Managing the Risk of Natural Disasters in Coastal Zone: Lesson Learned From Tsunami Disaster in Nanggroe Aceh Darussalam Province

THESIS

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Preface

The position of NAD province causes it is vulnerable for earthquake and tsunami. Thus, it needs good management regarding to managing the risk of tsunami disaster in its coastal zone. This research is about how to manage the risk of tsunami disaster in coastal zone to safe more life and property. Tsunami happened on December 26, 2004 has motivated me to know more about this kind of disaster and how to manage the risk of tsunami. In addition, the lecture from Dr. Johan Woltjer about Flooding in the course of Water Management has inspired me to study about tsunami mitigation measures in coastal zone from tsunami affected countries.

First and foremost, thanks to Allah Almighty, finally I can finish this research. I wish to thank to my supervisors, Prof. Dr. Ir. G.J.J. Linden of University of Groningen and Arief Rosyidie, M. Arch;PhD of Institut Teknologi Bandung, for their valuable guidance during the process of finishing my thesis in limited time.

I am grateful for the support of BAPPENAS and NESO for giving me the chance to continue my study in Bandung and Groningen. I am very fortune to have had the possibility to study in such stimulating environment. It also enabled me to explore life in Netherlands and interface with different culture. In particular, I wish to thank to the faculty members in SAPPK of Institute of Technology Bandung, Faculty of Spatial Sciences of University of Groningen, UPT Bahasa ITB, and all my colleagues. I also would like to thank to all people whom helped me in finishing this thesis.

Unending gratitude goes out to my family: mom, dad, mother in-law, sister, brother and especially for my lovely husband, Mawardi S.E and my children, Nurusyifa and Muhammad Daffa for supporting me during my study in Bandung and Groningen. Without their tireless encouragement I would never made it half this far.

Groningen, 4 August 2007
Tetty Meutia

Abstract

Tsunami disaster that hit Aceh on December 26, 2004 was really destructive. Although, the epicenter of this disaster was located in the western coast of Aceh, but the impact was experienced by other Indonesian neighbor countries. It did not only damage the property and community in Aceh coastal area but also in inland area. This made the tsunami affected area up to more than 3 km inland Banda Aceh.

NAD Province is located in earthquake prone area, and most of tsunami in Aceh are generated by earthquakes. In the past, were tsunamis happened in this area and there will be tsunami in the future. Because of this, tsunami risk management measures become essential elements to reduce the impact of the next tsunami disasters.

This research elaborates some tsunami risk management measures from India, Thailand and Japan regarding how to mitigate the impact of tsunami in the future, and considers some possibilities to be implemented and appropriate with the condition of NAD Province coastal zone.

Tsunami risk management measures proposed by this research are technical, spatial and community measures. Technical measures are the measures related to physical construction in tsunami prone area. Spatial measures deal with land use planning related to tsunami disaster. Community measures are how to inform community about tsunami regarding to minimize the loss of life in the future. Some recommendations to implement those measures well are provided at the end part of this research.

Key words: *tsunami, earthquake, tsunami risk management measures; technical, spatial and community measures.*

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CHAPTER 1 INTRODUCTION

1.1 Background

Nanggroe Aceh Darussalam (NAD) Province is one of the affected areas that were destroyed by tsunami disaster on December 26, 2004. The impact caused by that disaster was not only on coastal area but also inland area. The tsunami destroyed most public facilities in coastal zone and the area around it.

Many countries in the world have concerned to tsunami that happened in Aceh. The tsunami was stated as the world disaster because the effect of tsunami on December 26, 2006 was also experienced by other countries such as India, Thailand, Malaysia, Sri Lanka, Somalia, Kenya, etc.

NAD Province is chosen in this study because in the history of tsunami in Sumatra there were tsunamis in this area in the past. Besides, it is located in area that is always threatened by earthquake and tsunami disasters so that it is important to know mitigation measures applicable for this area. There were so many people died and many properties were damaged. That is why this research wants to study the appropriate measures for the case of Aceh.

This research is about how to manage the tsunami risk in Aceh regarding disaster prevention in order to mitigate the impact of tsunami disaster. Besides introduction, this chapter also mentions a simple overview about coastal zone, natural disaster in coastal zone, tsunamis, problem definition, research objective and research question, scope of research and research methodology, theoretical framework and structure of research.

1.1.1 Natural Disaster in Coastal Zone

Coastal zone is the border between the land and water. This zone is important because a majority of the world's population occupies in this zone. Coastal zones are frequently changing because of the dynamic interaction between the oceans and the land. Waves and winds along the coast are both eroding rock and depositing sediment on a continuous basis, and rates of erosion and deposition vary significantly from day to day along these zones. The energy getting the coast can become high during storms, and such high energies make coastal zones areas of high vulnerability to natural disasters. Thus, it is necessary to understand the interactions of the oceans and the land related to understand the disasters associated with coastal zones (Nelson, 2007).

After tsunami disaster in Aceh, the border between the land and the water is more than before tsunami. It is because the earthquake and tsunami caused the land become lower than before tsunami such as in Ulee Lheu, Meulaboh, etc, while in other area the land coming up like in Simeulu. Thus, because the areas changed and gave the impact to people and property, this research wants to study tsunami mitigation measures for the area affected by tsunami disaster. The pictures of changes in Aceh coastal zone after tsunami can be seen in figure 1.

Figure 1. Changes in Aceh coastal zone.

Source: http://soundwaves.usgs.gov/2005/03/ and http://www.1906eqconf.org/tutorials/Intro-Tsunamis_Dengler5.pdf (last visited August 2, 2007)

Natural disasters can be defined as the impact of natural hazards upon a vulnerable community, resulting in disruption, damage and casualties that cannot relieved by an unaided capacity of locally-mobilized resources (United Nations Disaster Relief Coordinator, 1991)

Natural disaster is a phenomenon that we can not predict when it happens, but it causes big impact to the potential area for this disaster. No place in the world can escape from this kind of disaster. Bendimerad (2001) in Skinner and Mersham (2002) argued that natural disasters can be said as the most unexpected and high cost disasters in terms of loss of human life and resources. Many people died and loss of resources and infrastructures occurred. This loss needs a lot of fund for rehabilitation and reconstruction on the destroyed area.

In general, natural disasters that happened in coastal zone are earthquake, storm, hurricane, tsunami and flood. The major disaster in coastal zone is tsunami, as stated by Bernard (1999) "Tsunami are a major hazard to coastal residents in earthquake-prone regions". The wave caused by tsunami swept the people, all the resources and infrastructures in this area.

This research focuses on earthquake that causes tsunami and tsunami as coastal natural disasters, because in the history of tsunami in Indonesia, earthquake has caused the highest number of tsunami. The history of tsunami events in the period 1600-2000 in Sumatra-Java Region can be seen in Appendix 1. Most of those tsunamis happened in Sumatra as presented in Table 1.

Table 1. List of Tsunamis in Sumatra Region

No	Year	Location	Long.	Lat.	Mag.	Ca	Pro	I	Max Run Up	Reference
1	1681.12.11	Sumatra				1	4			Newcomb& McCann
2	1770	Southwest Sumatra	102	-5	Ms 7	1	3	0.5	(1)	NNGDC/NOAA
3	1797.02.10	Southwest Sumatra	99	-1	Ms 8	1	4	3.0	(1)	Berninghausen
4	1799	Southeast Sumatra	104.75	-2.983		1	2			Berninghausen
5	1818.03.18	Bengkulu, Sumatra	102.267	-3.77	Ms 7	3	3	1.5	(1)	
6	1833.01.29	Bengkulu, Sumatera								Berninghausen
7	1833.11.24	Southwest Sumatra	102.2	-3.5	Mw.8.7	1	4		(3)	NGDC/NOAA, Newcomb & McCann (1987)
8	Sep. 1837	**Banda Aceh**	96	5.5	Ms. 7.2	4	2	0.5	(1)	NGDC/NOAA
9	1843.01.05	Southwest Sumatra	98	1.5	Ms 7.2	1	4		(3)	Berninghausen (1966), Heck 1947
10	1843.01.06	Southwest Sumatra	97.33	1.05						Berninghausen (1966), Heck 1947
11	1852.11.11	Sibolga, Sumatra	98.8	1.7	Ms 6.8	1	1		(1)	NGDC/NOAA
12	1861.02.16	Southwest Sumatra	97.5	-1	Ms 8.5	1	4	3.0	(9)	Berninghausen (1966)
13	1861.03.09	Southwest Sumatra	99.37	0.3	Ms 7	1	4	2.0	(4)	NGDC/NOAA
14	1861.04.26	Southwest Sumatra	97.5	1	Ms 7	1	4	1.5	(1)	NGDC/NOAA
15	1861.06.17	Southwest Sumatra	97.5	1	Ms 6.8	1	3			NOAA/NESDIS
16	1861.09.25	Southwest Sumatra	100	-1.5	Ms 6.5	1	3	1.5	(1)	Berninghausen (1966)
17	1864	Sumatra								Berninghausen
18	Feb. 1884	Krakatau	105.423	-6.10		1	2			Murty et al. (1999)
19	1896.10.10	Southwest Sumatra	102.5	-3.5	Ms 6.8	1	2		1 (1)	NGDC/NOAA
20	1904.07.04	Sumatra								
21	1907.01.04	Southwest Sumatra	94.5	2	Ms 7.6	1	4	2.0	2.8 (7)	NGDC/NOAA/ Newcomb & McCann
22	1908.02.06	Southwest Sumatra	100	-5	Ms 7.5	1	4	1.0	1.4 (1)	NGDC/NOAA
23	1909.06.03	Sumatra	101	-2	Ms 7.7	1	2	1.0	1.4	NGDC/NOAA
24	1914.06.25	West Coast of South Sumatra	102.5	-4.5	Ms 8.1	1	0			NGDC/NOAA
25	1922.07.08	**Lhoknga, Aceh**	95.233	5.467		1	1			NGDC/NOAA
26	1926.06.28	Southwest Sumatra	99.5	-1.5	Ms 6.7	1	0			NGDC/NOAA
27	1931.09.25	Southwest Sumatra	102.7	-5	Ms 7.5	1	3		31.4	NGDC/NOAA
28	1935.12.28	Southwest Sumatra	98.25	.001	Ms 8.1	1	1			NGDC/NOAA
29	1958.04.22	Southwest Sumatra	104	-4.5	Ms 6.5	1	2		1	NGDC/NOAA
30	1984	Off West Coast of Sumatra	97.955	0.18	Ms 7.2					Engdahl et al. (1988)
31	1994.02.15	Southern Sumatra	104.3	-5	Ms 7.0	1				
32	2000.06.04	Off West Coast of Sumatra	102.09	-4.72	Ms 7.8				(1)	USGS/NEIC (PDE)
33	2000.06.18	South Indian	97.45	-13.8	Ms 7.8	1	4		0.3	NOAA/NESDI

No	Year	Location	Long.	Lat.	Mag.	Ca	Pro	I	Max Run Up	Reference
		Ocean								S
34	2004.12.26	**Off West Coast of Sumatra**	95.947	3.307	Mw 9.3	1	4	3.0	24 (302)	NGDC/NOAA
35	2005.03.28	Off West Coast of Sumatra	97.013	2.074	Mw 8.7	1	4		4 (2)	NOAA/NESDIS

Source: Rastogi and Jaiswal (2006)

NAD Province experienced three times of tsunamis, which occurred in 1837, in 1922 and in 2004. It indicates that there will be the next tsunamis in NAD, as it was happened in the past so it will happen again in the future. Until now, there is no exact prediction of tsunami. Experts predict the events of tsunami based on the history of tsunami in certain region.

Earthquake and tsunami in Aceh on December 26, 2004 damaged most of coastal area in Aceh. This disaster also destroyed the infrastructures not only in area covered by tsunami but also inland area, such as settlements, schools, offices, hospitals and other social facilities. Earthquake and tsunami also destroyed the center of economic activities in Banda Aceh as the capital city of Nanggroe Aceh Darussalam (NAD) Province that give impact to social and economic condition of people in this area.

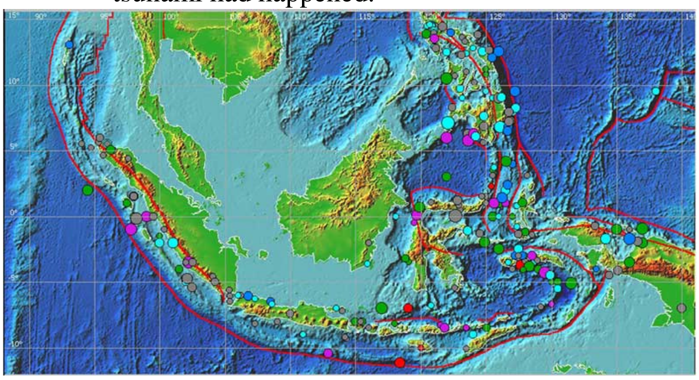
Many people in coastal zone have no experience with tsunami before so that when this tsunami happened, most of the people, not only in this area but also the people inland who were affected by the wave of tsunami do not know what they should do. However, most of people who live in islands in NAD Province like Simeulu, Aceh Island and Weh Island have experienced of tsunami before, they called it as “seumong” or “ie beuna” which means great wave.

This research proposes risk management, in this case mitigation measures to decrease the impact of tsunami, in order to prepare the people what they should do if there are tsunami disasters in the future and people have time to do something (warning time) so hopefully it can reduce loss of life. Besides that, this risk management is also as mitigation for the loss of property in coastal zone because of tsunami.

1.1.2 Case Study

NAD Province is as one of the areas that are always threatened by earthquake and tsnami disaster because this area is located in the line with the earth plate meets (red line in figure 2). Thus, it makes Sumatra Island, especially Aceh as tectonic earthquake and tsunami potential area. The earthquake that causes tsunami is influenced by the characteristic of the fault. The detailed explanation about this fault can be seen in chapter 2.

Figure 2. Map of Earth Plate Meets in Indonesia (red line). The color circle is the area where tsunami had happened.



Source: http://www.pirba.ristek.go.id/isi/aceh/mengurangi_resiko.htm (Last visited January 16, 2007)

Moreover, in the history of earthquake and tsunami in Indonesia in the last ten years, this area has the highest victims of those disasters. It can be seen in table 2.

Table 2. Destructive Tsunami Last 10 Years

Location	Year	Fatalities (human)
Flores	1992	1950
Jawa Timur	1994	238
Irian Jaya	1996	110
Toli-Toli	1996	6
Taliabu	1996	18
Banggai	2000	4
Aceh	**2004**	**295,000**

Source: http://www.soi.wide.ad.jp/soi-asia/conference/tsunami/material/hamzah.pdf (Last visited January 7, 2007)

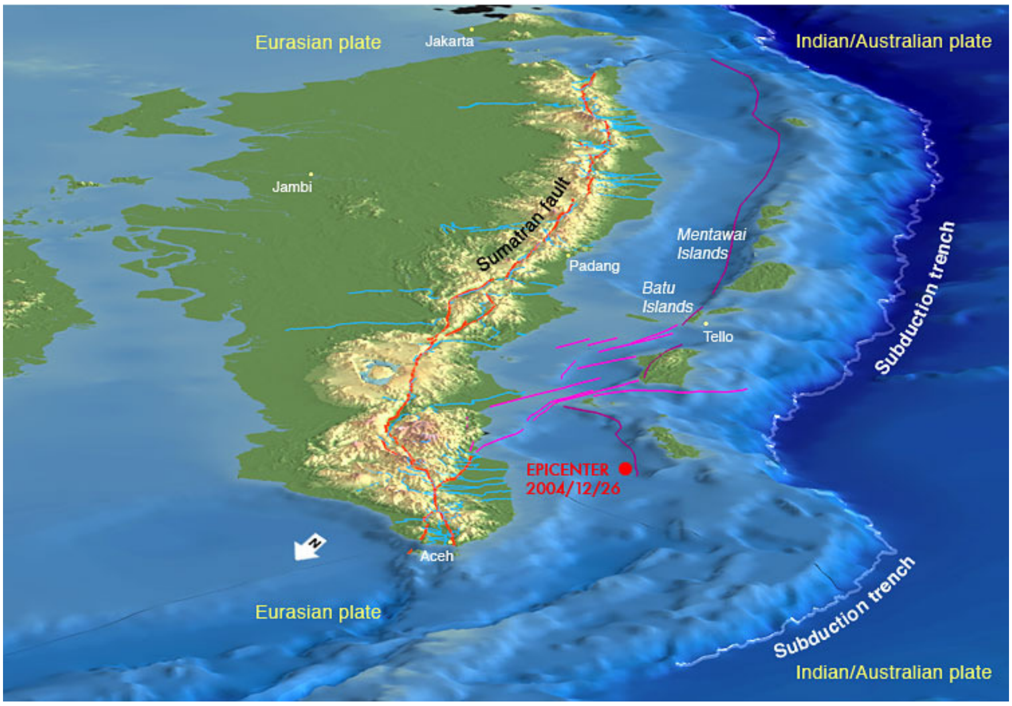
The fourth largest earthquake in the world since 1900 has happened on December 26, 2004, at 07:58:53 local time, off the west of Northern Sumatra, Indonesia. The magnitude was 9.0, the central depth was 30 km, and the epicenter position is latitude 3.30 north and longitude 95.96 east. The epicenter is 255 km from Banda Aceh, the nearest provincial capital in Sumatra (Iemura et al, 2006). The strong earthquake that happened in this area can be the best indicator for tsunami, because after that earthquake there was tsunami which swept the coastal area, the first area that hit by tsunami before it damaged the inland area. This indicator is also stated by Bernard (1999) "Most tsunamis are caused by large earthquake". For nearby coastal residents, strong ground shaking is the best indicator of tsunami potential.

1.1.3 Problem Definition

NAD Province is located between two big plates, Eurasia and Australia plate (both of these plates are active) and in the line of Sumatra Fault which is at risk for earthquake. According to http://www.tectonics.caltech.edu/sumatra/index.html (last visited July 31, 2007), there are two component of convergence in the Sumatran Plate Boundary which are vertical and horizontal. The vertical component is across the Sumatran subduction zone, while the horizontal component is across the Great Sumatran fault. Because of the movement of those two plates, the earth crust and produced earthquake with scale 9. Along the Great Sumatran Fault, the earthquakes with magnitudes up to about 7.5 are common. The map of Sumatran Fault is presented in figure 3.

Tsunami that happened in Aceh was generated by earthquake. Thus, in the future there will be other tsunamis happening in this area. Furthermore, because most of population in this area is concentrated in coastal zone and there is limited buffer zone such as mangrove and greenbelts, if the tsunami hits this area, it can damage all the things in this area directly. In addition, most of coastal zones in this area are flat, such as the northern shoreline and the western shoreline of Banda Aceh, so it needs treatments to safe it from the next tsunami disasters.

Figure 3. Sumatran Fault Map



Source: http://today.caltech.edu/today/images/sumatra_05jan2005_01.jpg (last visited August 2, 2007)

As an area located between those two plates, Aceh is vulnerable for the earthquake followed by tsunami in the future. It is because based on the history, this area experienced earthquake and tsunami. As stated by Natawijaya (2002) that there would be a big earthquake in the Mentawai zone area with the prediction of the period between 170 and 200 year. Mentawai Island is located in the western part of Sumatra. Meanwhile, based on the earthquake history in Sumatra, the earthquake with 9 Richter scale followed by tsunami had happened in November 1833 in the western part of Sumatra. The epicenter of earthquake on December 26, 2004 is located in the western part of Sumatra. This proved Aceh as earthquake prone-area. It is also supported by the statement of Surono (2004) that there were earthquakes in

Aceh in 1983, 1990 and 2003 and tsunamis happened in this area in 1837, 1907 and 1948 (Surachman et al, 2004).

