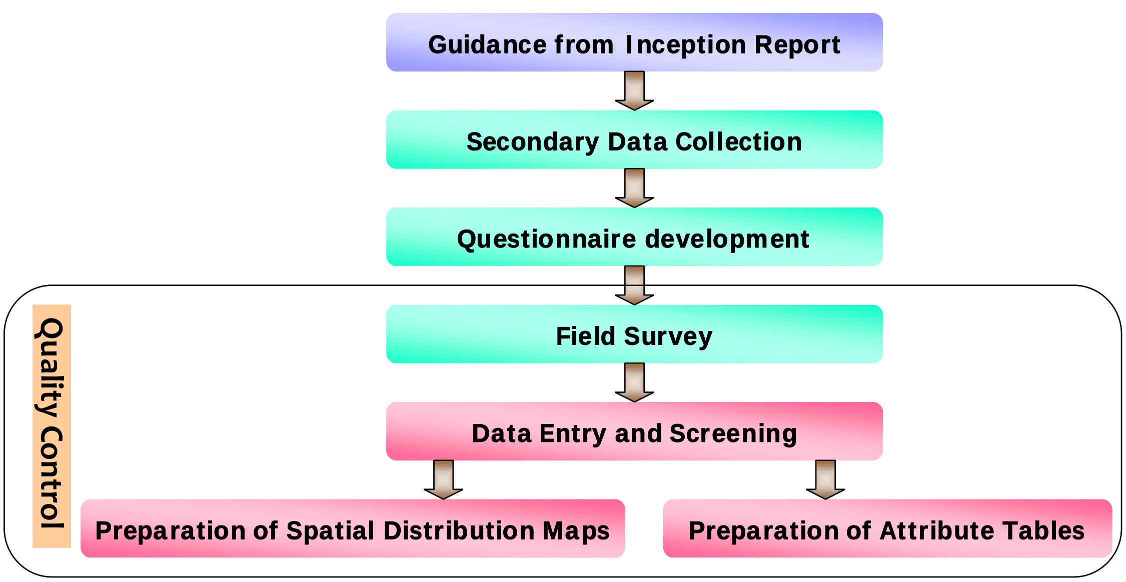


Figure 3.1: Methodology for preparing spatial distribution maps and attributes

Based on the information collected during the questionnaire survey, Upazila-wise spatial distribution maps were prepared using a GIS tool (ArcGIS). The maps were prepared using the Bangladesh Transverse Mercator (BTM) projection and JICA suggested parameters. The base maps were prepared comprising roads, rivers, embankments, administrative boundaries (upazila and union), settlements and forests using the National Water Resources Database (NWRD) and recent available satellite images (mainly IRS panchromatic images of 2002-2004). Using all these information, spatial distribution maps and attributes of cyclone shelters were prepared. The Quality of field survey and data collection, data entry and screening and preparation of maps and attribute tables were ensured by a quality control process.

3.3 Survey Results

The survey results are presented in the spatial distribution maps. The spatial distribution maps were prepared for each upazila of the study area, a sample of which is shown in figure 3.2. The sample map shows the location of cyclone shelters along with the respective upazila head-quarters, administrative boundaries (district, upazila, union), road network, rivers, embankments, settlements and forests. The spatial locations of cyclone shelters were identified by GPS reading taken during field survey. The maps include legends, the north direction and scale. The attribute tables of cyclone shelters include mainly four types of information, shelter ID, location, capacity and management related information.

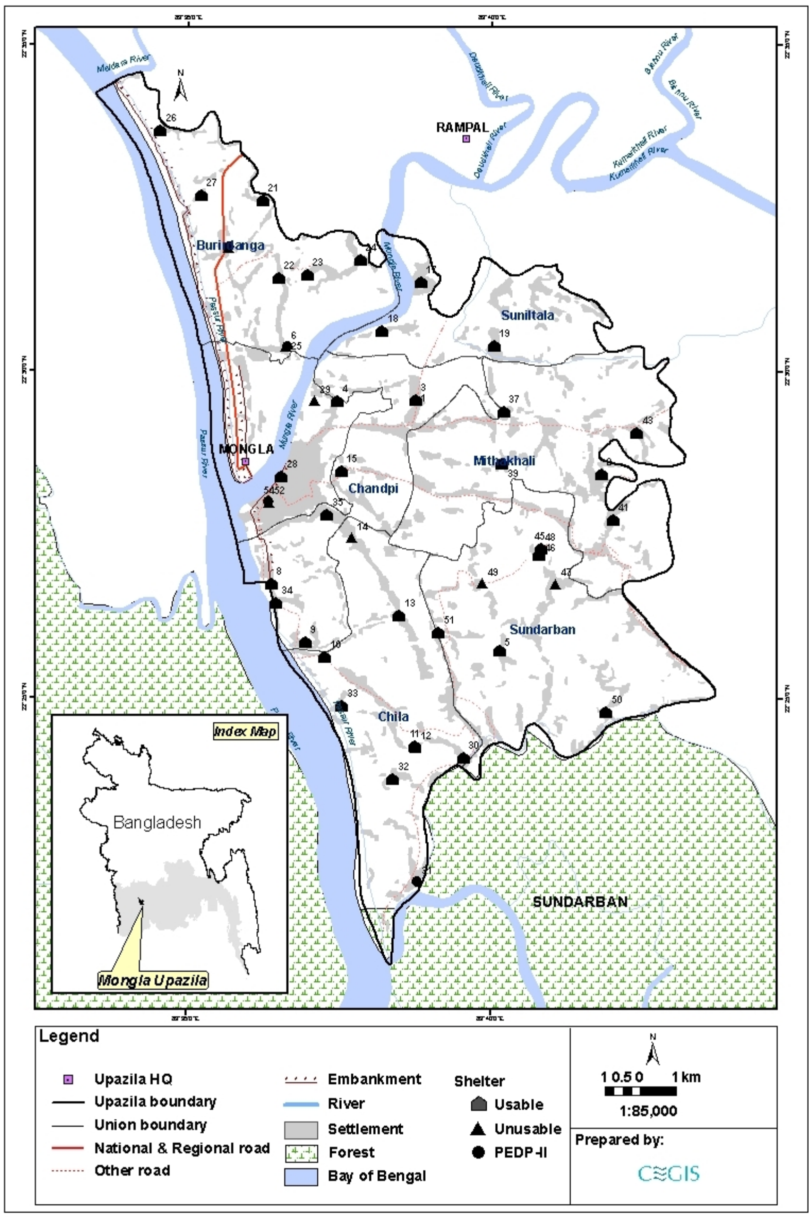


Figure 3.2: Spatial distribution map of Kala Para upazila, Patuakhali district

The shelters shown in maps were mainly separated in two broad categories, shelters and shelter-cum-killas. Each of these categories was classified into two groups (usable and unusable) based on the condition of the shelter. Figure 3.3 presents a map of the coastal area showing the locations of all existing cyclone shelters. There are a total of 2,583 cyclone shelters and 924 school buildings (PEDP-II) located in the coastal districts. Figure 3.3 shows that the concentration of shelters is higher in the east coast (Noakhali, Chittagong, Cox's Bazar and Feni) than the west coast. The are fewer shelters in the west coast districts.

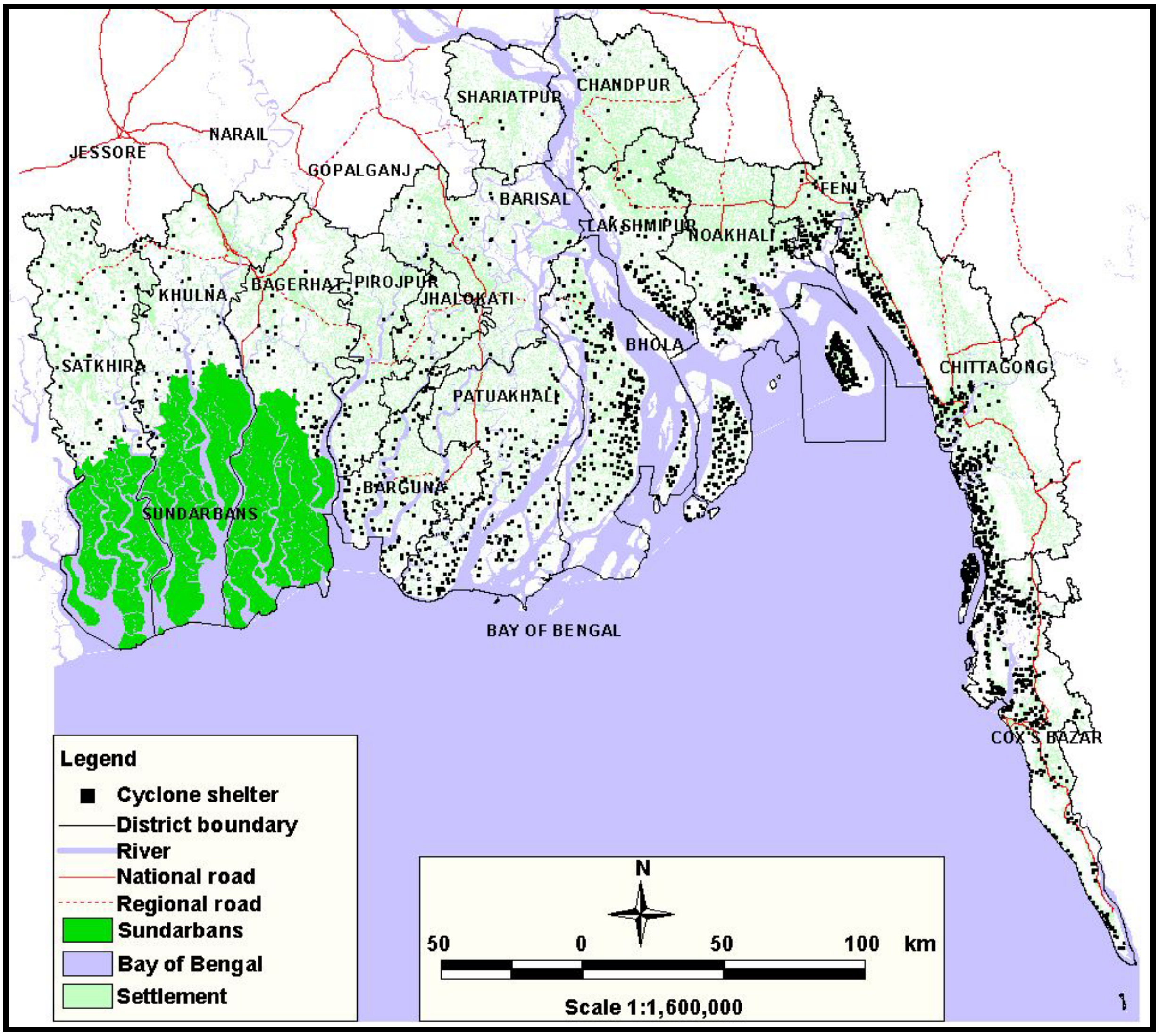


Figure 3.3: Spatial locations of cyclone shelters in the coastal area

3.4 Result Analysis

During the field investigation a total of 3,841 cyclone shelters were surveyed. Among these 67% (2,583) are usable, 6.4% (246) not usable, 2.3% (88) washed away/destroyed/dismantled and 24% (924) open ground floor structures/schools which are constructed under Primary Education Development Programme, Phase II (PEDP-II). Although people take shelter in PEDP-II structures in worst cases, but these structures are not suitable as shelters. A summary of the distribution of cyclone shelters based on their conditions is presented in the following table.

Table 3.1 Distribution of cyclone shelters based on their condition

Total surveyed cyclone shelters	**3,841**
Shelters washed away/destroyed/dismantled	**88**
Unusable shelters (Beyond repair)	**246**
School/Open ground floor structures/Not suitable for shelters/PEDP-II (School constructed under Primary Education Development Programme, Phase II)	**924**
Usable Shelters	**2,583**

The population of these 16 coastal districts was 31 million in 2001 while the projected population in 2009 is 38.2 million. There are 2,583 usable cyclone shelters located in this area with the capacity to serve 2.8 million people, which is only 7.3% of the total coastal population. A district-wise Summary of Cyclone Shelters and PEDP-II Buildings along with population data is presented in the following table.

Table 3.2: District-wise Summary of Cyclone Shelters and PEDP-II Buildings

District	Population (2001)	Population (2009 Projected)	Nos of Upazila	Shelters washed away/ destroyed	Unusable	PEDP-II	Usable	
							Nos	Capacity
Bagerhat	1,549,031	1,791,666	8		11	54	98	86,159
Barguna	848,554	1,010,525	5	2	10	59	147	147,590
Barisal	2,355,967	2,658,166	9		-	15	37	41,050
Bhola	1,703,117	2,055,226	7	49	53	195	429	390,050
Chandpur	2,271,229	2,714,329	6		1	58	21	26,350
Chittagong	6,612,140	8,657,530	22	11	29	71	573	683,010
Cox`s Bazar	1,773,709	2,318,343	7	6	10	104	504	607,310
Feni	1,240,384	1,455,142	4	3	12	5	57	61,275
Jhalokati	694,231	899,504	4		2	3	12	7,650
Khulna	2,378,971	3,079,694	6		2	46	77	76,541
Lakshmipur	1,489,901	1,761,806	4	5	10	119	106	118,000
Noakhali	2,577,244	3,034,143	*3*	5	33	16	245	266,112
Patuakhali	1,460,781	1,794,098	7	7	72	103	165	157,675
Pirojpur	1,111,068	1,250,245	6		1	33	36	32,300
Satkhira	1,864,704	2,430,898	6		-	16	65	55,071
Shariatpur	1,082,300	1,280,954	4		-	27	11	14,375
Total	**31,013,331**	**38,192,269**	**108**	**88**	**246**	**924**	**2,583**	**2,770,518**

A district-wise summary of cyclone shelters is presented in figure 3.4. The figure shows, Bhola, Chittagong and Cox's Bazar districts have the highest and Shariatpur, Jhalokati and Chandpur districts have the lowest number of shelters.

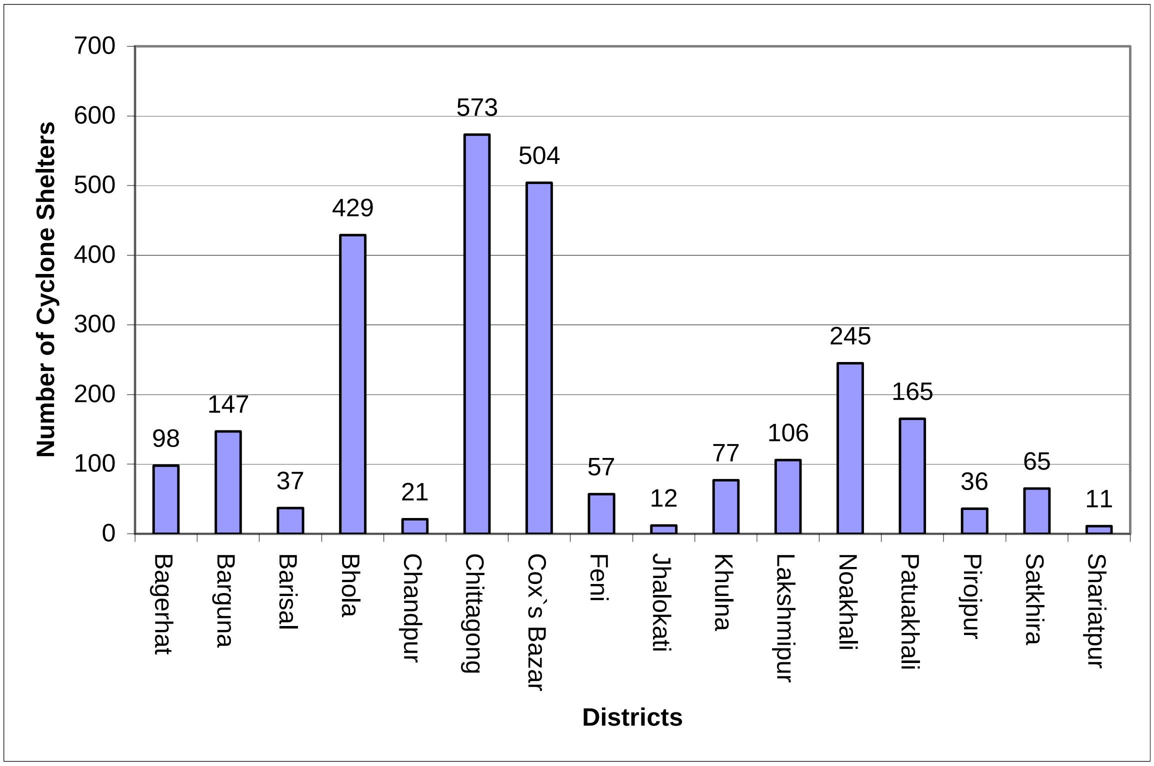


Figure 3.4: District-wise distribution of cyclone shelters

Cyclone shelters are constructed for multipurpose use. It was found from field investigation that among 2,583 shelters 82% was used as education centres, 8 % as offices, 1% as community centres, 1% as health centres and 6% do not have any normal time use. A summary of the use of cyclone shelters during normal time is presented in figure 3.5.

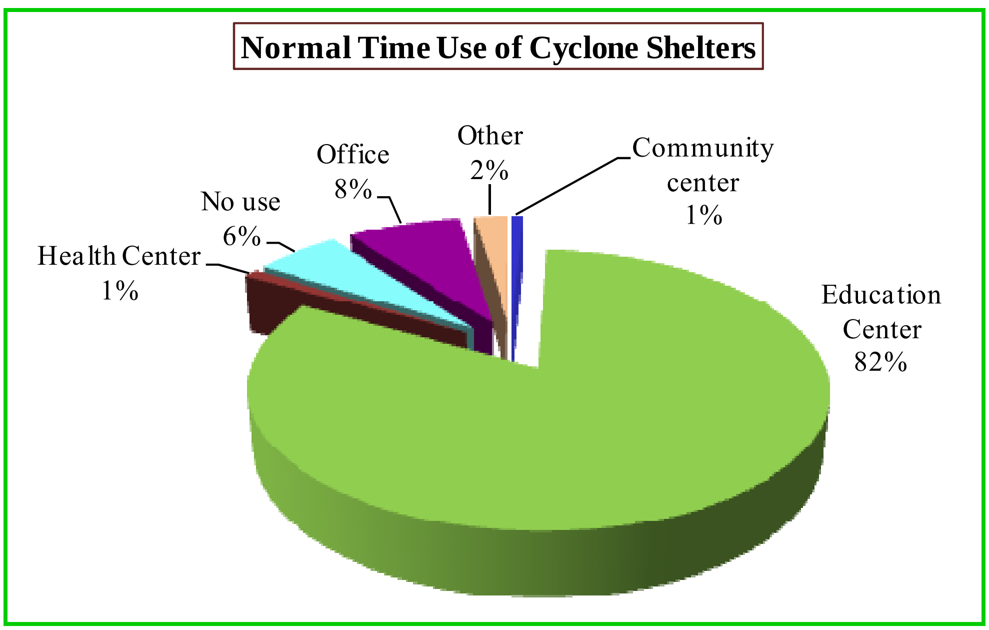


Figure 3.5: Normal time use of cyclone shelters

The access roads to the cyclone shelters were divided into three categories, good, average and poor based on their condition. The condition of the access roads to the cyclone shelters are presented in figure 3.6. The figure shows that the access roads are in average condition in most of the districts. They are, however, in good condition in the districts of Jhalokati (for 58% of the shelters), Lakshmipur (for 36% of the shelters), Chittagong (for 35% of the shelters) and Stakhira (for 31% of the shelters), and poor in the districts of Patuakhali (for 60% of the shelters), Barguna (for 58 % of the shelters), Chandpur (for 57% of the shelters) and Khulna (for 55% of the shelters).

