

# **TSUNAMI HAZARDS – ASSESSMENT OF EXPOSURE OF SRI LANKA**

By

P. K. C. De Silva

A thesis submitted to University of Moratuwa  
for the Degree in Master of Science



University of Moratuwa, Sri Lanka.  
Electronic Theses and Dissertations  
www.lib.mru.ac.lk



Research Supervised

by

Mr. A. H. R. Ratnasooriya

Prof. S. P. Samarawickrama

**DEPARTMENT OF CIVIL ENGINEERING  
UNIVERSITY OF MORATUWA  
SRI LANKA**

**September 2010**

**ABSTRACT**

The coastal belts of several Indian Ocean countries including Indonesia, Sri Lanka, India and Thailand suffered massive loss of life and damage to property due to the tsunami unleashed by the great earthquake in the Sunda trench on 26 December 2004 which is now called as Indian Ocean Tsunami. In the context of Sri Lanka the extent of inundation and the associated damage varied significantly with the local near shore wave height, topography and the resistance offered to the overland flow and due to the lack of preparedness and unawareness about tsunamis, death toll and the damage was quite high around two third of the coastal zone of the country.

As indicated by the Indian Ocean Tsunami and subsequent tsunami alerts in 2005 and 2007, it will be important to assess the risk of tsunamis for Sri Lanka from possible undersea earthquake zones around the country to mitigate the adverse effects of a future tsunami. That kind of study should assess the exposure of the country in terms of tsunami arrival time, nearshore wave height and extent of inundation for possible tsunami scenarios which could affect the country. Also according to the geographical location of the country, Sri Lanka is threatened by far field tsunamis with tsunami travel time of hours. So the ideal tsunami impact mitigation measure is an early warning and evacuation system. Therefore this study was focussed on assessing the exposure of Sri Lanka to potential tsunami events from Sunda trench and arranging the information from such assessment to be effectively utilized by an early warning system and evacuation system.

## ACKNOWLEDGMENT

First and foremost I wish to acknowledge the forbearance and support of my supervisors Mr. A.H.R. Ratnasooriya and Prof S.P. Samarawickrama, who suggested this research problem and offered the most valuable guidance and encouragement throughout this study. I also have the pleasure in thanking Prof. S.S.L. Hettiarachchi and Prof. J.M.S.J. Bandara, who served on my review panel, for having reviewed my research work and advising me in improving it.

I also want to thank the Head of the Department of Civil Engineering for permitting me to make use of the resources of the department which indeed facilitated me to carry out my work unhindered.

I am grateful to Prof. Pattiarachchi for the fruitful guidance on ComMIT model and Mr. Thisara Welhena and Mr. Kithsiri Nandasena for providing guidance and support for the research work.

I am thankful to the staff members of the Hydraulic and Water Engineering Laboratory and also I would like to record my appreciation to Ms. A.V.A.U. Karunathilaka, Mr. R.B.C.D. Manawasekara, Mr. I.S.K. Wijewardena and Mr. R.M.J. Bamunawala for supporting and motivating me in carrying out the research work. I thank all my colleagues for the numerous support they have given me for the fulfillment of this challenging task.

I extend my gratitude to the University of Moratuwa Senate Research Fund for financial assistance provided for my research work.

I wish to thank my parents and sisters for the encouragement given and standing by me throughout. My warm gratitude is for my wife who always stood by me during difficult moments and for nourishing my mind with hope.

*P. K. C. De Silva*

## DECLARATION

This thesis is a report of research carried out in the Department of Civil Engineering, University of Moratuwa, between July 2008 and August 2010. Except where references are made to other work, the contents of this thesis are original and have been carried out by the undersigned. The work has not been submitted in part or whole to any other university. This thesis contains 100 pages.

.....

P. K. C. De Silva,  
Department of Civil Engineering,  
University of Moratuwa.

Sri Lanka.



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

.....

Supervisor  
Mr. A. H. R. Ratnasooriya,  
Department of Civil Engineering,  
University of Moratuwa.  
Sri Lanka.

.....

Supervisor  
Prof. S.P. Samarawickrama,  
Department of Civil Engineering,  
University of Moratuwa.  
Sri Lanka.

