CHAPTER 6

DISASTER MANAGEMENT PLAN BY TSUNAMI EARLY WARNING SYSTEM ALONG GUJARAT COAST

6.1 Introduction

The great Sumatra earthquake (Mw 9.3) of 26th December, 2004, was rated as the world’s second largest recorded earthquake. This earthquake generated a devastating tsunami, which caused unprecedented loss of life and damage to property in the Indian Ocean rim countries. The tsunami was considered as one of the deadliest natural hazards in the history, killing over 225,000 people in fourteen countries (Titov et al., 2005; Geist et al., 2006; Okal and Synolakis, 2008, Mishra et al., 2007a, b; 2011; Singh et al., 2012). In India it claimed 10,745 lives according to official estimates. In response to this disaster, the government of India took up the task of establishing an Early Warning System for Tsunamis. Finally, the tsunami warning system has been established by Ministry of Earth Sciences (MoES) as nodal ministry at Indian National Centre for Ocean Information Services (INCOIS), Hyderabad. The major objective of INCOIS is to detect, locate, and determine the magnitude of potentially tsunamigenic earthquakes occurring in the Indian Ocean Basin. A database of all possible earthquake scenarios for the Indian Ocean is used to identify the regions under risk at the time of event. However, many efforts have been done to develop large scale tsunami scenarios and models for the Bay of Bengal. In this thesis early warning of tsunami waves in the Arabian Sea are of great concern.

6.2 Disaster Management Plan by Tsunami Early Warning System along Gujarat Coast

Indian National Centre for Ocean Information Services (INCOIS), Hyderabad is providing tsunami early warning information to the coastal communities and some other agencies
with the help of numerical modeling and tide gauges along the Indian Ocean. However, INCOIS’s early warning system is mainly focused on Andmanda-Sumatra tsunamigenic earthquake source. But the present Thiess work is focused on if any tsunamigenic earthquake processes in Arabian Sea. In this study various scenarios are generated for the tsunamigenic earthquakes in the Arabian Sea that affect along the Gujarat coast. The work is fully focused on the Tsunami early warning system for the Gujarat coast.

6.2.1 Early Warn Coastal Community by Worst Scenario Detection

The use of numerical modeling to determine the potential run-ups and inundation from a local or distant tsunami is recognized as useful and important tool, since data from past tsunamis are usually insufficient to plan future disaster mitigation and management plans. It is well know that tsunami early warning system involves critical analysis of historical tsunamigenic events, tsunami generation, propagation, inundation and amplification. The criteria for generation early warning system are based on the tsunamigenic potential of an earthquake, travel time (i.e. time taken by the tsunami wave to reach the particular coast), run-up and likely inundation. NAMIDANCE numerical model (Yalciner et al. 2006) has been used to estimate travel time and run-up height for a particular earthquake. Since the model cannot be run at the time of an event, due to large computing time as well as due to non-availability of required fault parameters in real-time, a database of pre-run scenarios is essential. In this study tsunami early warning system is try to develop by modeling of various tsunami scenarios and the worst case detect for location along coastal area of Gujarat, India (Figures 6.1). At the time of event, the closest scenario is picked from the database for emergency management of disaster and early warns to coastal community.
Figure 6.1: Worst scenario detection for seven different source alternatives
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CHAPTER 7
CONCLUSION AND FUTURE PERSPECTIVES

Early warning technologies have greatly benefited from recent advances in geo-information technologies and an improved knowledge on natural hazards and the underlying science. Natural disaster management is a complex and critical activity that can more effectively with the support of geo-information technologies and spatial decision support systems. The 1945 Makran tsunamigenic earthquake is modeled using rupture parameters suggested by Byrne et al. (1992). In most cases, the coastal regions which are far from the source have smaller tsunami height and longer tsunami travel times compared with the coastal regions near the source that have higher tsunami heights and shorter tsunami travel times. As a part of a tsunami emergency response system the 3D coastal maps should be produced for countries in the vicinity of the MSZ, namely, Pakistan, India, Iran and Oman. The lessons learnt from the Dec 2004 tsunami could be used for future planning. Ports, jetties, estuarine areas, river deltas and population in and around the coast of Pakistan, India, Iran and Oman could be protected with proper methods of mitigation and disaster management. In the future scientists/researchers need to focus on 3D visualization and animation of tsunami risk. The study was performed to show the advantages of 3D GIS/CAD models and satellite images in tsunami risk assessment of the Okha coast, Gujarat. The main aim of the 3D Okha model is to visualize each building’s tsunami risk level which improves decision maker’s understanding of the disaster level. Merging of SRTM elevation data with satellite images is suitable for tsunami risk zone classification. Combining the advanced computer aided modeling, GIS based modeling, marine parameter measurements by ocean bottom seismometers and satellite, installations of tide gauges and tsunami
detection systems and also using conventional and traditional knowledge, it is possible
to develop a suitable tsunami disaster management plan.