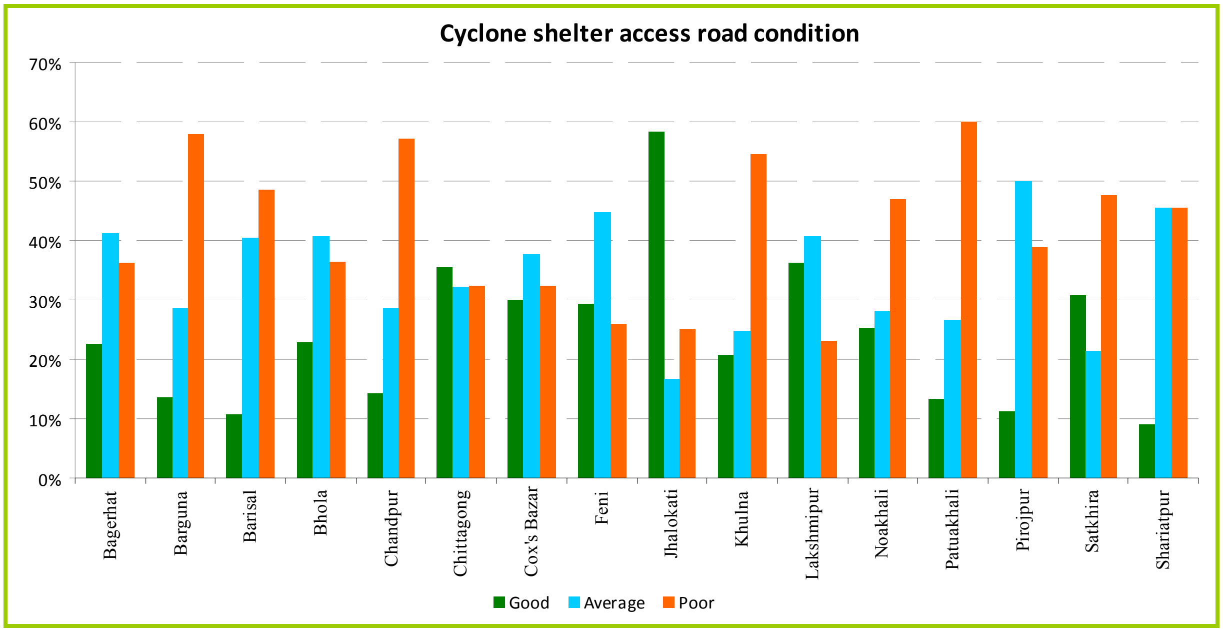
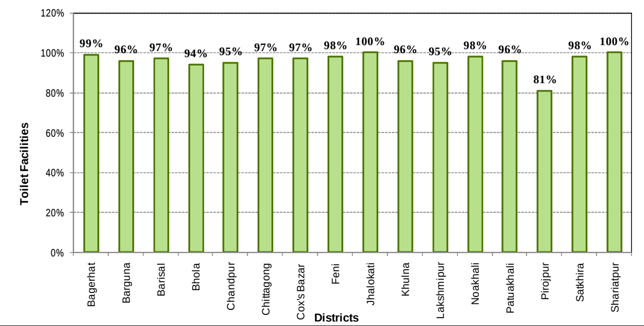


Figure 3.6: Condition of access roads to the cyclone shelters

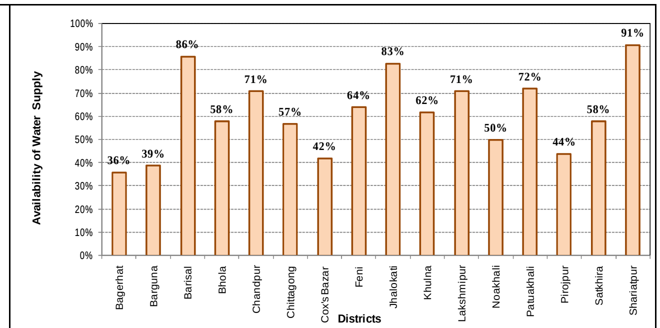
During the field survey information on both shelter location and shelter attribute were collected. The facilities available in the shelters are presented in figure 3.7. The figure shows that almost 100% of the shelters have sanitation facilities, but water supply is poor. It can be noted that over 80% of the shelters in Shariatpur, Barisal and Jhalokati districts and less than 50% of the shelters in Barguna, Bagerhat, Cox's Bazaar and Pirojpur districts have water supply facilities.

As we know women, children, disabled and elderly people are more vulnerable to the impact of cyclones than others. The shelters need to provide necessary and adequate facilities (separate space and toilet for women, and access facilities for the disabled) so that they are willing to come to the shelters during cyclones. However, the figure shows that most of the shelters fail to provide facilities for women. Only 32% of the shelters of Lakshmipur, 30% of Noakhali and 27% of Shariatpur have separate space for women. None of the shelters in Jhalokati district has separate spaces for women. There are also no separate toilets for women in many shelters. However, every shelter in Shariatpur district has separate toilets for women. In Barisal 70%, in Khulna 62%, in Chandpur 57%, and in Feni, Noakhali and Satkhira district 52% of the shelters have separate toilet facility for women. Most of the shelters lack in access facility for disabled. Only Chandpur (5%), Barguna (3%), Bhola (2%), Cox's Bazaar (1%), Lakshmipur (1%) and Noakhali (1%) districts have access facilities for disabled.

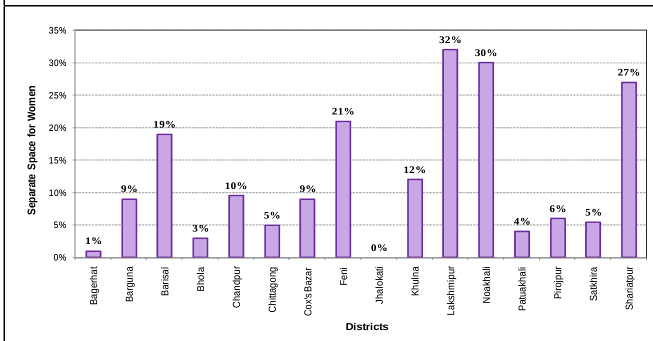
Cyclone shelters should have storage facilities for the valuable goods of people who take shelter in them during cyclones. However, this facility too is not available in many shelters. The following figure shows that 33% of shelters in Lakshmipur, 29% in Noakhali, 19% in Barisal and 17% in Pirojpur have storage facilities for valuable goods.



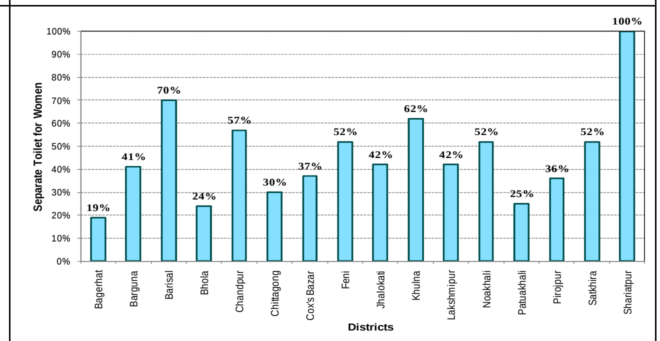
Toilet facilities of cyclone shelters



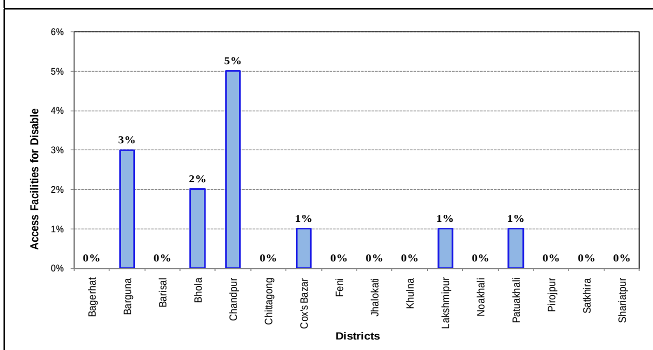
Water Supply facilities of cyclone shelters



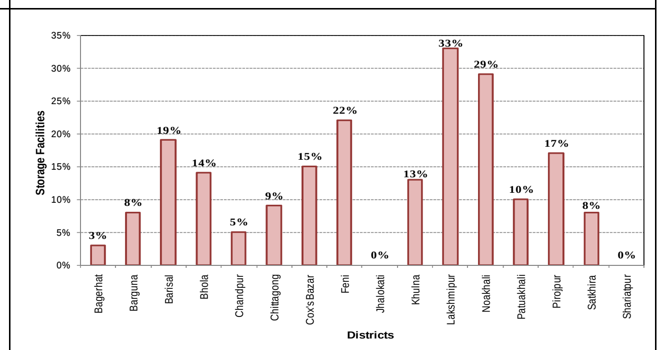
Available space for women in cyclone shelters



Separate toilet facilities for women in cyclone shelters



Access facilities of cyclone shelters



Storage facilities of cyclone shelters

Figure 3.7: Available facilities in cyclone shelters in different districts

Cyclone shelters should have community participation in their management committees. It is also essential to have maintenance fund for emergency maintenance of cyclone shelters. Survey results shows that, only 18.6% (480 shelters) shelters have community participation in their management committees. It is also found that, only 3% (78 shelters) shelters have a maintenance fund for cyclone shelter management. Table 3.3 presents the district-wise distribution of cyclone shelters having community participation in management committees and maintenance funds. Based on the table, it is seen that, Barisal and Bhola districts community participation is more than 40%, while in Shariatpur community participation is nil. In most of the districts, maintenance fund availability is nearly zero percent. This information depicts the lack of maintenance of the cyclone shelters.

Table 3.3: Cyclone shelters having community participation and maintenance fund

District	Total No. of Shelters	Community Participation		Maintenance Fund	
		No. of Shelter	%	No. of Shelter	%
Bagerhat	98	16	16.33	1	1.02
Barguna	147	45	30.61	8	5.44
Barisal	37	16	43.24	14	37.84
Bhola	429	179	41.72	2	0.47
Chandpur	21	1	4.76	-	0.0
Chittagong	573	52	9.08	16	2.79
Cox's Bazar	504	70	13.89	9	1.79
Feni	57	6	10.53	-	0.0
Jhalokati	12	1	8.33	-	0.0
Khulna	77	8	10.39	-	0.0
Lakshmipur	106	7	6.60	-	0.0
Noakhali	245	16	6.53	1	0.41
Patuakhali	165	44	26.67	23	13.94
Pirojpur	36	8	22.22	3	8.33
Satkhira	65	11	16.92	1	1.54
Shariatpur	11	-	0.00	-	0.0
Total	**2583**	**480**	**18.58**	**78**	**3.02**

3.5 Need for Information Update

Cyclone shelters are providing safe haven facilities to the coastal people. In order to reduce risk due to natural hazards, every year new shelters are being constructed. So, the information about number and spatial locations of shelters is always changing. In order to plan for requirement of new shelter, this type of information is very important. Some system should exist within corresponding authorities like DMB to update the information regarding cyclone shelters.

Chapter 4

Structural Vulnerability of Cyclone Shelters

4.1 Introduction

Cyclone shelters are used as safe havens in the coastal area for protecting the lives of people during cyclone or tsunami induced storm surge. Therefore, the structural strength of the shelters in disaster situations like cyclone, tsunami and earthquake is of great importance.

4.2 Approach

The structural strength of cyclone shelters were assessed through several steps such as:

- Grouping of cyclone shelters based on similar design type
- Field strength tests of cyclone shelters
- Analysis of the structural strength of the shelters using suitable analysis tools under different hazard conditions like cyclone, tsunami and earthquake and
- Vulnerability analysis of shelters using spatial location, design type and hazard risk maps

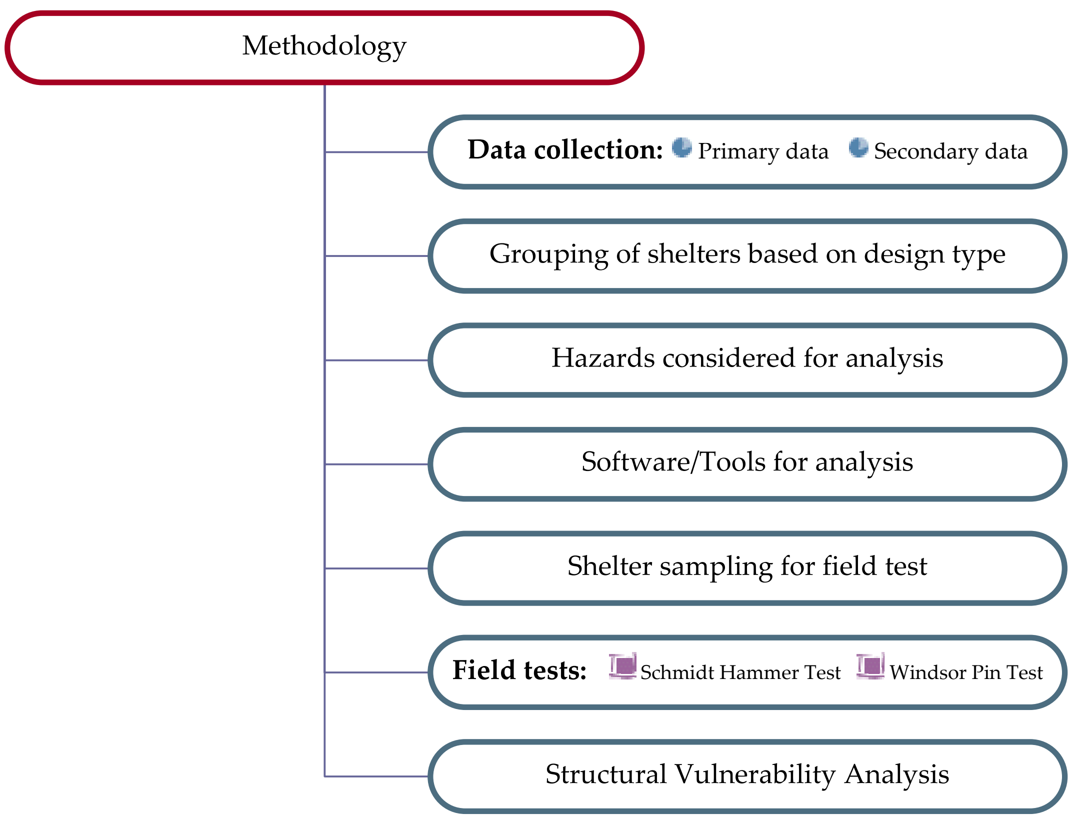


Figure 4.1: Methodology of Structural Vulnerability analysis of shelters

Figure 4.1 describes the overall methodology of structural vulnerability analysis for cyclone shelters. The structural strength analysis was conducted with the help of primary data collected through a field survey and various necessary secondary data collected from relevant organizations. Based on the structural dimensions, construction and funding agencies and period of construction, the cyclone shelters were grouped into thirteen major design types. As a part of the study, field tests of cyclone shelters have been carried out. Schmidt Hammer test and James Windsor Pin test have been conducted for assessing the concrete strength of structures. Based on the test results, concrete strength of different types of buildings has been assumed for structural analysis. Linear 3D Finite Element Method (FEM) analyses have been conducted for assessing the structural strength of the shelters. In the present study, ETABS (version 8.5) has been used for this purpose. Structural analyses have been conducted for all 13 types of shelters and for forces induced by tsunami, cyclone and earthquake. After the FEM analysis, the results are combined with the spatial locations of the shelters. With the help of recently developed inundation risk maps under the study titled "*Use existing data on available digital elevation models to prepare useable tsunami and storm surge inundation risk maps for the entire coastal region*" (IWM, 2008), structural vulnerability analysis has been carried out. The vulnerability analysis has been accomplished using GIS tools, by combining inundation risk maps for cyclone and tsunami, as well as design type of the shelters and shelter capacity to withstand storm surge, wind and earthquake forces.

4.3 Shelter Type Based on Design

Various types of structures have been constructed by a number of organizations, which are serving as cyclone shelters. Based on the primary data collected from the field survey, similar type of structures were grouped according to structural dimensions, construction and funding agencies and year of construction. The shelters were assembled into 13 major groups classified as types 1 to 13. Besides these, there are some other types of shelters as well.

A brief description of all 13 types of shelters are presented in the following section. Table 4.1 presents a summary of the structural elements of these cyclone shelters.

Type 1

Figure 4.2: Type 1 cyclone shelter

Type 1 shelters were constructed by the Bangladesh Red Crescent Society (BDRCS)/ Caritas/World Vision/CCDB and funded by BDRCS/Caritas/CAFOD/World Vision/German Red Cross/CCDB. According to the survey, there are 377 type 1 shelters, spread over 37 Upazilas of 12 Districts. The shelters were constructed between 1976 and 2003. Most of them have multipurpose use.

The building is a RCC framed structure. There are 6 rectangular bays measuring 9.85 x 15.75 ft. and two triangular bays at the centre. The structure is supported by 19.685 inch dia round columns and 14.75 x 9.84 inch rectangular beams. A 6 ft wide straight run stair connects the verandah from the ground. Two additional 3 ft wide stairs at each end of the building run from first floor to the roof.

The structure is a two-storied building with an open ground story about 10 ft high. The shape of the building is like an arrow-head. There is a cantilever part at the outer periphery of the building.

Table 4.1: Summary of Structural Components and Elements of Cyclone Shelters

	Building Data	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Type 11	Type 12	Type 13
1	Costructing Agency	BDRCS/ CARITAS/ World vision/ CCDB	BRAC/ LGED	LGED	EU/ PMED	LGED	Grameen Bank	JICA	JICA	LGED/ CDSP	PWD	Facilities Department	LGED	LGED
2	Funding Agency	BDRCS/ CARITAS/ World vision/ CCDB/ CAFOD/	BRAC	Cabinet Division, GoB	EU	KFW	Grameen Bank	JICA	JICA	CDSP/ Netherlands govt.	GoB/ World Bank	Saudi Grant	GoB	PEDP-II/ ADB/ GoB
3	Floor to ceiling height in first & second floor (ft)	9.84	3.28, 9.84	10	9.84,8	10.83, 6.89	9.35	10.83, 9.84	10.83, 8.37	10, 7	11	9.84	10	10
4	Ground to First floor height (ft)	9.84	13.78	10	11.81	10.83	9.35	13.12	14.11	10	17	12	10	11.5
5	Total Length of Structure (ft)	74.8	103.38	89.67	49.54	146.49	42.65	75.46	91.86	98.5	55.5	40.68	91.92	61.25
6	Total Width of Structure (ft)	44.23	89.65	27.42	49.02	29.86	50.2	39.37	46.1	29.67	38	42.16	69	27.92
7	Total Number of Bays	6 rectangular & 2 triangular	6	6	4	9	6	6	8	6	8	4	8	7

	Building Data		Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	Type 8	Type 9	Type 10	Type 11	Type 12	Type 13
8	Bay Length (ft)	Longitudinal Direction	9.25	Length is variable	15.92, 9.83,16	20.67, 8.2, 10.33	10.66, 17.88	14	9.84, 13.12	11.48	16,10.83, 18, 17.83	9.25, 4.58, 4.67	10.17	8.75	11.42, 6.42, 5, 20, 14.42, 14.84, 6.25 & 13.58
		Transverse Direction	21	Length is variable	9.25,18.17	9.12	13.53,6.48, 9.84	25	15.42, 8.63	15.75, 9.84, 4.76	9.67, 20	12, 10.5	17.72, 6.73	4.63, 9.25, 9.42	11.83, 7.83, 6, 5.83, 5.75, 2.83, 5.25, 9.83, 2
9	Size of Columns (in)		19.69 dia	Inner 11x11, Outer 31.5x9.85	Inner 12x12, Outer 12x15	Inner 15x15, Outer 25x15	20x12	15 dia	15.75 x15.75	15.75 x15.75	Inner 10x10, Outer 10x15	20x12	Inner 15x12, Outer 18x15	Inner 10x10, Outer 15x10	Inner 10x10, Outer 10x12
10	Size of Beams (in)		14.75x9.84	15.75 x 9.84	Inner 15x12, Outer 20x12	Inner 18x10, Outer 18x11	20x13	Inner 16x10, Outer 18x12	18x13	18x13	18x10	Inner 18x10, Outer 30x10	15x10	21x10, 15x10, 36x20, 24x10, 12x10, 13x10	Inner 12x10, Outer 18x10
11	Width of Stair (ft)		Main 6ft 1st floor to roof 3ft	3.28	4.3	5.25	7.88	3.33	4.3	5.2	4.8	4.63	4	Inner 3.3, outer 8	Inner 3.67, Outer 4.25
12	Number of Windows		12	12	18	22	22	38	21	24	11	44	48	35	11
13	Number of Doors		2	11	12	6	16	12	12	7	4	8	6	21	4

Type 2

Figure 4.3: Type 2 cyclone shelter

Type 2 shelters were constructed and funded by BRAC/ Local Government and Engineering Department (LGED). According to the survey total number of type 2 shelter is 19 and these shelters are spread in 3 Upazilas of 2 Districts. Most of the shelters were constructed in Kutubdia area. The construction period is 1986 - 1999.The design of the shelters show a distinct difference in conceptual and formal aspects from those designed by other agencies. At normal time most of these shelters are used as Community centres, Education centres or offices. Only 3 shelters are used for other purposes e.g. to live in or Madrassa, while 5 are not used at all during normal time.

