International Tsunami Information Center
A UNESCO IOC – NOAA – SHOA Partnership
April 2026

# Good Practices

# Vertical Evacuation Tsunami Guidance

ITIC Vertical Evacuation Website:
https://www.weather.gov/itic-car/vertical_evacucation_guidance

Dr. Laura Kong
Director, ITIC, USA NOAA

# Compilation of Good Practices - ITIC Website

**Vertical Evacuation Best Practices for the International Community**
International Tsunami Information Center (ITIC), 17 August 2020
For more info, contact ITIC: itic.tsunami@noaa.gov

Vertical evacuation may be a life-saving solution where natural high ground does not exist, or a local tsunami does not allow sufficient advance warning time to enable evacuate to high ground. Strong vertical evacuation buildings should provide a safe refuge for people to escape a tsunami. By simple definition, a vertical evacuation building is a structure with sufficient height and strength to resist tsunami wave effects.

In response to a request from the UNESCO IOC TOWS Inter-ICG Task Team on Disaster Management and Preparedness, ITIC has compiled international best practices in tsunami vertical evacuation. Highlights have been posted to the ITIC Vertical Evacuation web site http://itic.ioc-unesco.org/index.php?option=com_content&view=article&id=2070&Itemid=2927 and a complete listing is provided below. Best practices were categorized by country and the keywords engineering assessment, building code, mitigation, and response. Each reference contains a brief summary for rapid comprehension. A total of 117 references were found, and are listed below. USA, Japan, and Indonesia had the most references.

ITIC welcomes additional contributions to this compilation (please send to itic.tsunami@noaa.gov)

**References, as of 17 August 2020**
**EndNoteX9, Unedited APA 6th Format**
**Keywords: Engineering Assessment, Response, Mitigation, Building Code**

| Ocean | References per Ocean | Country | References per Country |
|---|---|---|---|
| General | 9 | Building Code | 6 |
| | | General Countries | 3 |
| Pacific | 79 | Australia | 1 |
| | | Canada | 3 |
| | | Chile | 6 |
| | | China | 4 |
| | | Ecuador | 1 |
| | | Japan | 12 |
| | | South Korea | 2 |
| | | New Zealand | 8 |
| | | USA | 41 |
| | | Vietnam | 1 |
| Indian | 26 | Indian Ocean Region | 1 |
| | | India | 3 |
| | | Indonesia | 20 |
| | | Maldives, Thailand, Indonesia, Sri Lanka | 1 |
| | | Sri Lanka | 1 |
| North Atlantic and Mediterranean | 3 | Morocco | 1 |
| | | Turkey | 1 |
| | | Europe | 1 |

https://www.weather.gov/itic-car/vertical_evacucation_guidance

**COUNTRIES** (Click a link below to go to a highlights)

GENERAL (9 references): BUILDING CODE (6), COUNTRIES (3)

PACIFIC OCEAN (79 references): AUSTRALIA (1), CANADA (3), CHILE (6), CHINA (4), ECUADOR (1), JAPAN (12), SOUTH KOREA (2), NEW ZEALAND (8), USA (41), VIETNAM (1)

INDIAN OCEAN (26 references): INDIA (3), INDONESIA (20), SRI LANKA (1)

NORTH ATLANTIC AND MEDITERRANEAN (3 references): MOROCCO, TURKEY (1)

| Vertical Evacuation |
|---|
| Engineering Assessment |
| Building Code |
| Response |
| Mitigation |