Moreover, Indonesian Institute of Sciences (LIPI) states that based on researches and history of tsunamis, there is possibility of tsunamis in NAD Province that comes from Andaman Island. Sumatra has potency of tsunami because this area is located in the tectonic area lying from Lampung to Aceh Island and as the movement plates along the ocean. For Sumatra, the center of tsunami potency area is in the northern part of Rondo Island and in the southern part of Mentawai Islands (Research Center of Geotechnology, 2007). Rondo Island is one of islands located in NAD Province, exactly in the area of Weh Island. It means that there will be possibilities the next tsunamis will occur in this area in the future.

Furthermore, Sanny (2005) argues that Indonesian region is vulnerable region for disasters, starting from the tip of western part to the eastern part of Indonesia with the various sea depths. Aceh, located in Burma Micro plate (as part of Eurasia plate), will be hit by other tsunami in the future. He predicted that the period of tsunami in Aceh is once in every 50 years. Meanwhile, based on data of tsunamis in Sumatra (Table 1) the period of tsunami in NAD Province might happen between 82 and 85 years.

In addition, Surono (2004) stated that there are three prone-areas for tsunami and earthquake in the future, that is, NAD Province, West Sumatra, Bengkulu and South Sumatra. It is because of the location of the movement of the fault happen between Sumatra Island and islands string along Sumatra Island such as Nias Island and Mentawai Island.

Based on the explanation above, this study is conducted to find ways to mitigate the impact of tsunami disasters in the future in order to reduce loss of human life and property especially in coastal zone. Hopefully, what happened in Aceh can become a lesson for other countries or other regions which have the same problems with Aceh in managing risk of tsunami on coastal zone. This study tries to find out what kind of mitigation measures appropriate for tsunami in Aceh related to the number of possibilities to coping with tsunami like physical measures, building, mount, spatial measures, community measures, etc.

1.2 Research Objective and Research Question

The objective of this research is to know risk management measures from other countries that can be applied in order to prevent and mitigate the impact of earthquake and tsunami disasters in coastal zone in the future, not only to save more lives but also to reduce loss of property.

This research would like to see what other countries are doing with these measures, what people do, how they tackle tsunami disasters in these countries which have experienced earthquake and tsunami disaster. Then, this research wants to know if there are possibilities of those measures to make it applicable with the condition of Aceh coastal zone, so that in the future if there is tsunami disaster the impact can be reduced. The questions link to that are:

1. *What kind of risk management measures for tsunami are there?*
2. *What risk management possibilities which are applicable for Aceh?*
3. *How to manage land use planning in coastal zone related to risk management to mitigate the impact of tsunami disasters in the future?*

1.3 Scope of Research and Research Methodology

This study focuses on risk mitigation measures that are applicable for Aceh coastal zone by exploring mitigation measures in other countries which are appropriate with the condition of Aceh coastal zone.

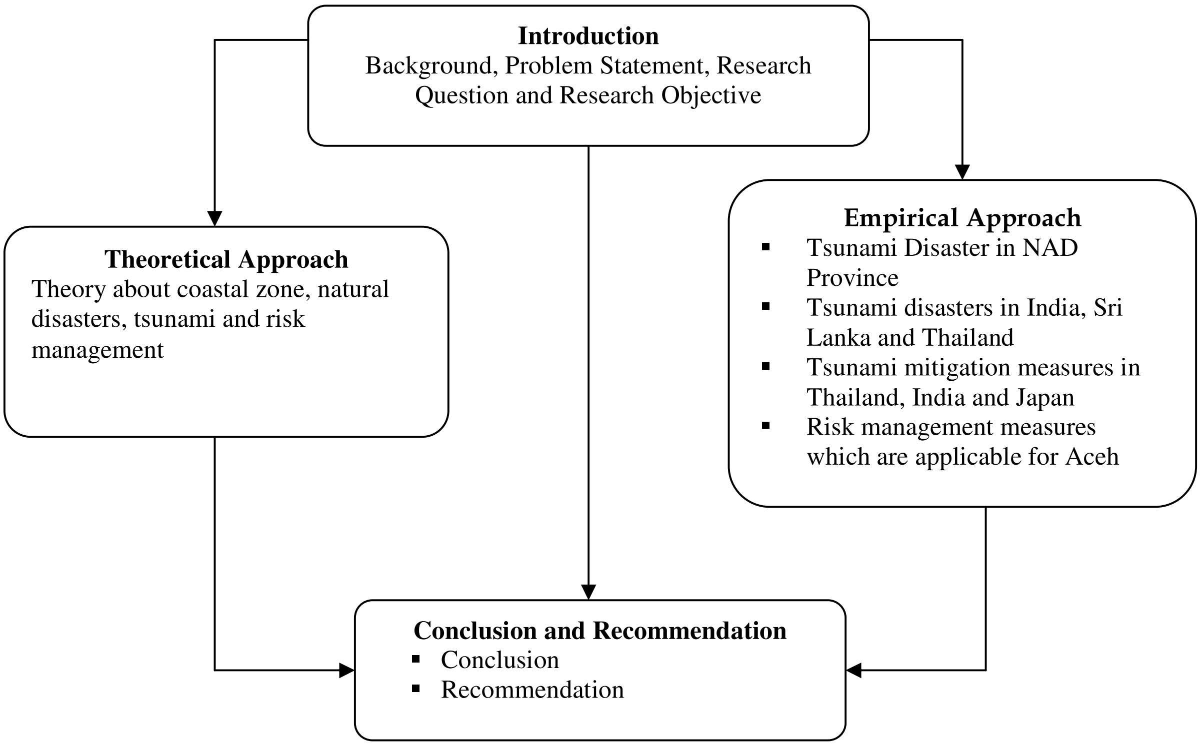
The used in this research is literature study, and it is more on literature review and secondary data analysis. It explores theoretical and empirical aspects related to Managing the Risk of Natural Disasters in Coastal Zone, especially earthquake and tsunami disasters. It uses literature of books, journals, articles, seminar proceeding, working paper, secondary data from official document and internet, and other sources which are relevant to this research. All the literatures are obtained from library and internet access.

1.4 Framework of Research

This research starts with the introduction that consists of background, research objective and research question, scope of research and research methodology, framework of research and structure of research. There are two approach used in this research, theoretical approach (theoretical framework) and empirical approach. These approaches are obtained based on literature review.

The theoretical approach will elaborate the concepts of coastal zone, natural disasters in coastal zone, tsunami and risk management. Meanwhile, the empirical approach analyses tsunami disaster in Aceh and other countries that already had experience with tsunami disaster, and try to get lesson from tsunami disasters and risk management measures from other countries to find ways to mitigate the impact of tsunami disasters in the future. The framework of this research can be seen in figure 4.

Figure 4. Framework of Research



1.5 Structure of Research

There are 5 chapters in this research.

Chapter 1: Introduction

This chapter describes background, research problem, research objectives and research questions, scope of research and research methodology, framework of research, and structure of research. The importance of the study is described in this chapter 1.

Chapter 2: Theoretical Framework

Framework of analysis related to the concept tsunami and tsunami risk management in coastal zone from theoretical point of view will be elaborated in this chapter.

Chapter 3: Case Study

This chapter illustrates tsunami disaster in Aceh and other countries.

Chapter 4: Risk Management Measures in Some Countries

This chapter describes some risk management measures in some countries

Chapter 5: Risk management measures for tsunami and tsunami risk management measures which are applicable for Aceh

Some risk management measures for tsunami are elaborated in this chapter and also the possibilities of the measures to be applied in Aceh.

Chapter 6: Conclusions and Recommendation

Conclusions are drawn in this chapter to answer the research questions in Chapter 1. General recommendations area also developed in this last chapter on the basis of Aceh.

CHAPTER 2 THEORETICAL FRAMEWORK

Coastal zone as an area between the sea and the land needs specific treatment in its management and its development. Besides its vulnerability, this area also as the center of various activities, thus it makes this area as a place for people to live. The development in this area should consider all the ecosystems and the human need to support their activities. The development in this area is not only for people who live in coastal zone but also for people who live far away from this area. Furthermore, the development in this area should also consider the possibilities that come from the nature, such as natural disasters which will threat the population and the development that already exist in coastal zone.

2.1 What is Coastal Zone?

"Coastal zone is a term used to define a transition between terrestrial and freshwater ecosystem and the marine ecosystem" (Banica, et al, 2003 p.8). This area has many potencies that can fulfill the human need, not only who live around this area but also who live far away from this area. Besides that, coastal zones are subject to intense uses by humans for many kinds of activities such as fisheries, human settlement, transportation, industry, tourism, etc. Because of the importance of coastal zone then this area must be well managed. It is significant to maintain coastal zone because besides the importance of this area, the resources in this area are very vulnerable and fragile. The damage happened in this area not only caused by human activities but also by natural disaster.

Many definitions of coastal zone and mostly coastal zone are defined related to the problem. The coastal zone in this research is the area affected by tsunami disaster and can be damaged by the next tsunami, in this case up to more than 3 km inland. This definition can be as a guideline for the development planning to be more careful in deciding in which area of this coastal zone is safe for certain development in the future regarding to risk management for tsunami.

Furthermore, Fabbri (2002) in p. 42 believed "the coastal zone is a highly dynamic and complex environment characterized by a multitude of processes and activities". Fabbri also divided the coastal zone into two main subsystems. The first sub system is a socio-economic system includes activities such as industry, mining, urbanization, recreation, transportation, and flood protection. The other subsystem is natural system, consists of land, shoreline, fresh water and coastal water sub-system, which are characterized by the interaction of biotic and abiotic processes. Changes in this both subsystems caused by nature, climate change, or by human activities will generate impacts on both these systems.

Isobe (http://www.glocom.ac.jp, last visited 21 February 2007) stated that coastal zones have unique ecosystems and these areas are also the first lines of defense against inland disasters. They are buffer zones against the damage of tsunamis, rough waves, flooding, and erosion. There are three functional aspects, ecological services, disaster prevention, and human utilization-which are part of the human relationship to coastal zones. These aspects have complicated interrelationship. As a result, humans must monitor and manage these three components of the coastal zone in an integrated manner to ensure that the human relationship to coastal zones is in harmony.

It is true that changes in both subsystems as stated by Fabbri (2002) can give impact for both systems. Like tsunami disaster happened on December 26, 2004, the impact causes changes in natural system for example the mangrove and the coral reef ecosystem around coastal area were destroyed. This can cause lost of certain species of fish which live in both ecosystems and led to decrease on fish production in coastal area. This disaster also gives impacts on the socio-economic system for example:

people lost their homes, transportation facilities were broken, public facilities were destroyed, affected area have no access to non-affected area to get help.

In Aceh, for certain areas the natural activities of the sea have big impact to the coastal zone. In western coast of Aceh such as in Meulaboh, West Aceh, almost every year the lands in coastal zone are flooded by water when the great tide wave happens and many houses are damaged. It is because there is no barrier to protect the coastal zone and the settlements that are very close to the coastline.

Generally, in the case of Aceh, the damage caused by tsunami happens because there is decreasing of sea defense such as green belt to protect the coastal areas from tsunami. Since the increase of population and the need of development in coastal areas, for years the natural barriers such as mangrove forest is converted into fisheries activities like fish and shrimp ponds and other facilities to fulfill the human needs. Because of this condition, when the tsunami comes very fast and hit the land, it can damage all the things in this area directly and it is so destructive. It is important to indicate what is the coastal zone in this study that related to the area can be damaged by the next tsunami or damage by the last one. The map of coastal area in NAD Province affected by tsunami on December 26, 2004 can be seen in appendix 3 and 4.

2.2 Land contour of Coastal Zone and Types of Coasts

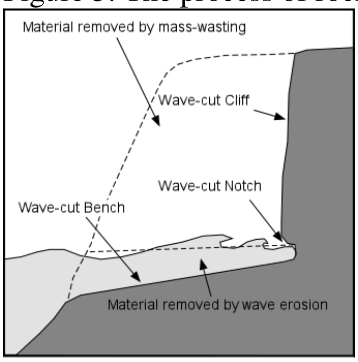
The land contour of coastal zone in Aceh varies between western coast and eastern coast. The western coast of Aceh is flat and open, and there is coral reef near the beach. In the eastern coast of Aceh is also flat but not open because there are many mangrove forests (before tsunami). That is why there are many ponds (locally known as"*tambak*") that can be found in this area.

In addition, it is significant to understand the nature of coast. The character and shape of coasts depends on factors such as tectonic activity, the ease of erosion of the rocks making up the coast, the input of sediments from rivers, the effects of dynamic changes in sea level, and the length of time these processes have been operating. According to Nelson in http://www.tulane.edu/~sanelson/geol204/coas-talzones.htm (last visited 21 February 2007), there are some types of coasts as presented in the following:

2.2.1 Rocky Coasts

This kind of coasts with cliff along the shoreline is formed after the coastlines have experienced recent tectonic uplift as a result of either active tectonic process. Anywhere wave action has not had time to lower the coastline to sea level, a rocky coast may occur. Because of the resistance to erosion, a wave cut bench and wave cut cliff develops. The cliff may retreat by undercutting and resulting mass-wasting processes. The process of rocky coasts is formation can be seen in figure 5.

Figure 5. The process of rocky coast is formed

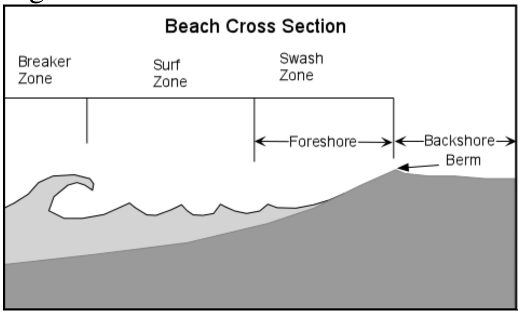


Source: http://www.tulane.edu/~sanelson/geol204/coastalzones.htm (last visited February 21, 2007)

2.2.2 Beaches

A beach is the wave washed sediment along a coast. Beaches occur where sand, sediment, gravel, etc are deposited along the shoreline. A beach can be divided into a foreshore zone, which is equivalent to the swash zone, and backshore zone, which is commonly separated from the foreshore by a distinct ridge, called a berm. Behind the backshore may be a zone of cliffs, marshes, or sand dunes. The division of the beach is presented in figure 6.

Figure 6. The division of the beach



Source: http://www.tulane.edu/~sanelson/geol204/coastalzones.htm (last visited February 21, 2007)

2.2.3 Barrier Islands

A barrier island is a long narrow ridge of sand just offshore running parallel to the coast. Separating the island and coast is a narrow channel of water called a lagoon. Most barrier islands came about during after the last glaciations as a result of sea level rise. Barrier islands are constantly changing. They grow parallel to the coast by beach drift and long shore drift, and they are eroded by storm surges that often cut them into smaller islands. Barrier islands are common along the east and Gulf coasts of the United States. The barrier island is shown in figure 7.

Figure 7. Barrier Islands in the Coast of Southwest Florida

Source: www.flgulfhomes.com/images/gasparview.jpg (last visited July 20, 2007)

2.2.4 Coral Reefs

Reefs consist of colonies of organisms, like corals, which secrete calcium carbonate. Since these organisms can only live in warm waters and need sunlight to survive, reefs are only formed in shallow tropical seas. Fringing reefs form along coastlines close to the sea shore, whereas barrier reefs form offshore, separated from the land by a lagoon. Both types of reefs are formed shallow water and thus protect the coastline from waves. However, reefs are highly vulnerable to human activity and the high energy waves of storms. The coral reef coast is exposed in figure 8.

Figure 8. Coral Reef Coast

Source: http://hartanto.wordpress.com/2006/02/16/iboih/ (last visited July 20, 2007)

Those kinds of coasts above are as a defense for coastal area to survive from natural disasters. Coastal line with rocky coast, especially with high rocky coast can slow down the strong wave coming from the sea. The coastal zone with Barrier Island around it also can reduce direct impacts that caused by disasters from the sea.

Most of coastal zone in Aceh can be classified in the beach category. It can be seen from the sand which is deposited along the shoreline. There are two kinds of sand, white sand and black sand. In west coast of Aceh, the sand is commonly white. The white sand comes from coral reefs around this area which is brought from the sea to coastal area. Meanwhile in east coast, the sand is black, it comes from volcanic extraction or the mud brought from the land.

2.3 Different Characteristic of Aceh Coastal Zone

Knowing the difference characteristic and shape of the coast is important because not all coastal zones have the same characteristics and shape. This knowledge is related to mitigation measures which will be proposed related to tsunami disasters. What kind of measures will be implemented depends on the conditions of those areas.

Commonly, there are differences in the coastal substrate and contours between the east and west coasts of Sumatra. The east coast of Sumatra faces the Straits of Malaka, which is relatively shallow and narrow. This condition causes the contours of the east coast of Sumatra tend to be flat/smooth with calm water, meaning that mud from the land which is carried to the sea by rivers can be silted up in the coastal areas. On the other hand, the west coast of Sumatra, which is deep and open, faces directly into the Indian Ocean. There are large waves, and the contours of the coast are steep and the substrate is sand (Wetlands International-Indonesia Programme, 2005).

Based on geographical characteristic, the coast of Aceh can be divided into two major sections (cited from Wetlands International-Indonesia Programme, 2005):

- The east coast, moving from the north eastward, includes the city of Banda Aceh, Aceh Besar, Pidie, Bireun, the city of Lhokseumawe, Aceh Utara, Aceh Timur, Kota Langsa, and Aceh Tamiang.
- The west coast, moving from north to south, includes Aceh Besar, Aceh Jaya, Aceh Barat, Kota Meulaboh, Nagan Raya, Aceh Barat Daya, Aceh Selatan, and Aceh Singkil.

2.4 Tsunami

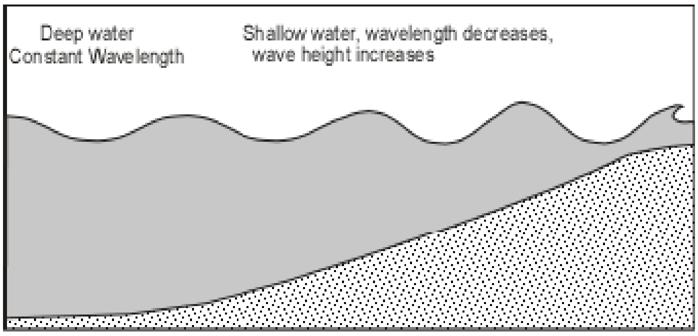
"A tsunami is a series of waves with a long wavelength and period (time between crest)". There is difference between crest of the wave of tsunami from a few minute to more than an hour" (Ministry of Home Affairs of India, 2005 p.3). Tsunamis are ocean waves produced by earthquakes or underwater landslides. The word comes from Japanese, “tsu” means harbour and “nami” means wave. Thus, tsunami can be defined as "harbour wave". Japanese gave this name because of the devastating effects these waves have had on low-lying Japanese coastal communities.

NOAA stated, “Tsunamis are often incorrectly referred to as tidal waves, but a tsunami can travel at speeds averaging 450 (and up to 600) miles per hour in the open ocean. In the open ocean, tsunamis would not be felt by ships because the wavelength would be hundreds of miles long, with amplitude of only a few feet”.

The fishermen who went for fishing when tsunami happened in NAD province on December 26, 2004 did not know what was going on. They realized the disaster when they went back from fishing and saw damages on the beach. The process of tsunami formation can be seen in figure 10.

