



# Vertical Evacuation from Tsunamis: A Guide for Community Officials

FEMA P646A / June 2009



**FEMA**





# Vertical Evacuation from Tsunamis: A Guide for Community Officials

Prepared by

APPLIED TECHNOLOGY COUNCIL  
201 Redwood Shores Pkwy, Suite 240  
Redwood City, California 94065  
www.ATCouncil.org

Prepared for

FEDERAL EMERGENCY MANAGEMENT AGENCY  
National Earthquake Hazard Reduction Program

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION  
National Tsunami Hazard Mitigation Program

Michael Mahoney, FEMA Project Officer  
Chris Jonientz-Trisler, FEMA Program Specialist  
Michael Hornick, FEMA Program Specialist

## ATC MANAGEMENT AND OVERSIGHT

Christopher Rojahn (Project Executive)  
Jon A. Heintz (Project Quality Control Monitor)  
Ayse Hortacsu (Project Manager)

## PROJECT CONSULTANTS

J. L. Clark (Lead Report Preparation Consultant)  
George Crawford (Report Preparation  
Consultant)

## PROJECT REVIEW PANEL

Lesley Ewing  
James D. Goltz  
William T. Holmes  
Ervin Petty  
George Priest  
Althea Turner  
Timothy J. Walsh



**FEMA**



## **Notice**

---

Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of the Department of Homeland Security's Federal Emergency Management Agency (FEMA), the National Oceanic & Atmospheric Administration (NOAA), or the Applied Technology Council (ATC). Additionally, neither ATC, DHS, FEMA, NOAA, nor any of their employees, makes any warranty, expressed or implied, nor assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, product, or process included in this publication. Users of information from this publication assume all liability arising from such use.

Cover photographs provided courtesy of Magnusson Klemencic Associates, Seattle, Washington.

---

# Foreword

This publication was equally funded by the National Oceanic and Atmospheric Administration (NOAA), which leads the National Tsunami Hazard Mitigation Program (NTHMP) and by the Federal Emergency Management Agency (FEMA), which is responsible for the implementation portion of the National Earthquake Hazard Reduction Program (NEHRP).

This project was originally undertaken to address the need for guidance on how to build a structure that would be capable of resisting the extreme forces of both a tsunami and an earthquake. This question was driven by the fact that there are many communities along our nation's west coast that are vulnerable to a tsunami triggered by an earthquake on the Cascadia subduction zone, which could potentially generate a tsunami of 20 feet in elevation or more within 20 minutes. Given their location, it would be impossible to evacuate these communities in time, which could result in a significant loss of life.

This issue came into sharp relief with the December 26, 2004 Sumatra earthquake and Indian Ocean tsunami. While this event resulted in a tremendous loss of life, this would have been even worse had not many people been able to take shelter in multi-story reinforced concrete buildings. Without realizing it, these survivors were among the first to demonstrate the concept of vertical evacuation from a tsunami.

Many coastal communities subject to tsunami located in other parts of the country also have the same issue. In these cases, the only feasible alternative is vertical evacuation, using specially designed, constructed and designated structures built to resist both tsunami and earthquake loads. The design of such structures was the focus of the earlier work on this project, which resulted in the FEMA publication, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis* (FEMA P646).

This is a companion publication intended to present information on how vertical evacuation design guidance can be used and encouraged at the state and local level. It is meant to help state and local government officials and interested citizens by providing them with the information they would need to address the tsunami hazard in their community, to help determine if vertical evacuation is an option they should consider, and if so, how to fund, design and build such a refuge.

FEMA is grateful to all who worked on this publication. They are listed at the end of the document. We also wish to acknowledge the staff and consultants of the Applied Technology Council. Their hard work has provided the citizens of our nation with guidance on how they would be able to survive a tsunami.

– Federal Emergency Management Agency

---

# Preface

This document was prepared under a “Seismic and Multi-Hazard Technical Guidance Development and Support” contract (HSFEHQ-04-D-0641), which was awarded to the Applied Technology Council (ATC) in 2004 by the Federal Emergency Management Agency (FEMA) to conduct a variety of tasks, including development of the companion FEMA P646 Report, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis* (ATC-64 Project). The effort was co-funded by FEMA and the National Oceanic and Atmospheric Administration (NOAA).