## CONTENTS

Abstract .....	i
Acknowledgement .....	ii
Declaration .....	iii
Contents .....	iv
List of Figures .....	vi
List of Tables .....	viii
List of Abbreviations .....	xi

### Chapter 1 : Introduction

1.1 General .....	1
1.2 Exposure of Sri Lanka to Tsunami Hazards .....	6
1.3 Tsunami Impact Mitigation Measures .....	9
1.3.1 Countermeasures to Mitigate the Impact of Tsunami .....	10
1.3.2 Countermeasures for Successful Evacuation from Tsunami .....	12
1.4 Tsunami Early Warning System .....	14
1.5 Objectives of the Study .....	17
1.6 Guide to the Thesis .....	18

### Chapter 2 : Tsunamis: Physical Processes

2.1 General .....	19
2.2 Tsunami Generation .....	20
2.2.1 Tsunami Generation by Undersea Earthquakes .....	20
2.2.2 Tsunami Generation by Volcanic Eruptions .....	25
2.2.3 Tsunami Generation by Land Slides .....	26
2.2.4 Tsunami Generation by Asteroid Impacts .....	28
2.2.5 Tsunami Generation by Large Explosions .....	29

2.3 Deep Water Propagation .....	30
2.4 Shallow Water Transformation .....	31
2.5 Inundation .....	33
<b>Chapter 3 : Tsunamis: Physical Processes</b>	
3.1 General .....	34
3.2 Tsunami Generation by Earthquakes .....	35
3.3 Deep Water Propagation and Shallow Water Transformation of Tsunamis ...	41
3.4 Inundation of Tsunamis .....	43
<b>Chapter 4 : ComMIT</b>	
4.1 General .....	44
4.2 Input Data for ComMIT	
4.2.1 Tsunami Generation .....	45
4.2.2 Bathymetry & Topography Data .....	47
4.2.3 Other Model Run Parameters .....	48
4.3 Tsunami Propagation Modelling of ComMIT .....	49
4.4 Output Data from ComMIT .....	51
<b>Chapter 5 : Numerical Modelling Using ComMIT</b>	
5.1 General .....	52
5.2 Methodology .....	53
<b>Chapter 6 : Results &amp; Discussion</b>	57
6.1 Determination of Risk .....	60
<b>Chapter 7 : Conclusion</b>	62
<b>References</b>	64
<b>Annex 1 : Tsunami Model Run Details</b>	66
<b>Annex 2 : Tsunami Model Run Results</b>	72
<b>Annex 3 : Risk Analysis</b>	90

## LIST OF FIGURES

Figure	Description	Page
Figure 1.1	Spatial distribution of (a) inundation, (b) tsunami height for east coast of Sri Lanka	3
Figure 1.2	Spatial distribution of (a) inundation, (b) tsunami height for south coast of Sri Lanka	4
Figure 1.3	Spatial distribution of (a) inundation, (b) tsunami height for west coast of Sri Lanka	5
Figure 1.4	Locations of possible tsunami sources of Sri Lanka	9
Figure 1.5	Artificial methods for tsunami mitigation	10
Figure 1.6	Natural methods for tsunami mitigation	11
Figure 1.7	Arrival times (local) of IOT 2004 to Sri Lanka	13
Figure 1.8	Components of a DART system	15
Figure 1.9	Operation of a TWS	16
Figure 2.1	Plate arrangement of lithosphere of earth	21
Figure 2.2	Generation of tsunami from an earthquake	23
Figure 2.3	2004 earthquake parameters	24
Figure 2.4	Pacific Ring of Fire	26
Figure 2.5	Possible asteroid locations on oceans	28
Figure 2.6	Reflection and transformation from the continental shelf	32
Figure 2.7	Coastal processes around Sri Lanka	33
Figure 3.1	Tsunami modelling framework	35
Figure 3.2	Typical earthquake parameters	36
Figure 3.3	Typical fault (slip) types	39
Figure 4.1	Initial surface wave	45
Figure 4.2	Unit sources (Sunda Trench)	45
Figure 4.3	Indian Ocean subduction zone unit sources parameters	46
Figure 4.4	Specification of model run parameters	47

Figure 4.5	Wave amplitude at time series locations	51
Figure 4.6	Maximum wave amplitude of grid C	51
Figure 6.1	Point locations	57
Figure 6.2	Spatial distribution of (a) inundation, (b) tsunami height for south coast of Sri Lanka	59
Figure 6.3	Distribution of tsunami heights along the coastline of Sri Lanka	59
Figure 6.4	Selected points for determination of risk	60
Figure 6.5	Possible earthquake locations of Sunda trench	61
Figure A2.1	Wave amplitude at Point locations for Dec. 2004 Tsunami	89
Figure A3.1	Some possible earthquake locations of Sunda trench for $M_w = 8.0$	91
Figure A3.2	Some possible earthquake locations of Sunda trench for $M_w = 8.5$	94
Figure A3.3	Some possible earthquake locations of Sunda trench for $M_w = 9.0$	96
Figure A3.4	Some possible earthquake locations of Sunda trench for $M_w = 9.2$	98
Figure A3.5	Some possible earthquake locations of Sunda trench for $M_w = 9.5$	100