Moreover, Nelson (2006 p.2) argued that the wavelength of tsunami has relationship with the rate where a wave loses its energy. A tsunami will lose little energy as it propagates, in the meantime, it has a very large wavelength. Therefore, a tsunami will travel at high speeds with little loss of energy in very deep water. Tsunami undergoes a transformation as it leaves the deep water of the open sea and arrives at the shallow waters near the coast. The water depth also influences the velocity of tsunami, as the depth of the water decreases, the velocity of the tsunami decreases. It is supported by Dilisi and Rarick (2006 p.585-586) who pointed out that the tsunami’s wavelength and speed decrease as the tsunami’s amplitude increases. The amplitude of tsunami wave is shown in figure 9.

Figure 9. The Amplitude of Tsunami Wave

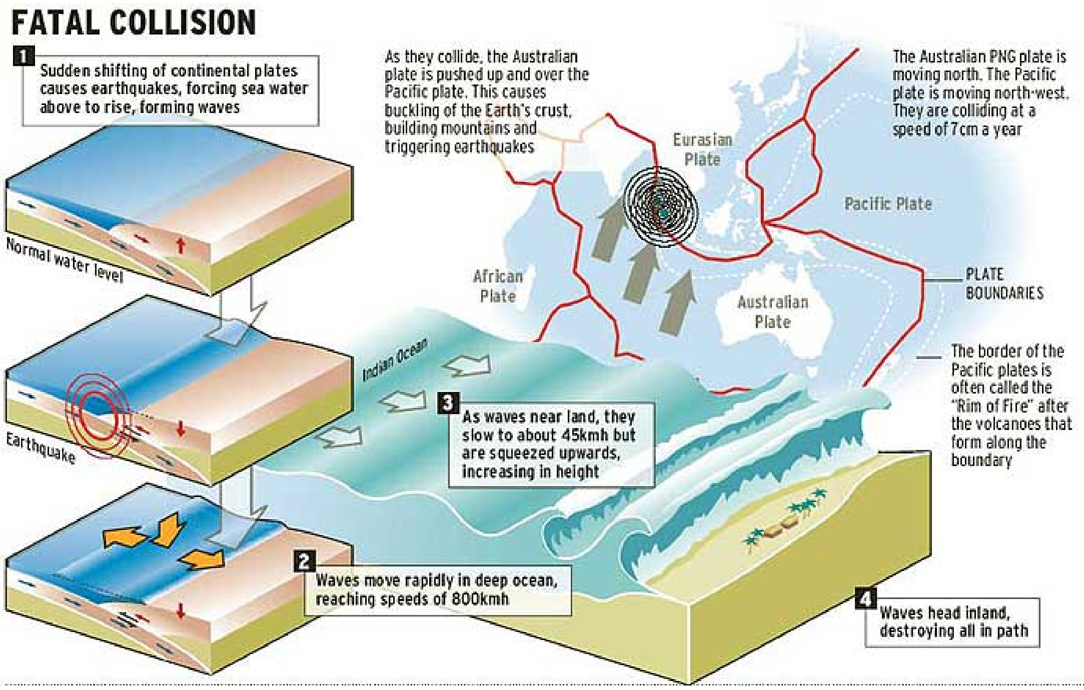


Source: Nelson (2006)

According to NOAA,"when tsunami reaches shallow water near coastal areas, the tsunami becomes slow but increases in height. The only sign came just before the tsunami struck when the waterline suddenly retreated, exposing hundreds of meters of beach and seabed".

In Aceh, before tsunami, the waterline retreats about 50 to 100 meters, and people did not realize that it is one of indications that tsunami will happen. Besides earthquake as one of signs of tsunami, the waterline move back after strong earthquake also as the sign there will be tsunami. The tsunami will come if the waterline move back differs than usual.

Figure 10. The process of tsunami is formed



Source: http://www.smh.com.au/specials/tsunami/ (last visited May 13, 2007)

Furthermore, besides the definition of tsunami, it is also important to know the characteristic of tsunami. The characteristics are (http://www.acehtsunami.com, last visited, January 16, 2007):

1. "Tsunamis move in the seabed and the depth can be up to several kilometers, thus they have huge energy and can travel at high speed and great distance with little energy loss.
2. A tsunami can cause damage thousands of kilometers from its origin, so it needs about several hours between its creation and its impact on a coast. In open water, tsunamis have extremely long periods (the time for the next wave top to pass a point after the previous one), from minutes to hours, and long wave length of up to several hundred kilometers
3. The actual height of a tsunami wave in open water is often less than one meter. This is often practically unnoticeable to people on ships

4. The energy of a tsunami passes through the entire water column to the sea bed, unlike surface waves, which typically reach only down to a depth of 10 m or so.
5. The wave travels across the ocean at speeds from 500 to 1,000 km/h. As the wave approaches land, the sea shallows and the wave no longer travels as quickly, so it begins to 'pile-up'; the wave-front becomes steeper and taller, and there is less distance between crests
6. A wave becomes a 'shallow-water wave' when the ratio between the water depth and its wavelength gets very small, and since a tsunami has an extremely large wavelength (hundreds of kilometers), tsunamis act as a shallow-water wave even in deep oceanic water. Shallow-water waves move at a speed that is equal to the square root of the product of the acceleration of gravity (9.8 m/s2) and the water depth
7. Tsunamis propagate outward from their source, so coasts in the "shadow" of affected land masses are usually fairly safe. However, tsunami waves can diffract around land masses. They also need not be symmetrical; tsunami waves may be much stronger in one direction than another, depending on the nature of the source and the surrounding geography".

NOAA also stated,"the several waves of the tsunami came at the intervals of between 5 and 40 minutes. Unusual wave heights have been known to be over 100 feet high. In deep water (more than 200 m), tsunamis are infrequently over 1 m high and will not be noticed by ships due to their long period (time between crests). As tsunamis spread into shallow water, the wave height can increase more than 10 times. Tsunami heights can vary greatly along a coast. However, waves that are 10 to 20 feet high can be very destructive and cause many deaths or injuries". The arrival time and height of tsunami in Aceh tsunami vary in west and east coast of Aceh. These are presented in table 2 of chapter 3.

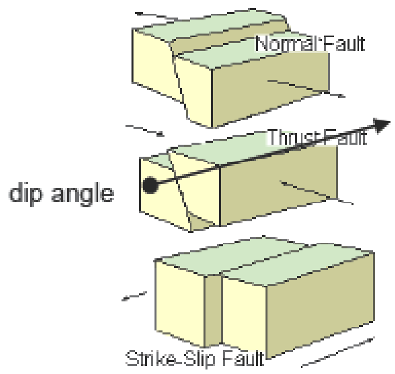
"A large tsunami can flood land up to more than 1.5 km from the coast" (Government of India, 2005 p.5). Tsunami disaster in December 26, 2004, flooded land area in Banda Aceh up to more than 3 km. The tsunami that hit Aceh can be said as very large tsunami because it can flood land more than 1.5 km from the coastline as stated by Government of India above.

The earthquake-induced seabed displacements depend on the depth and direction of the earthquake slip along the subdiction zone (Norwegian Geotechnical Institute, 2006). Not all earthquakes can cause tsunami, but it depends on the characteristic of the fault. According to Sutowijoyo (2005), there are some main factors of fault that can generate tsunami:

1. Thrust/ reverse fault (figure 11)

   This type is very effective to travel the water volume above the plate to move, as the beginning of tsunami.

   Figure 11. Type of Fault

   Source: Sutowijoyo (2005)

2. Dip angle

   The more the angle (up to 90^{o}), the more the tsunami will be formed.

3. Hypocenter (< 70 km)

   The shallower the hypocenter, the more effective the tsunami generated.

Suwitowijoyo (2005) also described that although the earthquake is relatively small (6.0-7.0 R), if all the main factors above are fulfilled, there is possibility that the tsunami will be generated. Yet, even though the earthquake is strong (> 7.0 R), swallow and the type of fault is not the trust fault so the formation of tsunami is difficult. Earthquake with the strength is 7.0 R, trust fault and swallow can form tsunami with the height up to 3 to 5 m. Meanwhile, the Government of India (2005) argued that earthquakes generate tsunamis by vertical movement of the sea floor. If the sea floor movement is horizontal, a tsunami is not generated. Earthquake of M>6.5 m are critical for tsunami generation. Both Suwitowijoyo and Government of India agree that tsunami will happen if the movement of sea floor is vertical.

Furthermore, Suwitowijoyo (2005) mentioned that tsunami can move to all direction from its source and hit wide areas, even in the bend area, sheltered area, or the area which is far away from its origin. Tsunami can be called as local tsunami if it only happens in limited areas. It is because the source of tsunami is located in a narrow or closed area, such as straits or lake, for example tsunami which was on August 16, 1976 in Moro bay, Philippine. There is also distant tsunami which happens if tsunami hits very wide areas and far away from its source, for example tsunami in Chili on May 22, 1960 which caused damages in Chili, Japan, Hawaii and Philippine. The Sumatra tsunami on December 26, 2004 is also included in distant tsunami because it caused damages in some countries as stated in chapter 1.

2.5 Tsunami Risk Management in Coastal Zone

Cardona in Ingleton (1999. p. 153) stated, “Risk is a curious and complex concept. In a sense it is unreal in that it is always concerned with future, with possibilities, with what has not yet happened. If there is certainty, there is no risk. Risk is always associated with decision. Something has to be done; an action has to be taken”. Risk is much related to which decision should be taken to reduce or avoid the impact of the risk. The decision is about development that can be implemented in coastal zone and land use planning to reduce the impact tsunami disaster in this area. It is obvious that by knowing the risk we can prepare what should be done and what should not be done if unexpected events happened in the future.

Moreover, Salter in Ingleton (1999. p. 111) argued “It is important to recognize that the risk management approach is no ‘business as usual’, but it is an approach to provide a fundamental basis for the systemic application of management policies, procedures and practices to the tasks of identifying, analyzing, evaluating, treating and monitoring risk”. When it happens, natural disasters can be diminished through assessment, prediction, prevention and mitigation. FEMA (Federal Emergency Management Agency) defined mitigation as the “sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects”. FEMA also mentioned there are several types of mitigation strategies which are:

- Prevention
- Property Protection
- Natural Resource Protection
- Structural Projects
- Public Information

Mangrove representative, such as *Rhizophora* spp., as one of mitigation strategies to reduce the impact of tsunami disaster can function as a physical barrier against tidal and ocean influences by means of their large above-ground aerial root systems and standing crop. It is argued by Dahdouh-Guebas (2005) in p. 443.

Natural barriers such as mangrove and other kinds of coastal trees can be used as natural defense to protect the coastal zone from tsunami wave. These natural barriers can be as ecological function for ecosystem in coastal areas. Besides that, it is also as coastal barriers from the disasters come from the sea.

Nevertheless, reducing the impact of natural hazards is not an easy task. It is cross disciplinary in nature-requiring interaction between physical and social scientists, government bureaucrats and the public they serve. This interaction is complex, and includes defining phrases like hazard identification and risk assessment; research and technology transfer and public awareness" (Purdom in Ingleton, 1999. p. 118).

It is difficult to implement planning programs regarding to risk management and control the sustainability of natural resources in coastal zone without participation and awareness from communities and all related parties. It is supported by the statement of Ranade (2005), "while tsunamis cannot be prevented, levels of risk can be reduced and sometimes even eliminated. However, to be effective a tsunami mitigation strategy needs long-term support within coastal communities. Those should be capable of implementing and maintaining local and regional tsunami preparedness programs, provided with essential planning tools, and willing to raise the awareness and commitment of individuals, businesses, emergency responders and government decision makers ".

Hawaiian Volcano Observatory (1995) argued that at any government level, the biggest problem is that risk management addresses a long-term problem, and government is not good at preparing long-term planning or at spending money to reduce long-term risks. This statement is also supported by Cardona in Ingleton (1999. p. 153) who stated, "the event impact, the capacity of the city to sustain that impact, and the implications of the impact to the city, the country or region are related to lack of institutional and community organization, weakness in the emergency response preparedness, political instability, and the lack potential consequences".

Mitigation of the impact of natural disaster through risk management the coordination from all related sectors is needed. The disaster risk management is not useful if only done by a certain sector, but it needs integrated management from all levels of government and also people who live in coastal zone and inland area. They together find ways to reduce the loss of life and property. Rodda in Ingleton (1999, p.33) pointed out that other important elements of progress in disaster management are raising public awareness of disasters and improving education and training.

In general, there are some key elements of risk management proposed by IDB (Inter-American Development Bank) (2000b) in Freeman et al (2003) that consist of two phases, pre-disaster phase and post-disaster phase. The actions in pre-disaster phase are risk identification, risk mitigation, risk transfer, and preparedness. Meanwhile, the post-disaster phase is aimed to emergency response and rehabilitation and reconstruction. The detail of those key elements is drawn in Table 3.

Table 3. Key elements of risk management

Pre-disaster phase				**Post-disaster phase**	
Risk identification	**Risk mitigation**	**Risk transfer**	**Preparedness**	**Emergency response**	**Rehabilitation and reconstruction**
Hazards assessment (frequency, and location)	Physical/structural mitigation	Insurance and re-insurance of public infrastructure and private asset	Early warning systems and communication systems	Humanitarian assistance	Rehabilitation and reconstruction of damaged critical infrastructure
Vulnerability assessment (population and assets exposed	Land-use planning and building codes	Financial market instruments (catastrophe bonds and weather-indexed hedge funds)	Contingency planning (utility companies and public services)	Clean-up, temporary repairs, and restoration of services	Macroeconomic and budget management (stabilization and protection of social expenditures)
Risk assessment (a function of hazard and vulnerability)	Economic incentives for pro-mitigation behavior	Privatization of public services with safety regulation (energy, water, and transportation)	Networks of emergency responders (local and national)	Damage assessment	Revitalization for affected sectors (exports, tourism, and agriculture)

Pre-disaster phase				Post-disaster phase	
Risk identification	**Risk mitigation**	**Risk transfer**	**Preparedness**	**Emergency response**	**Rehabilitation and reconstruction**
Hazard monitoring and forecasting (GIS, mapping, and scenario building)	Education, training and awareness about risks and prevention	Calamity Funds (national or local level)	Shelter facilities and evacuation plans	Mobilization of recovery resources (public, multilateral, and insurance)	Incorporation of disaster mitigation components in reconstruction activities

Source: IDB (2000b) in Freeman et al (2003)

The mitigation strategies recommended by FEMA are related to both of the two phases of key elements in risk management. The two phases are risk mitigation and emergency response. Point one and two of risk mitigation in table 1 include in prevention, property protection and structural projects of mitigation strategies. Meanwhile, point three and four of risk mitigation and emergency response include in public information.

"Disaster risk based on several geological, structural, economic, social, political, cultural or any other characteristics of a city, for instance, may be very useful to guide risk mitigation decisions" (Cardona in Ingleton (1999) in p.153). Related to the risk management in coastal zone, risk mitigation that can be done relies on the conditions of this area. The coastal zone in each country is different, it depends on the physical characteristic (rocky coasts, beaches, etc) and the socio-economic structure of the region that can be urban area or rural area.

Further more, Sato et al (2003) in p.326 stated counter measure different from location to location as follows,

> "The most effective counter measure differs from location to location. In areas where the tsunami arrives very fast, the breakwaters and seawalls should be constructed first because residents will have no time for evacuation. If the height of tsunami is evaluated to be low, evacuation facilities should be maintained first. The government should grasp the

> effect of these measures, and should decide which ones to adopt. The safety of residents should be considered as the top issue. In particular, "ease of evacuation" becomes most important for reduction of damage to human beings".

Because of the differences of characteristic between west coast and east coast of Aceh, so this research will try to elaborate the most appropriate risk mitigation measures in the case of Aceh. The measures will be different between the coast which has high of tsunami wave such as in western coast of Aceh and the coast with low of tsunami wave for example in eastern coast of Aceh. The information about the height of tsunami wave in some locations in Aceh is presented in table 2 in chapter 3.

According to International Tsunami Information Center (ITIC) cited from APELL, there are some tsunami safety rules. These rules are necessary to know in order to safe people and property in tsunami prone-areas. The rules are as follows:

1. "All earthquakes do not cause tsunamis, but many do. When you hear that an earthquake has occurred, stand by for a tsunami emergency.
2. An earthquake in your area is a natural tsunami warning. Do not stay in low-lying coastal areas after a strong earthquake has been felt.
3. Approaching tsunamis are sometimes preceded by a noticeable rise or fall of coastal water. This is nature's tsunami warning and should be heeded.
4. A small tsunami at one point on the shore can be extremely large a few miles away. Don't let the modest size of one make you lose respect for all.
5. When a warning is issued, a tsunami exists.
6. Like hurricanes, all tsunamis are potentially dangerous even though they may not damage every coastline they strike.
7. Never go down to the shore to watch for a tsunami. When you can see the wave you are too close to escape it. Never try to surf a tsunami; tsunamis do not curl or break like surfing waves.

8. Sooner or later, tsunamis visit every coastline. Warnings apply to you if you live in any coastal area.
9. During a tsunami emergency, your local civil defence, police, and other emergency organizations will try to save your life. Give them your fullest cooperation".

The rules recommended by ITIC should be known by all the interest groups in tsunami prone area in order to be aware about tsunami and its characteristics, so that they can be well prepared if there are tsunamis in the future. These rules more related to public information in the mitigation strategies suggested by FEMA. It is because the rules give information to the community about how to deal with earthquake and tsunami. These rules inform the community what they should do and not do when there is earthquake and tsunami.

2.6 Land Use Planning and Risk Management in Coastal Zone

Disaster risk management in coastal zone is related with land use planning. Disaster risk management in this area is needed to recognize the relationships between population growth, the physical demands of human settlement, economic planning and the use of available land. This relation is also stated by Bonino in Ingleton (1999) in p.130, "better development policy (in this case better land-use planning) and a more efficient aid policy focused on sustainable development are the keys to preventing disasters and mitigating the impact of hazards, mainly by taking into account of the risks, in particular major risks".

Better land use planning means that the use of available land for development planning should not only consider all aspects in development for economic purposes or the interests of certain group but also for the impact of the planning to environment and people who live around. Besides that, development policy regarding to land use planning can give more attention to community not only for today development but also for the next development, so that the development that has been done can stand for longer period of time and can stand for the risk caused by natural disasters.

Land use in coastal zone is always changing to fulfill the need of development in this area. In other word, it is caused by the human activities and by natural disasters that happen in unpredicted time. As stated by Duran in Ingleton (1999) in p.16 “It is necessary to include the variable of vulnerability as a main idea in all the stages of development taking on the challenges of setting out clear objectives and not falling into the trap of mere words and expressions”. Thus, it is crucial to consider the vulnerability and risks in the development planning to reduce and prevent this area from the damage that caused by human and natural disasters.

Land use planning in coastal zone also can also become as one of alternatives to reduce the risk of tsunami, for instance by deciding the distance from coastline that can be used for settlement, industry, port, fishery, public facility. As a result the effects of using unplanned land use can be minimized and the ecosystem in coastal zone such as mangrove, coral reef, etc can be sustained as efforts to prevent this area come from natural disasters.

Human activities on coastal environment can generate more harmful effect on environment which causes the environment cannot stand for natural disasters. In order to mitigate this impact on human and environment, the issues of development policy should be discussed between all interests involved.

According to Hawaiian Volcano Observatory (1995), the most important ways to reduce risk from natural disaster is land use planning. The first thing is to identify high-hazard areas, the risk can be reduced by not building or living in prone-area or by limiting the density and type of development in this area. This kind of land use planning is especially effective for floods and tsunami, which affect only limited areas along rivers and coastlines.

The statement by Hawaiian Volcano Observatory about land use planning is one of alternatives to be considered in coastal area related to tsunami risk management. However, in practice it is difficult to be realized because people who live in coastal areas tend to go back to their land and rebuild their house in this areas. Although they know they will be threatened by other disasters in the future, they come back again to build their village after the disaster.