The structure has 10 internal columns to support the beams. The inner column size is 11 x 11 inch and the outer column size is 31.5 x 9.85 inch. The structure is supported by 15.75 x 9.84 inch rectangular beams. The outer wall is also 9.84 inch thick. BRAC shelters have a single stair 3.28 ft wide.

This is an eye-shaped two-storied building with a 17 ft high open ground story. There are two shear walls only at one end of the building.

Type 3

Figure 4.4: Type 3 cyclone shelter

This type of Shelters were constructed by LGED and funded by the Cabinet Division of GoB. According to the survey there were only 4 type 3 structures spread over 4 upazilas of 4 different districts. These shelters were constructed during 1991-2003. One of these shelters is used as Police Camp and the rest as education centres.

The buildings are RCC framed structures. The inner columns are 12″ square and outer columns are 12 x 15 inch. The structure comprises 20″x 12″ outer beams and 15″x12″ inner beams. There are 6 rectangular bays measuring 15.92, 9.83 and 16 ft in X and in Y directions; the spacing are 9.25 and 18.17 ft. These shelters each comprise a 4.3 ft wide stair located at one side of the structure.

It is a three-storied building having planer regular grids. The ground story is open and 10 ft high. The staircase is asymmetrically placed in the building.

Type 4

Figure 4.5: Type 4 cyclone shelter

These shelters were constructed by PMED/EU and funded by EU. A total of 194 Type 4 cyclone shelters were surveyed and found spread over 8 upazilas of 6 districts. The shelters were constructed between 1955 and 2003. Normally all shelters are used as Education centres, but one shelter is used as a health centre and another shelter is not used during normal time.

The structure has RCC framed structure. The inner columns are 15″ square and the outer columns are 25″x15″. The structural frame includes 18″x11″ outer beams and 18″x10″ inner beams. There are 4 rectangular bays measuring 20.67, 8.2 and 10.33 ft in X and Y directions with each bay having a spacing of 9.12 ft. The EU type shelters have 5.25 ft wide single stair. This type of shelter is a two-storied building with an open ground story about 12 ft high.

Type 5

Figure 4.6: Type 5 cyclone shelter

Shelters of this design type were constructed by LGED and funded by German Grant (KFW). According to the survey there are a total of 112 Type 5 shelters spread over 52 upazilas of 15 districts. These shelters were constructed during is 1972-2008. All type 5 shelters are used as Education centres during normal time.

These buildings are RCC framed structures. There are 9 rectangular bays measuring 10.66 ft (first and last spacing) and 17.88 ft for middle spacing in X direction. In Y direction the spacings are 13.53, 6.48 and 9.84 ft. The structure comprises 20″x12″ columns, 20″x13″ beams and 7.88 ft wide stairs in the middle.

This type of shelter is a two-storied building with planar regularity. The open ground story is about 11 ft high.

Type 6

The Type 6 shelters were constructed and funded by Grameen Bank. A total of 20 shelters of this type were surveyed and found spread over 11 Upazilas of 5 Districts. The shelters were constructed between 1992 and 2004. Normally all shelters are used as Grameen Bank offices, but one is used as an education centre, two for family and banking purposes and two have no normal time use.

Figure 4.7: Type 6 cyclone shelter

The Grameen Bank type shelter is hexagonal in shape each side of which measures 25 ft. The structure stands on 18 round columns 15″ in diameter. The structure comprises 18″x12″ outer beams and 16″x10″ inner beams. The stair is placed outside the hexagon and supported on 4 round columns. The width of the stair is 3.33 ft.

This type of shelter is a hexagon shaped two-storied building. Being hexagonal the plan is regular. The open ground story height is about 11 ft.

Type 7

Figure 4.8: Type 7 cyclone shelter

Shelters of this type were constructed by the Japan International Cooperation Agency (JICA)/LGED and funded by JICA. A total of 45 Type 7 cyclone shelters were surveyed and found spread over 12 upazilas of 4 districts. The shelters were constructed between 1994 and 2008. Most of the shelters are used as education centres, 3 shelters are used as community centres, offices or other purposes while 3 shelters have no normal time use.

This type of structure has three variants having 3,4 or 5 classrooms. The stair is on the side of the structure and has a width of 4.3 ft. There are 6-8 rectangular bays measuring 9.84 ft for the first span and 13.12 ft for the other spans in X and Y directions. There are three spans measuring 15.42 and 8.63 ft. The structure is supported by 18″x13″ rectangular beams and 15.75″ square columns.

This is a two-storied building with open ground story. The ground story is more than 13 ft high and the columns are arranged in a regular grid.

Type 8

This type of shelters were constructed by JICA/LGED and funded by JICA. A total of 28 Type 8 cyclone shelters were surveyed and are spread over 9 Upazilas of 3 Districts. The shelters were constructed between 1995 and 2005. All these shelters are now used as education centres.

Figure 4.9: Type 8 cyclone shelter

Type 8 structures have three variants having 3,4 or 5 classrooms. The stair is in the middle and is 5.2 ft wide. There are 6-8 rectangular bays measuring 11.48 ft each in X and Y directions. There are four spans measuring 15.75, 9.84 and 4.76 ft. The structure is supported by 18″x13″ rectangular beams and 15.75″ square columns.

This type of shelters are two storied buildings with more or less regular planer grid. These buildings however, have two reentrant corners. The open ground story is 14 ft high.

Type 9

Figure 4.10: Type 9 cyclone shelter

This design type has been constructed by LGED/Char Development and Settlement Project (CDSP) and funded by CDSP/Netherlands Government. According to the survey there are a total of 33 Type 9 cyclone shelters spread over 4 upazilas of 2 districts. There are some other types of shelters constructed by LGED that are very similar to Type 9 shelters. The type 9 shelters were constructed in 2000-2008 and most of them are now used as education centres. However, three shelters are used as offices and 3 have other uses, while only 2 shelters are used as health centres. Other shelters have no normal time use.

The building comprises RCC framed structural system. The inner columns are 10″ square, outer columns are 10″x15″. The structure is supported by 18″x10″ rectangular beams. There are 6 rectangular bays measuring 16, 10.83, 18 and 17.83 ft in X and Y directions the spacings of which are 9.67 and 20 ft. This type of building has a 4.8 ft wide single stair.

There is open ground story in this structure. The ground story height is 10 ft.

Type 10

This type of shelter was constructed by the Public Works Department (PWD) and funded by GoB/World Bank/PWD. A total of 214 shelters of this type were surveyed and these shelters are spread over 37 Upazilas of 9 Districts. The shelters were constructed between 1947 and 2002. Most of the shelters are used as education centres, offices and for other purposes while two shelters are used as health centres. A few have no normal time use.

Figure 4.11: Type 10 cyclone shelter

The structural design of the shelter is based on RCC framed system. The building has 8 bays measuring 9.25 ft for 1st, 2nd, 7th, 8th span; 4.58 ft for 3rd and 6th span and 4.67 ft for 4th and 5th span in X direction. The dimension in Y direction is 12 and 10.5 ft. The structure is supported by 20″x12″ columns. The outer beams are 30″x10″ and inner beams are 16″x10″. The building has a stair in front side having 4.63 ft width.

These type of structures are three storied buildings with a 17 ft high open ground story. Most of the frames in shorter direction are single bay frames.

Type 11

Figure 4.12: Type 11 cyclone shelter

Shelters of this design type were set up by the Facilities department and funded by Saudi Grant. A total of 446 Type 11 cyclone shelters were surveyed and these shelters are spread over 36 upazilas of 5 districts. The shelters were constructed during 1991-2000. Normally, these shelters are used as education centres and health centres. Only 1 shelter is used as mosque and 3 have no normal time use.

The buildings are RCC framed structures. There are 20 structural columns and the inner columns are 15″x12″ and outer ones are 18″x15″. The structure is supported by 15″x10″ beams. There are 4 rectangular bays measuring 10.17 ft each in X and Y directions and the spacings are 17.72 ft, 6.73 ft and 17.72 ft. These shelters have a 4 ft wide central stair.

This type of shelters are three storied buildings with a 12 ft high open ground story. The plan is completely regular.

Type 12

This type of shelters were constructed by LGED and funded by GoB/LGED. According to the survey there are a total of 133 type 12 shelters that are spread over 39 upazilas of 12 districts. The shelters were constructed between 1997 and 2008. Most of these shelters are used as education centres and offices, however, 5 are used for other purposes and 1 has no normal time use.

Figure 4.13: Type 12 cyclone shelter

The structural design of the shelter is based on RCC frame system. The building has 8 bays measuring 11.42, 6.42, 5, 20, 14.42, 14.84, 6.2 and 13.58 ft in X direction and 11.83, 7.83, 6, 5.83, 5.75, 2.83, 5.25, 9.83 and 2 ft in Y direction. The inner columns are 10″ square, and the outer columns are 15″x10″. The structure is supported by 21″x10″, 15″x10″, 36″x20″, 24″x 10″, 12″x10″ and 13″x10″ rectangular beams. These buildings comprise two sections, one two-storied and the other three-storied. There is a straight run stair in front of the 8 ft wide two-storied section and the three-storied section has another stair that is 3.3 ft wide.

The Type 12 cyclone shelter is a complicated shaped structure with two distinct parts. The building is three storied. There is an open ground story of 10 ft height.

Type 13

Figure 4.14: Type 13 cyclone shelter

This design type was constructed by LGED and funded by Primary Education Development Program (PEDP II)/Asian Development Bank (ADB)/LGED/GoB. According to the survey tyere are 924 Type 13 cyclone shelters/buildings spread over 72 upazilas of 16 districts. The shelters were constructed during 1910-2009. Most of the shelters are used as education centres with only 5 used as offices and 9 have no normal time use.

The structure stands on 10″x12″ columns. The inner beams are 12″x10″ and outer beams are 18″x10″. There are 7 rectangular bays measuring 8.75 ft each in X and Y directions the spacings of which are 4.63, 9.25 and 9.42 ft.

The structure has two stairs, one 4.25 ft wide running straight from the ground to the first floor located at the front and the other 3.67 ft running from the ground floor to the roof located on one side of the shelter. This type of structure is a two storied building with open ground story of 11.5 ft height.

4.4 Field Tests

The field testing of cyclone shelters included two tests, the *Schmidt Hammer Test* and the *Windsor Pin Test*. A total of thirteen shelters were selected for field testing. The Schmidt Hammer test was carried out for 13 shelters, while the Windsor Pin test was conducted for 7 shelters.

The Windsor pin test was conducted to cross check the results of the Schmidt hammer test. The test results are presented in Table 4.2. The results show that, the concrete strength of the structures varies from 1,240 pound/sq. inch (psi) to 5,970 psi. Based on these results, the concrete strength of the different types of structures was assumed for conducting the Finite Element Method (FEM) analysis.

Table 4.2: Summary of test results of cyclone shelters

Schmidt Hammer Test Results

Design Type	Concrete Strength (psi)		
	Spot-1	Spot-2	Spot-3
Type 1	**5550**	**5340**	**3270**
Type 2	**4360**	**5110**	**4180**
Type 3	**2920**	**2400**	**3880**
Type 4	**4110**	**3120**	**3200**
Type 5	**3270**	**2950**	**2880**
Type 6	**1690**	**1240**	**3060**
Type 8 (sample 1)	**5040**	**4990**	**5260**
Type 8 (sample 2)	**4720**	**4740**	**5300**
Type 9	**3450**	**2520**	**3270**
Type 10	**3600**	**3490**	**2500**
Type 11	**2990**	**3270**	**2840**
Type 12	**3920**	**3820**	**3140**
Caritas	**2590**	**5970**	**3860**

Windsor Pin Test Results

Design Type	Concrete Strength (psi)
Type 2	**2760**
Type 4	**2740**
Type 6	**2520**
Type 8 (sample 1)	**3050**
Type 8 (sample 2)	**2930**
Type 9	**2440**
Type 11	**2810**

4.5 Finite Element Method Analysis of the Structures

Linear 3D Finite Element Method (FEM) analyses have been conducted for assessing the capacity of shelters to withstand cyclone, tsunami and earthquake. A wide spectrum of FEM software and tools are available for such analyses. In the present study, ETABS (version 8.5) has been used for this purpose. Material property was considered as linear elastic. Loading on the structures like, dead load, live load, wind load, earthquake load and storm surge load are calculated based on the guidelines of Bangladesh National Building Code (BNBC). The American Concrete Institute Code (ACI 318-99) has also been consulted to complement BNBC. Besides these, UBC 97, IBC 2000, Federal Emergency Management Agency Coastal Construction Manual (FEMA CCM, 2000) and Design Guidelines for tsunami vertical evacuation sites of the Washington State Department of Natural Resources (Yeh et al., 2005) have been followed to assess the hydrodynamic and impact forces due to tsunami. MCSP proposed maximum flow velocity has been utilized in calculating hydrodynamic forces for cyclonic storms.

In finite element modeling of the cyclone shelter buildings, beams and columns are modeled as frame elements, slabs as plate elements and shear walls as membrane elements. Based on the information available, some assumptions have been made in analyzing the structures. Dead load, live load, wind load and earthquake load are calculated as per BNBC. Regarding the grade of steel reinforcement, it is assumed that 40-grade steel has been used. The detailing is assumed to be as per Intermediate moment resisting frame (IMRF). Soil condition is assumed to be S3. Wind exposure category is considered as C. While determining adequacy of column sections, it is assumed that they contain 3% longitudinal reinforcement. Dead loads used consisted of, 150 pcf (Reinforced concrete), 120 pcf (Brickwork), 25 psf (Floor finish) and 70 psf (Partition wall); while Live loads are taken as 100 psf, as per the requirements of BNBC and MCSP suggestions.

Equivalent strut model has been used to consider the effect of infill masonry walls. The masonry infill panel is represented by an equivalent diagonal strut of width, a and net thickness, t_{eff}. The equivalent strut width depends on the relative flexural stiffness of the infill to that of the columns of the confining frame. The relative infill-to-frame stiffness is evaluated as (Stafford-Smith and Carter, 1969):

$$\lambda_1 H = H[(E_m t \sin\theta)/(4E_c I_{col} h_w)]^{1/4}$$

Where, H is the height of the story, E_m is modulus of elasticity of the masonry work, t is the thickness of masonry wall, θ is the angle of the diagonal with the horizontal, E_c is modulus of elasticity of concrete, I_{col} is the moment of inertia of column section and h_w is the height of the masonry work.

The equivalent strut width is given by,

$$a = 0.175D(\lambda_1 H)^{-0.4}$$

Where, D is the diagonal length of wall. In the FEM model strut is modeled using frame elements.

There are several forces associated with tsunami, such as, hydrostatic forces, buoyant forces, hydrodynamic forces, surge forces, impact forces and breaking wave forces. According to FEMA CCM, Hydrodynamic force (drag force), F_d is calculated as,

$$F_d = \frac{1}{2}\rho C_d A u_p^2$$

Where C_d is the drag coefficient, and A is the projected area of the body on the plane normal to the flow direction. The FEMA CCM recommends $C_d = 2.0$ for square or rectangular columns and 1.2 for round columns. FEMA CCM provides the following estimate of flood velocity u in the surge depth d_s:

$$u = 2\sqrt{g d_s}$$

Impact loads are those that result from debris such as driftwood, small boats, portions of houses, etc., or any object transported by floodwaters, striking against buildings and structures or parts thereof. According to FEMA CCM and ASCE 7 the generalized expression for impact force, F_I acting at the still water level is:

$$F_I = m\frac{du_b}{dt} = m\frac{u_I}{\Delta t}$$

Where u_b is the velocity of the impacting body, u_I is its approach velocity that is assumed equal to the flow velocity, m is the mass of the body, Δt is the impact duration that is equal to the time between the initial contact of the body with the building and the maximum impact force. The City and County of Honolulu Building Code (CCH) recommends $\Delta t = 0.1$ second for reinforced concrete.

Forces due to cyclone are mainly Storm Surge force and wind force. Calculations of storm surge load due to cyclone are similar to that of tsunami load. In this case, flood velocity of storm surge is much less compared to tsunami. According to MCSP the maximum flood velocity of storm surge can be taken as 2.5 m/s.

For wind loading, BNBC recommended basic wind speed of 260 km/h for cyclone of 50-year return period at coastal areas is used. Apart from that, other parameters used in wind load calculation are: Exposure category =C and Structure Importance coefficient C_I=1.25.

For earthquake resistant structural design, it is essential that a specific design code is followed. For the analysis and design checking of shelters, *Equivalent Static Force Method* and *Dynamic Response Method* of BNBC are followed. BNBC requires that the Dynamic Response Method must be used for structures having a stiffness, weight or geometric vertical irregularity. In all shelters, there is an open ground story causing vertical stiffness irregularity. So, Dynamic Response Method, particularly the *Response Spectrum Analysis*, has been used to analyze these structures. However, in order to perform Response Spectrum Analysis, Equivalent Static Force Method is needed to calculate the base shear. The main considerations for calculating earthquake load are: C_I=1.25 and Response modification co-efficient, R = 8.0. For Response Spectrum Analysis, normalized response spectrum for soil type S_3 and 5% damping ratio, as per BNBC, has been used.

3D FEM model of all thirteen types of shelters are built in ETABS 8.5. All types of structures are analyzed for different load combinations as per BNBC and for different storm surge heights. Basically three different loading conditions have been studied in the present study; e.g., tsunami, cyclone with storm surge and earthquake.

Tsunami loading is characterized by hydrodynamic forces of long water waves with high velocity transferring a lot of energy to the structure. It is also associated with impact of debris flowing with water on to the structure. The hydrodynamic and impact forces incident at the bottom part of the structure causing high stress concentration at that level. The upper part of the structure is stressed due to the deformation of the overall indeterminate structure. For analysis of this loading the following load combinations have been studied:

Comb-1 = 1.4 D + 1.7L

Comb-2 = 1.4 D

Comb-3 = 0.75 (1.4 D + 1.7L +1.87 H +1.87 I) = 1.05 D+1.275L+1.4025 H+1.4025 I

Comb-4 = 0.75 (1.4 D + 1.7L +1.87 H +1.87 I) = 1.05 D+1.275L-1.4025 H-1.4025 I

Comb-5 = 0.9 D + 1.43 H + 1.43 I

Comb-6 = 0.9 D - 1.43 H - 1.43 I

Where, D: Dead Load, L: Live Load, H: Hydrodynamic Load, I: Impact Load.

Cyclone is associated with hydrodynamic forces of wind induced storm surge, impact forces of debris flow and wind forces due to storm. The hydrodynamic and impact forces are much smaller compared to tsunami load. In case of tsunami, for only 3 ft inundation flood velocity becomes about 20 ft/s whereas the maximum velocity in case of storm surge is around 7.5 ft/s. Due to higher flood velocity, tsunami exerts greater hydrodynamic and impact forces on a structure. Similar to tsunami, the hydrodynamic and impact forces incident at the bottom part of the structure causing high stress concentration at that level. However, the wind forces are resisted by the whole structure. For analysis of this loading the following load combinations have been studied:

Comb-1 = 1.4 D + 1.7 L

Comb-2 = 0.75 (1.4 D + 1.7 L + 1.7 W) = 1.05D + 1.275L + 1.275W

Comb-3 = 0.75 (1.4 D + 1.7 L - 1.7 W) = 1.05D + 1.275L - 1.275W

Comb-4 = 0.75(1.4D+1.7L+1.7W+1.7H+1.7I) = 1.05D+1.275L+1.275W+1.275H+1.275I

Comb-5 = 0.75(1.4D+1.7L-1.7W-1.7H-1.7I) = 1.05D+1.275L-1.275W-1.275H-1.275I

Where, D: Dead Load, L: Live Load, W: Wind Load, H: Hydrodynamic Load, I: Impact Load.