## LIST OF TABLES

<b>Table</b>	<b>Description</b>	<b>Page</b>
Table 1.1	No of reported deaths and displaced people of December 2004 Tsunami	1
Table 1.2	Summary of some tsunamis occurred in the world	8
Table 2.1	Tsunamis and their source of generations	20
Table 2.2	Asteroid impact statistics (based on Paine, 2001)	29
Table 3.1	Relationship between surface rupture length (L), subsurface rupture length ( $L_D$ ), downward rupture width (W), rupture area (A) and Moment magnitude ( $M_w$ )	37
Table 4.1	Suitable resolutions for Grids	47
Table 5.1	No. of unit sources - Sample calculation	54
Table 5.2	Adjusted no. of unit sources - Sample calculation	54
Table 6.1	Details of point locations	58
Table A1.1	Selection of no. of unit sources	66
Table A1.2	Comparison of slip values with the model	67
Table A1.3	Comparison of slip values with the model for adjusted values	68
Table A1.4	Coverage and resolutions of grid sets	69
Table A1.5.1	Model Run Details	70
Table A1.5.2	Model Run Details	71
Table A2.1.1	Maximum wave heights in Grid C ( $M_w = 7.5$ )	72
Table A2.1.2	Maximum wave heights in Grid C ( $M_w = 8.0$ )	73
Table A2.1.3	Maximum wave heights in Grid C ( $M_w = 8.5$ )	74
Table A2.1.4	Maximum wave heights in Grid C ( $M_w = 9.0$ & $9.2$ )	75
Table A2.1.5	Maximum wave heights in Grid C ( $M_w = 9.5$ )	76
Table A2.2	Point locations' details	76

Table A2.3.1.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 7.5$ )	77
Table A2.3.1.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 7.5$ )	78
Table A2.3.2.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 8.0$ )	79
Table A2.3.2.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 8.0$ )	80
Table A2.3.3.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 8.5$ )	81
Table A2.3.3.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 8.5$ )	82
Table A2.3.4.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.0$ )	83
Table A2.3.4.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.0$ )	84
Table A2.3.5.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.2$ )	85
Table A2.3.5.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.2$ )	86
Table A2.3.6.1	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.5$ )	87
Table A2.3.6.2	Maximum wave heights/Arrival times at Point locations ( $M_w = 9.5$ )	88
Table A3.1.1	Risk analysis for selected points along Southern coast line from earthquake locations of $M_w = 8.0$ of Sunda trench	90
Table A3.1.2	Details of some possible earthquake locations of Sunda trench for $M_w = 8.0$	92
Table A3.2.1	Risk analysis for selected points along Southern coast line from earthquake locations of $M_w = 8.5$ of Sunda trench	92
Table A3.2.2	Details of some possible earthquake locations of Sunda trench for $M_w = 8.5$	93
Table A3.3.1	Risk analysis for selected points along Southern coast line from earthquake locations of $M_w = 9.0$ of Sunda trench	95
Table A3.3.2	Details of some possible earthquake locations of Sunda trench for $M_w = 9.0$	95

Table A3.4.1	Risk analysis for selected points along Southern coast line from earthquake locations of $M_w = 9.2$ of Sunda trench	97
Table A3.4.2	Details of some possible earthquake locations of Sunda trench for $M_w = 9.2$	97
Table A3.5.1	Risk analysis for selected points along Southern coast line from earthquake locations of $M_w = 9.5$ of Sunda trench	99
Table A3.5.2	Details of some possible earthquake locations of Sunda trench for $M_w = 9.5$	99



University of Moratuwa, Sri Lanka.  
Electronic Theses & Dissertations  
[www.lib.mrt.ac.lk](http://www.lib.mrt.ac.lk)

## LIST OF ABBREVIATIONS

<b>Abbreviation</b>	<b>Description</b>
ASCII	American Standard Code for Information Interchange
BPR package	Seafloor Bottom Pressure Recording package
CFL condition	Courant–Friedrichs–Lewy condition
ComMIT	Community Model Interface for Tsunami
DART	Deep-ocean Assessment and Reporting of Tsunamis
DEMs	Digital Elevation Models
IOT	Indian Ocean Tsunami
ITWS	International Tsunami Warning System
MOST	Method of Splitting Tsunamis
NCTR	NOAA Centre for Tsunami Research
NetCDF	Network Common Data Form
NGA	National Geospatial-Intelligence Agency
NOAA	National Oceanic and Atmospheric Administration
PTWC	Pacific Tsunami Warning Centre
SIMs	Standby Inundation Models
SRTM	Shuttle Radar Topography Mission
SWE	Shallow Water Equations
TWS	Tsunami Warning System
USA	United States of America