Meanwhile, National Tsunami Hazard Mitigation Program (NTHMP) proposed the approach to promote land use planning and development practice of tsunami mitigation in Designing for Tsunamis: Seven principles for Planning and Designing for Tsunami Hazards (NTHMP, 2001 in Eisner 2005). This approach is as a guideline for local government, planners, and related sectors responsible for community development and redevelopment. The focuses are on land use and development policy, building design and site planning. Those seven principles are as follows:

1. *"Know your Community's Tsunami Risk, Hazard, Vulnerability, and Exposure*

   The guide outlines a methodology for identifying a community's risk, and recommends the use of tsunami specialists for preparing scenarios and loss studies (p.157).
2. *Avoid new development in tsunami run-up areas to minimize future tsunami losses*

   A key to long-term reduction of community risk is the use of land use planning processes to guide future development, with the objective is to reduce new development at risk so that future losses are minimized (p.158).
3. *Locate and configure new development that occurs in tsunami run-up areas to minimize future tsunami losses*

   The guide proposes the creation of a development review process that emphasizes the incorporation of mitigation techniques at project inception, an approach that ensures that new development incorporates a community's mitigation priorities (p.158)

4. *Design and construct new buildings to minimize tsunami damage*

   The guide provides ‘‘performance objectives’’ for buildings in tsunami inundation zones, including location and configuration, elevation, structural and non-structural design standards, structural materials, and location of utilities (p.159).

5. *Protect existing development from tsunami losses through redevelopment, retrofit, and land reuse plans and projects*

   The guide outlines a process that identifies opportunities for gradually improving community safety and resilience through identification of at-risk areas, evaluation of proposals for redevelopment, and the retrofit and reuse of existing structures (p.159).

6. *Take special precautions in locating and designing infrastructure and critical facilities to minimize tsunami damage*

   The guide recommends the adoption of a comprehensive risk management policy that includes all stakeholders with interests in the coastal inundation zone (p.160).

7. *Plan for evacuation*

   The guide discusses horizontal (out of buildings to high ground) and vertical (within buildings to upper floors) evacuation as options, depending on location and structure type, and provides a process for developing a plan and strategy for evacuation (p.160)”.

Through land use and development planning in coastal zone, the government can arrange development in this area and decide which areas are vulnerable to tsunamis in order to safe the existing development and people who live in prone-area to reduce loss. Beside that, the government can also prepare areas suitable to relocate or prevent the development that are vulnerable to or from tsunamis. As argued by Eisner (2005 p.161), “land use and development decisions that will reduce losses from future tsunamis rest with local governments in most states. The challenge for the national and state programs is to provide local decision makers with credible data on the threat of tsunami, and cost effective tools for reducing risk, without the imposition of unreasonable constraints on coastal development”.

The importance of land use planning to reduce the impact of natural disaster is also offered by the secretariat of United Nations International Strategy Disaster Reduction (UN/ISDR, 2006) in its eleven lessons for a safer future. The eleven lessons are:

1. *“Public awareness is an essential element of preparedness for saving lives and livelihoods.*

   Everyone in the community, especially residents living in vulnerable areas, but also the government and key sectors, such as the tourism industry for example, need to understand the basic facts on the risks faced and on the warning and evacuation processes (p.4).

2. *Individuals and communities play important roles in managing risks from natural hazards.*

   Countries are less vulnerable to the effects of natural hazards if their communities and people are directly involved in risk assessments and disaster risk reduction activities and have the capacities to understand and respond to events (p.5).

3. *Diverse livelihood systems and micro-financial services help poor people to survive disaster events.*

   Access to diverse sources of income, microfinance, insurance, and property rights strengthen the capacity of individuals and small enterprises to prepare for and recover from the impact of disasters (p.5).

4. *Traditional knowledge is valuable and can inform and protect communities.*

   It is important to incorporate traditional wisdom and local knowledge into future disaster risk reduction strategies and to ensure that such knowledge continues to be communicated through generations and to migrants and newcomers to the affected areas (p.6).

5. *Disaster knowledge should be included in formal education curricula*.

   Formal education can help children make sense of the experience of a large disaster and assist them to respond appropriately in future hazard events (p.7).

6. *Early warning systems are needed for all hazards and all people*.

   Early warning system can enable people to act promptly and in a manner that reduces injuries, loss of life and damage to property (p.7).

7. *Land use planning and protection of ecological systems can reduce disaster risks*.

   Forests can act as "bioshields" to protect people and other assets against tsunamis and other coastal hazards, so forests and reefs need to be protected from damaging and unsustainable economic exploitation. Governments and local authorities need to undertake long-term land use planning to minimize disaster risks for all types of natural hazards (p.8).

8. *Developing and adhering to building codes can minimize risks and losses*.

   If properly constructed, buildings can provide effective shelter from natural hazards such as earthquakes, tsunamis and tropical cyclones (p.9).

9. *Political and public commitment to reduce the risk of disasters is imperative*.

   Strong government commitment and community involvement are needed to build a safer future for both present and future generations (p. 9)

10. *Humanitarian and development innovations are needed to reduce disaster risks*.

    It makes sense to invest in risk-reducing activities that will bring down the scale and costs of disaster events. Disaster risk reduction measures are particularly important in the post-disaster recovery stage, to ensure that we do not resurrect the past risks but instead 'build back better' (p.10).

11. *Natural hazards span borders and their management requires global cooperation*.

    Natural hazards do not respect national borders and frequently affect multiple countries. Regional and international cooperation and coordination are essential to reduce disaster risks and to manage disaster events (p.11)".

The principles recommended by NTHMP are more on technical and spatial measures, such as the principles point 2, 3, 4, 5, 6 and 7. Meanwhile, the principles suggested by UN/ISDR are more on the awareness and knowledge about tsunami of the community, although there is also some points about land use planning and other spatial and technical measures.

Both the principles proposed by NTHMP and UN/ISDR can be used in determining the possible tsunami risk management measures in the case of Aceh because those principles reflect not only the technical and spatial measures but also measures related to community. Based on those both principles, the other principles proposed by this research can be as follows:

1. Tsunami warnings system and tsunami warning center, not only in local level but also in international level, should be provided to inform people that there will be tsunami soon after the earthquake as soon as possible.
2. Good coordination among institutions involved should be provided to avoid overlapping programs related to tsunami mitigation.
3. Protection barriers construction and greenbelt must be provided along the coastline to defense the community and property in tsunami prone area.
4. A good evacuation route and place should be provided in order to make the community easier to escape.
5. Land use planning which is done well can increase the secure of community and property, particularly land use planning for infrastructure/building development in coastal area. The land use planning should consider the impact of the development on the ecosystems in coastal zone.
6. Identification of risk community in tsunami prone area to know which area from the coastline is safe from tsunami risk and other natural disasters.
7. Infrastructure/building construction standard is essential for tsunami vulnerable area. It is to make sure that the quality of those building or infrastructure is strong

enough to withstand with earthquake and tsunami. This measure includes the design and the location of those building.

8. Provide evacuation signs and plan to make the people in coastal zone easier to run quickly to evacuation place at the right time.
9. Always keep traditional/local term of tsunami in order to inform the community easily, especially local community.
10. Tsunami knowledge is very important to include in formal education from kindergarten until university. It is meant to keep the awareness of tsunami disaster.

CHAPTER 3 Case Study

Coastal zone as an area between land and sea, provide resources and space for human living. This area is as the center of various kinds of activity like economic, settlement, industry, fisheries, transportation, tourism and others. Besides, the resources from the ecosystems in this area are very important to fulfill human needs not only for people who lives in coastal area but also who lives in land area. To support those activities, there are also infrastructure developments. The development done in this area tends to damage the ecosystem that has already been there. As mentioned by Clark (1996) in p.1, "coastal zone is the place where agency authority changes abruptly, where storms hit, where waterfront development locates, where boats make there landfalls, and where some of the richest aquatic habitats are found. It is also the place where terrestrial-type planning and resource management programs are at their weakest". This chapter elaborates the impact of tsunami disasters in NAD Province and overview of tsunami in some other countries like India, Sri Lanka and Thailand.

3.1 Tsunami Disaster in Nanggroe Aceh Darussalam Province

Nanggroe Aceh Darussalam Province is located on the northern part of Sumatra Island. The area of NAD Province is 57,365.57 km² with population of 4,010,860 (http://en.wikipedia.org/wiki/Aceh#Tsunami_disaster, last visited March 24, 2007). There are 21 regencies/cities in this province, divided into 17 regencies and 4 cities. Banda Aceh is the largest city and the capital city of this province which is located on the coast near the northern tip of Sumatra. The map of NAD Province can be seen in appendix 2.

From the past until now the majority of Acehnese live in the coastal area, it can be seen from the history of Aceh culture. Usman (2003 p.39 and p.73) mentioned that one of ethnics in Aceh is called as ethnic Aceh or Aceh coastal community. Maybe it is because in the past Acehnese were known for their trading activity that concerned in the coastal area. Beside that, the central government of Aceh was located in this area. The majority of this ethnic was dominant in politic, economic and trading in Aceh. This ethnic was also recognized as hard working, withstand to the challenge, very easy to adapt not only with their surrounding, but also outside their region. They also like to help each other ("gotong royong") and are very tolerant with other people. Besides, Acehnese people really respect with the scholar of Islam in their community ("Teungku" or tokoh agama).

Acehnese have close relation with their environment. Bustamam et al (2005) stated, "Specifically, ecology relationship of Aceh community divide into three ecosystem which are "uteun" (forest), "blang" (agricultural area) and "laot" (sea). Each ecological bond has their own adat (traditional) institution with a leader, a set of rules, autonomic power, borders, and a traditional court system (pengadilan adat)".

Furthermore, Bustamam et al (2005) pointed out "the smallest unit in "laot" community is "Lhok", lead by "Panglima Laot Lhok". Each "Lhok" consists of one or more "gampong" (village), some settlements, or even a sub-district. Based on its social structure, "Panglima Laot Lhok" plays an actual and constituent role to upheld traditional regulations (adat Laot) in combination with Shariah Law. This proves that the institution takes a bottom-up approach instead of top down. To carry out his duty, the "Panglima Laot Lhok" works closely with other institutions in the community. To maintain the coordination and cooperation in between "Lhok", a coordination body was formed in every level under the name of "Panglima Laot Kabupaten (District "Panglima Laot") and "Panglima Laot" Province.

A very strong earthquake (9.0 Richter scale) on December 26, 2004 shocked most of NAD Province area, and other areas like Nias in North Sumatra, part of Thailand, Sri Lanka, Maldives, Bangladesh, even to Somalia coast of East Africa. The west coast of NAD Province is the most destructed area hit by tsunami on December 26, 2004. This occurred because the epicenter of earthquake generated tsunami is in the Indian Ocean on the western part offshore this area. The areas of NAD Province hit by tsunami are presented in appendix 3. The areas with red color experienced with tsunami disaster. From this figure it can be seen that most of western coast of NAD Province suffered damage caused by tsunami disaster, even the northern part of this area such as northern shore of Banda Aceh (Ulee Lheue) and Sabang.

Acehnese, especially who live in islands like Simeulue, Aceh Island and Weh Island (Sabang) have known the tsunami for along time. People in Simeulu and western shore of Aceh call tsunami as "seumong" and some of them call it as a term "ie beuna" which means great wave. It indicates that there have been tsunamis in these areas. Meanwhile, Aceh cultural observer, Syamsuddin Jalil (Beudoh Aceh magazine, 2005) tends to called tsunami as "teuseunom-ie" (means sink into water). The last term if mentioned in Aceh language, the spelling of the last term is almost similar to the term of tsunami.

As the time goes on, the local term is replaced by the term of tsunami that comes from Japanese. It can be said, it might be because the generation has changed and the events of tsunami are happened in long period of time so that people have not really known the traditional term of tsunami. After the earthquake on December 26, 2004, almost all the people in coastal zone of Simeulu, Aceh Island, and Weh Island run away to the higher land. The people in this area are used to with this phenomenon, they know what they should do after the earthquake. Thus, there are no many victims in this area when the tsunami hit Aceh in 2004.

On 2004 tsunami, NAD Province has the most victims of tsunami (220,240 people). This disaster also damage the public facilities such as education (1,168 schools), health (6 hospital and other health supporting facilities), religious facilities (1,069 mosques, 8 churches and 2 Hindus facilities) and economic (29 bank). In agricultural sector, this disaster damaged 23.330 ha paddy field and 22.785 ha other crop area.

Table 4. Number of victims of tsunami disaster in affected areas on December 26, 2004.

Country	**Fatalities**	**Missing**	**Total**	**Source**
Aceh	*126,602*	*93,638*	*220,240*	Main Book of Rehabilitation and Reconstruction, April 2005(*)
Sri Lanka	35,322		35,322	Joint One Year Report, December 2005
India	12,405	5,640	18,045	Government of India, January 2006.
Maldives	82	26	108	Government of the Maldives, National Disaster Management Center, December 2005.
Thailand	8,212		8,212	Department of Disaster Prevention and Mitigation, Ministry of Interior, October 2005.
Myanmar	61		61	UN Office for the Coordination of Humanitarian Affairs (OCHA) - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Malaysia	69	6	75	OCHA - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Somalia	78	211	289	OCHA - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Tanzania	13		13	OCHA - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Seychelles	2		2	OCHA - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Bangladesh	2		2	Press reports.
Kenya	1		1	OCHA - UNDP, Brief on Tsunami Response in Six Less Affected Countries, November 2005.
Total	**182,849**	**99,521**	**282,370**	

Source: http://www.tsunamispecialenvoy.org/country/humantoll.asp (last visited, March 24, 2007)

(*) Regulation of the President of Republic of Indonesia Number 30 Year 2005

The damage of tsunami was caused by limited greenbelt in coastal zone, the type of housing and other buildings can withstand with the wave of tsunami. Most of housing in coastal zone and inland area are not suitable with earthquake and tsunami disaster. Actually, traditional house of Aceh or "Rumoh Aceh" is a high rise building with open ground structural storey. It is supported by the statement in Aceh Heritage site that mentions the high of "Rumoh Aceh" is 2.5-3.5 metres above the ground and the open ground storey is used to anticipate from flooding and wild animal. The compound of this type of housing can survive from earthquake and tsunami (http://www.lestariheritage.net/aceh/webpages/sites03.html, last visited July 15, 2007).

This traditional house is built by using good quality of wood. Because of the difficulty in providing a good quality of material, traditional houses are not built anymore. The original architecture of Aceh traditional houses can be seen in Aceh Museum, Great Aceh, Aceh Pidie, etc. Aceh. This kind of house uses wood for its pole, "*rumbia*" leaves for its roof (taken from "*rumbia*" tree, a kind of tree grows in Aceh) and bamboo or wood for its floor. Traditional house of Aceh is presented in Figure 12.

Figure 12. Traditional House of Aceh or "Rumoh Aceh"

Source: http://www.lestariheritage.net/aceh/webpages/sites03.html (last visited July 15, 2007)

Tsunami that happened in NAD Province has made most of shoreline in Banda Aceh lost. The changes of Banda Aceh shore line can be seen in figure 13 and 14.

Figure 13. Banda Aceh Northern Shore before Tsunami (23 June 2004)

Source: http://space.about.com/library/weekly/blindonesiatsunami.htm (last visited February2, 2007)

Figure 13 shows that before tsunami disaster, the coastline is still clear and there are many activities in coastal zone in the northern shore of Banda Aceh NAD Province such as settlement, fisheries, transportation, economic (market), recreation (tourism) etc. In this area, there is a port which is called Ulee Lheue port that is used to transport people from Banda Aceh to Sabang and vice versa.

Figure 14. Banda Aceh Northern Shore after Tsunami (28 December 2004)

Source: http://space.about.com/library/weekly/blindonesiatsunami.htm (last visited February2, 2007)

From figure 14 and 15, compared to figure 13, it can be seen that because of tsunami disaster, most of coastline in Banda Aceh was missing, especially in the northern shore of Banda Aceh. One of the missing shoreline is the area in the way to the Ulee Lheue port, even as presented in figure 2, the buildings in other area was completely destroyed. Meanwhile, in figure 14, the picture shows more areas flooded by tsunami disasters. The flood caused by the wave of tsunami also hit up to more than 3 km into inland area.

Figure 15. The impact of tsunami disaster on coastal and inland area in Banda Aceh

Source: http://space.about.com/library/weekly/blindonesiatsunami.htm (last visited February2, 2007)

The height of tsunami differs in each coastal area. It is supported by field observation held by Borrero et al (2006), Yalciner (2005), Tsuji (2005) and my experience in western and northern coast of Sumatra. It can be seen from the variation of maximum run-up (above sea level) of tsunami in each site. Based on this observation, in the western part of Aceh (Breuh and Deudap Islands, Lhoknga, Simeulue, Meulaboh and Lhokruet) and the northern part of Aceh (Banda Aceh, Krueng Raya and Weh Island), the run-up is higher than in eastern part of Aceh (Panteraja and Idi). It is possibly because the western part of Aceh is close to the epicenter of the earthquake which generates tsunami, and the coast is more open. The time of earthquake until the water reach the inland area and the inundation line also vary in each observed location. It is shown in Table 5.

Table 5. The Arrival Time of Tsunami, Inundation Distance and Height of Tsunami

Location	Arrival time of tsunami minimal after the earthquake (minute)	Inundation distance (km)	Tsunami height (m)
Center of Banda Aceh	30	3 - 4	3.52 – 34.25
Krueng Raya	No data	No data	3.68 - 8
Lhoknga (West Coast of Banda Aceh)	No data	No data	12 – 34.25
Weh Island	No data	> 0.5 *	3 – 6.2
Breuh and Deudap Island	No data	No data	10 - 20
Panteraja	25	up to 1	4.2 - 4.7
Idi	90	> 0.5	2.5
Sigli	No data	No data	3.68 – 4.82
Simeulue	± 30	0.01-2	0.3 - 4
Meulaboh	± 40	± 5	9 - >15

Source: Borrero, Synolakis and Fritz (2006), Yalciner (2005), Tsuji (2005) and my experience (*)

By knowing the time tsunami reach inland area, we will able to know how much time the people in coastal zone need to evacuate from tsunami wave to higher land. This data is also useful to decide what kind of physical measures can be used to save the people from tsunami. For people in inland area, they can use this time to decide whether they have to go to higher place or they can stay in their place if possible.

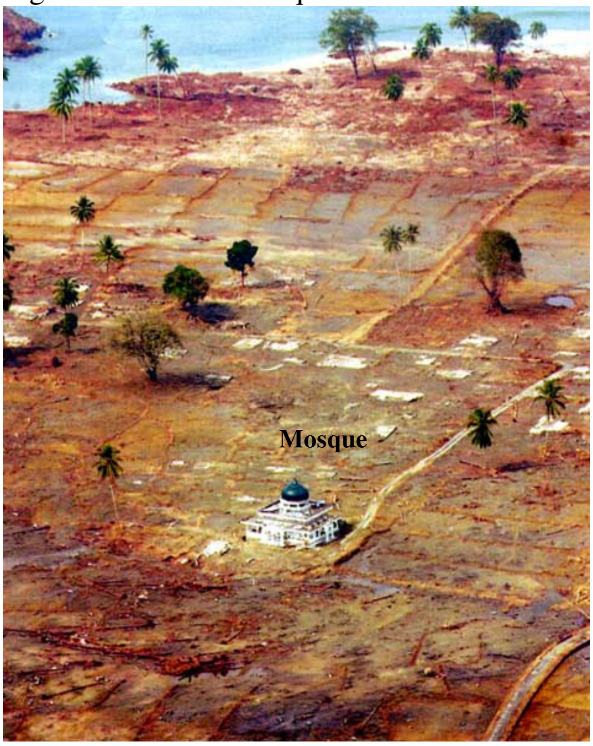
The inundation information can be used to know how far from the coastline the areas can be used for development; what kind of mitigation measures to prevent the existing development and people in coastal area from tsunami waves; to divide this area into several zoning, for example very dangerous area, dangerous area, safe area and very safe area; to know whether it is needed to relocate the people from prone-area or not, etc. Besides that, the local government can decide where to place the public facilities such as school, hospitals, etc.