Earthquake loading is associated with lateral loads which depend on the type of structure and type of underlying soil. Since all the cyclone shelters have open ground story causing vertical irregularity in the structural system, the code instructs for Dynamic Analysis. Actually the difference in stiffness of ground story and other stories changes the dynamic mode of the structure along with the predominant natural frequency. For analysis of this loading condition the following loading combinations have been studied:

Comb-1 = 1.4 D + 1.7 L

Comb-2 = 0.75 (1.4 D + 1.7 L + 1.87 EQX) =1.05D+1.275L+1.4025EQX

Comb-3 = 0.75 (1.4 D + 1.7 L - 1.87 EQX) =1.05D+1.275L-1.4025EQX

Comb-4 = 0.75 (1.4 D + 1.7 L + 1.87 EQY) =1.05D+1.275L+1.4025EQY

Comb-5 = 0.75 (1.4 D + 1.7 L - 1.87 EQY) =1.05D+1.275L-1.4025EQY

Comb-6 = 0.9 D + 1.43 EQX = 0.9D+1.43EQX

Comb-7 = 0.9 D - 1.43 EQX= 0.9D-1.43EQX

Comb-8 = 0.9 D + 1.43 EQY= 0.9D+1.43EQY

Comb-9 = 0.9 D - 1.43 EQY= 0.9D-1.43EQY

Comb-10= 1.4 D + 1.4 L + 1.4 EQX = 1.4D+1.4L+1.4EQX

Comb-11= 1.4 D + 1.4 L - 1.4 EQX = 1.4D+1.4L-1.4EQX

Comb-12= 1.4 D + 1.4 L + 1.4 EQY = 1.4D+1.4L+1.4EQY

Comb-13= 1.4 D + 1.4 L - 1.4 EQY = 1.4D+1.4L-1.4EQY

Where, D: Dead Load, L: Live Load, EQX: Earthquake Load in X direction, EQY: Earthquake Load in Y direction.

4.6 FEM Analysis Results

From the structural analysis using ETABS, three types of structures, Types 2, 3 and 13, were found unable to meet code requirements even under dead and live loads. So, these structures need to be strengthened irrespective of their location and hazard potential. Most of other types of shelters, in general, can withstand storm surge inundation of about 20 ft (± 5 ft, depending on the structure type) even for severe cyclones. However, for tsunami, due to its excessive flood velocity, few structures can sustain a tsunami height of more than 6 ft.

In Earthquake analysis conducted for the structures, it was found that structures of Types 1, 4, 6, 8 and 11 have adequate capacity to resist earthquakes. Only one column of Type 7 shelter is inadequate under earthquake loading. Other types of shelters located in Seismic Zone-II are not capable of resisting earthquake forces.

4.7 Geotechnical aspects of the shelters

Bangladesh is an almost flat, alluvial, deltaic country. According to MCSP study (BUET & BIDS, 1993d) the coastal area of Bangladesh can be placed under four physiographic units, namely;

- The Chittagong Coastal Plain: Grey piedmont clay
- Estuarine Flood Plain: Alluvial deltaic deposits of silt
- Ganges Tidal Flood Plain: Grey floodplain clay
- The Sunderbans: Swampy soils

Based on the MCSP study, the net allowable bearing capacity for a square footing and a strip footing at a depth of 1 m from ground surface is estimated for ten locations for which soil investigations were performed. According to MCSP study, the net allowable bearing capacity ranges from 76 kPa (1590 psf) to 127 kPa (2590 psf) for square footings and from 60 kPa (1120 psf) to 100 kPa (2040 psf) for strip footings placed at 1 m depth from the ground level (BUET & BIDS, 1993d). Based on these bearing capacity results, MCSP study suggested that it may be possible to place shallow spread footing type foundations in these soils from bearing capacity considerations. The MCSP study also provides simplified soil profiles and charts of standard penetration test (SPT) values for different places along the coast. Using this soil information and based on available drawings and layouts of foundations, adequacy of foundation has been checked for Types 3, 5 and 12.

Types 3 and 5 have pile foundations while Type 12 has shallow foundation. For type 3, different places along the coast shows pile capacity ranging between 52-134 kip, where the required pile capacity is 122.5 kip. Using the SPT values from MCSP report (BUET & BIDS, 1993d) it is found that, in Koyra (Khulna), Hatiya (Noakhali) and Ramgati (Lakshmipur) the pile capacity is adequate, while in Kalapara (Patuakhali), Anwara (Chittagong), Mognama (Cox's Bazar) and Sarankhola (Bagerhat) the pile capacity is not adequate due to poor soil condition. Similarly, for Type 5 structure, pile capacity ranged between 22-92 kip, while required capacity is 72.4 kip. The capacity of pile is adequate in Koyra, Hatiya and Ramgati. Pile capacity in other four places were found inadequate. Type 12 structures have shallow foundations placed at a depth of 5 ft. There are nine types of footings. According to the available drawings, the required soil bearing capacity ranges between 0.625 and 3.59 ksf for different type of footing. All the nine footings were found to be adequate against punching and beam shear failure. From available SPT values from MCSP report (BUET & BIDS, 1993d) it is found that, in Koyra, Hatiya and Ramgati the bearing capacity of soil is adequate, while in Kalapara, Anwara, Mognama and Sarankhola soil bearing capacity is not adequate.

4.8 Structural Vulnerability Analysis

Structural vulnerability analysis was conducted utilizing the inundation risk maps generated by the Institute of Water Modelling (IWM) for cyclone and tsunami induced storm surge. GIS techniques were used for identifying spatial distribution of shelters vulnerable under different hazard conditions. Spatial distribution maps have been produced for tsunami and cyclonic storms. Maps showing the distribution of vulnerable shelters under cyclone and tsunami induced risk are presented in figures 4.15 and 4.16.

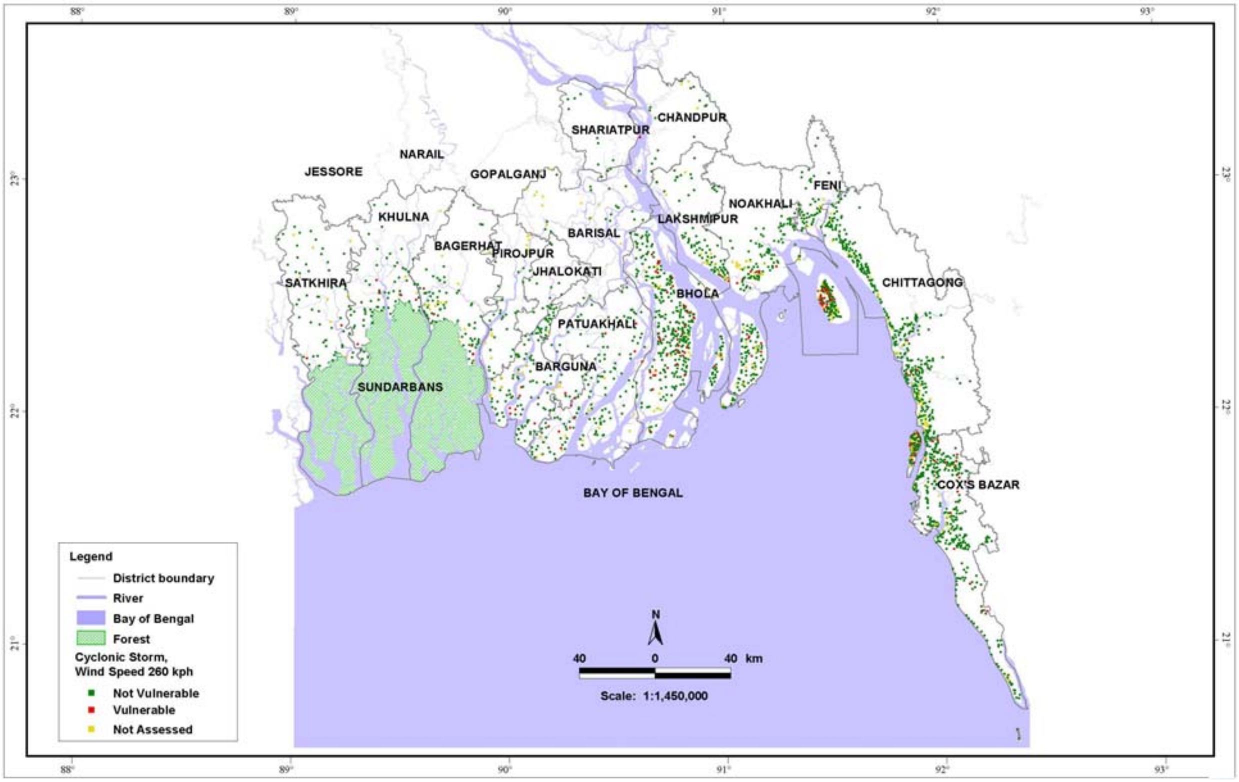


Figure 4.15: Cyclone Shelter Vulnerability Map: Cyclone

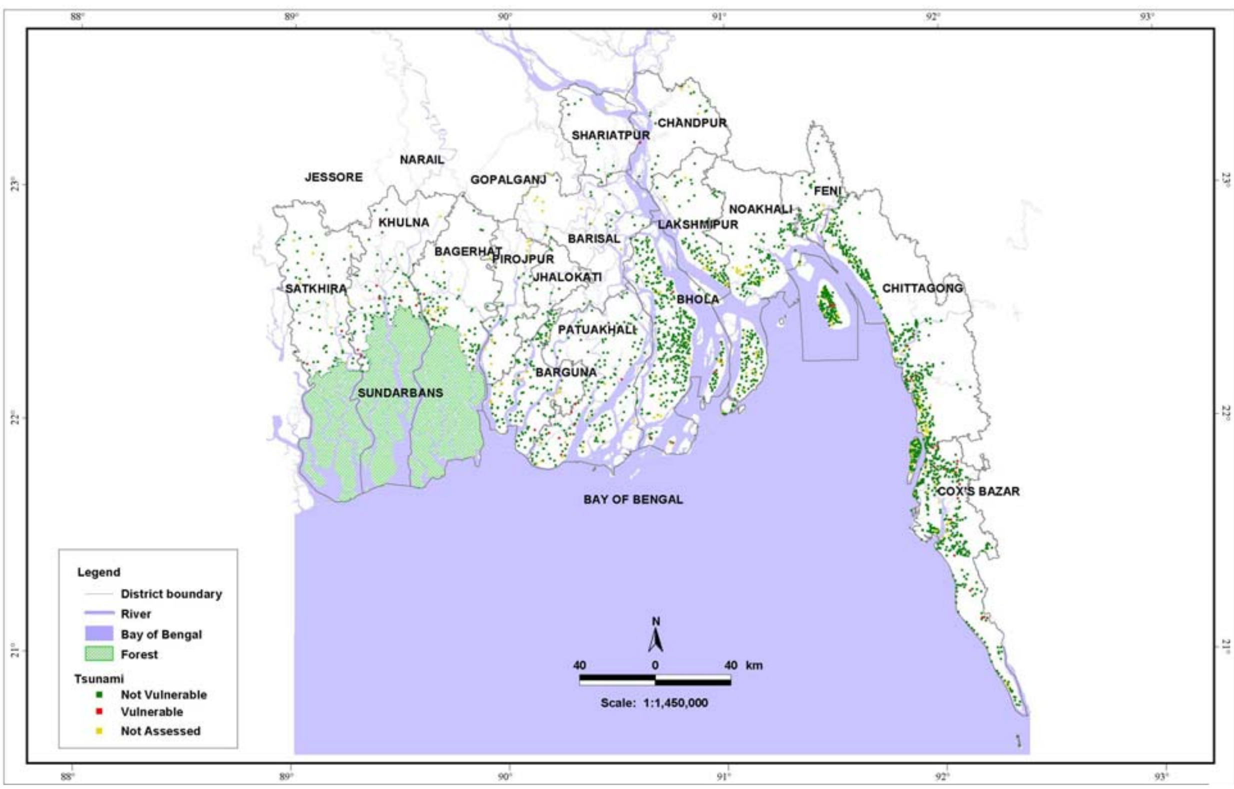


Figure 4.16: Cyclone Shelter Vulnerability Map: Tsunami

The structural vulnerability analysis revealed that 81 (3%) shelters are vulnerable to tsunami and 208 (8%) shelters are vulnerable to cyclone. The analysis showed that the most vulnerable districts to hazards like tsunami or cyclone, are Bhola, Patuakhsli, Bagerhat, Chittagong, Khulna and Cox's Bazar. It was also found that 1,881 (72.8%) shelters are vulnerable to earthquake. In the structural vulnerability analysis, a total of 225 shelters were not assessed as those are of various types and unlike any of the 13 major design types. Table 4.3 presents district wise distribution of vulnerable shelters.

Table 4.3: Distribution of Vulnerable Cyclone Shelters in coastal areas

District	Total No. of Shelters	No. of Vulnerable Shelters			Not Assessed Shelters
		Cyclone	Tsunami	Earthquake	
Bagerhat	98	7	5	54	12
Barguna	147	8	2	88	13
Barisal	37			13	11
Bhola	429	66	19	298	24
Chandpur	21	1	1	9	3
Chittagong	573	42	13	477	49
Cox's Bazar	504	41	22	374	29
Feni	57	1	1	52	3
Jhalokati	12			11	
Khulna	77	5	5	51	5
Lakshmipur	106	4		86	13
Noakhali	245	16	1	202	32
Patuakhali	165	15	9	113	11
Pirojpur	36			17	12
Satkhira	65	2	3	31	7
Shariatpur	11			5	1
Total	**2583**	**208**	**81**	**1881**	**225**

4.9 Suggestions

The cyclone shelters have a wide variety of design patterns. The structures were designed using different guidelines. It is required that, a standard procedure and guideline approved by the government of Bangladesh should be followed for designing the cyclone shelters. Average capacity of a shelter is around 1500. Depending on population density a capacity of around 2000-3000 is required. The capacity of shelters could be increased by constructing another floor if allowed by BNBC guidelines.

There are a number of vulnerable shelters. The vulnerability of these shelters are mainly due to large forces induced by storm surge. The surge force impacts on structures could be reduced by constructing shelters on Killas. In this regard, vulnerable shelters might be protected by land filling upto ground floor ceiling. For doing this, availability of land around the shelter and cost for earthwork is the only concern.

Chapter 5

Evacuation Route Mapping

5.1 Introduction

Cyclone shelters provide shelter to the coastal community and reduce the number of casualties in the coastal areas during cyclone and tsunami. Normally, people prefer taking refuge in nearby cyclone shelters during hazard periods. If they knew where to go during such times, they could reach the shelters more quickly. This could be possible only if the catchment area for each shelter is identified. For this reason, delineation of catchment area and mapping of the evacuation routes to the shelters is of great importance.

5.2 Methodology

The Methodology for catchment area delineation for each cyclone shelter follows a four-step procedure which is presented in the following figure. The steps include several activities such as (a) Assessment of location, capacity and structural vulnerability of cyclone shelters based on cyclone shelter inventory; (b) Assessment of population to be evacuated to the shelters; (c) Accessibility analysis for identification of evacuation routes for each shelter connecting the settlements to the shelters; and (d) Delineation of catchment area for the cyclone shelters and allocation of settlement population to each shelter for evacuation during disasters. The detailed methodology for catchment delineation of cyclone shelters are given below:

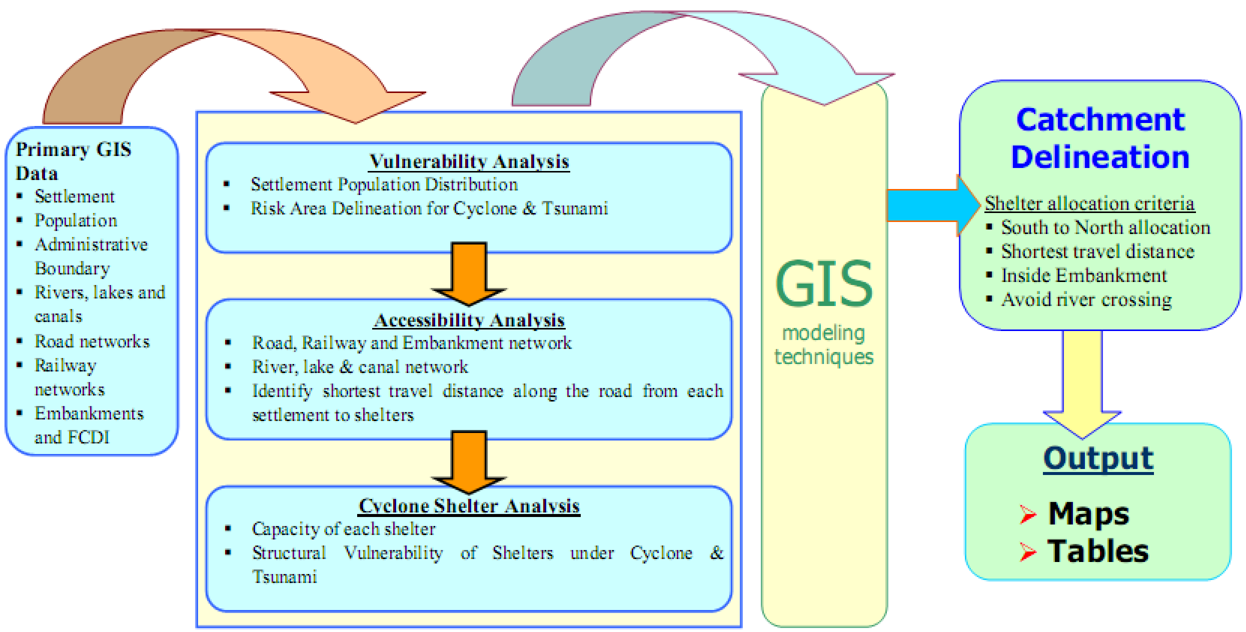


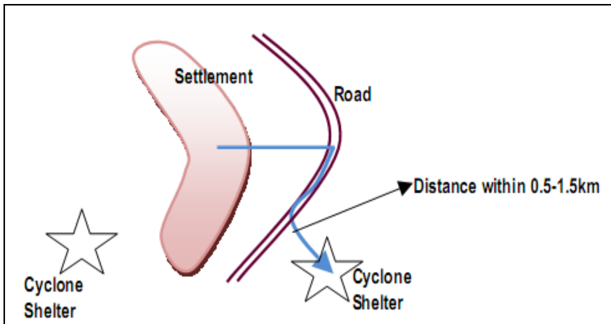
Figure 5.1: Overall Methodology for Catchment Delineation of Cyclone Shelters

Vulnerability analysis

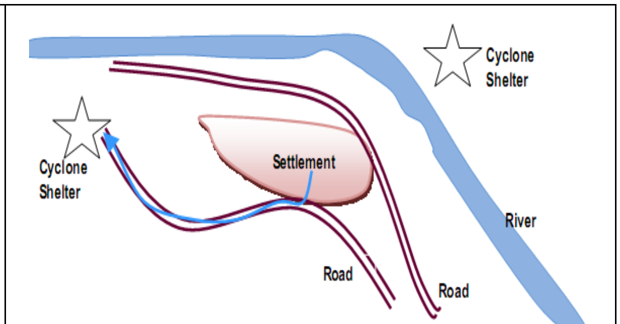
The level of risks for hazards in different areas of the coast was analyzed first for delineating the catchment area for each shelter. Risk maps for cyclone and tsunami were generated based on inundation risk map prepared by IWM (IWM, 2008). The risk areas are defined as High Risk (more than 3 meter inundation depth), Moderate Risk (1-3 m), Low Risk (up to 1 m) and No/Wind Risk (0 m). For Tsunami, 0 m inundation depth poses no risk to the area. After risk area identification, population has been distributed to each settlement (Settlement is defined as cluster of houses within a close proximity). Population of 2009 was calculated by increasing the 2001 population by district wise growth rate given in the population census 2001. Location of settlements in the coastal area was captured using Remote Sensing (RS) data. After estimating the population for each settlement under a union, the information was stored in a GIS attribute file linked with Settlement ID and Geocode.

Accessibility analysis

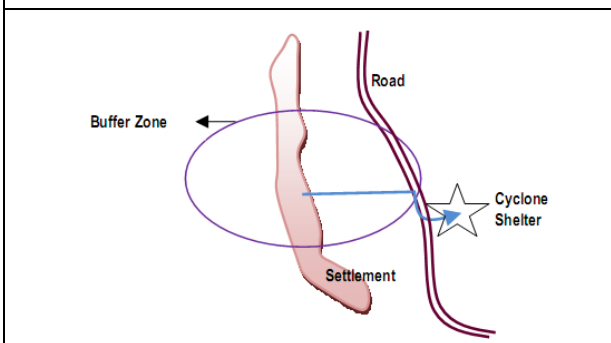
The accessibility analysis computes the shortest distances along the road from a settlement to nearby shelters. This process was completed using GIS based network analysis, to compute along the road distances of nearest four shelters from each settlement. Afterwards, this information is stored in the GIS attribute file. During these analysis, several cases/issues were addressed. These are illustrated in figure 5.2.