In conclusion, coastal zone management by tsunami-warning system not only
includes a preparation of tsunami dataset, but also should be included with aware
coastal community at the time of tsunami event. Properly issued tsunami warning if
coupled with proper disaster management system can save lives. This thesis attempted
to develop tsunami early warning system by modeling of various tsunami scenarios and
the worst case detect for location along coastal area of Gujarat, India. At the time of
event, the closest scenario is picked from the database for emergency management of
disaster and early warns to coastal community. The Gujarat coast of India is vulnerable
to tsunami attack. The Okha coast could be severely hit and economic losses would be
too high. The lessons learnt from the Dec 2004 tsunami could be used for future
planning. Ports, jetties, estuarine areas, river deltas and population in and around the
Okha could be protected with proper methods of mitigation and disaster management.
In future more need to focus on 3D visualization and animation of tsunami risk along
the coast of Gujarat. The study performed to produces advantages of 3D GIS models
and satellite images in tsunami risk assessment of the Okha coast, Gujarat. The main
aim of 3D Okha model is to visualize each building’s tsunami risk level which
improves decision maker’s understanding of disaster level. The merging of SRTM
elevation data with satellite images is suitable for tsunami risk zone classification.
Clubbing the advanced computer aided modeling, GIS based modeling, marine
parameter measurements by ocean bottom seismometers and satellite, installations of
tide gauges and tsunami detection systems and also using conventional and traditional
knowledge, it is possible to develop a suitable tsunami disaster management plan.
The tsunami sources used in this study reports only seismic sources. The rupture parameters are estimated according to available scientific publications. The rupture parameters may vary and new estimations can be available at later stages. Then if the rupture parameters are modified, new simulations may be necessary for re-evaluation of the simulation results. Furthermore, new selected forecast points can be added in the need of tsunami effect investigation for desired location. Nested simulations should widely apply for selected locations in future considerations.

We believe that parallel to the technology developments, disaster management requires a serious progress in structuring, analysis and visualization of geo-information and more specifically of 3D geo-information.

A catalog prepared for tsunamis in the Indian Ocean includes about 100 tsunamis. Eighty percent of the tsunamis in the Indian Ocean are from Sunda arc region where on an average tsunamis are generated once in three years. In rest of the Indian Ocean tsunamis can be generated once in ten years or so. This comprehensive catalog and broad list of tsunamis that affected the Indian region and vicinity will be useful for tsunami researchers and tsunami early warning centers of Indian Ocean.

Eastern and western parts of the MSZ of southern Pakistan Iran are potential zones for great earthquakes that can generate tsunamis affecting west coast of India. Some sectors of the Makran zone are un-ruptured for a long time and can produce large earthquakes in near future. Indus Delta and may be the coasts of Kachchh and Saurashtra are also potential zones for great earthquakes and tsunami. Earthquakes in the southernmost Myanmar and Bangladesh have generated tsunamis in the past. Earthquakes in future also in these regions can possibly generate tsunamis.

The NAMI-DANCE model results of tsunami event of November 1945 are qualitatively consistent with the reported damage. Our model gives maximum
amplitude along the creeks at the coast of Gujarat. So the most vulnerable areas of the coast need to be provided greater protection when planning for preparedness. Tide gauges should be installed where the tsunami amplitude is greater. For a tsunami generated from MSZ, which propagates across the Arabian Sea or Indian Ocean, there is 1 h arrival time for more accurate and reliable warning for Gujarat Coast and western coast of India. Any large earthquake in the world can be located in 7–15 min using seismic body waves recorded on the global seismic network. For accurate estimation of earthquake size, a few tens of minutes may be needed until surface waves are recorded around the globe. Because there is only 2 hours 10 min time before tsunami arrival at the Gujarat coast, it is very important to actually confirm the tsunami generation. For this purpose, sea level monitoring systems, located on western coasts and offshore of India, are necessary. The seismic and sea level data need to be shared in real-time, using satellite communication. An effective tsunami early warning system is achieved when all the persons in vulnerable western coastal communities are prepared and respond appropriately, and in a timely manner, upon recognizing that a potentially destructive tsunami is approaching. Timely tsunami warnings issued by a recognized tsunami warning center are essential. When these warning messages are received by the designated government agency, tsunami emergency response plans must already be In place in coastal communities so that standard and efficient actions are immediately taken for evacuation, if necessary.