Meanwhile, information about run-up height is also used to find out what kind of measures can be implemented, for example what species of mangrove can be planted in this area to slow down the wave of tsunami; is it enough to plant only one layer of mangrove or it need several layers or whether it is needed to build artificial hill in coastal zone as evacuate place for people or not, etc.

Based on my parents' experience, friends' experience and also the observation held by Borrero (2005), there are three times of tsunami waves in Banda Aceh. First, the wave was going up only to the foundation of the building, and then followed by second and the third waves after a large withdrawal of the sea.

The Grand Mosque which is located in the city center of Banda Aceh was also suffered with this wave of tsunami, but this building still standing there although many building around it were damaged. It is amazing that most of mosques in NAD Province like in Banda Aceh, Ulee Lheue, Krueng Raya, Lampuuk, Meulaboh, etc still survive from the earthquake and tsunami. Figure 16 show that only mosque still stands when tsunami hit one of coastal areas in western coast of NAD Province.

Figure 16. One of Mosques in Western Coast of NAD Province.



Source: http://www.andaman.org/BOOK/denis_pics/denis.htm (last visited June 25, 2007)

The event of earthquake and tsunami has to be important factors that should be considered in the spatial planning in NAD Province. If we want to do something in Aceh coastal zone to anticipate the next tsunami which might happen in 82 or 85 years or earlier, then we should do something in certain parts of Aceh that are potentially covered by tsunami. It is by considering the characteristic of Aceh coast which are different between west coast and east coast as mention in chapter 2.

3.2 Overview of Tsunami Disasters in India, Sri Lanka, Thailand

As mentioned above, India, Sri Lanka and Thailand were also hit by tsunami disaster on December 26, 2004. The impact of tsunami in India were perceived by population where 75 percent of the fatalities were women and children (787 women became widow and 480 children were orphaned). Approximately 1,089 villages were affected in Andhra, Pradesh, Kerala, Tamil Nadu, Pondicherry, and the Andaman and Nicobar Islands. An estimated, 235,377 houses were destroyed, 730,000 individuals lost their homes, 31,755 livestock were lost, and 39,035 hectares of cropped area was damaged (UN Office of the Special Envoy for Tsunami Recovery). The map of tsunami affected countries is presented in figure 17.

Figure 17. Map of Tsunami Affected Countries on December 26, 2004.

Source: http://www.air-worldwide.com/_public/html/air_currentsitem.asp?ID=1094 (last visited June 25, 2007)

Meanwhile, in Sri Lanka 14 out of 28 districts were affected, 90 percent of working men and women lost their sources of livelihood, 23,449 acres of cultivated land were affected, including 9,000 acres of paddy, 645 acres of other crop fields, 27,710 home garden units, 559 acres of vegetable farms, and 317 acres of fruit trees, 65,275 houses were completely damaged and 38,561 houses partially damaged, 16,919 fishing boats were damaged, representing approximately 75 percent of the total fishing fleet. Some 100 hospitals/dispensaries, Ministry of Health offices, and health centers were completely or partially damaged, a total of 195 educational facilities including universities and vocational training centers were damaged with 59 schools totally destroyed and 117 partially damaged (UN Office of the Special Envoy for Tsunami Recovery). In Sri Lanka, the height of tsunami is between 2.35 and 10.04 meter, with the arrival time of tsunami is between 5 minute and 1 hour. Meanwhile, the inundation distance of tsunami is between 6 and 306 meter (Kawata, Y, 2005). The following figure 18 displays the coastal area in Sri Lanka before the wave of tsunami affected this area.

Figure 18. Kalutara, Srilanka before tsunami (January 1, 2004)

Source: http://www.waveofdestruction.org/tsunami-photos/v/satellit-/srilanka_kalutara_beach-_jan1_2004_dg.jpg.html (last visited March 24, 2007)

The changes of the coastline because of tsunami disaster in Kalutara beach can be seen in figure 8 where some of the lands were destroyed when tsunami hit this area.

Figure 19. Tsunami hits Kalutara, Srilanka (December 26, 2004)

Source: http://www.waveofdestruction.org/tsunami-photos/v/satellite/srilanka_kalutara_beach_jan1-_2004_dg.jpg.html (last visited March 24, 2007)

Moreover in Thailand, this destructive disaster also gave impact to people and property in this area. Number of fatalities in Thailand are 8,212 (includes 2,448 people from 37 other countries), 2,817 number of people area missing, 6,000 people were displaced, an estimated 50,000 children were affected by the tsunami, and 1,480 children lost one or both parents.

The area that affected by tsunami in Thailand are six southern provinces along the Andaman coastline. Over 120,000 individuals working in the tourism sector lost their jobs and 30,000 individuals employed in the fisheries sector lost their sources of livelihood. A total of 4,806 houses were affected (3,302 were completely destroyed, and 1,504 were partially damaged), approximately 5,000 boats were lost or damaged, 2,000 hectares of agricultural land were destroyed, total of 305 acres of mangroves, 3,600 acres of coral, and 400 sea grass beds were impacted (UN Office of the Special Envoy for Tsunami Recovery). Along the most affected part of the west coast of Thailand, the tsunami wave caused an inundation or flooding level from about 5 m to 10-12 m above mean sea level (Harbitz C.B, 2006). The area of coastal zone in Thailand which was hit by tsunami disaster is presented in figure 20.

Figure 20. Satellite photo of Khao Lak, Thailand Before and After Tsunami

Source: http://www.waveofdestruction.org/tsunamiphotos/v/satellite/satellite_khao_lak_before-after.jpg.html (last visited March 24, 2007)

Similar with coastal zone in NAD province, in figure 20 it can be seen that some of land areas in coastal zone become water because of flood of tsunami. This also changed the border of coastline. In the left figure it can be seen that before tsunami there are many vegetation in this area (from green color) and after tsunami most of this area become brown (right figure). It also proves that coastal zone is the first area that should be well managed in order to mitigate the impact of natural disaster especially tsunami in coastal zone.

CHAPTER 4 Risk Management Measures

Tsunami as a natural phenomenon can not be prohibited, but the impact can be reduced through managing the risk in prone-area. Through risk management, loss of life and property in prone-area and inland area affected by tsunami can be reduced. Based on risk management measures implemented or will be implemented in some tsunami affected countries and other related resources from article and internet, this chapter elaborates mitigation measures for tsunami in general and then tries to propose tsunami management measures applicable for Aceh.

4.1 Tsunami Risk Management Measures in Some Countries

Risk management or mitigation measures in each country can be the same or different each other depending on the condition of the coastal areas in the country. Yet, in general, the mitigation measures are implemented or planned in order to reduce the impacts of tsunami risk in the future. Tsunami risk management measures in some countries affected by tsunami are as follows.

4.1.1 Tsunami Risk Management Measures in India

The government of India (2005 p.19-20) proposed general and specific measures for tsunami as the approach toward multi hazard safety measures in coastal areas. The measures are as follows:

1. General Measures:
    - Adopting integrated multi-hazard approach with emphasis on cyclone and tsunami risk mitigation in coastal areas
    - Implementation of early warning system for cyclone and tsunamis
    - Streamlining the relief distribution system in disaster affected areas

- Design, practice and implementation of evacuation plans with emphasis on self reliance for sustenance with the locals (coastal community)
- Component on planning for reconstruction and rehabilitation should be added in disaster management plans in all levels
- Emphasis on mental health and to socio-psychological issues should be accorded in every plan
- Identification and strengthening of existing academic centers in order to improve disaster prevention, reduction and mitigation capabilities
- Capacity building programmes to be taken up on priority basis:
  - Training of all concerned including community
  - Public awareness programmes
  - Enhancing capabilities of the Institutes working in field of disaster mitigation and management

2. Specific Measures

   The specific measures are divided into structural measures and non-structural measures. Those measures are:

   a. Structural measures

      The structural measures are as follows:

      - Construction of cyclone shelters
      - Plantation of mangroves and coastal forests along the coastline
      - Development of a network of local knowledge centers (rural/urban) along the coastlines to provide necessary training and emergency communication during crisis time
      - Construction of location specific sea walls and coral reefs in consultation with experts
      - Development of break waters along the coast to provide necessary cushion against cyclone and tsunami

- Development of tsunami detection, forecasting and warning dissemination centers
- Development of a “Bio-Shield” – a narrow strip of land along coastline. Permanent structures should come up in this zone with strict implementation of suggested norms. Bio-Shield can be developed as coastal zone disaster management sanctuary, which must have thick plantation and public spaces for public awareness, dissemination and demonstration.
- Identification of vulnerable structures as well as appropriate planning, designing, construction of new facilities like:
    1. Critical infrastructures e.g. power stations, warehouses, oil and other storage tanks etc. located along the coastline
    2. All other infrastructure facilities located in the coastal areas
    3. Public buildings and private houses
    4. All marine structures
    5. Construction and maintenance of national and state highways and other coastal roads

b. Non-structural measures

There are eight non-structural measures proposed by the government of India, which are:

1. Strict implementation of the coastal regulations (within 500 m of the high tide line with elevation of less than 10 m above mean sea level). A proposed damage Risk Zone classification on sea coast for consideration is showed in Table 6.

Table 6. Proposed damage Risk Zone Classification on Sea Coasts

0-1 m above High tide Level	Very High Damage Risk Zone
1-3 m above High tide Level	High Damage Risk Zone
3-5 m above High tide Level	Moderate Damage Risk Zone
5-10 m above High tide Level	Low Damage Risk Zone
10 m above High tide Level	No Damage Risk Zone

2. Mapping the coastal area for multiple hazards, vulnerability and risk analysis up to village level. Development of Disaster Information Management System (DIMS) in all the coastal states.
3. Aggressive capacity building requirements for the local people and the administration for facing the disasters in wake of tsunami and cyclone, 'based on cutting edge level'
4. Developing tools and techniques for risk transfer in highly vulnerable areas
5. Launching a series of public awareness campaign throughout the coastal area by various means
6. Training of local administration in forecasting warning dissemination and evacuation techniques
7. Awareness generation and training among the fishermen, coast guards, officials from fisheries department and port authorities and local district officials etc., in connection with evacuation and post tsunami storm surge management activities.

Moreover, the government of India (2005 p.20-21) also suggested some activities required to achieve the satisfactory level of disaster mitigation in coastal areas. These actions are:

1. Revision of Coastal Zone Regulation Act in the wake of tsunami storm surge hazards and strict implementation of the same. This responsibility may involve various departments of the government and other relevant organizations such as

Departments of Forestry, Fisheries, Soil Conservation, Town and Country Planning Organization, Navy, Coast Guards, etc.

2. Monitoring
3. Initiating disaster watch (bay watch) safety measures along important beaches in the country, providing round the clock monitoring, warning, lifeguard facilities and creation of website for missing personal etc.
4. Organization of sensitization workshops on cyclone/tsunami risk mitigation in various states for senior bureaucrats/politicians for these states
5. Organizing drills on regular basis to check the viability of all plans and to check the readiness of all concerned
6. Training of professionals, policy planners and others involved with disaster mitigation and management programmes in the states
7. Retrofitting of important buildings:
    - Fire stations/police stations/army structures/hospitals
    - VIP residences/offices/railways, airport, etc
    - Schools/colleges
    - Hazardous industries
    - Other critical structures (i.e. power stations, warehouses, oil and other storage tanks, etc)
8. Designing incentives: providing legislative back up to encourage people to adopt cyclone, tsunami resistant features in their homes e.g. tax rebate in terms of house tax and/or income tax
9. Developing public-private partnerships

For special prevention measures for safety from tsunami, the government of India (2005 p. 22-23) recommended some solutions to be implemented. Those specific measures are presented in Table 7 as follows:

Table 7. Phenomenon of Inundation, Currents, Drawdown and Fire

EFFECT	DESIGN SOLUTION
A. Phenomenon of Inundation: ▪ Flooded basement ▪ Flooding of lower floors ▪ Flooding of mechanical electrical and communication system and equipment ▪ Damage to building materials and contents ▪ Contamination of affected areas with water borne pollutants	▪ Choose sites at higher elevations ▪ Raise the building above flood elevation ▪ Do not stack or install vital material or equipments on floors or basement lying below tsunami inundation level ▪ Protect hazardous material storage facility located in tsunami prone area ▪ Locate mechanical systems and equipments at higher location in the building ▪ Use corrosion resistant concrete and steel for the portions of the building
▪ Hydrostatic forces (pressures on walls by variation in water depth on opposites sides)	▪ Elevate building above flood level; provide adequate openings to allow water to reach equal heights inside and outside the buildings ▪ Design for static water pressure on walls
▪ Buoyancy floatation or uplift forces caused by buoyancy	▪ Elevate building to avoid flooding ▪ Anchor building to foundation to prevent floatation
▪ Saturation of soil causing slope instability and/or loss of bearing capacity	▪ Evaluate bearing capacity and shear strength of soil that support building foundation and embankments slopes under condition of saturation ▪ Avoid slopes or setbacks from slope that may be destabilized when inundated
B. Phenomenon of Currents (wave break and bore): ▪ Hydrodynamic forces (pushing forces on the front face of the building and drag caused by flow around the building)	▪ Elevate building to avoid ▪ Design for dynamic water forces on walls and building elements ▪ Anchor building to foundation
▪ Debris impact	▪ Elevate building to avoid and design for impact loads
▪ Scour	▪ Use deeper foundation (piles or piers) and protect against scour and

EFFECT	DESIGN SOLUTION
	erosion around foundation
C. Phenomenon of Drawdown: ▪ Embankment instability ▪ Scour	 ▪ Design water front slopes, walls and buttresses to resist saturated soils without water in front ▪ Provide adequate drainage ▪ Design for scour and erosion of soil around foundation and piles
D. Phenomenon of Fire: ▪ Waterborne flammable materials and ignition increase in buildings	 ▪ Use fire resistant materials ▪ Locate flammable materials storage outside of high-hazards areas

Source: Cited from Government of India (2005)

Besides the preventions measures as describe in Table 4, the government of India (2005 p.23-24) also intended specific design principles for tsunami. The design principles are:

1. Know the tsunami risk at the site
   - Distance from the sea
   - Elevation above mean sea level
   - Height of high tide above mean sea level
   - Maximum run-up of the tsunami above the site elevation
   - Depth and speed of the tsunami wave for design purposes
2. Avoid new developments in tsunami run-up areas
   - Role of land use planning
     - Local context
     - Understanding trade offs
     - Review and update existing safety elements
     - Review and update existing land use elements
     - Review and update existing zoning, and other regulations
   - Land use planning strategies
3. Site strategies to reduce tsunami risk
   - Avoiding by building on higher ground – necessary for vital installations

- Slowing the tsunami wave by frictional techniques – forests, ditches, slopes and berms
- Deflecting the tsunami away by using angled walls - suitable for important installations
- Brute resistance through stiffened strong structural design – costly buildings
- High rise buildings with open ground structural storey, designed for wave forces – hotels, offices, etc
- Stilted buildings for various uses

4. Tsunami resistant buildings – new developments
   - Locally applicable Tsunami Information on Design Intensities
   - Performance Objectives
   - Mandatory use of building codes – design criteria
   - Safety under multi-hazard environment
   - Qualified engineers and architects – knowledge about earthquake, wind and tsunami resistant planning and design
   - Ensure quality construction
5. Protection of existing building and infrastructure – assessment, retrofit, protection measures
   - Inventory of existing assets
   - Assessment of vulnerability and deficiencies to be taken care of through retrofitting
   - Methods of retrofitting and use in design
   - External protection methods from the onslaught of tsunami
6. Special precautions in locating and designing infrastructure and critical facilities
   - Considerations in relocating and redevelopment of infrastructure
   - Considerations in relocating and redevelopment of critical facilities
7. Planning for evacuation
   - Vertical evacuation – high rise buildings, special shelters
   - Horizontal evacuation areas and routes

The government of India considers all the prevention and design principles needed by the prediction of potential maximum wave heights which is more than 4 m. It is based on the observation in some coast where the height of tsunami wave in Indian coast is more than 4 m.

In the case of Aceh, these measures need adjustments because the height of tsunami is more than in India and the area damaged by tsunami is also different. For example, risk zone classification of the sea coast in India will not be the same with Aceh coastal zone because as stated in chapter 1 and 2 that the affected areas in Aceh are more than 3 km.

4.1.2 Tsunami Risk Management Measures in Thailand

Norwegian Geotechnical Institute (NGI) in 2006 predicted that within the next 50-100 years the largest credible earthquake, which could cause a tsunami hitting the coasts of Thailand, is magnitude 8.5 earthquake on the Sunda Arc. Based on this prediction, NGI proposed tsunami management measures in Thailand for short to medium term and long term.

For short to medium term, the risk management measures to be implemented within the next 50 to 100 years should be designed for maximum water level of 2.5 to 3.0 m above the mean sea level (1.5 – 2.0 m due to tsunami and about 1.0 due to possible high tide). The long term (100 to 200 years) risk management measures should protect the exposed population from a tsunami similar to the one that occurred on 26 December 2004, for example 5 to 12 m above the mean sea level.

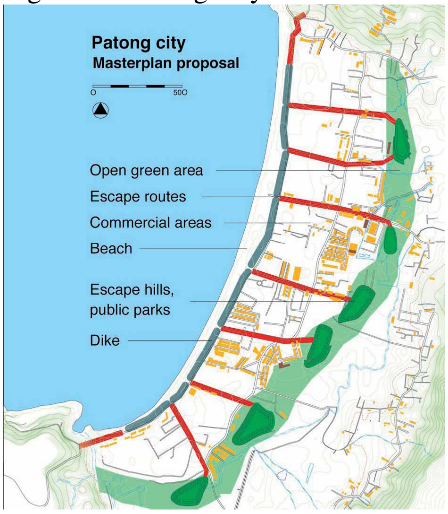
The management measures which recommended by NGI (2006) for the authorities in Thailand are awareness building and warning systems; land use master plans; project planning; developing functional networks of escape routes and safe escape places; and constructing physical protection barriers.

Ensuring a lasting long term awareness of the tsunami risk can be conducted through constructing monuments along the coast that can give a clear warning for the next generation about the risk of tsunami. These monuments can also be functioned as part of the physical protection measures against tsunamis. Thailand authorities have already planned and implemented several monuments of this type. The authorities should also consider the inclusion of tsunami risk in school curriculum and textbooks, establishing a yearly national tsunami or natural hazard day, and showing the inundation zone for the 2004 tsunami in the land use master plans.

For the long term, Thailand together with affected countries establishes a tsunami warning system for the Indian Ocean region. Thailand itself has already started implementing a tsunami warning system which will be important in long term and will help maintain the public awareness.

Raising existing sea wall and dike between the road and the beach are the other alternative that will be implemented in Thailand coastal zone. In Patong City, the example master plan proposes elevated green-belt areas about 400 meters inland from the beach, which is used as safe escape hills, and an easily accessible system and escape routes with well marked escape routes. Normal car traffic should be banned from these escape routes. The master plan is shown in Figure 21.