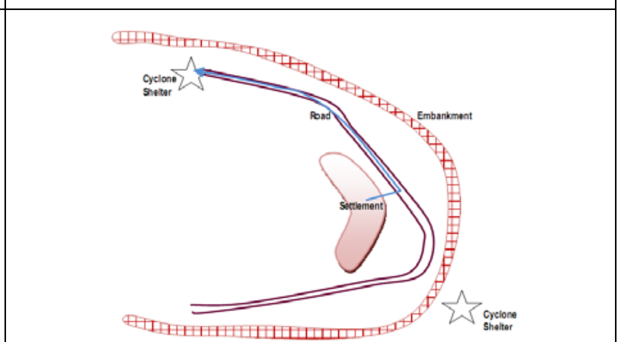
Case-1: Route from settlement to nearest shelter



Case-2: Route for settlement near river



Case-3: Route for settlement having no connecting road



Case-4: Route for settlement near embankment

Figure 5.2 Access routes for settlement toward shelter

Cyclone shelter capacity and vulnerability analysis

Cyclone shelter capacity has been estimated using the MCSP proposed 2 square feet (sft) area per person (BUET & BIDS, 1993a). According to this assumption, capacity of a shelter is half of the shelters floor area. After computing the capacity of shelters, this information is linked with the shelter ID and entered in the shelter attribute. It was found that, condition of many shelters are not good due to poor construction / lack of proper maintenance. Based on the structural vulnerability analysis, the vulnerability information of each shelter with regard to hazards like tsunami, cyclone and earthquake are linked to the respective shelter ID and added to the attribute.

Catchment area delineation

The catchment area of a cyclone shelter (or killa) is the area from which people (or livestock) come to take shelter during cyclonic storms and surges (BUET & BIDS, 1993b).

Based on literature review some basic criteria were identified to delineate the catchment area of each shelter for evacuation. These are as follows,

- People prefer to go to the nearest shelter. The acceptable distance to a shelter is about 1.5 km from their houses.
- People do not like to cross waterways to reach a shelter.
- People want to travel away from the sea during cyclones. They do not like to travel against the wind.
- People feel secure to stay inside coastal embankments. During disasters, they travel even 3-4 km to take shelter in cyclone shelters within an embankment.
- People prefer shelters having good road communication.

Information about settlement population, distance from four nearest shelters to that settlement is computed and stored in the attribute of settlement and linked with the attribute of shelters. Based on shortest distance, shelters are filled with population from settlements. If a shelter is not filled by the first settlement, then people from the second nearest settlement are used. This process is followed until the shelter is filled. If a shelter cannot accommodate the full population of a settlement, then the left population is allocated to the next nearest shelter. Shelters are filled geographically, moving from south to north for the coast from the Sundarbans to Noakhali and from west to east for coast from Feni to Teknaf. All these tasks are completed using GIS techniques.

After allocating the population to shelters, maps are generated showing the settlements, shelters, communication network, river network, administrative boundaries and evacuation routes from settlements to shelters. These maps also show shelter ID and symbol showing vulnerability of the shelter for different disasters.

5.3 Analysis Result

Vulnerability Analysis

From vulnerability analysis, it is observed that about 11,000 km^2 area of coastal districts is under high risk zone, about 12,500 km^2 is under moderate risk zone, 3,800 km^2 area is under low risk zone and 10,000 km^2 area is under no risk zone of cyclone and storm surge. It is also found that high risk area is larger in the districts of Bhola, Noakhali and Patuakhali whereas area under moderate risk has been seen in Khulna, Bagerhat, Satkhira, Barisal, Chittagong and Pirojpur districts mainly. Low risk area is almost small in all districts. The wind/no risk areas are larger in Chittagong, Satkhira and Khulna than in other areas.

Table 5.1: Area distribution of districts in different risk zones

Districts	Area (km^2)			
	High Risk (> 3 m)	Moderate Risk (1–3 m)	Low Risk (0-1 m)	No Risk
Bagerhat	856	1,492	577	915
Barguna	403	773	287	0
Barisal	842	1,116	309	250
Bhola	2,239	295	0	0
Chandpur	32	187	214	1,264
Chittagong	995	1,090	0	2,412
Cox's Bazar	484	965	0	784
Feni	452	217	65	167
Jhalokati	0	486	252	0
Khulna	0	1,554	810	1,522
Lakshmipur	689	548	149	119
Noakhali	2,118	511	115	13
Patuakhali	1,766	702	305	0
Pirojpur	13	1,036	163	60
Satkhira	0	1,204	389	2,064
Shariatpur	13	247	168	794
Total	**10,902**	**12,423**	**3,803**	**10,364**

Population census 2001 gives a growth rate of 1.54% per year which was used to estimate the growth rate of population for 2009. Based on the estimates it is seen that about 48.8% of the population are women. Other than this, about 19.7% of the total population comprises children and elderly people. During disasters, children, elderly people and women are the most vulnerable as proven by death statistics from previous cyclones.

Accessibility Analysis

According to IWM study on inundation risk map the lead-time for tsunami is 50 minutes to 6 hours (IWM, 2008). So, in the worst case, a maximum of 30 minutes may be available for people to move after being warned. People can travel a maximum of 0.5 km within 30 minutes. However, they do not wish to travel more than 1.5 to 2km during a cyclone. For this reason, the road condition should be favorable. During disasters, roads of different types, embankments and railways are used by the people as evacuation routes. So, all these networks were considered for the accessibility analysis. Table 5.2 gives a summary of communication networks (roads and railways) in the coastal area. It is estimated that 14,963 km of communication network is under high risk zone, 7,012 km under low risk zone, 17,024 under moderate risk zone and 17,502 km under wind risk zone. Also it is found that there are 14300 km^2 area protected by coastal embankments (FCDI projects) in the study area.

Table 5.2: District-wise communication network and FCDI area in different risk zone

Districts	Communication network (km)				FCDI Area (km^2)
	High Risk	Low Risk	Moderate Risk	Wind Risk	
Bagerhat	63.36	655.47	1027.04	1825.98	698.61
Barguna	554.55	970.16	1247.70	0.00	999.01
Barisal	1145.23	703.34	2441.41	465.09	215.00

Districts	Communication network (km)				FCDI Area (km^2)
	High Risk	Low Risk	Moderate Risk	Wind Risk	
Bhola	3214.39	0.00	15.14	0.00	1361.15
Chandpur	6.36	504.54	97.06	2563.98	621.13
Chittagong	2078.61	0.00	2476.70	3320.20	1192.35
Cox's Bazar	678.80	0.00	869.47	957.65	524.36
Feni	880.12	70.17	375.01	342.60	654.23
Jhalokati	0.00	604.73	1260.58	0.00	148.82
Khulna	0.00	941.32	31.28	2684.92	1625.58
Lakshmipur	775.28	468.53	1140.17	436.57	810.75
Noakhali	2936.79	324.76	1289.26	18.94	1677.98
Patuakhali	2624.50	870.78	1959.38	0.00	1517.02
Pirojpur	5.24	260.84	2393.69	54.36	431.18
Satkhira	0.00	386.93	74.49	3726.36	1755.24
Shariatpur	0.00	250.71	326.27	1105.69	67.04
Total	14963.23	7012.28	17024.65	17502.34	14299.45

Cyclone shelter capacity and vulnerability analysis

A total of 2,583 cyclone shelters has been found by this study. It is estimated that based on 2 ft^2 area per person, total capacity of cyclone shelters is about 2.77 million persons. However, it is found that 2.58 million persons took shelter in different cyclone shelters during last cyclone Sidr in 2007. So, it can be said that the existing shelters could provide safe haven facilities to a maximum of 7.3% of the total coastal population. The vulnerability of cyclone shelters were identified through the structural vulnerability analysis.

Catchment Area Delineation

The task of catchment area delineation and allocation of settlements to cyclone shelters for evacuation has been done using GIS network analysis. For this purpose a step-by-step process has been followed as illustrated in the following:

1. Establish links between settlement ID and Shelter ID.
2. Select Shelters based on geographic location and start allocating population from the southern-most shelter and proceed to the north.
3. Fill each shelter first from the nearest settlement, then the second one, then the third and so on.
4. When a shelter fills up, move to the second one selected in step 2. This shelter is filled in a process similar to step 3.
5. If a shelter fills up before accommodating the population from a settlement, try to allocate the remaining population to the second nearest shelter (if available).
6. Draw the shelter vulnerability and evacuation route maps of the area showing settlements, shelters with ID, communication routes, rivers, evacuation routes and shelter symbols with shelter vulnerability.

For example, a sample map of Mongla Upazila of Bagerhat district showing cyclone shelter evacuation routes and shelter vulnerability condition is presented in figure 5.3. In this map, vulnerable structures like, Type 13 (PEDP-II) and unusable shelters are shown with different symbols. The shelters which were not assessed during structural analysis are also shown in the map. Shelters are marked with their serial number. Vulnerability of each usable shelter is presented in a pie chart. The filled segment for a disaster (Cyclone, Tsunami or Earthquake) indicates a vulnerable shelter to that disaster. The evacuation routes from settlement to shelters are marked by green solid line. Besides this, each settlement which is allocated to a shelter, is marked with the number of the shelter. There are two markings on settlements, one for cyclone (in black colour) and one for tsunami (in red colour). Detail maps and attribute tables for each upazila is presented in annexes D and E respectively. From catchment area delineation analysis, it has been found that, only 15% of the coastal population could be served by these 2583 shelters.

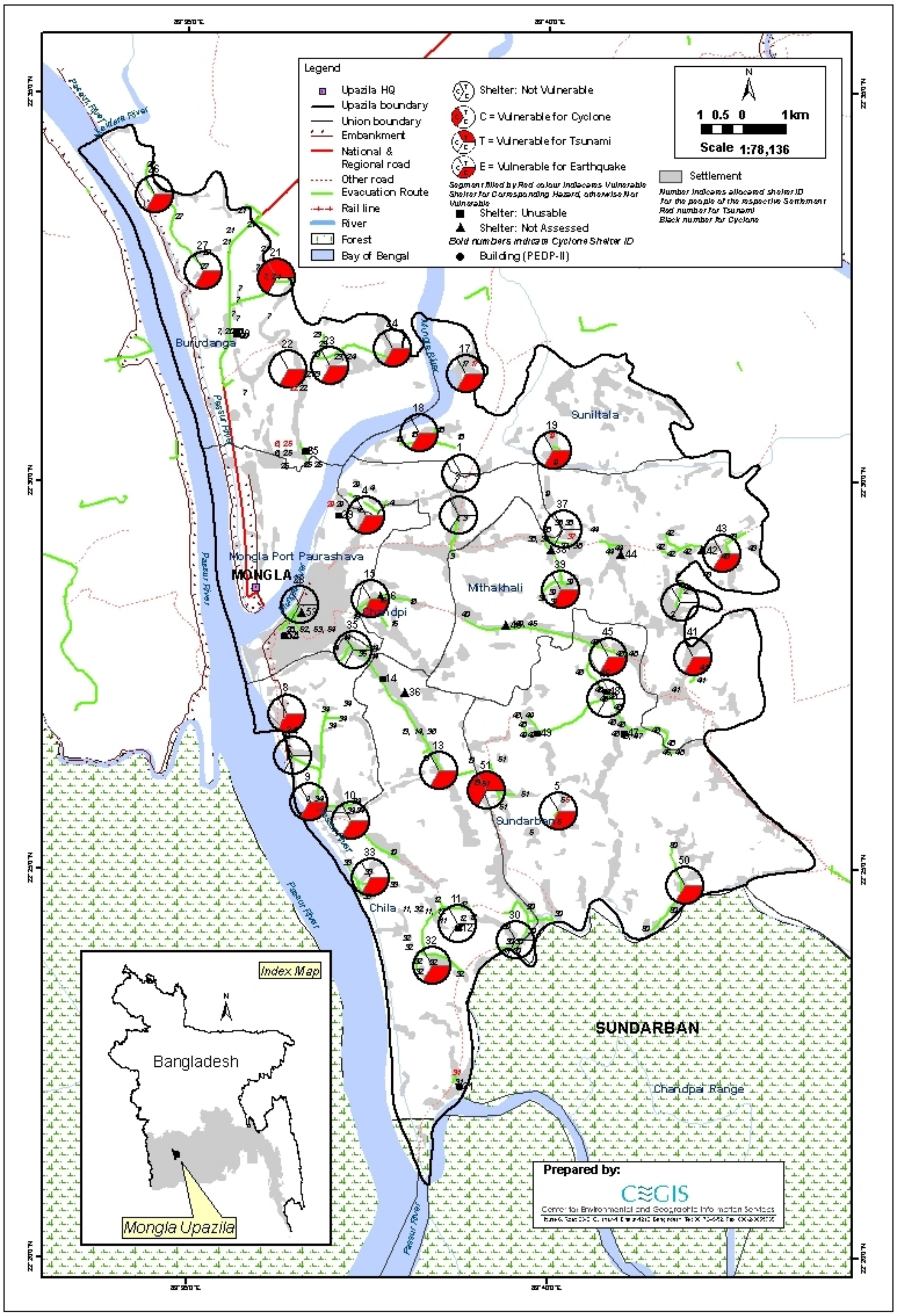


Figure 5.3: Shelter Vulnerability and Evacuation Route Map

5.4 Suggestions

In the evacuation route mapping process evacuation routes from settlements to shelters were identified.

The allocation of settlement population to a specific shelter should be known by the people. This could be ensured by roadside direction and a unique identification mark for shelters.

Many shelters have poor access road. The access roads to each shelter should be immediately restored. The roadside trees should be selected carefully, which will not be uprooted during disasters.

Chapter 6

Approach for Shelter Management

6.1 Introduction

The cyclone shelter management against Tsunami hazards has been prepared following a three step approach which comprised, (a) Literature review, (b) Consultation with community and local level managers, and (c) Guideline development for construction, management and maintenance of cyclone shelters. Cyclone shelter management issues for present and future contexts were analyzed with respect to cyclone and tsunami hazards. The detailed methodology for this study is presented in the following sections.

6.2 Detail Methodology

The methodology for developing framework of cyclone shelter management for tsunami, includes the following steps. The chronology and linkage of the steps is shown in Figure 3.1. Description of these steps is given in the following sections.

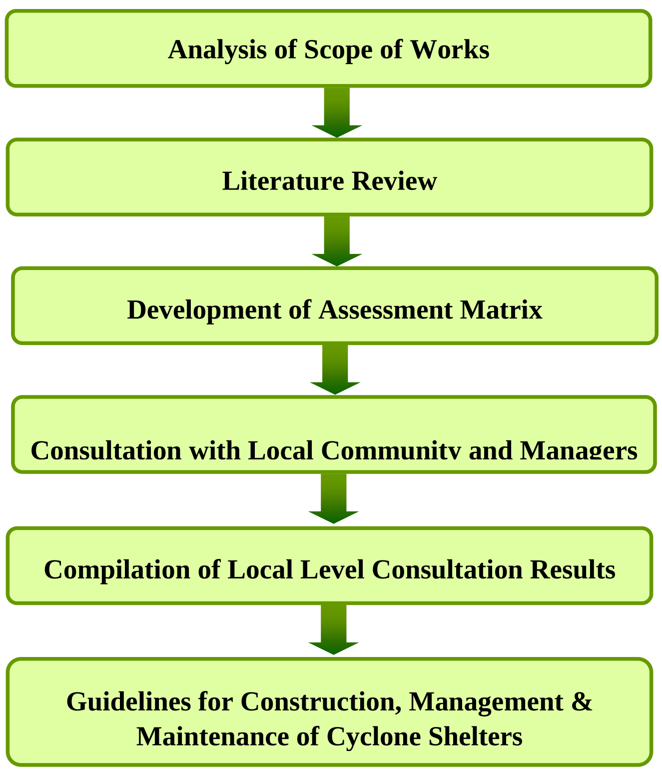


Figure 6.1: Major steps of developing management framework

Analysis of Scope of Works

The scope of work of the cyclone shelter management study has been analyzed discussing with study team members, experts and the client. The detail of the study activities were defined and plan was set accordingly.

Literature Review

Since Bangladesh has no experience of Tsunami, there is no literature on shelter management for this particular hazard. Therefore, international experience of management options for tsunami hazard has been reviewed along with cyclone shelter management related reports of Bangladesh. The reports "Multi purpose Cyclone Shelter Programme reports", "Report on Cyclone Shelter Management Information System" and "Evaluation of Cyclone Shelter Management Information System" has been reviewed to identify the management issues for cyclone shelters in context of cyclone and storm surge hazards. Since the effect of tsunami is similar to cyclonic storm surge, cyclone shelter management issues related to storm surge has been given emphasis while reviewing the reports. Review of the reports also helped to develop the assessment matrix of cyclone shelter management issues in the present context.

Development of Assessment Matrix

A criteria based matrix has been developed to assess the cyclone shelter management issues for tsunami in the present context. At first a draft assessment matrix has been developed and it is tested in the field through reconnaissance survey. The assessment matrix has been finalized incorporating suggestions obtained from field visits. The format of the assessment matrix is given as follows. The social, accessibility, early warning and management criteria has been identified using this matrix in pre, during and post disaster situation for users, Shelter Management Committee and Organizational Shelter Managers.

Table 6.1: Assessment Matrix

Group	Pre-Disaster	During-Disaster	Post-Disaster
Users	**Social criteria** - xxx - yyy **Accessibility criteria** - xxx - yyy **Early warning criteria** - xxx - yyy **Management criteria** - xxx - yyy	**Social criteria** - xxx - yyy **Accessibility criteria** - xxx - yyy **Early warning criteria** - xxx - yyy **Management criteria** - xxx - yyy	**Management criteria** - xxx - yyy
Shelter Management Committee	**Early warning criteria** - xxx - yyy **Management criteria** - xxx - yyy	**Early warning criteria** - xxx - yyy **Management criteria** - xxx - yyy	**Management criteria** - xxx - yyy

Group	Pre-Disaster	During-Disaster	Post-Disaster
Organizational Shelter Managers	**Social criteria** - xxx - yyy **Management criteria** - xxx - yyy **Early warning criteria** - xxx - yyy	**Management criteria** - xxx - yyy	**Management criteria** - xxx - yyy

Moreover, issue based management options in pre, during and post disaster situations has been synthesized from the above matrix and are presented as follows.

Table 6.2: Issue Based Management Matrix

Issues	Pre-Disaster	During-Disaster	Post-Disaster
Institution	- xxx - yyy	- xxx - yyy	- xxx - yyy
Early Warning	- xxx - yyy	- xxx - yyy	- xxx - yyy
Accessibility	- xxx - yyy	- xxx - yyy	- xxx - yyy
Location	- xxx - yyy	*N/A*	N/A

These matrices were used to gather insight into the perception of local community and managers regard to the cyclone shelter management for tsunami. These information are one of the key elements for developing the management framework.

Consultation with local community and managers

Consultations were held with local people, union disaster management committees, school committees and shelter management committees (CPP, Red Crescent etc.) for assessing the cyclone shelter management issues and criteria. The assessment matrix is used to collect information in the meetings. Six meetings were held with UDMC and shelter management committees in Patuakhali, Barguna, Bhola and Cox's Bazar. Informal consultations were also held with local people or users of the cyclone shelters in the visited sites. The sites were selected mainly in the high risk zone. A list of the consultation meetings is given in the following table.

Sl. No.	*Place of Meeting*	*Date*	*No. of participants*	
			Male	**Female**
1.	Venue : Auliapur Cyclone Shelter Union : Auliapur Upazila : Patuakhali Sadar District : Patuakhali	18.10.2008	20	11
2.	Venue : Shofir Bill Cyclone Shelter Union : Enani Upazila : Ukhia District : Cox's bazar	28.11.2008	28	9

Sl. No.	***Place of Meeting***	***Date***	***No. of participants***	
			Male	**Female**
3.	Venue : Kakchira Union Parisad Union : 6 no. Kakchira Union Parisad Upazila : Pathorghata District : Barguna	04.12.2008	23	8
4.	Venue : Aishabag Cyclone Shelter Union : Aslampur Upazila : Charfasson District : Bhola	18.12.2008	21	6

Compilation of local level consultation results

All the information collected at the local level consultation meetings were compiled and used to develop the management framework. The compiled information of the local consultation meetings were verified and incorporated in the final management framework. Details of consultation meeting with local people are presented in appendix-1.

Guidelines for Construction, Management & Maintenance of Cyclone Shelters

Finally, a guideline was developed for the construction, management and maintenance of cyclone shelters to ensure efficient management and structural safety of the shelters.