The guidance for community officials contained in this document is based on the information provided in the companion FEMA P646 Report, which covers a broad range of technical topics, including characterization of the tsunami hazard, choosing between various options for vertical evacuation structures, locating and sizing vertical evacuation structures, estimation of tsunami load effects, structural design criteria, and design concepts and other considerations. The FEMA P646 Report also includes examples of vertical evacuation structures from Japan, and illustrates the concepts of designing and configuring a series of evacuation structures for a hypothetical community.

In contrast to the technical engineering information provided in FEMA P646, this document contains information and guidance specifically designed for community officials written in layman’s terms. Included are background information on tsunami types and historic tsunami activity, in-depth discussions of issues to be considered when planning the design and construction of a structure for vertical evacuation from tsunamis, discussions on funding issues, and information on operation and maintenance of vertical evacuation structures.

ATC is indebted to the members of the ATC-64 Project Team who participated in the development of this document. J. L. Clark served as Lead Report Preparation Consultant, and George Crawford served as Assistant Report Preparation Consultant. Review and guidance were provided by the Project Review Panel, consisting of Lesley Ewing, James Goltz, William Holmes, Ervin Petty, George Priest, Althea Turner, and Timothy Walsh. Ayse Hortacsu served as ATC project manager for this work and Peter N. Mork provided ATC report production services. The affiliations of these individuals are provided in the list of Project Participants.

ATC also gratefully acknowledges the input and guidance provided by Michael Mahoney (FEMA Project Officer), Chris Jonientz-Trisler (FEMA Program Specialist), and Michael Hornick (FEMA Program Specialist).

Jon A. Heintz  
ATC Director of Projects

Christopher Rojahn  
ATC Executive Director



---

# Table of Contents

Foreword.....	iii
Preface .....	v
List of Figures.....	ix
List of Tables .....	xi
1. INTRODUCTION.....	1
1.1 Objectives and Scope.....	1
1.2 Limitations.....	1
1.3 Organization .....	2
2. BACKGROUND.....	3
2.1 Categorization of Tsunamis.....	3
2.2 Historic Tsunami Activity .....	5
3. PLANNING.....	9
3.1 Decision-making Process .....	10
3.2 Making Tough Choices .....	11
3.3 Determining the Tsunami Hazard.....	12
3.4 Consideration of Concurrent Hazards .....	14
3.5 Tsunami Preparation.....	14
3.5.1 Pre-tsunami Public Education .....	16
3.5.2 TsunamiReady Program .....	17
3.6 Vertical Evacuation Structures .....	17
3.6.1 Analyzing the Need for a Vertical Evacuation Structure.....	18
3.6.2 Vulnerability Assessment .....	19
3.7 Siting Considerations.....	20
3.7.1 Travel Time to Safety .....	20
3.7.2 Considerations in Site Selection .....	21
3.7.3 Number of Sites.....	22
3.8 Land Use Planning.....	23
3.9 Cost Considerations.....	23
3.10 Liability .....	23
3.11 Long-term Planning.....	24
4. DESIGN AND CONSTRUCTION.....	25
4.1 Design Considerations.....	25
4.1.1 Use of Existing Structures .....	25
4.1.2 Designing New Structures .....	25
4.2 Use of Vertical Evacuation Structures.....	26
4.3 Types of vertical Evacuation Structures .....	27
4.3.1 Existing or Engineered High Ground .....	28
4.3.2 Parking Garages.....	29
4.3.3 Community Facilities .....	29

4.3.4	Commercial Buildings .....	30
4.3.5	School Facilities.....	32
4.3.6	Existing Buildings.....	33
4.4	Quality Assurance .....	33
4.4.1	Peer Review .....	33
4.4.2	Plan Checks.....	33
4.4.3	Construction Quality Assurance and Quality Control .....	34
5.	FUNDING .....	35
5.1	Potential Funding .....	35
5.1.1	Federal Funds.....	36
5.1.2	Public-private Partnership.....	36
5.1.3	Self-funding .....	36
5.1.4	State and Local Revenue.....	37
6.	OPERATION AND MAINTENANCE.....	39
6.1	Facility Operations Plan.....	39
6.2	Tsunami Warnings .....	39
6.3	Opening the Vertical Evacuation Structure.....	40
6.4	Operating the Vertical Evacuation Structure .....	42
6.5	Leaving the Vertical Evacuation Structure .....	44
6.6	Maintenance .....	44
6.7	Long-term Issues.....	45
	REFERENCES.....	47
	PROJECT PARTICIPANTS.....	49