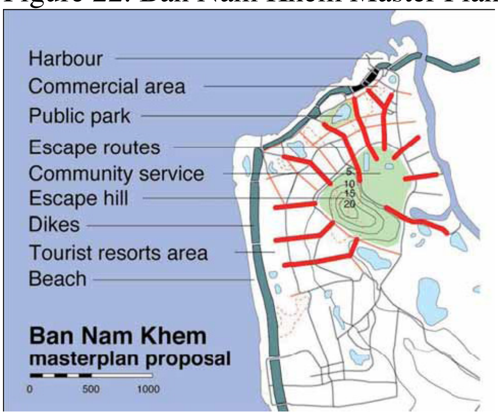
Figure 21. Patong City Master Plan Proposal



Source: Norwegian Geotechnical Institute (2006)

Meanwhile, in Nam Khem fundamental long term changes should be measured. Moving the main part of the village to tsunami safe areas could have been an option, but does not seem a **possible** option because the reconstruction of the village is nearly completed and the fishermen need to have easy access to the sea. The most attractive solution is by combining a protection dike with a new system of well marked and accessible escape roads. The layout of possible protection dike around Nam Khem with escape routes to safe high areas shown in proposed master plan in Figure 22 (NGI, 2006).

Figure 22. Ban Nam Khem Master Plan Proposal



Source: Norwegian Geotechnical Institute (2006)

Besides, Thai government in Thanawood (2006) has adopted and implemented vulnerability reduction programmes through two measures: disaster prevention and/or mitigation measures to reduce an area's susceptibility to the impact of the tsunami hazards, and preparedness measures to build tsunami resilient communities. These measures are (p.214-215):

1. Mitigation measures.
    a. Establishment of land use plan for coastal areas based on vulnerability assessments and risk analysis. Critical facilities such as schools, hospital, hotels or high occupancy buildings should not be built in vulnerable areas. Existing tourism facilities, shrimp farms and aquaculture infrastructure located in areas at risk should be relocated.
    b. Provision of appropriate incentive packages and attractive livelihood opportunities to encourage coastal communities to abandon settling in vulnerable locations and/or living in poor-designed houses, particularly along low-lying areas of the coast.
    c. Maintenance of environmental and ecological stability of the coastal areas through the enrichment of mangrove and beach forests to act as the first line of defense from tsunami waves and rehabilitation of lost and degraded coral reefs and sea grass beds to help stabilize the coastline and prevent beach erosion.
    d. Reconstructing removed coastal sand dunes and protecting the remaining sand dunes to act as a barrier against giant waves. Creating buffer zones along the coastlines to protect coastal communities from tsunami waves are established. The buffer zones or green belts can be created through the establishment of buffer strips of between 300-400 meters, planted with mixed vegetation.
2. Preparedness measures.
    a. Installation of a local tsunami warning system, which includes siren towers at popular and crowded beaches and a tsunami warning sensor floating offshore in the most vulnerable provinces along the Andaman coastline, not only to

address the safety and security concerns of the coastal communities, but also to establish southern Thailand as a safe destination for foreign tourists.

b. Development of education programme through school and university curricula to educate vulnerable coastal communities about the nature and processes of the tsunami hazard and how to protect themselves at the time of impact as well as the importance of mangrove forests, beach forests and coastal sand dunes in mitigating tsunami effects.
c. Formulation of a detailed plan for emergency evacuation of vulnerable coastal communities as well as organizing evacuation drills in order to make the appropriate response more of an instinctive reaction, requiring less thinking during an actual emergency situation.

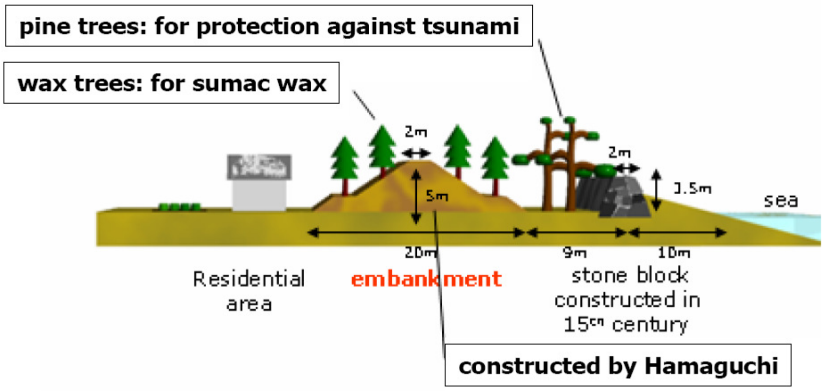
In the case of Aceh coastal zone, the measures suggested in Thailand will also need some adjustments to make it appropriate with the condition of Aceh coastal zone and the culture of Aceh community, mainly the characteristic of the coast and the area damaged by tsunami on December 2004. For example, in Aceh case it is necessary to plant mangrove or forest coast behind the seawall or build the embankment to slow down the height of tsunami and to save the people and property in this area.

4.1.3 Tsunami Risk Mitigation Measures in Japan

For the Japanese people, there are many stories of tsunami in the past. One of them is the story about the most influential resident of Hiro village that was periodically hit by tsunami. The resident's name is Gihei (Gohei) Hamaguchi. When the tsunami hit this village in 1854, he sent a message to the people in the village by firing the rice-stacks because he realized that tsunami would come soon after the earthquake and he saw that the sea was running away from the beach. The rice-stacks were the crystal of farmers' labor of the year. Because of this fire, people from the village came up to the plateau in a hurry and saved from tsunami.

After the tsunami in 1854, Gihei Hamaguchi promoted the village people to construct a protective embankment 5 m high and 20 m wide at the base which was placed along the shoreline with length 600 m protecting the main part of the village. The construction took time about 3 years, from February 1855 to December 1858. On the sea side (in front of the embankment) they had an old stone wall (3.5 m high and 2 m wide at the top).This stone wall was re-built by the village people. Between the old stone and the constructed embankment (9 m wide), the village people planted black pine trees to withstand the sea breeze. Meanwhile, spindle trees were planted on the sea side slope of the embankment and wax trees on the other slope. In Figure 23, it can be seen the cross section of the protective embankment in Hiro village.

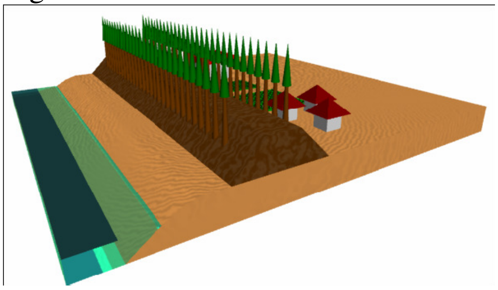
Figure 23. The Protective Embankment in Hiro Village



Source: Ohta et al (2005)

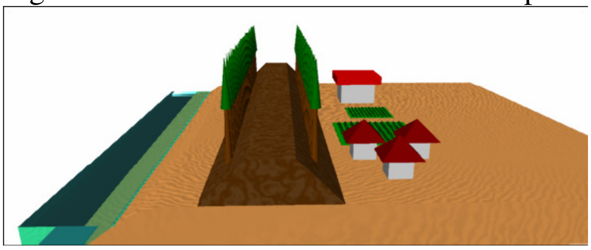
Moreover, Ohta et al (2005) in their paper introduced an example of many case histories in Japan. They also stated that there are tree planting and embankment along the shoreline area Japanese traditional measures of tsunami disaster mitigation and rehabilitation. Figure 24a, 24b, 25a and 25b are examples that are showed in their paper. Figure 24a and 24b show a small-scaled embankment possibly placed along the shoreline to protect a small village, while Figure 24a and 24b show a large-scaled one to protect a seaside resort.

Figure 24a. Small-scaled embankment to protect a small village



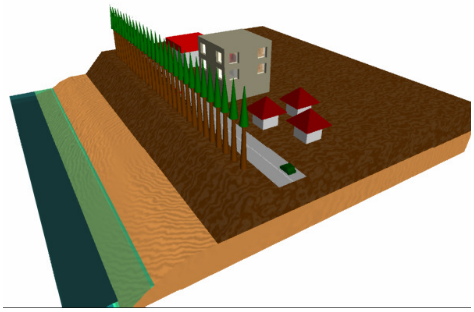
Source: Ohta et al (2005)

Figure 24b. Small-scaled embankment to protect a small village



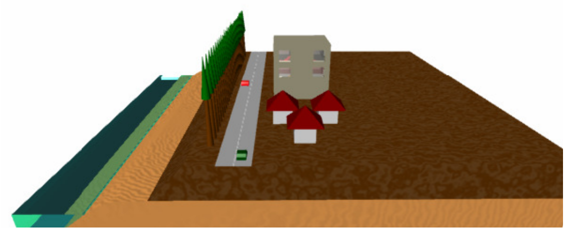
Source: Ohta et al (2005)

Figure 25a. Large-scaled embankment to protect a seaside resort



Source: Ohta et al (2005)

Figure 25b. Large-scaled embankment to protect a seaside resort



Source: Ohta et al (2005)

In their paper, Ohta et al (2005) proposed to take the case of Hiro village as a material taught for children in the school in the Asian coastal areas. They also suggest to performing a continuous campaign on the school as part of the joint project of geotechnical community in Asian region.

Moreover, Japan is as one of the most earthquake and tsunami prone-area and has suffered from tsunamis. Japan Meteorology Agency (JMA) has been implementing seismological observation since 1880s and established warning tsunami service in 1952. Japan Meteorological Agency (JMA) is responsible to issue tsunami warnings in Japan. JMA uses data from hundreds of seismic stations to detect tsunamigenic earthquakes, and data from sea level monitoring stations to confirm the tsunami generation. JMA has constantly improved the tsunami warning system. If there is likely earthquake that can generate tsunami, the JMA gives an alert within three minute after it identified. The alerts are informed by all radio and television channels. The warnings are also gotten by local authorities, central government and disaster relief organizations through special channels so that they can give quick response to a disaster.

Miyazaki (2005) argued that JMA's network can predict the height, speed, and destination and arrival time of any tsunami destined for Japanese shores. There are six regional centers connected up to 300 sensors located across Japan's islands, including around 80 water-borne sensors, monitor seismic activity round the clock. Besides that, there are strict new building laws to protect against tsunamis and quakes, and good disaster planning that reduce the victims of Japanese from earthquake and tsunami. Japan also has tsunami walls that circle other parts of the coast to prevent damage from disasters.

The way of Japanese people protect their coastal zone from tsunami can be considered as example to prevent the coastal area in Aceh from tsunami. It is because in Japan, the physical construction to mitigate the impact of tsunami proved that it can save more life and property. Besides, the way of information provided can also increase the awareness of the people about tsunami.

Generally, the proposed measures vary in each country above. Some of them are the same, for example, the early warning system, plantation of mangrove and coastal forest, construction of seawall are recommended in India, Thailand and Japan. In the case of Aceh, the proposed measures in India, Thailand and Japan such as the artificial hill, the seawall, the embankment with coastal forests might be implemented by considering the contour of the coast, the culture of Acehnese people, the possible land use, etc.

The description of the above mentioned measures is used to elaborate risk management measures for tsunami and tsunami mitigation measures applicable for Aceh. The measures in some countries will be divided into three kinds of measures which are technical, spatial, and community measures. The detailed discussion from each of those measures can be seen in chapter 5.

CHAPTER 5 Risk Management Measures for Tsunami

This chapter illustrates the risk management measures for tsunami which consist of technical, spatial, and community measures. Then, it is followed by the applicable measures in the case of Aceh.

5.1 Technical, Spatial and Community Measures for Tsunami

Based on tsunami risk management measures in several countries that had experience with tsunami disaster described in chapter 4, this research divides the mitigation measures into technical measures, spatial measures, and community measures. The following elements will depict those measures.

5.1.1 Technical Measures

Technical measures are physical measures that are needed to mitigate the impact of tsunami in coastal zone. These measures are to slow down tsunami wave and defense the tsunami prone-area from total damage of this kind of disaster. This research also discusses the possibilities for those measures to be implemented in the case of Aceh. The technical measures are as follows:

1. Construction of location specific sea walls and restoring coral reefs in consultation with experts.

   Construction of location specific sea wall should be implemented in Aceh because the absence of seawall caused big damage of property and lost of life in Aceh coastal area, even into inland area. This measure not only can reduce tsunami wave, but also can protect the coastal community and public facilities from other coastal disaster such as high tide.

The sea wall should provide access for the fishermen from and to the coast to make them easy to go to the beach for fishing. Before the construction, there should be Environmental Impact Assessment (EIA) study to minimize the impact of the construction to the vicinity environment and to other activities such as tourism, fisheries, etc which located behind this seawall.

Coral reefs can also slow down the wave of tsunami. In Aceh, there are many coral reefs destroyed not only because of tsunami wave but also because of things brought by tsunami from the land to the sea. Thus, it needs to be replanted to rehabilitate the availability of this ecosystem as protective defence from tsunami disaster and also as place for fish and other sea animals for breeding.

The local government should discuss the suitable location for seawall by involving the coastal community, experts, developers and "Panglima Laot" as the leader in traditional fisheries community.

2. Using angled walls to deflect the tsunami away - suitable for important installations

   For the area where the coast is open and the wave is large, the angled walls are needed to slow down the speed of tsunami wave. This measure is more appropriate for the western coast of Aceh which faces directly to the Indian Ocean.

3. The development of break waters along the coast to provide necessary cushion against tsunami

   The need of development of break waters in coast of Aceh depends on the conditions of the coast. In my opinion, not all the coastal zones need to build break waters. For the coast which is open and has large wave like in western coast of Aceh, the break water is needed. Besides, the development of break water should be suited with the coast environment. If it only needs the seawall so the break water should not build.

4. Plantation of mangroves and coastal forests along the coastline

Mangroves and coastal forests are as greenbelt for coastal area can be used to protect the tsunami prone area from damages. Both these kinds of ecosystem proved that some areas in Aceh were saved by these plants.

In the case of Aceh, the area where mangroves are proved as protection for the community and property in coastal area from tsunami wave, such as in east Aceh, north Aceh, etc, it is better to maintain this ecosystem as the green protection against tsunami.

Meanwhile, in the area where coastal trees such as coconut trees, sea pines, etc can withstand from tsunami wave, such as in Ulee Lheu, this research suggests to plant this kind of trees together with mangrove along the coast and in the location of fish and shrimp ponds.

Plantation of mangroves and coastal forests can not be implemented without active participation from coastal community, local government, and NGO (non government organization). The coastal community is as the active participant to plant and maintain the plantation of mangroves and coastal forests. Meanwhile, the local government and NGO supply the seeds of those trees and give incentives for the community who involve in this activity and succeed in planting the mangrove and coastal trees. This plantation activity not only can provide green protection from tsunami but also can help the victims of tsunami, who mostly live in coastal area. Even less living cost for victims of tsunami had not given anymore since March 2006.

5. The development of tsunami warning system and tsunami warning center among tsunami affected countries integratedly.

   The development of integrated tsunami warning system and tsunami warning center among affected countries is not possible for Aceh because it needs high cost to implement. It can possibly be developed in national level and the location can be discussed among the affected countries.

   For the province level, tsunami warning system has already been built in some locations in Aceh, such as in Kajhu, Blang Oi, etc. All these tsunami warning system were developed by donor countries that concern with the damages caused by tsunami on December 2004.

6. Identification of vulnerable structures as well as appropriate planning, designing, construction of new facilities like:
   - Critical infrastructures e.g. power stations, warehouses, oil and other storage tanks etc. located along the coastline
   - All other infrastructure facilities located in the coastal areas
   - Public buildings and private houses
   - All marine structures
   - Construction and maintenance of national and state highways and other coastal roads

   This measure related to land use planning and can be implemented in Aceh case because most of vital structures located in damaged coastal areas. By identifying the vulnerable structures and developing these structures to higher ground (if possible), the damage can be reduced.

   The identification should be discussed with related sectors, local government, experts, NGO, developers and also the community, whose land is used for new developments of vulnerable structures, so that in the future the loss of property as happened on December 2004 and the budget for reconstructing those structure is not much. As we know that without the aid from donor countries, it is impossible for Aceh to rehabilitate and reconstruct the damage caused by the tsunami. Thus, the identification of vulnerable structure is important to be done.
7. Constructing monuments along the coast that can give a clear warning for the next generation about the risk of tsunami. These monuments can also be functioned as part of the physical protection measures against tsunamis

   These monuments can also be functioned as part of the physical protection measures against tsunamis. The construction of monument of tsunami along the coast in the case of Aceh can be done together with the construction of sea wall.

This is to make people always remember the event of tsunami and worry with this kind of disaster.

The monument can also be built in the entry of Aceh tsunami prone area, so that people who do not visit the beach can see this monument, especially those who never come to this area before. This monument not only functions as memorial building but also as an equipment to increase the awareness of people in coastal areas.

8. Raising existing sea wall and dike between the road and the beach

   This measure is not possible for Aceh because there is very limited sea wall. If this measure is done, it will be useless because the existing sea wall is not enough to defend the coastal area from tsunami. It is better to build sea wall in the area of suitable location rather than only raising the existing sea walls.

9. Constructing a protective embankment placed along the shoreline. The embankment like implemented by people in Hiro village in Japan can become an example to slow down tsunami wave.

   This embankment can be built because Aceh coastal area is flat and open, so that the embankment is placed behind the seawall. Coastal tree can be planted in both sides of the embankment to avoid the tsunami hit directly the area behind this embankment. In addition, it has function to slow down the speed of the wave.

10. Building vital installations on higher ground.

    It is difficult to be implemented in Aceh coastal zone because most of the coastal zones in Aceh is flat for example in Ulee Lheu, Aceh Jaya, Kota Meulaboh, etc. If there is development of artificial hills in coastal area as evacuation place, this measure can be built in these hills.

11. Constructing high rise buildings with open ground structural storey, designed for wave forces and earthquake such as housing, hotels, offices, etc

    This kind of buildings is very appropriate with the location of NAD Province as stated in Chapter 1 that this area is always threaten by earthquake and tsunami disasters because it is located between two big plate: Eurasia and Australia plate that are still active.

By constructing high rise buildings with open ground structural storey, if there is tsunami, the flood caused by tsunami can flow through this open ground storey and the top part of this building can be used as evacuation place for the people.

5.1.2 Spatial Measures

The spatial measure for tsunami risk management is related to the harmonization between land use planning and tsunami risk management in coastal zone. As stated in Chapter 2 by Bonino (1999) in Ingleton (1999) that better land-use planning and a more efficient aid policy focused on sustainable development are the keys to preventing disasters and mitigating the impact of hazards. This land use planning can be used as a guide to manage the available land for future development in order to safe life and property loss from tsunami. The spatial measures are:

a. Strict implementation of the coastal regulations by classifying damage risk zone on sea coast

   Before tsunami, there are no regulations that classify the coastal zone based on the risk, so that it is really needed by the coastal areas in Aceh as one of efforts to safe more life and property in this area. This measure is related to land use planning and Aceh local government has to consider in their development planning about which area for the new developments will be safe from the natural disasters (especially tsunami) in coastal zone.

b. Mapping the coastal area for tsunami and earthquake disaster, vulnerability and risk analysis up to village level.

   Aceh has limited data related to mapping the coastal area up to village level. Thus, this measure is really appropriate with Aceh in order to prepare this area for tsunami disaster in the future.

c. Avoid new developments in tsunami run-up areas

   - Role of land use planning

- Local context
- Understanding trade offs
- Review and update existing safety elements
- Review and update existing land use elements
- Review and update existing zoning, and other regulations

▪ Land use planning strategies

Aceh ethnic or Aceh coastal community for along time lives in coastal areas in Aceh. Most of them are fishermen that depending their life on fisheries. After tsunami, they return to their villages and rebuild their houses and villages. As community who is used to live in coastal zone, it is difficult to move this community to other area such as higher ground. To save this community from the tsunami disaster, the local government can provide a good protective sea defense against tsunami such as regulating safe zone for settlements from coastline, type of house that can be built in coastal area, etc.

d. Formulation of a detailed plan for emergency evacuation of vulnerable coastal communities

Tsunami disasters on December 2004 in Aceh caused many victims not only coastal community but also inland community. The victims were not that much if there were quick evacuation action. It is because very limited knowledge and information of the people in safe area from tsunami to evacuate those victims.