Chapter 7

Cyclone Shelter Management

7.1 Existing Management Practices

The existing management practice of cyclone shelters is extremely poor in Bangladesh. This is only because of a lack of coordination among the agencies and committees concerned. The Disaster Management Bureau (DMB) under the umbrella of the Ministry of Food and Disaster Management (MoFDM) is the main host for managing the shelters as suitable emergency sanctuaries for cyclone affected people. Under the supervision of DMB the hierarchical structure of shelter management is the District Disaster Management Committee (DDMC), Upazila Disaster Management Committee (UzDMC), Union Disaster Management Committee (UDMC) and Shelter Management Committee (SMC). The Comprehensive Disaster Management Programme (CDMP) assists the disaster managers and the shelter management committee by building capacity and awareness regarding cyclone and relevant hazards through training and awareness building programmes. The following diagram (Figure 7.1) shows the structure for cyclone shelter management.

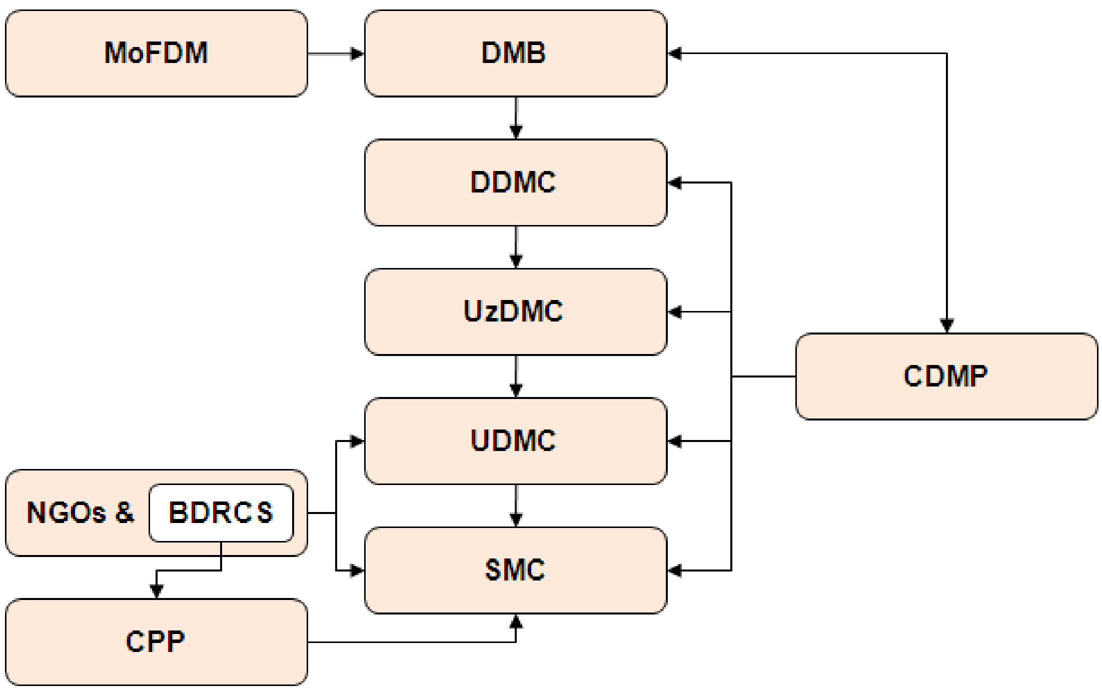


Figure 7.1: Hierarchy of shelter management structure

The Bangladesh Red Crescent Society (BDRCS) has been conducting shelter management activities as complementary services in close cooperation with GoB. In terms of cyclone preparedness, 112 Cyclone Shelter Management Committees/volunteers are trained annually, and equipment are maintained regularly for communications and immediate response. Since 1973, the shelter management committees and volunteers have been working under the guidance of the Cyclone Preparedness Programme (CPP) of BDRCS. The CPP is funded annually by the Federation secretariat, the Bangladesh Government and other partners, and a joint programme management mechanism has been set up by the creation of a programme Policy Committee and a programme Implementation Board.

Currently, around 40,000 volunteers have been trained in community level preparedness and response in cyclone prone coastal areas. CPP coverage is still limited to 30 upazilas of coastal districts within high risk area (HRA). It is reported that the shelter management committees are functional where CPP exists. The shelter management activities of CPP include dissemination of early warning signals to the community issued by Bangladesh Meteorological Department (BMD), assisting affected people in relocating to shelter, rescuing distressed people and providing first Aid to injured people, assisting in relief and rehabilitation operations, etc. They usually disseminate cyclone warning signals almost door-to-door using megaphones, hand sirens and public address systems.

Caritas Bangladesh has also been maintaining three shelters in Chakaria, Maheshkhali and Kutubdia of Cox's Bazar district under the commission of PRISM (Projects in Agriculture, Rural Industry, Science and Medicine - an NGO with a Bangladesh office). They serve as offices during normal time. PRISM maintains the shelters regularly and encourages affected people to take shelter during the disaster events through awareness building programmes.

The present shelter management committees comprise multi-sectoral people, such as ward members, local elite, teachers, imams, priests, farmers, businessmen, and women, and in some cases fishermen. The field investigation revealed that most of the cyclone shelters had no management committees. The local schools or madrasa committees usually take over the responsibility of managing the shelters. Some of the shelters were found to be poorly maintained due to lack of funds and ownership. The feeling in general is that the shelters are government property and therefore should be maintained by the government. At the same time, it was found that the shelter management committees were not functional due to lack of proactiveness of its members as well as lack of regular intra- (between DMCs and SMCs) and inter-coordination (among the SMC members) meetings. DMCs are indifferent to regular monitoring and assessment of SMC activities as well as to providing training for building capacity and awareness. It is death, misery and pain from recurring cyclones that finally mobilize the disaster managers. The shelter management authority and policy makers gear up their activities momentarily to reactivate the existing individual shelter management committees, key holders of the shelters, etc.

In case of a school-cum-shelter, its key remains in the custody of a schoolteacher or attendant whereas in case of a shelter the key remains either with the Union Parishad Chowkidar or an influential person who lives near the shelter. Therefore, there is no specific person appointed as custodian of the shelter key. The toilets and drinking water facilities in most cases are damaged and cannot serve the people taking shelter during disaster events. It is reported that due to lack of adequate fund and strong committees these facilities are not being restored for emergency use. Moreover, there is no separate facility for women and children in the shelters, which causes social problems. However, UDMC and other volunteers conduct miking to urge people to rush to safer places or nearby shelters.

7.2 Problems of current management practices

The problems and issues related to the current shelter management practices are based on three different time periods, such as pre-cyclone, during cyclone and post cyclone periods. The problems and concerns are as follows:

Structural management

A considerable number of shelters are in a vulnerable condition as most are damaged due to lack of day-to-day maintenance and other reasons such as river bank erosion, poor quality of construction materials, less consideration given to potential high wind speed at construction, etc. Currently, people of cyclone affected areas take shelter without considering the vulnerability of the buildings and at the same time they are in fear of the shelters collapsing on top of them during the event. This fear discourages them from taking shelter in these structures. According to the structural strength analysis of the 2,583 cyclone shelters conducted by CEGIS, around 3% (81) of shelters are vulnerable to tsunami, around 8% (208) to cyclone and around 72.8% (1,881) to earthquake.

Institutional management
Although there is a strong linkage between disaster managers and the shelter management committees (SMC) there is poor interaction between them due to lack of regular coordination meetings. Poor institutional arrangements are hampering spontaneous participation of rural people in shelter management and causing a break down of effective cooperation between the local government and NGOs. As a result, the shelter management committees remain vague and directionless with regard to their responsibilities of shelter maintenance.

Logistic support management
Although under proper cyclone shelter management provisions a number of shelter equipments are badly needed, there is currently a lack of such equipments. The equipments include first aid boxes, free kitchen utensils, inflatable tower lights, aluminum ladders, power saws, life buoys, life jackets, search lights, stretchers, sirens, flexi-water tanks, fire extinguishers, foldable stretchers, solar lanterns, water filters and handheld megaphones, etc. Most of these equipments are used for search and rescue and shelter purposes. SMC members and villagers could be trained on the use of these equipments during disasters.

Funding management
In current practice, there is no provision for shelter based fund generation. Therefore, shelter management and maintenance is completely dependent upon government and NGO fund allocation. However, funds from these sources are quite insufficient for maintaining the huge number of shelters.

Catchment area management
During construction of the shelters scientific catchment area delineation had not been considered. Therefore, the shelters are located at considerable distances from the villages to be served. This discourages the people especially women, children, the elderly and the disabled to avail the shelters during emergencies.

Table 7.1: Problem resolution of existing shelter management at a glance

Issues	Reasons of Issues
Limited separate facilities for women, children and the disabled	▪ Fewer shelters than needed ▪ Poor shelter management
Unavailability of food, drinking water and medical assistance immediately after the event	▪ Non functional or absence of shelter management committee ▪ Lack or inadequacy of fund
Damaged/dirty top floor rain water harvest tank	▪ Lack of regular monitoring and maintenance ▪ Lack or inadequacy of fund
Vulnerable shelters	▪ Lack of day-to-day maintenance of shelters
Ignorance about signaling systems and preparedness	▪ Limited number of awareness building programmes ▪ No programme for introducing the signaling system
Lack of emergency electricity facility	▪ Electricity crisis is a national problem
Very limited logistic support	▪ Inadequacy of fund

7.3 Areas of Improvement/Suggestions

A survey was conducted by CEGIS in the 16 coastal districts to identify the locations of cyclone shelters and their physical status. CEGIS also carried out a strength test analysis on a random basis as well as a vulnerability analysis of shelters, current management issues and measures for improvement. Catchment area delineation was done based on the collected information and it can be used for constructing new shelters in the coastal area. Improvement of shelter management can be optimized in several areas such as construction of new shelters, existing shelter management, institutional arrangements, etc.

In case of new shelter construction the following basic features need to be considered in deciding the location and capacity:–

- Shelters should be constructed for multipurpose use
- Identification of locations should need-based and as per the vulnerability analysis and need assessment done by DMB
- Standard structural requirements should be followed
- Information on new shelters must be made available to DMB
- A management committee must be formed for regular maintenance and management of each shelter

With regard to existing shelters the following measures need to be undertaken for their emergency use:

- Repairing/retrofitting of vulnerable shelters which are still usable
- Repairing of drinking water sources, such as, rainwater harvest tanks and tubewells; latrines; electricity facilities where available; doors and windows, etc
- Arrangement of facilities for women and the disabled

With regard to institutional arrangements for shelter management the following measures need to be undertaken:

- Reformation of the existing shelter management committees and ensuring involvement of proactive and energetic people in the committees
- Regular coordination meetings should be arranged with local government agencies and other disaster managers
- Arrangement of funds for regular maintenance of the shelters
- Training of the SMC for capacity building
- Provision of required equipment and first aid box to the committee

Chapter 8

Guidelines for Construction, Management & Maintenance of Cyclone Shelters

8.1 Introduction

CEGIS conducted a survey in the coastal districts for assessing the cyclone shelter management issues. During the survey, consultations with local people, union disaster management committees, school committees and shelter management committees (CPP, Red Crescent etc.) were carried out. A guideline for construction, management and maintenance of cyclone shelters has been developed based on the survey findings and literature review of studies on cyclone and tsunami preparedness in Bangladesh and other countries of the world. This guideline provides directions for construction, management and maintenance of new shelters and for management and maintenance of existing shelters. As Bangladesh has no recent memories of tsunami, tsunami impacts were carefully considered. Additional measures required for tsunami preparedness were looked at during preparation of the guideline. The guidelines are described in the following sections.

8.2 New shelter construction

In order to provide adequate safe haven facilities to the coastal population, it is essential to build new shelters. The process of building new shelters should follow a specific guideline. This guideline includes several aspects like Site selection for the shelter, Structural design criteria, Shelter information updating process and formation of shelter management committee.

8.2.1 Site selection

The site selection of new cyclone shelters should be coordinated at national and local level. The planning for construction of new shelters should be done nationally, on the basis of long and short-term requirements. The long-term plan is usually for 10-20 years while the short-term is for one to five years. National level planning should allocate resources for Upazila level. At the local level, planning should be targeted to identify specific locations of new shelters to reduce the risk of loss of life and damage to the property caused by cyclone and tsunami induced storm surges.

Planning at the national level

The main objectives of safe haven planning at the national level are to create adequate facilities for protection against natural hazards (tsunamis/cyclones) and to ensure optimal use of these infrastructures by maximizing the use of safe haven facilities during normal periods as primary schools, health centers and community activities. Consideration must be given in the planning process for providing safe haven facilities to both humans and livestock. Furthermore, the planning must include equitable distribution of the safe havens over risk areas. In order to make effective and useful planning of safe havens with the above mentioned objectives, allocation of new shelters at Upazila-level will be determined based on the following criteria:

- Efficient allocation
- Equitable allocation

Efficient allocation means providing safe haven facilities to populations at risk due to disasters. Indicators for efficiency are hazard index and vulnerability. Hazard index could be assessed by depth of inundation due to tsunami/cyclone induced storm surges. Vulnerability could be assessed from criteria like, the density of unsafe population, capacity of existing shelters and capacity of informal buildings.

The criteria "equitable allocation" means distribution of planned safe haven facilities in the risk areas with equal preference. Equitable allocation could be ensured through analysis of poverty level and percentage of unserved population.

Planning at local level

Local level planning will start from the allocated number of safe haven structures planned at the national level for each Upazila and location of the shelters or killas at appropriate sites within the high-risk area. In this phase of planning, selection of specific sites of shelter should be done based on the following criteria:

- Equity
- Suitability
- Usability

To confirm equitable distribution, new shelters have to be built in the communities where no shelter exists.

To address suitability issues, accessibility facilities like roads and their conditions, shelter safety issues like, soil condition, vulnerability due to erosion etc., risk level at the specific area and unserved population should be considered.

Usability of new shelters should be ensured through community preference in location selection and multipurpose use of the shelter during normal time.

The sites should be chosen in a way that maximizes disaster time use and ensures appropriate normal time use. Consideration should be also given to saving livestock as well as humans in the area. In addition, the minimum resource needs for construction should be considered also for choosing suitable locations.

8.2.2 Design Criteria

Design of new cyclone shelters should follow a specific sets of guidelines. The design criteria for new shelter construction are as follows,

- All new shelters should be designed as per the Bangladesh National Building Code (BNBC) guidelines and specifications.
- All new shelters should be RCC framed structures.
- During the design process, minimum design forces including dead load, live load, wind load, earthquake load, loads due to flood and surge and other miscellaneous loads should be selected as per BNBC.
- Foundation of all structures should be designed properly based on soil test report of the site and the BNBC requirements for foundations.
- Selection of various loads on the structure should be done considering the cyclone shelters as *Essential facility* type structure according to BNBC.
- All new structures should be designed to withstand a wind speed of 260 km/hr as per BNBC.
- All structures should be earthquake resistant buildings. In order to ensure that, structures should be designed using BNBC defined seismic forces. In selecting design seismic forces, either the *Equivalent Static Force Method* or the *Dynamic Response Method* should be followed as appropriate and as per BNBC requirements.
- Design Forces for tsunami/cyclone induced storm surges should be selected as per BNBC. In cases, where loads are not specified in BNBC, loading information should be obtained from

reliable references. Tsunami related loads used in this study could be used for designing tsunami resistant buildings.

- Calculation of tsunami and cyclone induced storm surge forces should be obtained using the storm surge inundation map prepared under the CDMP Study by IWM (IWM, 2008).
- The quality of construction should be ensured by proper authorities through continuous monitoring, supervision and quality control activities.
- Location of new cyclone shelters should be inside coastal embankments if possible. Shelters constructed outside the coastal embankment should be designed very carefully and it should be ensured that those structures are tsunami resistant.
- All new shelters should have separate facilities for women, sufficient numbers of toilets, drinking water supply facilities, storage facilities for valuable goods and separate access facilities for the disabled.
- New shelters should be designed considering 3 sq. ft area per person. New shelters should consist three stories for a larger capacity.
- If space is available, all shelters should be constructed on kllas. The ground floor of shelter-cum-killas could provide safe haven for livestock. Furthermore, shelters on killas are less vulnerable to storm surge forces.
- Corrosive materials used in cyclone shelters which are exposed to weather, should be coated with effective protective coatings.

8.2.3 Information Updating Process

The government of Bangladesh and various other humanitarian organizations have constructed cyclone shelters over the period. As there is no centralized system for collecting and updating the shelter related information, it becomes a problem when need assessment studies for new shelters are done. In order to resolve this problem and ensure updated information on cyclone shelters, several steps should be followed.

- All shelter related information and documents like, Name of the shelter, Specific location, Funding and Constructing agency, available facilities, Floor area and Capacity of the shelter, Layout plans and design criteria, soil test report, foundation layout and design details etc. should be collected and sent to the DMB.
- All shelters should have a big 'S' mark of ***8m x 5m*** dimensions on the roof. The 'S' mark should be painted on a black background and in white or florescent weather proof color which could be observed from remote sensing imagery (e.g., IKONOS) so that the specific locations of shelters could be updated through remote sensing (RS). A sample 'S' mark is shown in figure 8.1.
- A centralized cyclone shelter information database should be established which will be updated and monitored regularly. This activity could be done through the Disaster Management Information Centre (DMIC) of DMB.

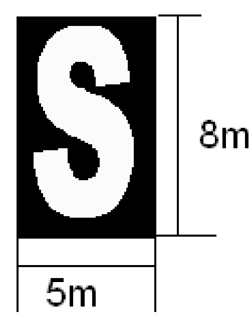


Figure 8.1: 'S' mark to be painted on shelter roofs

8.2.4 Formation of Shelter Management Committee

The MCSP report suggests that as cyclone shelters are intended to be used by people, it requires to be integrated into the local community. Therefore, a management committee is needed for each shelter. The management committee should include the head of the institution (of education centres or other normal time use), one male and one female member from the UDMC and members from the local community. One third of the committee members must be women. The head of the committee will be selected by the committee members. The key to shelter door should be kept with 2-3 selected persons of the management committee and this information must be known by the community people. Funds should be raised for the maintenance and management of the shelter and could come from the following three sources

- The managing committee of the institutions (education centres or other normal time use) might contribute a token amount of money to the shelter management fund.
- The shelter might be used for other income generating use and funds should be collected for maintenance.
- The government or donor agencies might provide funds for shelter maintenance.

The roles and responsibilities of the Shelter Management Committee are as follows:-

Before Disaster

- Maintain the shelters
- Ensure safe custody of the building and the equipment supplied/ to be supplied from time to time
- Establish and maintain relation with field level officials of the different departments of Government, UDMC members and NGOs for better preparedness and management of activities during disasters.

During Disaster

- Open the shelters for use by people during disasters
- Ensure safety and security of the population sheltered
- Ensure facilities for women and the disabled

After Disaster

- Vacate the shelters after disaster
- Clean the cyclone shelters after the event
- Make the shelters available for normal time use.

8.3 Existing Shelter

There are 2,583 cyclone shelters located along the coast that serve as sanctuaries for the local communities. But most of these shelters lack proper maintenance and management, and many do not have management committees. So there is an urgent need to immediately form a management committees where there are none and to reactive those that are inactive by reforming them and involving proactive and energetic people. The roles and responsibilities of the existing shelter management committee are similar to that of new shelters as described in section 8.2.4.

The periodic maintenance of shelters should be carried out by the management committee. Some shelters are in poor condition or are vulnerable to specific disasters. These shelters should be repaired or retrofitted properly to withstand the forces induced by disaster events. The management committee should maintain the existing facilities (e.g., water supply, sanitation etc.) of the shelter.

Chapter 9

Recommendations from National Workshop

A National Level Workshop was organized by MoFDM and CDMP on 18th August, 2009 to present the outcomes of the Study. The workshop was presided by Dr. Md. Abdur Razzaque, Honorable Minister, MoFDM. The workshop was participated by government, UNDP, EC, DFID and other donor organizations and various implementing organizations. From this workshop, several recommendations raised from the experts, officials and local community people present. The Recommendations are:

1. Cyclone shelter informations (maps, attributes etc.) are very useful for the stakeholders. These needs to be disseminated. These information should be made available to DMCs both in map and database format at district and upazila level.
2. Based on structural analysis results the buildings constructed by PEDP-II as school should not be considered as cyclone shelters.
3. Regarding the unusable cyclone shelters, a study is needed to assess the possibility and methods to make the shelters usable again.
4. The study produced useful evacuation route maps which should be disseminated to the local community. Further to this, the shelters and evacuation routes should be marked clearly and people should be made aware of this.
5. There is a huge interest from the participants about the required number of cyclone shelters to be constructed in future. Besides this, a study is needed for locating the places of shelter to be constructed in future using the guideline developed under current study.
6. A procedure should be developed to update the cyclone shelter information regularly which should also contain location information.
7. The participants felt strong need that government should immediately form shelter committee for each shelter and allocate fund for routine maintenance of the shelters.