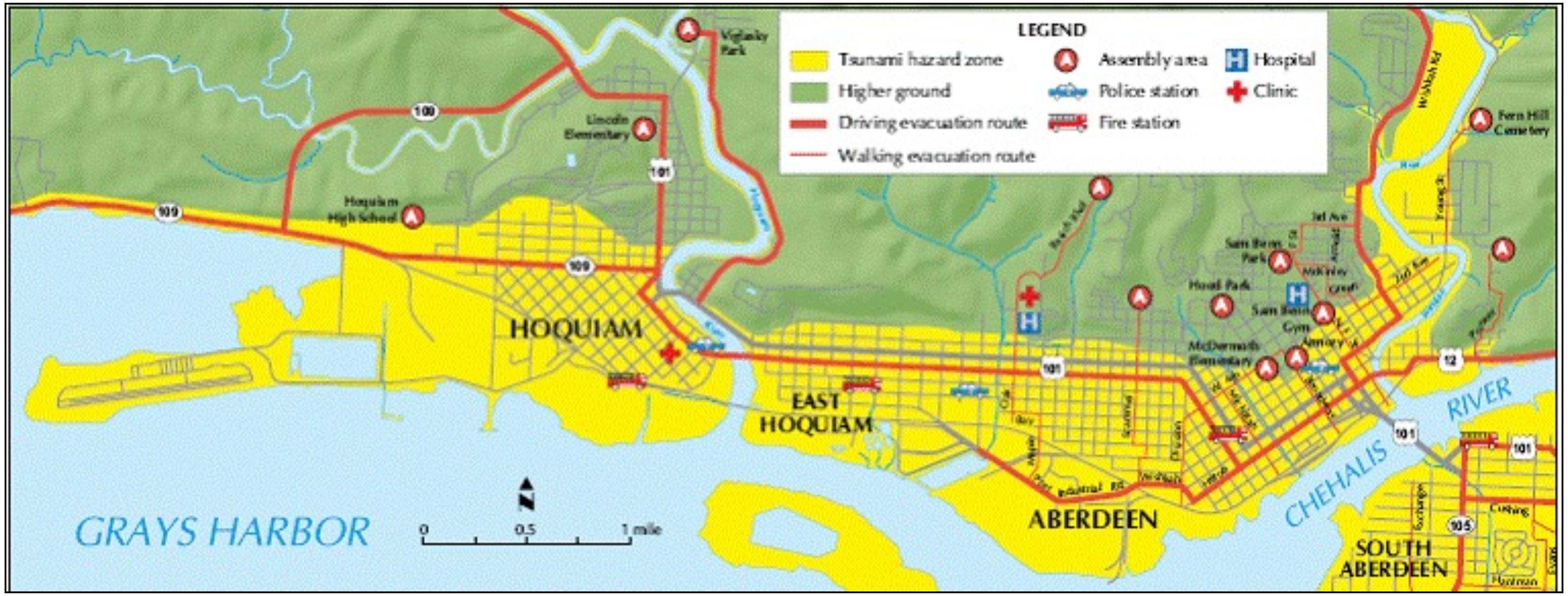
Reference:
- Citation (APA 6th)
- Summary
- Topic Keyword
- Hyperlink

*ITIC welcomes additional contributions to this compilation (please send to itic.tsunami@noaa.gov)*