The formulation of a detailed and clear plan for emergency evacuation can be used by the local community in Aceh to evacuate the victims of tsunami if there are tsunamis in the future, so that they can react quickly and the number of victims can be reduced.

5.1.3 Community Measures

People tend to remember one important event in short time, after that as the time goes on they start to forget it. Besides, tsunami happens not in one or two year but many years. That is why the awareness of people especially who live in tsunami prone-area should be improved or at least they still remember with the past experiences. People do care on one event after it happens and consider the prevention and mitigation action. Yet, they have to be aware to avoid and reduce the impact that will happen in the event.

Information and knowledge about tsunami is the important thing that community in coastal and inland area should know. By these information and knowledge, they know what they should do if tsunami happens. Without information, people do not know what is going on and do not know where to go to face the tsunami disaster. If there was warning system and good information in December 2004, the loss of life and property was possibly not that much. Related to information and communication, the community measures are:

a. The development of a network of local knowledge centers (rural/urban) along the coastlines to provide necessary training and emergency communication during crisis time

   A network of local knowledge centers can be provided through coordination with the leader of traditional coastal community, in Aceh case is "Panglima Laot". The "panglima laot' can inform its community about the information and action needed related to emergency communication during crisis situation.

b. Launching a series of public awareness campaign throughout the coastal area by various means such as tsunami signs, posters, brochures, etc, and awareness generation and training among the fishermen, coast guards, officials from fisheries department and port authorities and local district officials etc., in connection with evacuation and post tsunami storm surge management activities.

   As mentioned in chapter 3 that Acehnese people really believe with their "ulama", so that the public awareness campaign can also be done in coordination with "ulama" and also with "panglima laot" as the leader of traditional institute of fishermen community. Besides that, tsunami signs, posters, brochures, etc are supplied in public place in coastal area. The public awareness campaign, awareness generation, and training can also be implemented by involving the local government and local organization such as woman organization, NGO, etc.

c. The development of education programme through school and university curricula to educate vulnerable coastal communities about the nature and processes of the tsunami hazard and how to protect themselves at the time of impact as well as the importance of mangrove forests, beach forests, and coastal sand dunes in mitigating tsunami effects.

   The information and knowledge about tsunami must include in the curricula of formal education in Aceh from kindergarten until university. It is to give enough information about tsunami disaster and they are more aware with the importance of greenbelt in coastal zone, so that in the next generation they will be more careful in planning development in coastal zone by considering the impact of tsunami disaster in this area and prepare themselves to face tsunami disaster.

   Active participation of actors in education sector and local government of Aceh in implementing the development of education program are really needed. The programme should be presented in an attractive way for example by using pictures and arranging fieldtrip to affected areas or tsunami museum to make the students more interested with this programme.

d. Keep traditional knowledge about tsunami through generations and always inform it to new comers in affected-area such as what have been implemented in Japan

   Traditional knowledge about tsunami should be informed not only to coastal community but also to inland community and new comer. In Aceh, this traditional knowledge about tsunami is already known by community who live in islands such as in Simeulue, Aceh Island and Weh Island.

   The traditional knowledge can be easily informed to Acehnese people because most of them still use Acehnese language and in the formal education this language included in education curricula in Aceh. Meanwhile, the information to new comers can be performed by Acehnese people because as stated in chapter 3 that the culture Acehnese people are very easy to adapt and welcome with new comer.

e. Provide tsunami museum to make people aware about the danger of tsunami and to remember the tsunami destructive day.

   Tsunami museum is important to inform the next generation and to keep the evidence about the danger of tsunami. This is also to make them more aware to tsunami disaster.

   In Aceh, and also possibly in other regions in Indonesia, there are not many people visiting the museum. Thus, in Aceh to make tsunami museum more attractive and more visited by visitors, the active participation of local government in promoting this museum through education sector is needed for example visiting the museum is included in the education currila in schools. The students who visit this museum can inform their family and the people in their neighborhood about this museum.

f. Informing the people in safe area from tsunami about how to deal with emergency response in reacting at emergency time and after disaster.

   By informing the people in safe area in reacting in emergency situation, the people can be more prepared in helping the victims of tsunami and can have quick response after tsunami. This activity can be done through trainings by involving local government, health agency, medical staffs, community, etc.

g. Involving local community in managing the ecosystem and development in coastal zone, especially development of greenbelts, so that they will be aware with the prevention and mitigation development which has done by government and other donors

   It is important to involve the local community, especially coastal community in managing the ecosystem and development in coastal zone, in order to make them more concern with their environment.

   As mentioned in chapter 3 that Acehnese people have close relation with their environment and the also have a set of rules (for example adapt Laot in coastal community), borders, etc in managing their environment. Thus, by involving the local community, this measure can be well implemented in Aceh.

Based on the elaboration and possibilities of those measures above, this study considers some measures applicable for Aceh by relating the measures with the condition of coastal zone in Aceh and the culture of Aceh community.

5.2 Tsunami Risk Management Measures Applicable for Aceh

As explained in Chapter 2 that coastal zones in Sumatra have different characteristic. The measures are based on the substrate and contours between the east and west coasts of Sumatra as stated by Wetlands International-Indonesia Programme (2005). It means that tsunami risk management measures differ between eastern and western coast of Aceh, especially related to what kind of natural barriers or green belts can be implemented in both coast. Besides, the culture of Aceh community will also influence the implementation of those measures. There are 3 types of tsunami management measures proposed for Aceh based on elaboration of risk management measures for tsunami above and other sources, which are technical measures, spatial measures, and community measures. The measures are described in following explanation.

5.2.1 Technical measures

Technical measures in this case are the physical measures that applicable for Aceh in order to reduce the impact of tsunami in this area. The technical measures will be discussed as follows.

- *Tsunami Early Warning System (TEWS) and Tsunami Warning Center.* TEWS and also the natural signs such as big earthquake and retreat of sea water after the earthquake play an important role to warn the people in coastal and inland area that there will be tsunami. The information about what should be done after the siren from tsunami warning system and warning from tsunami warning center is very important in order to save more life. TWES is already applied in some locations in Aceh such as in Kajhu, Punge Blang Oi, Lhoknga, etc. However, this measure has limitation if there is technical error with the system like what happened on June 4, 2007 in which the TWES in Banda Aceh belled although there was no tsunami on that time. This TEWS should be supported by Tsunami Warning Center that operate and monitor this system in 24 hours a day. This TEWS is needed in Aceh because when tsunami happened on December 2004, many people did not know if there would be tsunami after the earthquake.

- *Planting Mangrove and Coastal Forest.* For the eastern part of Aceh, the soil condition makes this area possible for planting the mangrove for coastal defense from tsunami. Because of the height of tsunami as mention in Chapter 3, it is not enough to plant only one layer of mangrove to reduce the tsunami wave. It needs about several layers of mangrove, for example in Ulee Lheue where there are many activities in this area. Besides, mangrove, coconut trees, pine trees, and other coastal tress are also effective for reducing tsunami wave. When tsunami hit Aceh, in some areas, coconut trees and other beach trees saved the houses covered by these trees, although the houses were located on the seaside. The mangrove plant programme have also been implemented in Aceh for example re-planting of 10,000 mangrove trees in Tibang village, Syiah Kuala sub-district, Banda Aceh in 2005.

Meanwhile, in western coast of Aceh, the mangrove is difficult to plant because the large wave from the sea. In this area, other coastal trees such as coconut trees, pines, etc can be planted in order to reduce tsunami wave and to protect the community and property in tsunami prone areas. Thus, this measure should be implemented based on the condition of coastal area.

Figure 26. Coastal Forest and Mangrove that Saved Settlements

Source: Istiyanto (2007)

Planting mangrove and coastal forest is chosen as one of measures suitable for Aceh because as presented in figure 26, the coastal forest is effective to slow down the tsunami waves and save the settlements near the beach in the west coast of Aceh and Nias coast.

- *Constructing tsunami protection seawall*. The model of tsunami protection seawall implemented in Thailand and Japan can be applied in Aceh due to the maximum height of tsunami in this area, that is, 34.25 meters. Planting mangrove is not enough for Aceh, especially in western coast of Aceh where the coast is open, it need to be combined with other measures. To prevent the western coast of Aceh also need angled seawall as the first protection layer to slow down tsunami wave. The second layer is embankment with the trees in both its sides to protect the infrastructure such as settlement and public facilities, etc in coastal area. It should be slots on the seawall to make the water flow through the slots. These slots can also slow down the speed of tsunami wave because there are rooms for water to flow. Beside that if there are rainy season during the normal condition (no tsunami disaster) and high tide, this slot can prevent the area behind the seawall from flooding.

Tsunami protection seawall is very important in reducing the height of tsunami because as tsunami hit something when it reaches the land, the tsunami height will be decreased. This can be seen in figure 27 where there is difference between building face to shore and building face to inland.

Figure 27. Different height of tsunami wave.

Source: Kamataki et al (2005)

From Figure 27 it can be seen that a family house located about 0.9 km inland in Banda Aceh has different height of tsunami wave. On the shore side the height is 7.94 meters, while on the inland side the height is only 4.93 meters.

For the coast area where the height of tsunami is very high (34.25 m), the seawall is adjusted with the condition of the coast, for example for western coast of Aceh the seawall should be higher than in the eastern coast of Aceh. It is to anticipate the height of tsunami.

- *The development of break waters along the coast to provide necessary cushion against tsunami*. The development of break waters is necessary for certain coast in Aceh especially in west coast where the wave in this coast is large. Meanwhile, in east coast this break water is not necessary because in this coast the water is calm and mangrove can grow well.

Both developments of sea wall and break waters have constraint in implementation because it needs much budget for the construction. Because of this limitation, the construction of sea wall combined with mangrove or coastal forest is possibly more appropriate with Aceh condition.

- *Providing evacuation place*. If it is possible, artificial and escape hill can also be built in flat area. Artificial hill, escape hill for the coastal areas where there are no hill behind the beach, can be built as escape place for the community in and around coastal zone. Besides as escape hill when tsunami happens, this area can also be used as place for tourism activities in normal condition. The site for escape hill can be discussed by local government and community in this area. The routes to this escape hill must be provided to make people easier to reach the hill. These routes are also proposed for the areas with hill behind the beach, such as at Lhoknga near the mining facility where there is a steep hill about 300 m from shoreline. The signs of tsunami evacuation routes should be available in tsunami prone area so that it can guide people to the evacuation place.

When tsunami disaster happened in Aceh, many people did not know where to go to safe their life, especially people located in the beach on that time. They realized the very high wave come close to them but there was no time to escape.

Because the arrival time of tsunami varies in Aceh coastal area as presented in Chapter 3, a good evacuation route must be provided for people to give them enough time to get the evacuation place in the right time and in the right place, especially for people who live or are in the coastal zone if there is tsunami in the future.

- *Constructing tsunami building*. Constructing high rise buildings with open ground structural storey which are designed for earthquake and tsunami wave forces is applicable for Aceh. These allow the flooding caused by tsunami can flow through the ground structural storey such as housings, hotels, schools, offices, etc. Housings with open ground structural storey have been constructed in Aceh for example housing which was constructed in Ulee Lheue, Great Aceh after tsunami. This kind of building not only allow the water flow in its ground storey but also can function as place for coastal community to escape from tsunami.

After tsunami there are also tsunami houses built by Muslim Aid that take the architecture of "Rumoh Aceh", in Gampong Jawa, one of villages in Banda Aceh city. The picture of Aceh tsunami house can be seen in Figure 28. This type of house has been modified where the roof is from iron sheeting and the pole uses coconut trees or wood. This kind of house is more appropriate to construct for tsunami house than the type of tsunami houses that were constructed in Ulee Lheu.

Figure 28. Aceh Tsunami House in Gampong Jawa

Source: Sufi (2005)

• *Constructing monuments along the coast that can give a clear warning for the next generation about the risk of tsunami*. These monuments can also be functioned as part of the physical protection measures against tsunamis.

5.2.2 Spatial measures

Spatial measures are related to how the local government and other interest groups deal with land use planning related to tsunami disaster. Spatial measures proposed for tsunami risk management measures in Aceh consist of:

• *Strict implementation of coastal regulations by classifying damage risk zone on sea coast*. Damage risk zone in coastal area must be classified by Aceh local government in order to minimize the damage caused by tsunami. The safe and unsafe zone must be considered in land use planning and also in development planning in coastal area. It is because in Aceh there are many settlements and other public facilities built close to the coastline.

This measure should also consider the interest of Aceh coastal community who live in this area for years. The implementation of this measure is in cooperation and discussion with "*panglima laot*" and coastal community who has direct impact by this regulation. The local government should consistent with the implementation of this regulation. If local government forbids the community not to build in danger zone, the government should also not build in this zone. Otherwise, the community will not obey this regulation.

The local government through "*panglima laot*" can inform the coastal community that constructing building close to coast is vulnerable to tsunami wave and it needs regulation which regulates the distance from coastline which is safe for constructing buildings and other facilities.

- *Mapping the coastal area for tsunami and earthquake disaster, vulnerability and risk analysis up to village level*. The map of tsunami and earthquake disaster area in coastal zone can be used to decide where the safe area for development, the site to build escape place for people in tsunami prone area, the area to plant coastal forest, etc. This mapping activity should involve local government, coastal communities, experts and other interest groups.

This measure is related to land use planning, in this case how to organize the land in coastal zone for development by considering the risk that threatens the coastal community and infrastructure in this area. Through better land use planning, the sustainability of development in this area can be achieved and more life can be saved. As stated by Bonino in Ingleton (1999) in Chapter 2, "better land-use planning and a more efficient aid policy focused on sustainable development are the keys to preventing disasters and mitigating the impact of hazards, mainly by taking into account of the risks, in particular major risks".

In Aceh, the development considers more on the economic and sectoral interests rather than environment and community. It makes the development tend to damage the environment so that the impact caused by certain development is on the community in this area. For example when building the port in Ulee Lheu, the mangrove was cut. It makes the natural barrier that protected the coastal area was destroyed, and when tsunami happened, the wave of tsunami damage all the things in this area directly.

- *Providing Evacuation Map*. Map of evacuation plans should be provided to inform the coastal communities where to go in case of tsunami disaster in order to make them easier to reach the escape places. In providing this kind of map, it should involve not only the local government and expert but also the community in coastal area until lowest level. It means that the evacuation map should be made by direct involvement of coastal community because they really know the coastal surrounding area and if there is tsunami the coastal community is the first who experience with the impact of tsunami.

Although there is evacuation map, it needs good access from the tsunami prone area to evacuation place. Without good access, it is useless to evacuate the people from the coast because if tsunami happens, the people have limited time between the earthquake and tsunami as mentioned in table 2 in Chapter 3.

- *Formulation of a detailed plan for emergency evacuation of vulnerable coastal communities*. Besides the evacuation map, a detailed and clear plan for emergency evacuation action should be provided. It is to make the community in safe area to be able give quick response to the victims of tsunami, and to make them know what to do in emergency situation. The plan of alternative routes to the affected areas should be informed to make the people who will do evacuation action to be able to reach the affected areas easily. When tsunami hit Aceh on December 2004, one of reason why the evacuation action could not be done quickly because it was difficult to reach the affected areas.

5.2.3 Community measures

Community measures that can be implemented in Aceh are more on how to inform community about tsunami regarding to minimize the loss of life in the future. The community measures are as follows:

- *The development of a network of local knowledge centers along the coastlines to provide necessary training and emergency communication during crisis time*. In the case of Aceh, the development of a network of local knowledge can be done by involving 'panglima laot" in providing training and emergency communication during crisis time. This measure is chosen in order to prepare the coastal community to response with the tsunami disaster and to provide the community with enough information about tsunami.

- *Tsunami Museum.* Tsunami museum is needed to make the people to be aware with the term of tsunami. What happened in Aceh on December 26, 2005 has increased the awareness of Acehnese and people who were there on that day. They are really sensitive with tsunami word. Now, the people, especially who experienced with tsunami disaster, have deep sense with tsunami word. Yet, it does not guarantee that they will always remember what happened. Thus, the information about tsunami must be provided to make people always aware with this kind of disaster.

As the time goes on, and generations change, the people awareness will decrease. Therefore, providing tsunami museum is a very good idea. In Ulee Lheue there is already a tsunami museum to remember the destructive tsunami for present generation, next generation, and also other people from outside Aceh to make them always aware to this kind of disaster.

- *Keep traditional knowledge about tsunami through generations and always inform it to new comers in affected-area*. As stated in chapter 3 that Acehnese people, especially people who live in islands like in Simeulu, Aceh Island and Weh Island (Sabang), have known the tsunami for along time as the terms "*seumong*", "*ie beuna*" and "*teuseunom-ie*". These terms should be informed to people who live in inland area, people who live in other coastal area, and new comers in affected area so that they will always aware with tsunami.

The traditional information about tsunami can also be presented through the signs, posters, brochures, etc by using three languages: which are Indonesian, English, and Acehnese language. This is to make Acehnese easier to keep the tsunami information in their mind.

- *Empowerment of Aceh traditional local leaders of fishing communities ("Panglima Laot" Aceh)*. In Aceh, a "Panglima Laot" in all levels (Province, Municipality and Subdistrict), plays important role in managing the resources in coastal zone related to fishery activities and fishermen. One of the social roles of "Panglima Laot" and his fishermen community in sub district level is to take care and or monitor the sustainability of the trees near the coast because the fish will go far away from the coast (need adjustment with the condition and situation in surrounding area).

- *Informing the people in safe area from tsunami about how to deal with emergency response in reacting at emergency time and after disaster*. This regards to the preparedness of the people in safe area on how to react if there is tsunami and what they should do after the disaster to help affected people who come to their area.

It is not difficult to expect people in safe area in helping the victims of tsunami because as stated in Chapter 3 by Usman (2003) that Acehnese like to help each other ("gotong royong") and are very tolerant with other people.

After the discussion of all the chosen measures, this research proposes TEWS as the first important measure in the case of Aceh because as stated in Chapter 1 that this study wants to know the mitigation measures to minimize the impact on loss of life and property. TWES is the first measure to warn the people in coastal zone to go to higher ground and function as one of measures that should be provided to safe more life.

The second important measure to reduce loss of property in tsunami prone area is mangroves and coastal forests because these measures proved that it saved human settlement in some coastal area in Aceh.

The implementation of the above measures will succeed if there are monitoring and evaluation from all the interest parties especially local community and local government. It is because there is still manipulation done by developer in the development of technical measures in Aceh after tsunami.

CHAPTER 6 Conclusions and Recommendations

6.1 Conclusions

Earthquake and tsunami disaster in Aceh make all the people in the world realize that limited knowledge of community to face this kind of disasters and no preparedness of the government with early warning system, well infrastructures and information about tsunami caused big impact related to loss of life and property not only in coastal zone but also in inland area..

From what happened in Aceh, a lesson can be learned by other regions in Indonesia, especially for Aceh itself and other countries that tsunami disasters is really destructive and need risk management measures to mitigate the impact. Then, because of uncertainty of the risk in coastal zone, we have to prepare for the possibilities of tsunami disaster to be always realizing the importance of the natural ecosystem such as greenbelt to decrease the impact of tsunami disaster in the coastal zone. Besides that, we also should always inform the people about tsunami and escape or evacuation action in emergency time and prepare other tsunami risk management measures.