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Appendix-1

Community Level Consultation

Cyclone Shelter Management for Tsunami and Cyclone induced Strom Surge Preparedness

Consultation meeting - 01

Cox's Bazar

Date	28 November 2008
Meeting Venue	Shofir Bill Cyclone Shelter
Village	Shofir Bill
Union	Enani
Upazila	Ukhea
District :	Cox's bazar
Meeting starting time	15 : 00 hr

Participant	**Male**	**Female**
Union Parisad	1	1
Teacher	2	1
School committee	2	0
Farmer	4	0
Wage labor	6	0
Women	0	8
Fisher	4	0
CEGIS	3	0
Total	**28**	**9**

Consultation meeting was held on 28th November 2008 in the only cyclone shelter of Shafir bill. This shelter is located very close to the sea. The Consultation meeting out comes have explicated in the disaster management frame work.

Disaster Management Frame Work:

Group	**Pre-Disaster**	**During-Disaster**	**Post-Disaster**
Users	**Social criteria** Development of shelter management committee Separate facilities for women, children and disable Ensuring the easy community access to celebrate their social functions	**Social criteria** Separate toilet facilities for women Shelter management committee should be alert **Accessibility criteria** Arrangement of adequate transport (boat and vehicle)	**Management criteria** Ensure immediate rescue operation Ensuring food, drinking water and immediate medical assistance after the event

Group	Pre-Disaster	During-Disaster	Post-Disaster
	<u>Accessibility criteria</u> Ensure good road communication Need more cyclone shelter in side the embankment. The preferable distance between settlement to shelter is 1-1.5 km Arrange transportation facilities in critical period **<u>Early warning criteria</u>** Cautious about false EW Need Tsunami EW information Awareness building and preparedness program Provide radio to the community people Improve present EW system Training to the local communities etc. Mandatory use of EW flag in the fishing boat **<u>Management criteria</u>** Regular maintenance of cyclone shelter Construction of new shelters Government support for cyclone shelter maintenance	facilities to evacuate the affected people **<u>Early warning criteria</u>** Arrangement should be available to inform the prevailing weather condition **<u>Management criteria</u>** Arrangement of adequate emergency light Timely evacuation of the affected people Safe storage of their portable assets and belongings Drinking water and sanitation facilities Adequate accommodation facilities Separate accommodation facilities for women, children and disable	
Shelter Management Committee	**<u>Early warning criteria</u>** Do not clearly understand about fag signaling and meaning of signaling number Provide training to the community people EW Flag hosting in the cyclone shelter **<u>Management criteria</u>** Cyclone shelter should be constructed within one kilometer Increased CPP activities Strengthen cyclone shelter management committee Adequate fund allocation	**<u>Early warning criteria</u>** Provide radio to all cyclone shelter to be aware about weather update **<u>Management criteria</u>** Toilet and sanitation facilities in the first floor Ensure emergency electricity facilities Provided emergency food and medical facilities	**<u>Management criteria</u>** Damage assessment Listing of the really affected households Ensuring food and temporary shelter facilities for vulnerable people Especial care for pregnant women, children and elderly people

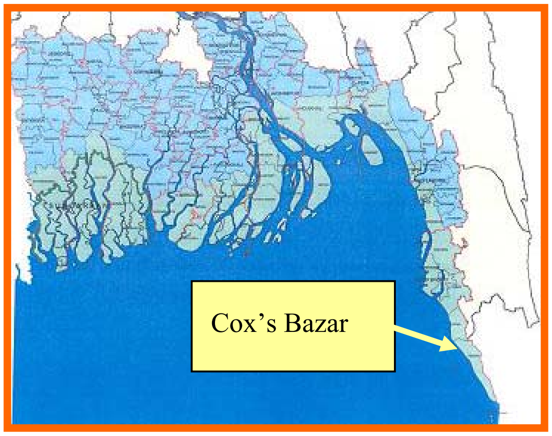
Group	Pre-Disaster	During-Disaster	Post-Disaster
	from the government for the shelter maintenance		
Organizational Shelter Managers	**<u>Social criteria</u>** Separate facilities for women **<u>Management criteria</u>** Bangladesh Red crescent society have constructed 32 cyclone shelter in eight upazilas of Cox's Bazaar Need more cyclone shelter Need more cooperation between UDMC and CPP Conduction of Training to the shelter managers Not giving any fake assurance to land owner Include Ansar and VDP and Upazila Education officer into the cyclone shelter management committee **<u>Early warning criteria</u>** Improve present EW system Preparation of early warning IEC materials for awareness	**<u>Management criteria</u>** Ensure two days emergency food and medical facilities Assure police protection Provide safe drinking water facilities	**<u>Management criteria</u>** Contact with UDMC and Upazila disaster management committee Emergency rescue Arrangement of food to the affected people

Issues Based Management

Issues	Pre-Disaster	During-Disaster	Post-Disaster
Institution	land owner of the cyclone shelter should be included in the management committee The committee should contain local farmers, elite persons, women, etc.	Open the cyclone shelter immediate after getting early warning Ensure security to the evacuated people Ensure the drinking water, latrine and food facilities Social security for women and disable Separate facilities for women, children and disable	Ensure temporary shelter facilities for highly affected families Emergency food supply Wash out the dirt and garbage from the shelter just after the departure of the emergency users and make it available for normal time use
Early Warning	Development of present early warning dissemination process along with mode of communication Reform the early warning devices (mike, drum, etc.) so that	Based on early warning the vulnerable people can take necessary preparedness	

Issues	Pre-Disaster	During-Disaster	Post-Disaster
	smooth early warning is possible		
Accessibility	Arrangement of vehicle, boat, etc Keeping alert the, CPP volunteers, VDP and Ansar Repair the shelter-access road	Conduction of rescue operation using the locally available access	Ensure transportation facilities for returning their homes
Location	Shelter should be located in the densely populated area Preferred distance between settlement to shelter is 1-1.5 km Cyclone shelter location should be in side of embankment	N/A	N/A

Key Informant's Interview-1



Location : Adinath Temple, Moheshkhali, Cox's Bazar

Preference:

- Need more cyclone shelter
- Improve cyclone signal
- EW dissemination to hilly area
- Effective CPP volunteers
- Improve TV network and electricity supply
- Improve road communication

Priest of Adinath Temple is memorizing his Sidr night experience

Rahul Chakrabarty, Priest of the Adinath Temple, Moheshkhali, Serving there for about 16 years. He is very intimate with the local community people. According to Mr Chakrabarty, major disaster was held in 1991. Thousands of people die in 1991 cyclone. This temple has used as a temporary shelter last SIDR time. Near about 400 people were taken shelter. Temple authority arranges separate facilities for women. People have carried many valuable jewelry, land papers and certificate with them. Mr. Rahul mentioned that general people do not understand weather signal properly. TV network and electricity has disturbed in critical situation. Many people leave in hilly area. CPP volunteers do not send warning in the hilly area. Only 4 cyclone shelters has been constructed in Moheshkhali and only 20% people can take shelter in critical period. No special transport facilities were available in the critical time. Mr. Rahul told, general people do not know the actual meaning of early warning signal meaning. So there is a urgent need for proper training and awareness program among the community. This training will help to protect their lives and assets.

Key Informant's Interview-2

Dr. Shubol Krishna Dey is a rural physician and an active member of CPP, Moheshkhali. He has been involved with CPP activities for a long time. There are 10 volunteers in his team. He receives early warning information from CPP by mobile phone. And the volunteers of his team disseminate that information to the community by using flags, megaphone, and siren. In his locality there is a cyclone shelter constructed by CCDB. Basically Hindu community people take shelters in this shelter because this is very close to their settlement. Muslim communities use another shelter which is about two kilometer away from this shelter. In SIDR night about 600 people took shelter in this school. This shelter lacks separate facilities for women. The women of this area do not prefer separate rooms for themselves because they feel secured with male family members. But a separate toilet facility is required for women. There are 3000 people live in this village but the shelter can accommodate only 400 persons. Dr. Shubol Kumer Dey emphasized on construction of new cyclone shelters to serve the whole population and early warning training for local community.

Location :
Sharoda Biddapith,
Thakurpara, Moheshkhali, Cox's Bazar

Preference:

- Need more cyclone shelter
- Emergency fund
- Separate toilet facilities
- Awareness program
- Early warning disseminate directly from district distraction
- Provide modern early warning dissemination instruments.

Key Informant's Interview-3

Location :
Bangladesh Red Crescent Society (BDRCS), Cox's Bazar

Contact persons :
Mr. Akram Ali Khan
Assistant Director

Preference:
- Signaling system upgrade
- Special security and separate facilities for women, children and disable
- 48 hours Emergency food storage
- Long term program for disaster management
- Cyclone shelter Land agreement papers will be preserved properly
- Include Education officer, Ansar and VDP in the cyclone management committee cyclone management

Mr. Akram Ali Khan (Rana), Assistant Director of Bangladesh Red Crescent Society (BDRCS). His working area is Cox's bazar. He coordinated the relief work in Myanmar after the devastating attack of Nargis in Myanmar. He informed that BDRCS have constructed 32 cyclone shelters in eight upazilas of Cox's bazar. They have trained 400 families under Cyclone Preparedness Programme during 1996 to 2000. They have already formed Village Disaster Preparedness Group and create a fund with the initiative of group members. BDRCS have formed shelter based four committees,

- Nurses,
- Rescue
- VDPC and
- First Aid

Approximate 1000 volunteerisms have been working in the field level with the close contact with BDRCS, District and Upazila administration. He has given some suggestion to the policymaker for future plan;

- Upazila Education officer, Ansar and VDP will be member of the cyclone shelter management committee
- Present signaling system need to be update
- Separate facilities for women and special accommodation for elderly, disable, blind and children
- Cyclone shelter land agreement document copy will be preserved in the concern Union Parisad , Upazila office, Upazila education office and DRRO office
- Every shelter should have minimum 2 days food storage in emergency period
- Ensure police security in emergency period

Key Informant's Interview-4

Location :
Zinjera, Moheshkhali, Cox'sbazar

Contact persons :
Mr. Abdur Rahman, Teacher
Zinjera Govt. Primary School

Preference:

- Improve early warning signaling system
- Use signaling flag in the fishing boat
- Need **Tsunami** and **Cyclone** preparedness program
- Need coast guard and Navy support in critical period
- People awareness program

Mr. Abdur Rahman, teacher of a primary school in Moheshkhali, Cox'sbazar. He has been living in this Island about 50 years. He is the witness of last two major cyclones in 1970 and 1991. Mr. Rahman told, in 2004 Tsunami wave also striked this island. Though no damage has occurred in 2004 tsunami. He thinks Tsunami will be a major hazard in this Island. Last false warning of Tsunami in October 2007, He took shelter in the hilly area of Teknuf. Most of the people of this Island are poor, illiterate and fishing is the major livelihood. Rahinga refuges also living here. They are not aware about early warning. Governments have constructed cyclone shelter and other infrastructure but those are not managed properly. Mr. Rahman suggests that every fishing boat will hoist flag after receiving early warning. Signaling number will be reduced and navy and coast guard will alert in critical period. He also added that there is no alternative of awareness among the general people to save life and property.

Appendix-2

Cyclone Preparedness Programme

Background of CPP:

After the devastating cyclone of 1970 that perished half a million lives, the League of Red Cross, now the International Federation was requested by the UN general assembly to undertake a leading role in pre-disaster planning for the country. The Cyclone Preparedness Programme (CPP) of Bangladesh Red Crescent Society (BDRCS) came into being in 1972. In June 1973, the Government of Bangladesh approved this new CPP programme and undertook the financial responsibility for some of the recurring expenses and setup a joint programme management mechanism by creation of a programme Policy Committee and a programme Implementation Board.

Goal:

The Goal of CPP is to minimize loss of lives and properties in cyclonic disaster by strengthening the capacity in disaster management of the coastal people of Bangladesh.

Objective:

The objectives of CPP are as follows:

1. To develop and strengthen the disaster preparedness and response capacity of coastal communities vulnerable to cyclones
2. To increase the efficiency of volunteers and officers.
3. To maintain and strengthen the CPP warning system and ensure effective response in the event of a cyclone.

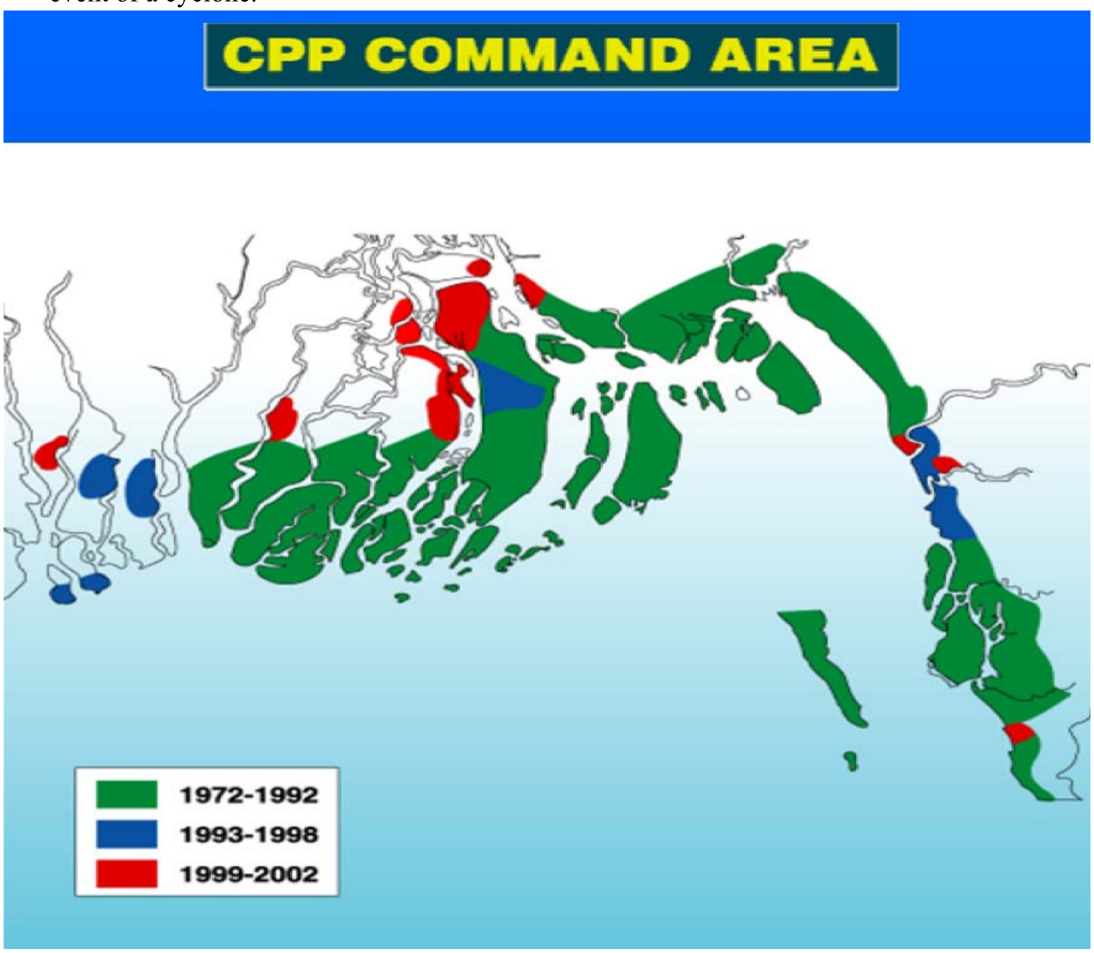


Figure A-2.1: Map showing the CPP command area during 1972 to 2002

Activities:

1. Disseminate early warning signals issued by the Bangladesh Meteorological Department to the community people.
2. Assist People in taking shelter.
3. Rescue distressed people affected by a cyclone.
4. Provide First Aid to the people injured by a cyclone.
5. Assist in relief and Rehabilitation operations.
6. Assist in the implementation of the BDRCS Disaster Preparedness Plan.
7. Assist in building public awareness and community capacity.
8. Assist in the co-ordination of disaster management and development activities.

The Working procedure of the volunteers in respect of early warning signal dissemination:

The system starts with the collection of meteorological data from the Bangladesh Meteorological Department (BMD), which issues bulletins including the designated warning signals of an approaching cyclone. The bulletins are transmitted to the 6 zonal offices and the 30 upazila level offices (sub-district) over HF radio. The upazila office in turn, pass it to unions and lower level through VHF radios. The union team leaders then conduct the unit team leaders immediately. The unit team leaders with his volunteers spread out in the villages and disseminate cyclone warning signals almost door to door using megaphones, hand sirens and public address system.

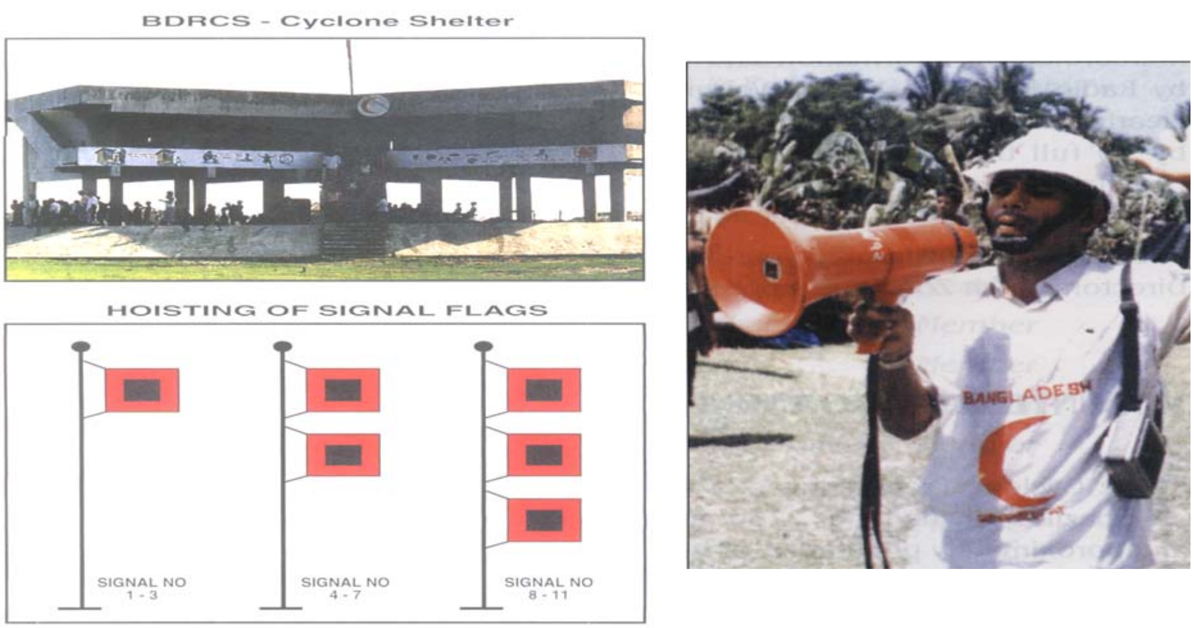


Figure A-2.2: CPP activities

Warning equipments used by the volunteers are:

- Transistor Radio
- Megaphone
- Life Jacket
- Torch Light
- Hand Siren
- Raincoat

- Gum boot
- Hard hat
- PA System
- First aid Kit
- Rescue kit
-

Benefits of Early Warning:

In respect of raising public awareness, motivation and effective early warning dissemination at the community level the loss of lives and properties of the community could reduce. During the November 1970 cyclone, with a wind speed of 223 km/hr, almost 500,000 people lost their lives in the coastal area. Whereas, in April 1991 cyclone, with a wind speed of 225 km/hr, only 140,000 people lost their lives although the population in the coastal area has doubled since 1970. In November 2007 a similar cyclone 'SIDR' hit the coastal region with a wind speed of 220 km/hr and out of that only 3,347 people lost their lives.