ITIC

# TER Saving Lives - Tsunami Evacuation

Modeling → Inundation map → Evacuation map



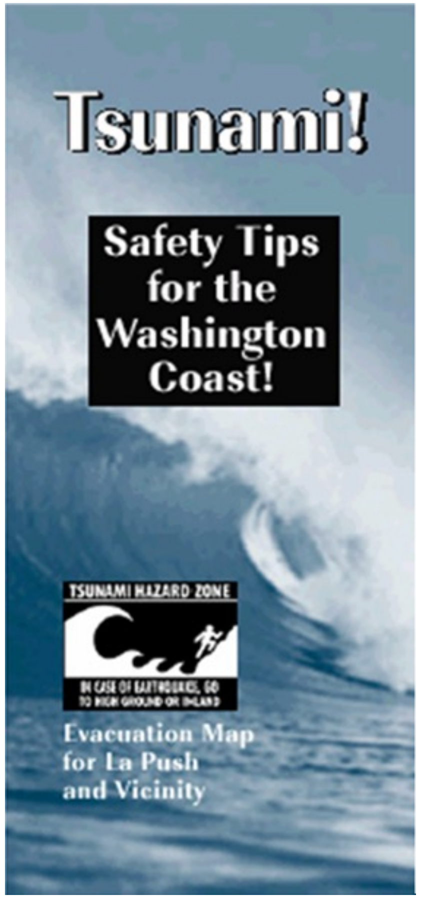

**Tsunami evacuation maps are community-owned**

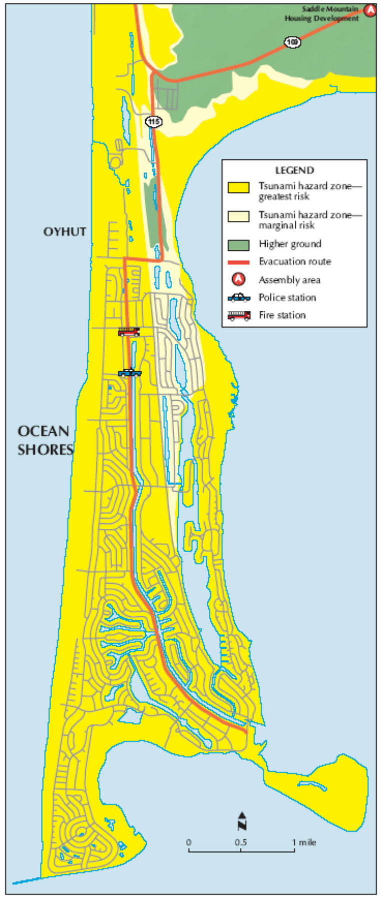
# Evacuation - Challenges

## Distant & Local tsunami responses:

- Day time or night time
- People awake or asleep
- Regular business / school hrs vs. non-duty hrs
- Weekday vs. weekends
- Tourist Peak vs. Off-season
- Traffic jams and rush-hour periods
- Television and radio stations off-air
- Little to no response personnel available to support evacuation (*during local tsunami*)

# Evacuation - Problems?




## Issues:

- No high ground
- No time to go inland
- Special needs populations

## Solution:

- Vertical evacuation
- How high, strong?

# Siting and Spacing

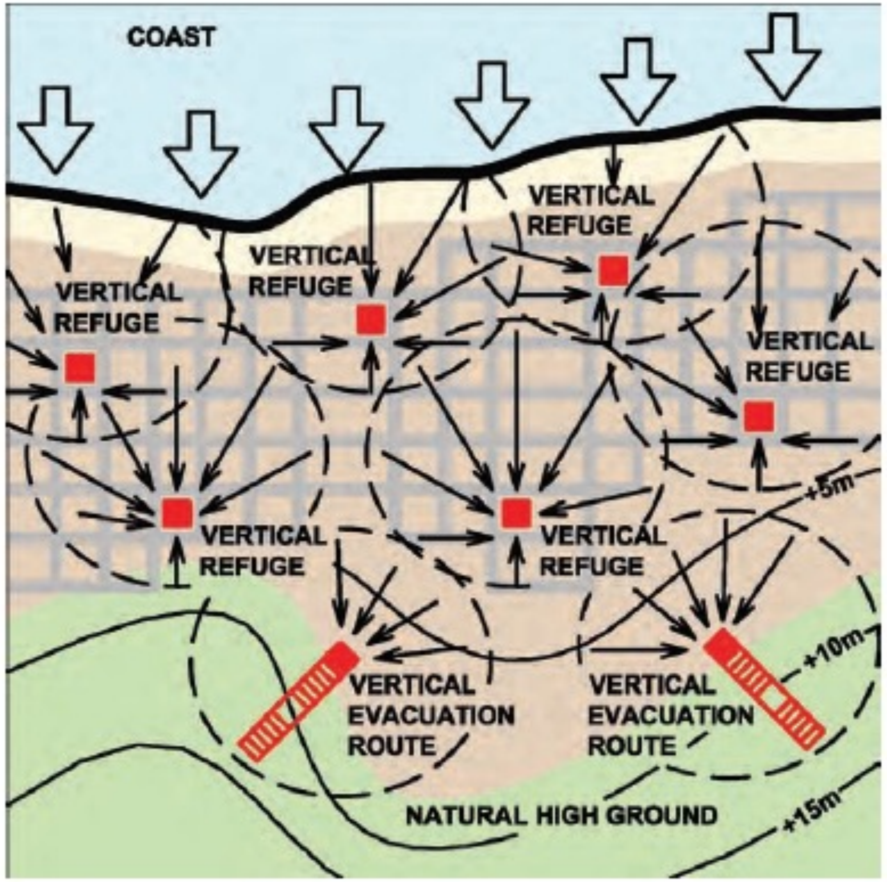



Figure 5-1 Vertical evacuation refuge locations considering travel distance, evacuation behavior, and naturally occurring high ground. Arrows show anticipated vertical evacuation routes.