Risk management measures for tsunami are the measures that should be implemented in certain areas in order to mitigate the impact of tsunami disasters in the future. This kind of management measures is as consideration for government and other related interest groups to be taken in the coming years. The tsunami risk management measures for tsunami are:

a. For Technical Measures:
   - Construction of location specific sea walls and restore coral reefs in consultation with experts

- Using angled walls to deflect the tsunami away - suitable for important installations
- The development of break waters along the coast to provide necessary cushion against tsunami
- Plantation of mangroves and coastal forests along the coastline
- The development of tsunami warning system and tsunami warning center among tsunami affected countries integratedly.
- The development of a “Bio-Shield”
- Identification of vulnerable structures
- Constructing monuments along the coast
- Raising existing sea wall and dike between the road and the beach
- Constructing a protective embankment placed along the shoreline.
- Building vital installations on higher ground.
- Constructing high rise buildings with open ground structural storey, designed for wave forces and earthquake

b. For Spatial Measures:
- Strict implementation of the coastal regulations by classify damage risk zone on sea coast
- Mapping the coastal area for tsunami and earthquake disaster, vulnerability and risk analysis up to village level.
- Avoid new developments in tsunami run-up areas
- Formulation of a detailed plan for emergency evacuation of vulnerable coastal communities

c. For Community Measures:
- The development of a network of local knowledge centers (rural/urban) along the coastlines
- Aggressive capacity building
- Launching a series of public awareness campaign throughout the coastal area

- Training of local administration in forecasting warning dissemination and evacuation techniques
- Awareness generation and training among the fishermen, coast guards, officials from fisheries department and port authorities and local district officials etc.
- The development of education programme through school and university curricula
- Keep traditional knowledge about tsunami through generations and always inform it to new comers in affected-area
- Provide tsunami museum
- Informing the people in safe area
- Involving local community in managing the ecosystem and development in coastal zone

Risk management measures applicable for Aceh that are proposed in this study are based on the risk management measures which are implemented and will be implemented in other countries in consideration that those countries have the same or almost the same characteristic: the coastal zone is flat, open, the contours of the coast are steep, and the substrate is sand. The consideration is taken based on the figures of the coastal zone in those countries. Risk management measures applicable for Aceh are:

- For Technical measures
    - Tsunami Early Warning System and Tsunami Warning Center
    - Planting Mangrove and Coastal Forest
    - Constructing tsunami protection seawall
    - The development of break waters along the coast to provide necessary cushion against tsunami
    - Providing evacuation place
    - Constructing tsunami building

- Constructing monuments along the coast

- For Spatial measures
- Strict implementation of coastal regulations by classify damage risk zone on sea coast
- Mapping the coastal area for tsunami and earthquake disaster, vulnerability and risk analysis up to village level.
- Providing Evacuation Map
- Formulation of a detailed plan for emergency evacuation of vulnerable coastal communities
- For Community measures
- The development of a network of local knowledge centers along the coastlines to provide necessary training and emergency communication during crisis time.
- Tsunami Museum
- Keep traditional knowledge about tsunami through generations and always inform it to new comers in affected-area
- Empowerment of Aceh Traditional Fishermen Community ("*Panglima Laot*" Aceh)
- Informing the people in safe area from tsunami how to deal with emergency response in reacting at emergency time and after disaster

The above measures are associated with how to manage land use planning in the affected area. Management of land use planning in coastal zone related to risk management to mitigate the impact of tsunami disasters in the future can be done by active participation of all interrelated stakeholders and sectors. Active participation of all related parties in managing land use planning is the most important thing that should be done to make the tsunami risk management action to be able to implement well. All these management should also be prepared integratedly among government in all levels, communities, non-government organization, developers, experts, all related sectors, etc.

6.2 Recommendations

This research proposes some recommendations that are necessary to consider in order to implement the tsunami risk management measures well. The recommendations might be useful to be adopted in the case of Aceh. Those will be illustrated in the following paragraphs.

Before constructing certain physical or technical risk management measures, it will be better if the government prepares the Environmental Impact Assessment (EIA) to reduce the impact of those developments to surrounding environment. It is to avoid new problems caused by those constructions, for example the people in one of areas in Aceh asked the government to build seawall. When the seawall was built, the people in that area face new problem caused by those development such as flooding when raining. The water coming from the rain can not flow through the seawall because there is no slot or space for the water to flow through it. It makes the area behind the seawall to be flooded. This problem occurs because there is no EIA study before the development is constructed.

A data base system about tsunami should be provided to keep the data about the history of tsunami in Aceh tsunami prone area, data of the result of tsunami simulation, data prediction about the area that will be hit by tsunami, the time of tsunami and the height of tsunami wave that will be coming, etc. All these data are as the basis for preparing the affected area to face the next tsunami disasters.

The information from tsunami warning center is not only connected to the local radio and local television channel but also connected to the hand phone networks and other related institutions. It is to make the information to be able to be received quickly by the people in emergency situation.

To increase the knowledge of communities in tsunami prone areas about the danger of various natural disasters and how to evacuate/escape from the disasters, we need to arrange yearly tsunami simulation and training held by local team SAR (Save and Rescue) for student in school up to university and communities. The training can also involve the staffs from related government institutions and the community to prepare them on how to evacuate the victims of tsunami when the tsunami occurs.

The monitoring and evaluation of all the implementation of the tsunami risk management measures and other new development in tsunami affected area should be held by all stakeholders and related sectors in order to make sure that the implementation is appropriately run with the plan.

The budget for implementing all those measures should be prepared by the government. It is because all those measures need a lot of funds, and it is impossible to expect the fund from donor countries. The fund can be prepared in stages and also the implementation of those measures. The fund can be supplied by including the budget for tsunami mitigation in the yearly budget of local government. This budget is only used for the tsunami risk management measures and emergency time of tsunami.

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APPENDIX

Appendix 1. The List of Tsunamis in Sumatra-Java Region

No.	Year	Location	Long.	Lat.	Mag.	Ca	Pro	I	Max Run Up	Reference
1	416.9.10	Java-S	120	-10		6	2			NOAA/NESDIS
2	1681.12.11	Sumatra				1	4			Newcomb& McCann
3	1768.06.22	Bali Sea	115	-7	Ms 7.5	1	4			NOAA/NESDIS
4	1770	Southwest Sumatra	102	-5	Ms 7	1	3	0.5	(1)	NGDC/NOAA
5	1797.02.10	Southwest Sumatra	99	-1	Ms 8	1	4	3.0	(1)	Berninghausen
6	1799	Southeast Sumatra	104.75	-2.983		1	2			Berninghausen
7	1815.04.10	Java-Flores Sea	118	-8.2		6	4			NOAA/NESDIS
8	1815.11.22	Bali Sea	115.2	-8	Ms 7	3	3			NOAA/NESDIS
9	1816.04.29	Penang Island	100.25	5.383		1	2		(1)	NGDC/NOAA
10	1818.03.18	Bengkulu, Sumatra	102.267	-3.77	Ms 7	3	3	1.5	(1)	
11	1818.11.08	Bali Sea	117	-7	Ms 8.5	1	2			NOAA/NESDIS
12	1820.12.29	Flores Sea	119	-7	Ms 7.5	1	4			NOAA/NESDIS
13	1823.09.09	Java	108.5	-6.5	Ms 6.8	1	2			NOAA/NESDIS
14	1833.01.29	Bengkulu, Sumatera								Berninghausen
15	1833.11.24	Southwest Sumatra	102.2	-3.5	Mw.8.7	1	4		(3)	NGDC/NOAA, Newcomb & McCann (1987)
16	Sep. 1837	Banda Aceh	96	5.5	Ms. 7.2	4	2	0.5	(1)	NGDC/NOAA
17	1843.01.05	Southwest Sumatra	98	1.5	Ms 7.2	1	4		(3)	Berninghausen (1966), Heck 1947
18	1843.01.06	Southwest Sumatra	97.33	1.05						Berninghausen (1966), Heck 1947
19	1852.11.11	Sibolga, Sumatera	98.8	1.7	Ms 6.8	1	1		(1)	NGDC/NOAA
20	1856.07.25	Java-Flores Sea	116	-8.5		1	2			NOAA/NESDIS
21	1857.05.13	Bali Sea	115.5	-8	Ms 7	1	4		(2)	NOAA/NESDIS
22	1859.10.20	South Java Sea	111	-9		1	2		(1)	Berninghausen (1966)
23	1861.02.16	Southwest Sumatra	97.5	-1	Ms 8.5	1	4	3.0	(9)	Berninghausen (1966)
24	1861.03.09	Southwest Sumatra	99.37	0.3	Ms 7	1	4	2.0	(4)	NGDC/NOAA
25	1861.04.26	Southwest Sumatra	97.5	1	Ms 7	1	4	1.5	(1)	NGDC/NOAA
26	1861.06.05	Java	107.3	-6.3			2			NOAA/NESDIS
27	1861.06.17	Southwest Sumatra	97.5	1	Ms 6.8	1	3			NOAA/NESDIS
28	1861.09.25	Southwest Sumatra	100	-1.5	Ms 6.5	1	3	1.5	(1)	Berninghausen (1966)
29	1864	Sumatra								Berninghausen
30	1883.08.26	Krakatau	105.423	-6.10		6	3	1.0	(8)	Berninghausen
31	1883.08.27	Krakatau (Volcano)	105.25	-6.06		6	4	4.5	35 (67)	Berninghausen
32	Feb. 1884	Krakatau	105.423	-6.10		1	2			Murty et al. (1999)
33	1885.07.29	Ajerbangis	99.383	0.2	Ms 6.8	1	2			NGDC/NOAA
34	1889.08.16	Java, Indonesia	106	-6	Ms 6	1	3	1.0		NGDC/NOAA
35	1892.05.17	Malay Peninsula	99.5	2.5	Ms 7.5	1	3		4 (4)	NGDC/NOAA

No.	Year	Location	Long.	Lat.	Mag.	Ca	Pro	I	Max Run Up	Reference
36	1896.10.10	Southwest Sumatra	102.5	-3.5	Ms 6.8	1	2		1 (1)	NGDC/NOAA
37	1904.07.04	Sumatra								
38	1907.01.04	Southwest Sumatra	94.5	2	Ms 7.6	1	4	2.0	2.8 (7)	NGDC/NOAA/ Newcomb & McCann
39	1908.02.06	Southwest Sumatra	100	-5	Ms 7.5	1	4	1.0	1.4 (1)	NGDC/NOAA
40	1909.06.03	Sumatra	101	-2	Ms 7.7	1	2	1.0	1.4	NGDC/NOAA
41	1914.06.25	West Coast of South Sumatra	102.5	-4.5	Ms 8.1	1	0			NGDC/NOAA
42	1917.01.21	Bali Sea	115.4	-8	Ms 6.5	1	3		2	NGDC/NOAA
43	1921.09.11	South Java Sea	111	-11	Ms 7.5	1	4		0.2	NGDC/NOAA/ Newcomb& McCann
44	1922.07.08	Lhoknga, Aceh	95.233	5.467		1	1			NGDC/NOAA
45	1926.06.28	Southwest Sumatra	99.5	-1.5	Ms 6.7	1	0			NGDC/NOAA
46	1928.03.26	Krakatau	105.423	-6.102		6	1			NGDC/NOAA
47	1930.03.17	Java-S.	105.4	-6.1		6	1			NGDC/NOAA
48	1930.06.19	Java-S.	105.3	-5.6	Ms 6	1	3		0.7	NGDC/NOAA
49	1930.07.19	South Java Sea	114.3	-9.3	Ms 6.5	1	2		0.1	NGDC/NOAA
50	1931.09.25	Southwest Sumatra	102.7	-5	Ms 7.5	1	3		31.4	NGDC/NOAA
51	1935.12.28	Southwest Sumatra	98.25	.001	Ms 8.1	1	1			NGDC/NOAA
52	1936.08.23	Malay Peninsula	95	6	Ms 7.3	1	2			NGDC/NOAA
53	1948.06.02	Malay Peninsula	94	5.5	Ms 6.5	1	2		0.7	NGDC/NOAA
54	1949.05.09	Malay Peninsula	95	5	Ms 6.7	1	2			NGDC/NOAA
55	1955.05.17	Malay Peninsula	94	6.5	Ms 7.2	1	2			NGDC/NOAA
56	1957.09.26	South Java Sea	107.3	-8.2	Ms 5.5	1	3		0.7	NGDC/NOAA
57	1958.04.22	Southwest Sumatra	104	-4.5	Ms 6.5	1	2		1	NGDC/NOAA
58	1963.12.16	Java	105.4	-6.2	6.5	1	2		0.7	NGDC/NOAA
59	1964.04.02	Off Northwest Coast of Indonesia	95.7	5.9	Ms 7.0	8	3		0.7	NOAA/NESDIS
60	1964.04.02	Malay Peninsula	95.7	5.9	Ms 7.0	1	3		2	NOAA/NESDIS
61	1967.04.12	Malay Peninsula	97.3	5.5	Ms 7.5	1	3	1.5		NGDC/NOAA
62	1977.08.19	Sunda Islands	118.4	-11	Ms 8	1	4			NOAA/NESDIS
63	1982.02.24	Java Trench	97.7	4.37	Ms 5.4	2	4			NGDC/NOAA
64	1984	Off West Coast of Sumatra	97.955	0.18	Ms 7.2					Engdahl et al. (1988)
65	1985.04.13	Bali Island	114.2	-9,2	Ms 6.2	1	2			NGDC/NOAA
66	1994.02.15	Southern Sumatra	104.3	-5	Ms 7.0	1				
67	1994.06.02	Java	112.8	-10.5	Ms 7.2				(1)	USGS/NEIC (PDE)
68	2000.06.04	Off West Coast of Sumatra	102.09	-4.72	Ms 7.8				(1)	USGS/NEIC (PDE)
69	2000.06.18	South Indian Ocean	97.45	-13.8	Ms 7.8	1	4		0.3	NOAA/NESDIS
70	2004.12.26	Off West Coast of Sumatra	95.947	3.307	Mw 9.3	1	4	3.0	24 (302)	NGDC/NOAA
71	2005.03.28	Off West Coast of Sumatra	97.013	2.074	Mw 8.7	1	4		4 (2)	NOAA/NESDIS
72	2005.04.10	Kepulauan mentavia	99.607	-1.64	Ms 6.7	1	4		1 (1)	NOAA/NESDIS

Source: Rastogi and Jaiswal (2006)

Note:
Long.: Longitude
Lat: Latitude
Mag: Magnitude
Ca: Cause
Pro: Probability
I: tsunami intensity
Max. (Maximum) run up is in meters, reported number of runups is given within brackets.

The data are taken from National Geophysical Data Center (NGDC), National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS)/National Earthquake Information Center (NEIC) and National Environmental Satellite, Data, and Information Service (NESDIS). A "-1" is used as a flag (missing) value in some fields. The cause and probability of the tsunamis are given by following codes.

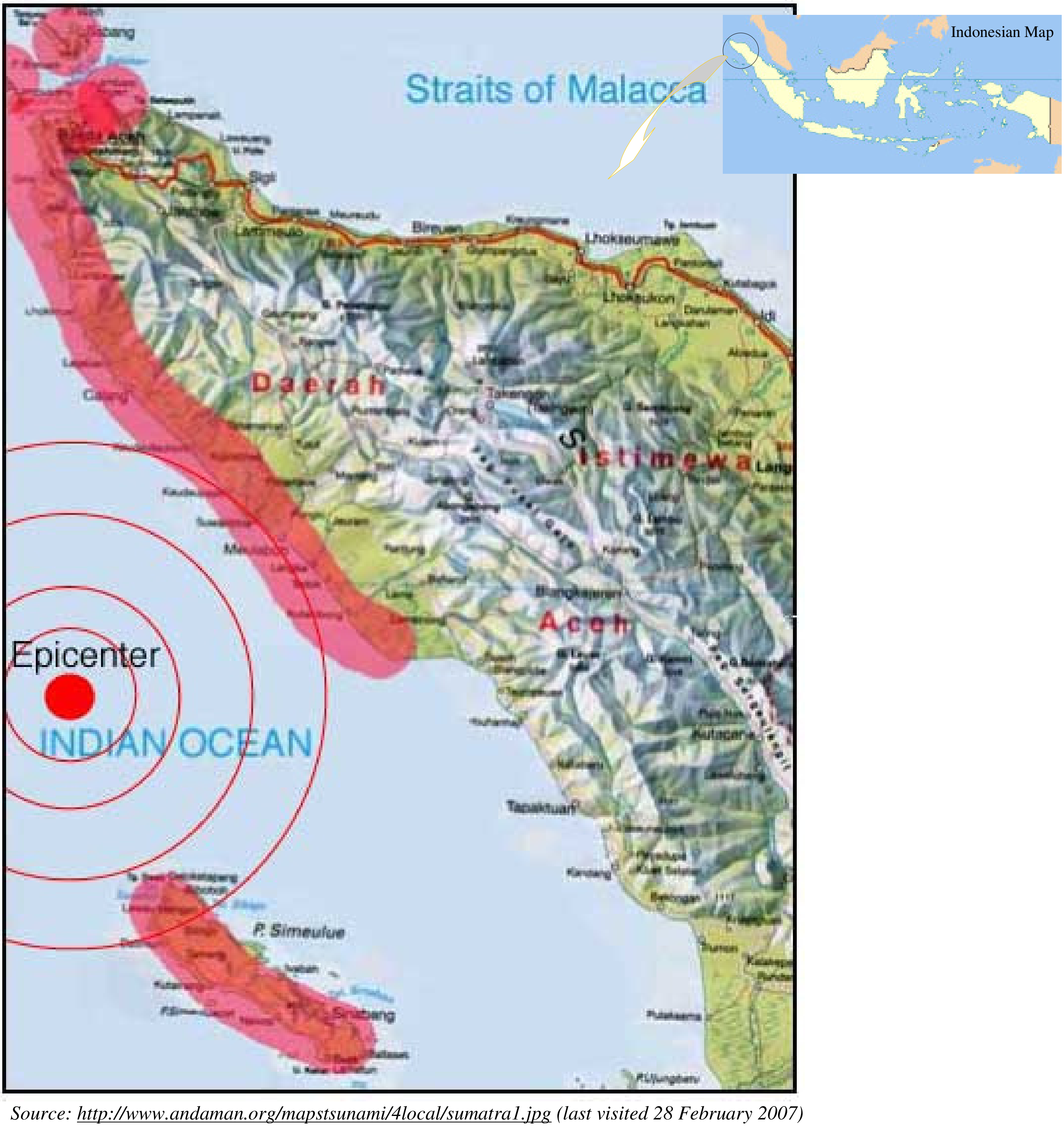
Cause Code:
Cause code indicates the cause or source of the tsunamis.
Valid values: **1 to 12**
1 = earthquake
2 = questionable earthquake
3 = earthquake and landslide
4 = earthquake and volcano
5 = earthquake, volcano and landslide
6 = volcano
7 = volcano and earthquake
8 = volcano and landslide
9 = volcano, earthquake, and landslide
10 = landslide
11 = meteorological
12 = explosion

Event Probability:
Probability of actual tsunami occurrence is indicated by a numerical rating of the validity of the reports of that event:
Valid values: 0 to 4
4 = definite tsunami
3 = probable tsunami
2 = questionable tsunami
1 = very doubtful tsunami
0 = erroneous entry

Appendix 2. Map of NAD Province

Source: <u>http://www.communitywebs.org/~NTAI/images/acehmap.jpg</u> (last visited June 25, 2007)

Appendix 3. The areas of NAD Province that hit by tsunami disaster



Source: <u>http://www.andaman.org/mapstsunami/4local/sumatra1.jpg</u> (last visited 28 February 2007)

Appendix 4. Example of Coastal Area in NAD Province Affected by Tsunami

BEFORE AFTER

- Eastern coast of Aceh:

- Western coast of Aceh:

Source: *http://www.crisp.nus.edu.sg/tsunami/Aceh_20041229_20030110/Aceh_20041229_20030110.html*
(last visited July 22, 2007)