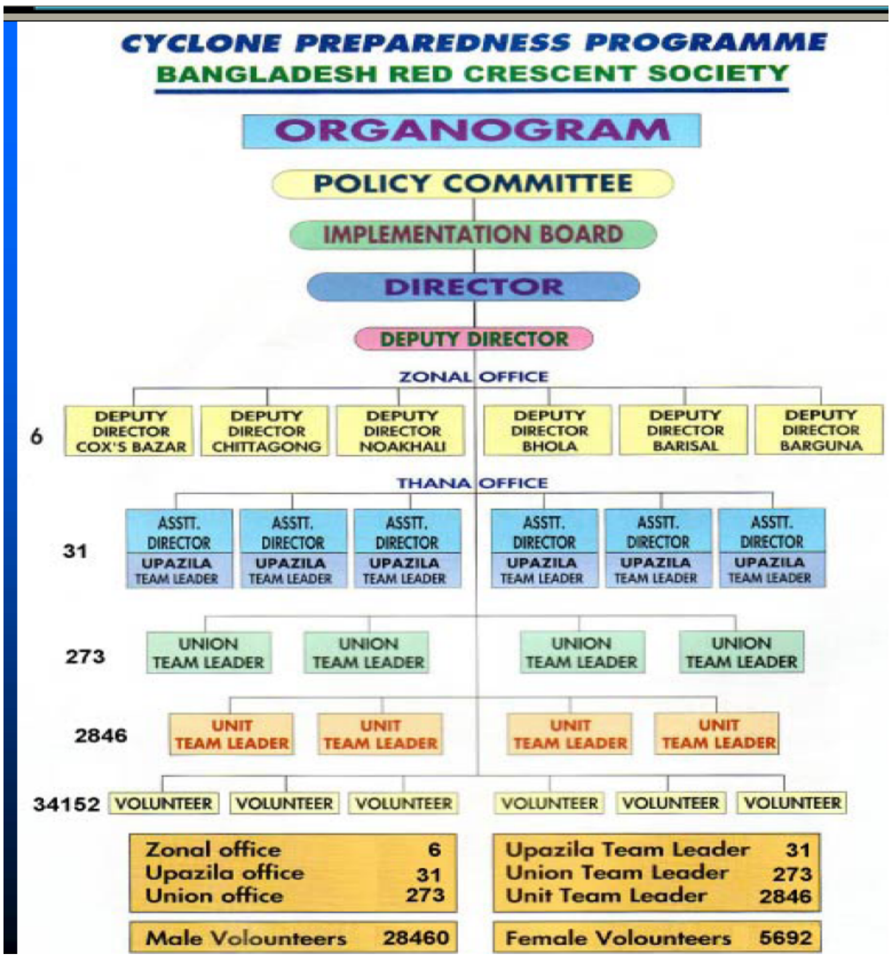


Figure A-2.3: CPP Organogram

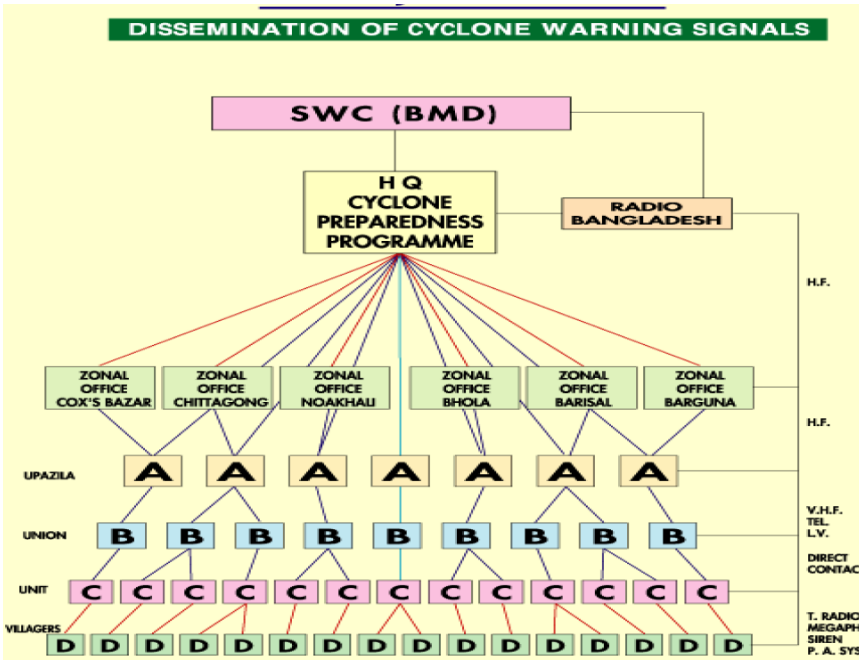


Figure A-2.3: CPP dissemination network

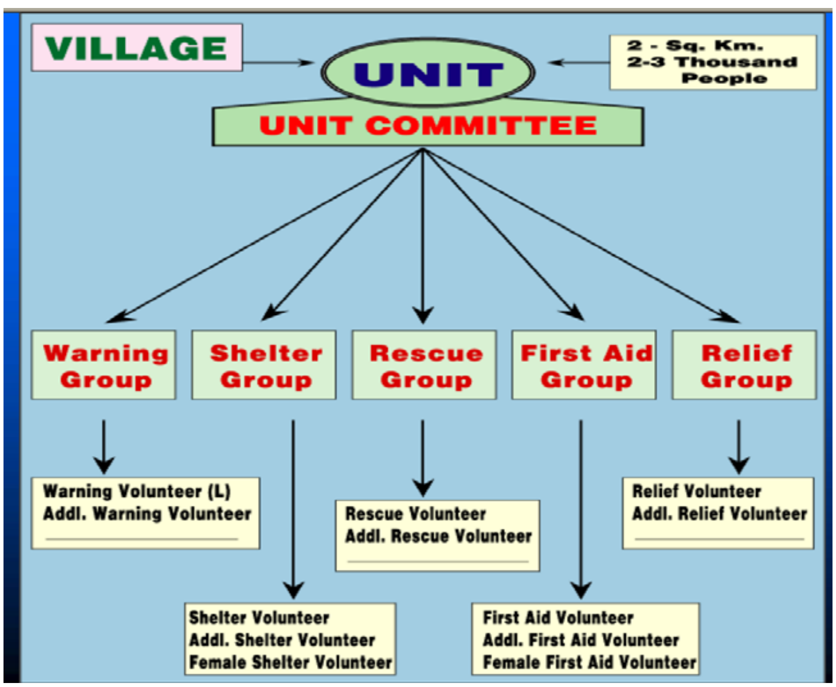


Figure A-2.4: Activity distribution of a CPP unit

Orientation/ Training Programme for Volunteers:

The orientation and training of the volunteers include the following topics;

1. Red Cross and Red Crescent Movement
2. Cyclone and its Behaviors
3. Warning Signals and their Dissemination

4. First Aid and Rescue
5. Disaster Management

Public Awareness Activities by CPP:

CPP conduct various public awareness programmes. Some of these are;

1. Volunteers social contact
2. Cyclone drills and demonstrations
3. Film/Video
4. Radio and Television
5. Posters, Leaflets and Booklets
6. Staging Dramas

Future Programme of CPP:

Future activities of CPP include;

- Expansion of command area
- Recruitment and Training of volunteers
- Replenishment of equipments
- Inclusion of Tsunami/Earthquake activities
- Increase public awareness activities

Welfare Activities by the volunteers:

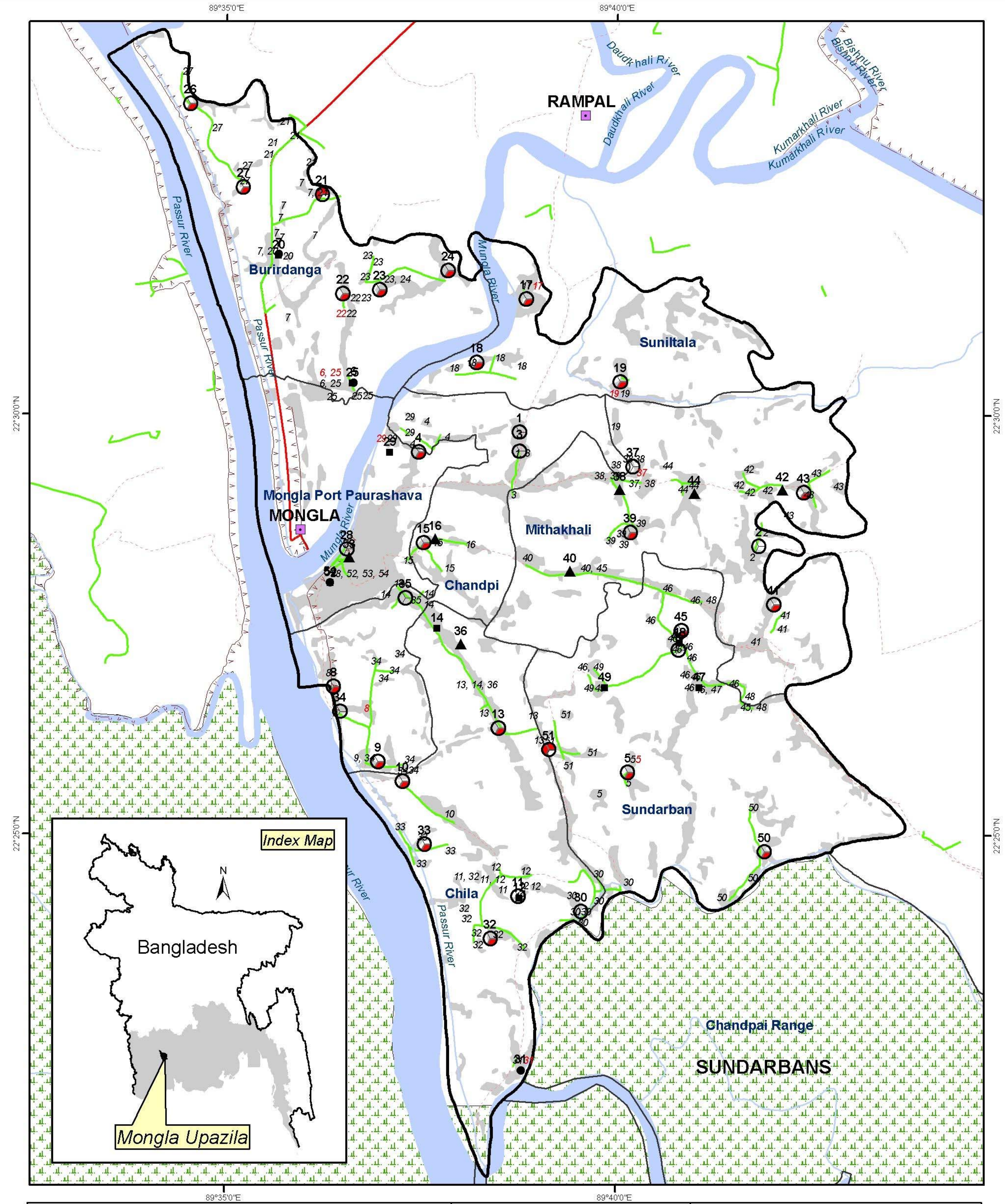
Other than the mandatory responsibilities, the volunteers are very much involved in performing social welfare activities by integrated themselves with local government administration, Ngo's, Upazila disaster management committee, education institutions, religious institutions, social club and other agencies in the event of road accident, fire, boat casize, river erosion, epidemic etc. On those situations the volunteers stand besides the helpless people with sincerity and offers wholehearted cooperation.

Appendix-3

Cyclone Shelter Maps and Attributes

Shelter Vulnerability & Evacuation Route Map
Upazila: Mongla, District: Bagerhat

CDMP



Legend

- Upazila HQ
- Upazila boundary
- Union boundary
- Embankment
- National & Regional road
- Other road
- Evacuation Route
- Rail line
- River
- Forest
- Bay of Bengal

- Shelter: Not Vulnerable
- C= Vulnerable for Cyclone
- T= Vulnerable for Tsunami
- E=Vulnerable for Earthquake

Segment filled by Red colour indiacates Vulnerable Shelter for Corresponding Hazard, otherwise Not Vulnerable

- Shelter: Unusable
- Shelter: Not Assessed

Bold numbers indicate Cyclone Shelter ID

- Building (PEDP-II)

N

2 1 0 2 km

Scale 1:85,000

Settlement

Number Indicates alocated shelter ID for the people of the respective Settlement
Red number for Tsunami
Black number for Cyclone

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In Cooperation with:

UNDP Bangladesh
DFID Department for International Development

Cyclone Shelter Attribute: District: Bagerhat, Upazila: Mongla

ID	Name	Union	Latitude			Longitude			Capacity	Design Type	Year of Construction	Floor Area (sft)	Vulnerability		
			D	M	S	D	M	S					Cyclone	Tsunami	Earthquake
1	Chandpai Pir mecher shah Dakhil Madrasha	Chandpi	22	29	37	89	38	36	450	Type 13	1997	900	N	N	N
2	Goalirmath GPS	Mithakhali	22	28	29	89	41	40	1,800	Type 5	2002	3,600	N	N	N
3	Malgazi GPS	Chandpi	22	29	37	89	38	36	1,800	Type 5	2002	3,600	N	N	N
4	Mokordon GPS	Chandpi	22	29	36	89	37	18	450	Type 11	1996	900	N	N	Y
5	Monglaport GPS	Sundarban	22	25	48	89	39	59	1,012	Type 9	2004	2,025	N	N	Y
6	2 No. Burirdanga GPS	Burirdanga	22	30	26	89	36	28	825	Type 13 / PEDP-II	2007	1,650	Y	Y	Y
7	Digray GPS	Burirdanga	22	31	57	89	35	30	825	Type 13 / PEDP-II	2007	1,650	Y	Y	Y
8	Kanainagar Fider school	Chandpi	22	26	49	89	36	13	850	Type 1	1993	1,700	N	N	Y
9	Saint Marish Primary School	Chandpi	22	25	55	89	36	47	1,166	Type 9	2003	2,333	N	N	Y
10	NEO Memorial School	Chila	22	25	41	89	37	6.4	1,166	Type 9	2003	2,333	N	N	Y
11	Dakshin Chila Siddikia Ahmedia Dakhil Madsarha	Chila	22	24	19	89	38	35	450	Type 13	1996	900	N	N	N
12	Dakshin Chila GPS	Chila	22	24	18	89	38	36	600	Not usable	1984	1,200	-	-	-
13	Moddha Holdia Highschool cum shelter	Chila	22	26	19	89	38	20	850	Type 1	1993	1,700	N	N	Y

ID	Name	Union	Latitude			Longitude			Capacity	Design Type	Year of Construction	Floor Area (sft)	Vulnerability		
			D	M	S	D	M	S					Cyclone	Tsunami	Earthquake
14	Uttar Holdibunia Cyclone shelter	Chila	22	27	30	89	37	33	600	Not usable	1985	1,200	-	-	-
15	Alhaz Korban Ali Alim Madrasha	Chandpi	22	28	32	89	37	22	1,166	Type 9	2003	2,333	N	N	Y
16	Malgazi BRAC Office	Chandpi	22	28	34	89	37	31	650	Others	2004	1,300	-	-	-
17	Ulubunia Forkania Hafizia madrasha cum shelter	Suniltala	22	31	26	89	38	41	850	Type 1	1993	1,700	N	N	Y
18	Joykha GPS	Suniltala	22	30	41	89	38	2.4	850	Type 1	1993	1,700	N	N	Y
19	Amratola Chapra GPS	Suniltala	22	30	27	89	39	53	450	Type 11	1996	900	N	N	Y
20	Digraj GPS	Burirdanga	22	31	56	89	35	30	600	Not usable	1984	1,200	-	-	-
21	Kapalirmeth GPS	Burirdanga	22	32	40	89	36	3.5	1,050	Caritas	1993	2,100	Y	Y	N
22	Burirdanga High school	Burirdanga	22	31	29	89	36	19	1,166	Type 9	2003	2,333	N	N	Y
23	Bairagikhali GPS	Burirdanga	22	31	32	89	36	48	450	Type 11	1995	900	N	N	Y
24	Shan bandha Fider School cum shelter	Burirdanga	22	31	46	89	37	41	850	Type 1	1993	1,700	N	N	Y
25	Burirdanga GPS	Burirdanga	22	30	25	89	36	27	600	Not usable	1984	1,200	-	-	-
26	GMS High school cum shelter	Burirdanga	22	33	45	89	34	22	1,166	Type 9	2003	2,333	N	N	Y
27	Bidyarbon GPS	Burirdanga	22	32	45	89	35	2.9	450	Type 11	1996	900	N	N	Y
28	Chalna Bandar Senior Fajil Madrasha	Ward No-02	22	28	27	89	36	23	450	Type 13	1998	900	N	N	N
29	Araji Mokardon cyclone shelter	Chandpi	22	29	36	89	36	56	600	Not usable	1984	1,200	-	-	-
30	6 no Chilla UP Complex	Chila	22	24	8.3	89	39	24	2,025	Type 12	2005	4,050	N	N	N

ID	Name	Union	Latitude			Longitude			Capacity	Design Type	Year of Construction	Floor Area (sft)	Vulnerability		
			D	M	S	D	M	S					Cyclone	Tsunami	Earthquake
31	Joymanirgol GPS	Chila	22	22	14	89	38	38	825	Type 13 / PEDP-II	2004	1,650	Y	Y	Y
32	Sabed Khan High school	Chila	22	23	49	89	38	14	1,200	Type 9	2004	2,400	N	N	Y
33	Munmia High Schoolcum cyclone shelter	Chila	22	24	56	89	37	23	850	Type 1	1992	1,700	N	N	Y
34	Kanainagar church of Bangladesh	Chandpi	22	26	31	89	36	18	1,450	Type 5	1992	2,900	N	N	N
35	Chandpi Union Complex Bhaban	Chandpi	22	27	52	89	37	8	560	Type 12	2005	1,120	N	N	N
36	Uttar Haldibunia Balurmath Cyclone shelter	Chila	22	27	19	89	37	51	1,500	Others	1999	3,000	-	-	-
37	Chouridanga Ahamedia Dakhil Madrasha	Mithakhali	22	29	26	89	40	2.5	450	Type 13	1997	900	N	N	N
38	12No. A.T.C. Govt. Primary School	Mithakhali	22	29	9.5	89	39	53	900	Others	1993	1,800	-	-	-
39	Andharia Siddikia Madrasha	Mithakhali	22	28	39	89	40	1	1,166	Type 9	2004	2,333	N	N	Y
40	Tatibunia High School	Mithakhali	22	28	11	89	39	15	1,400	Others	1995	2,800	-	-	-
41	Khonkarbad GPS	Mithakhali	22	27	48	89	41	51	450	Type 11	1995	900	N	N	Y
42	Khasherdanga ABS High School	Mithakhali	22	29	9.6	89	41	58	1,000	Others	1995	2,000	-	-	-
43	Khasherdanga Santimoy girls high school	Mithakhali	22	29	7.7	89	42	14	1,166	Type 9	1995	2,333	N	N	Y
44	Nitakhali Family Planning	Mithakhali	22	29	6.8	89	40	50	400	Others	1992	800	-	-	-
45	Younus Ali High School cum Caritas cyclone shelter	Sundarban	22	27	21	89	40	40	850	Type 1	1993	1,700	N	N	Y

ID	Name	Union	Latitude			Longitude			Capacity	Design Type	Year of Construction	Floor Area (sft)	Vulnerability		
			D	M	S	D	M	S					Cyclone	Tsunami	Earthquake
46	5 No. Sundarban Union Parishad	Sundarban	22	27	15	89	40	38	2,025	Type 12	2005	4,050	N	N	N
47	Madur Palta GPS Cum Cyclone shelter	Sundarban	22	26	48	89	40	54	600	Not usable	1984	1,200	-	-	-
48	Dhalir Khondo Yunis Ali Collegiate School	Sundarban	22	27	20	89	40	39	900	Not usable	1984	1,800	-	-	-
49	Burburia GPS cum Cyclone Shelter	Sundarban	22	26	48	89	39	42	600	Not usable	1984	1,200	-	-	-
50	Kachubunia GPS	Sundarban	22	24	51	89	41	44	450	Type 11	1995	900	N	N	Y
51	Uttar Banshtala GPS Caritas Shelter	Sundarban	22	26	4	89	38	59	1,050	Caritas	1993	2,100	Y	Y	N
52	Mongla Port GPS	Ward No-02	22	28	2.5	89	36	11	600	Not usable	1984	1,200	-	-	-
53	Diganta Prokalpa GPS	Ward No-02	22	28	21	89	36	25	700	Others	1993	1,400	-	-	-
54	Monglaport GPS	Ward No-02	22	28	3	89	36	11	825	Type 13 / PEDP-II	2005	1,650	Y	Y	Y

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