- Provide access to high ground
- Guidance on number and location of vertical refuges
- Spacing based on 2 mph walking speed and expected tsunami warning time
- Consideration given to proximity of large debris, hazardous or flammable materials
- Other additional precautions

# Assembly Area - Siting, Spacing, and Sizing

| Warning time | Ambulatory Speed* | Travel Distance** | Required Spacing |
|---|---|---|---|
| > 2 hrs | 3.2 km/hr (1 m/s)<br>2 mph | 6.4 km<br>4 miles | 12.8 km<br>8 miles |
| 30 min | 3.2 km/hr (1 m/s)<br>2 mph | 1.6 km<br>1 mile | 3.2 km<br>2 miles |
| 15 min | 3.2 km/hr (1 m/s)<br>2 mph | 0.8 km<br>0.5 mile | 1.6 km<br>1 mile |

* Assumed average speed of mobility-impaired population
** Must allow time for vertical circulation within refuge



*From ATC-64 Design and Construction Guidance for Vertical Evacuation from Tsunami*

# Evacuation Simulation – Owase, Japan



. Map of Owase City (Kii Peninsula, Japan)

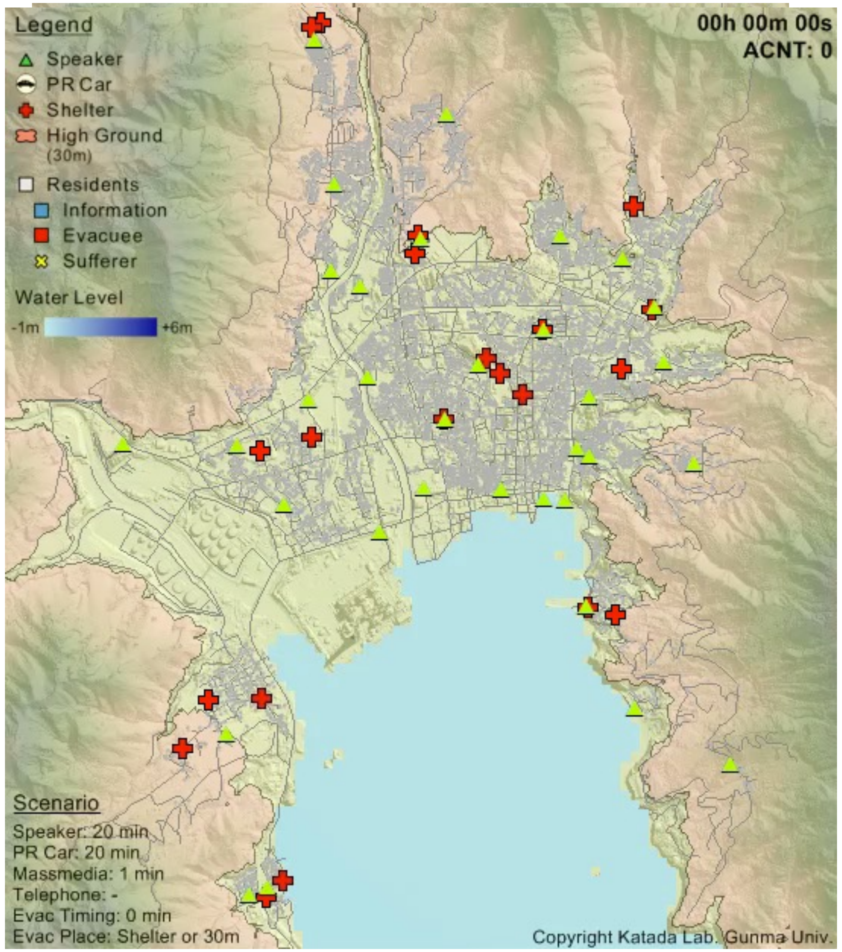




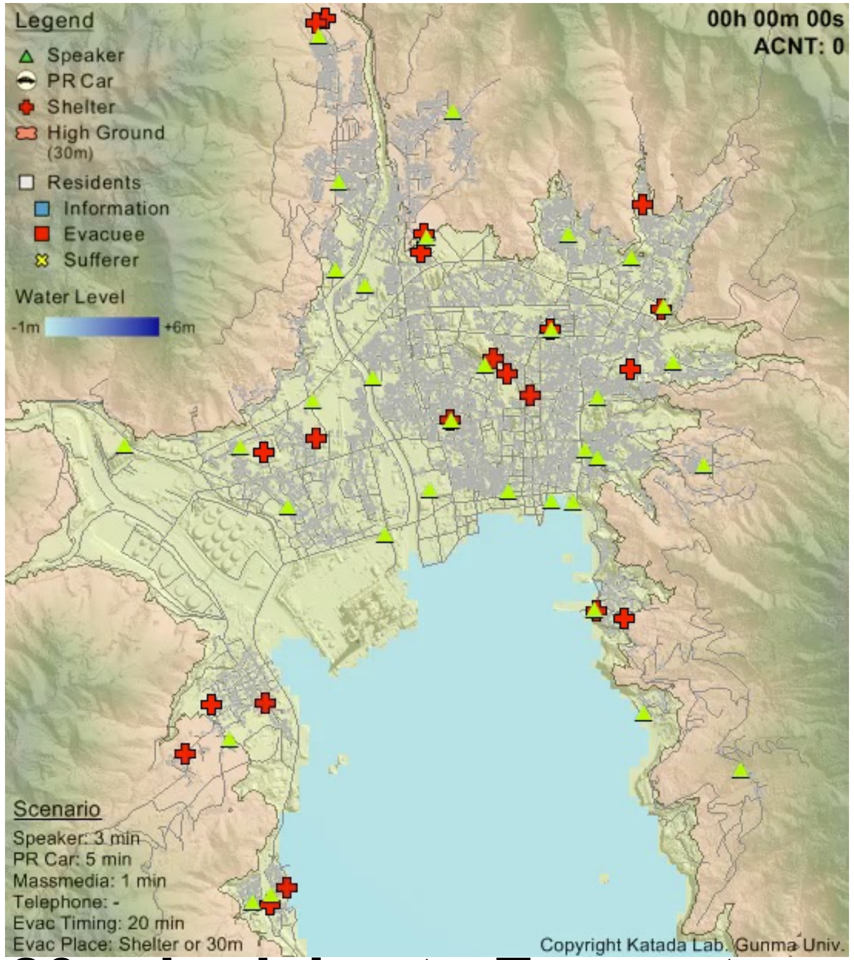
https://www.katada-lab.jp/doc/p067.pdf

# Evacuation Simulation – Owase, Japan

***Delay in Alert or Evacuation => more deaths***




**Immediate Evacuate**




**20-min delay to Evacuate**

# Evacuation Simulation – Owase, Japan

Examples of casualties resulting from simulation runs

| | | Timing (min) of Official Tsunami Warning | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 20 | 30 | 60 |
| Evacuation Start Timing (min) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 7 |
| | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 10 |
| | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 17 |
| | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 4 | 6 | 32 |
| | 4 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 4 | 3 | 7 | 14 | 50 |