Simulation result of the western part of the MSZ indicates that the tsunami wave reflected from Arabian Peninsula and Owen fracture zone (shallow bathymetry) sends energy towards southeast direction along the western coast of India that could cause devastation of loss of life in future. The tsunami wave height around the coast of Pasni (Pakistan) was 0.8 m, Kachchh was 0.4 m and Dawarka was 0.3 m respectively.
It reaches Surat after 2 hrs from the tsunami onset. Its amplitude becomes zero in 2 hrs. Tsunami will take more than two hours to reach the Surat. It is commonly observed that when the wave arrives on land it will be around 8 to 10 times greater than that of the tide gauges. So, in this case tsunami may strike the coast of Pasni with wave height around 6-8 m, Kachchh with 3-4 m, and Dwarka with 2-3 m respectively.

Inundation scenario in case 5 or 10 m high tsunami hits the Gujarat. Note that gulf of Kachchh and gulf of Cambay region are having low lying areas, where as Saurashtra is having high topography areas so less chances of inundation other than few places in Saurashtra. The NW part of the Kachchh coastline would be the first region to get affected by the tsunami due to the near shore topography is very low (1 – 5 m from MSL) and is covered with vast intertidal areas. The near shore bathymetry is steep up to (~5 m) so the waves could be amplified here. Thus, these regions are more prone to flooding due to tsunami. It is worth mentioning here that normal spring tides occasionally flood the region thus, there are all possibilities in the region of flooding. Jakhau port is located along the northern part of the gulf of Kachchh lying within the reach of the 5 m inundation case. The possible area inundated due to 5 m run up height in this part is approximately 623 sq. km. Apart from this, the coastline is ecologically also important as it is covered with the wetland vegetation which protects the coastal erosion, this can also be affected by the high run up conditions. Mandvi coast which is in the middle part of gulf of Kachchh is covered with the coastal dunes and linear beaches. The average height of the dunes is 5 – 10 m which may protect the backshore areas from inundation.

However, these dunes are composed of detritus, coarse grained sand which can be easily eroded with the wave splashes by the tsunamigenic conditions. The Saurashtra coastline which is protected with high cliffs (20 m) made up of Miliolitic limestones is
not showing any inundation except at few places i.e. near Porbandar in SW Saurashtra. Usually the tsunami run-up is twice the vertical movement of the ocean floor. The upward slip of the ocean floor along the rupture zone of recent

As a part of a tsunami emergency response system, the 3D coastal maps should be produced for countries in the vicinity of the MSZ, namely Pakistan, India, Iran and Oman. The lessons learnt from the December 2004 tsunami could be used for future planning. Ports, jetties, estuarine areas, river deltas and population in and around the coast of Pakistan, India, Iran and Oman could be protected with proper methods of mitigation and disaster management. In the future, scientists/researchers need to focus on 3D visualization and animation of tsunami risk. The study was performed to show the advantages of 3D GIS/CAD models and satellite images in tsunami risk assessment of the Okha coast, Gujarat. The main aim of the 3D Okha model is to visualize each building’s tsunami risk level which improves decision-maker’s understanding of the disaster level. Merging of SRTM elevation data with satellite images is suitable for tsunami risk zone classification. Combining the advanced computer-aided modeling, GIS-based modeling, and marine parameter measurements by ocean bottom seismometers and satellite, installations of tide gauges and tsunami detection systems and also using conventional and traditional knowledge, it is possible to develop a suitable tsunami disaster management plan.

The present research may be continued in future studies as summarized below:

1. To understand the physics of tsunamigenic earthquake rupture mechanics, we have to relate seismologically observable parameters to the dynamics of faulting. One of the key Tsunamigenic earthquake parameters that will help to achieve this objective is radiated energy. We have to estimate the radiated energy from regional data using an empirical Green's functions and by other appropriate methods for tsunamigenic
earthquakes in Indian Ocean. Rupture modeling will give clearer picture for the Tsunami hazard analysis.

2. Fractal grids will give more accurate results than finite difference and finite element models for tsunami modeling and simulation. Available tsunami model considers uniform slip distribution of the fault as input for tsunami simulation. But it needs to be generating model in future that can consider input of the slip distribution of the fault will be non-uniform. As during earthquake occurrences the distribution of slip (co-seismic slip) of fault is non-uniform. Co-seismic slip distribution of rupture zone estimated by seismic waveform inversion. Real time 3D rupture modeling is to be needed to accurately model the tsunami.

3. Near real-time coastal GPS data need for quick tsunami warning as real-time coastal GPS data could estimate earthquake magnitude faster than seismic data.

4. Coulomb stress analysis, GPS study and knowledge of velocity structure is to be needed for better understanding of seismotectonics and seismic gap along the Makran subduction zone.

5. Paleotsunami studies for Indian region will help us for better understanding of past tsunami that struck the Indian coast and assessment of such future events.

Approaches of the present thesis may be extended to the other source regions capable of generating tsunamigenic earthquake. The work presented in the thesis may provide some guidance and useful data to geoscientists, civil engineers and researches who are engaged in the field of Tsunami case study.