| | 5 | 0 | 0 | 0 | 1 | 2 | 4 | 6 | 7 | 8 | 7 | 12 | 20 | 75 |
| | 6 | 0 | 1 | 2 | 5 | 8 | 9 | 9 | 9 | 11 | 10 | 17 | 44 | 120 |
| | 7 | 1 | 2 | 7 | 9 | 9 | 13 | 14 | 13 | 12 | 12 | 36 | 94 | 190 |
| | 8 | 1 | 8 | 10 | 10 | 12 | 15 | 17 | 19 | 16 | 19 | 81 | 148 | 302 |
| | 9 | 9 | 11 | 13 | 12 | 12 | 24 | 26 | 51 | 53 | 56 | 189 | 273 | 440 |
| | 10 | 11 | 14 | 14 | 17 | 41 | 72 | 91 | 124 | 148 | 165 | 373 | 463 | 566 |

# Why Design Vertical Evacuation Refuge?

- **Not enough time to run to high ground**
  - Local tsunami means little to no tsunami warning
  - Bridges inoperable
  - Roadway congestion
- **Not easily accessible for vulnerable population**
  - Hospital patients, elderly, children, disabled
- **Human tendency to seek closest available building**

# Vertical Evacuation Options

- **Preference given to high ground**
- **Manmade high ground in form of mound**
- **Building or other structure designed for tsunami loads**

# Manmade high ground
# Sendai Port, Japan


- Earth mounds can act as effective evacuation sites
- Must be high and large enough

# Vertical Evacuation Building
# Designated Refuge

- Port Authority Bldg.
- Kessenuma, Japan
- Designated as tsunami refuge
- Flooded to third level
- Numerous survivors sought refuge on roof

# Vertical Evacuation Building
# Parking Garage


- Multi-level Parking structure
- Biloxi, Mississippi, USA
- Hurricane Katrina, USA
- Open to pedestrians 24 hours a day
- Ramps for easy access to roof

# Vertical Evacuation – Building Code

- 2018 International Building Code
  - American Society of Civil Engineers 7-16 Standard, Chapter 6 "Tsunami Loads and Effects"
- ASCE 7-16 only applicable to states of Alaska, Washington, Oregon, California, and Hawaii because tsunami hazards are quantifiable

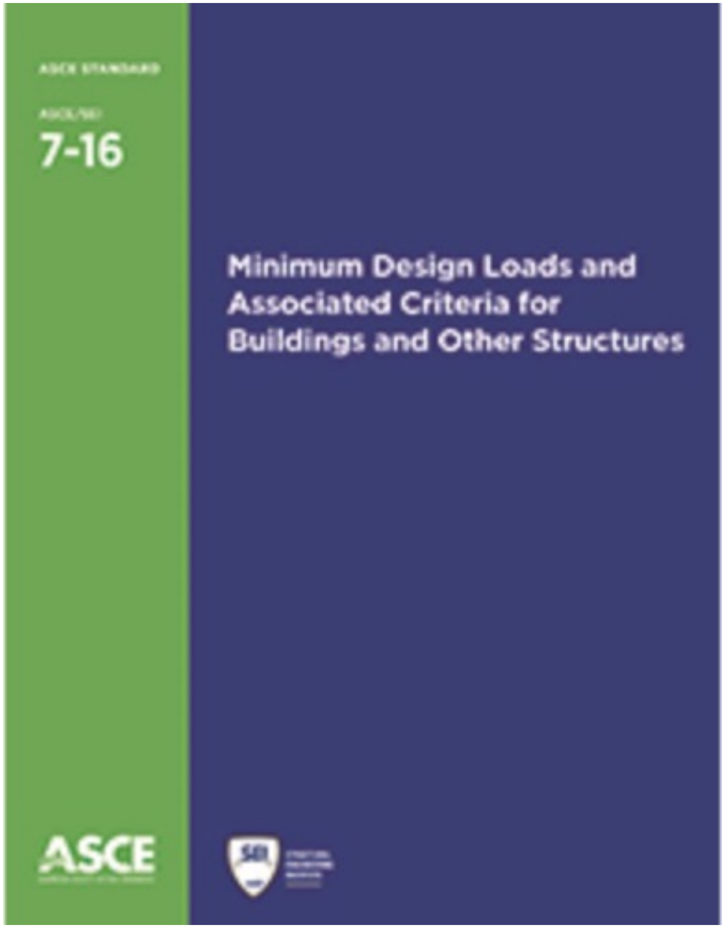
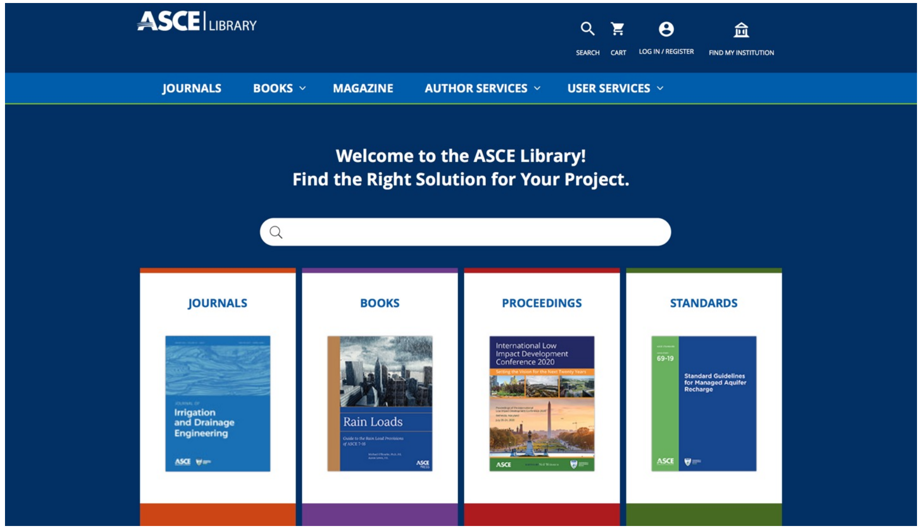



Image credit: https://www.asce.org/asce-7/

# Vertical Evacuation – Search Tool

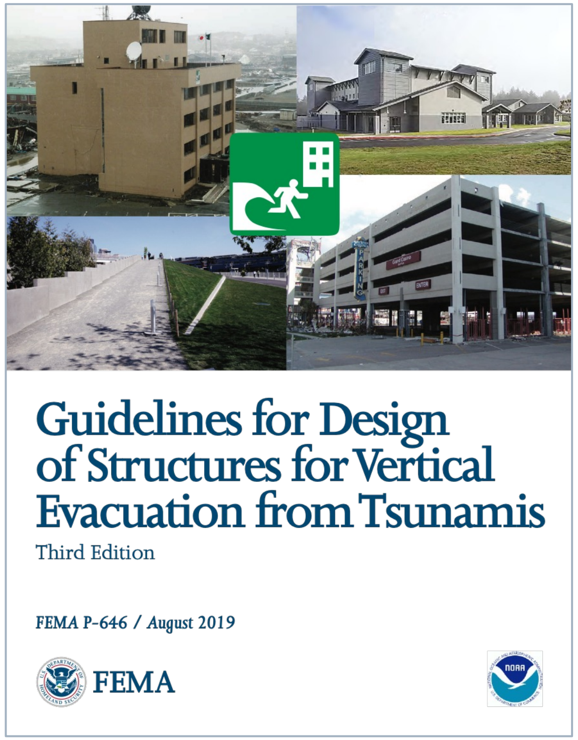
- **American Society of Civil Engineers database to find current research on vertical evacuation for a specific country. https://ascelibrary.org**
  - Technical Reports
  - ASCE 7-16 Standard
  - Proceedings




- **ASCE 7-16 Tsunami Design Zone Maps for Selected Locations:**
  - Alaska, California, Hawaii, Oregon, and Washington
  - https://ascelibrary.org/doi/book/10.1061/9780784480748

# Guidelines for Design of Structures for Vertical Evacuation from Tsunamis (FEMA, 2019, 3rd ed) - Guidance

- **Guidance on planning, location, operation, design, and construction of structures that could be used as a vertical evacuation refuge**
  - Provides information to technical and lay audiences
  - Additional technical design in ASCE/SEI 7-16
- **Intended for…**
  - State and Local Government Officials
  - Community Planners
  - Engineers
  - Architects
  - Building Officials
  - Emergency Managers
  - Tsunami Planning Activists
  - Building Owners



# Tsunami Evacuation: Lessons from the Great East Japan earthquake and tsunami of March 11th 2011 (NZ GNS, 2012)

- **Documents performance of vertical evacuation structures affected by the Great East Japan Earthquake and Tsunami of 2011**
  - Analysis of evacuation preparedness and response from interviews with local disaster prevention officials and emergency service officials with tsunami mitigation recommendations
  - Report shows examples of hazard and evacuation maps and signs in Tōhoku region.
  - Investigated locations within Iwate and Miyagi prefectures

**BIBLIOGRAPHIC REFERENCE**

Fraser, S.; Leonard, G.S.; Matsuo, I. and Murakami, H. 2012. Tsunami evacuation: Lessons from the Great East Japan earthquake and tsunami of March 11th 2011, *GNS Science Report* 2012/17. *89* p.

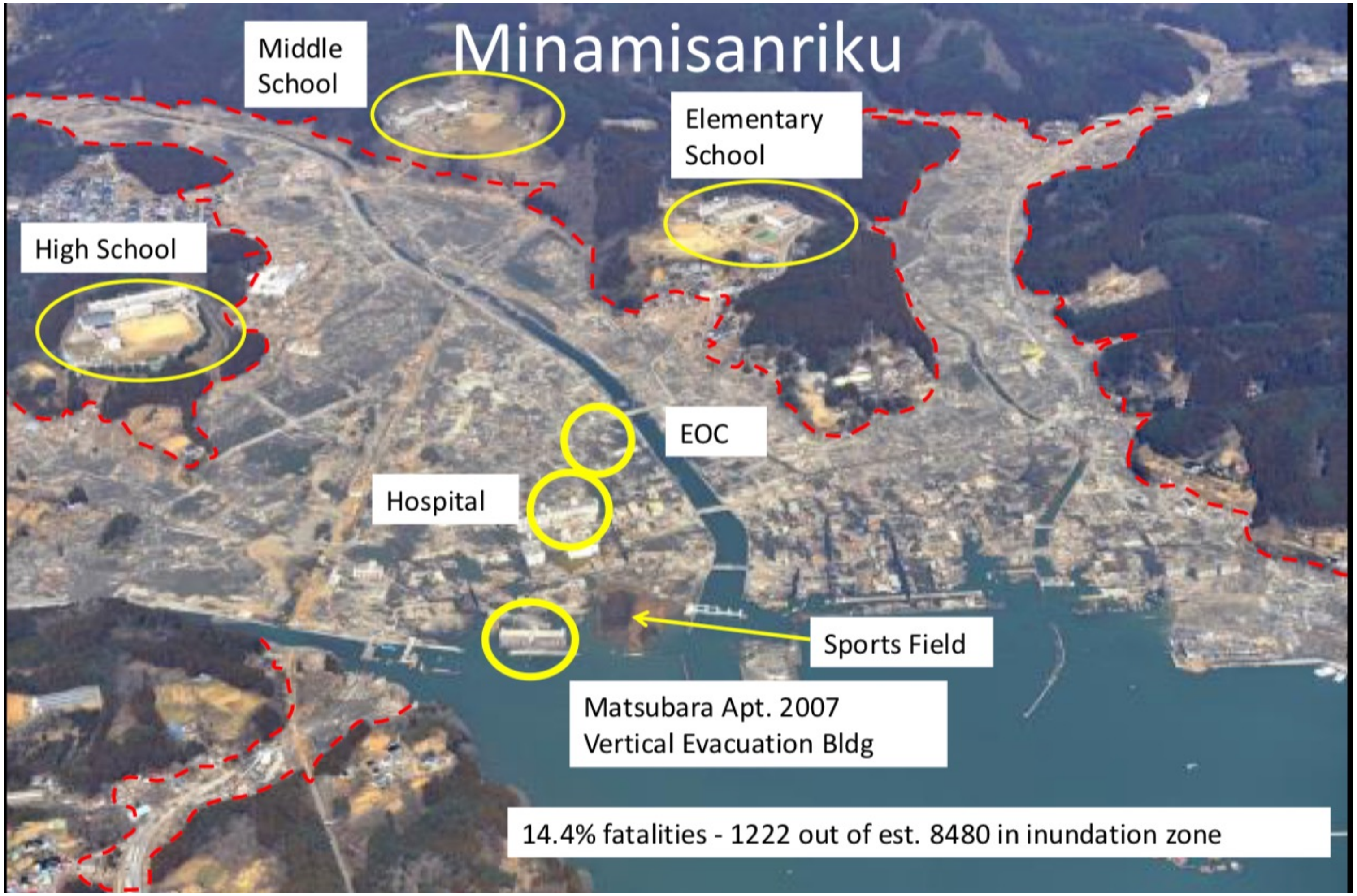

S. Fraser, GNS Science/Massey University Joint Centre for Disaster Research, PO Box 756, Wellington, New Zealand

G.S. Leonard, GNS Science, PO Box 30368, Lower Hutt

I. Matsuo, Crisis and Environment Management Policy Institute (CeMI), 1-22-505 Wakaba, Shinjyuku-ku, Tokyo 160-0011, Japan.

H Murakami, Division of Environmental Science and Engineering, Yamaguchi University, Tokiwadai, Ube 755-8611, Japan.


# Lesson: 2011 Great East Japan Tsunami




Matsubara Apt. 2007

Robertson, I. N. (Producer). (2020). Efficacy of Vertical Evacuation Refuge from Tsunamis (VERT). [PowerPoint PDF]

- Redline: Where tsunami reached
- Yellow Circles: Where people took refuge
- Tsunami arrived 20-30 minutes after earthquake

Ian Robertson, Univ of Hawaii

# Lesson:  2011 Great East Japan Tsunami

- **Historical records alone do not adequately measure a future tsunami's potential height**
  - For 2011 Japan Tsunami, designated vertical evacuation structures not tall enough, e.g., 2 ft of water above roof observed
  - Building structurally survived, but not tall enough


Concrete building survived tsunami, but roof evacuation area inundated by 0.7m water


44 refugees, including several children, survived on roof evacuation area

http://itic.ioc-unesco.org/images/stories/vertical_evac/ITIC-ASCE%207-16_2016.pdf

Ian Robertson, Univ of Hawaii

# Effective Vertical Evacuation
## Matsubara Community Apt. Bldg. - 2007

- Significant scour around corners of building
- Collapse prevented by deep foundations





Ian Robertson, Univ of Hawaii

# Use of Designated Tsunami Evacuation Buildings


Designated evacuation building

Ian Robertson, Univ of Hawaii


Ian Robertson, Univ of Hawaii

EOC  and Hospital in Background at Minamisanriku

- **But only Sato and 8 others survived**
- **Tragically large loss of lives at adjacent hospital**

Ian Robertson, Univ of Hawaii

# Lesson:  2004 Indian Ocean Tsunami

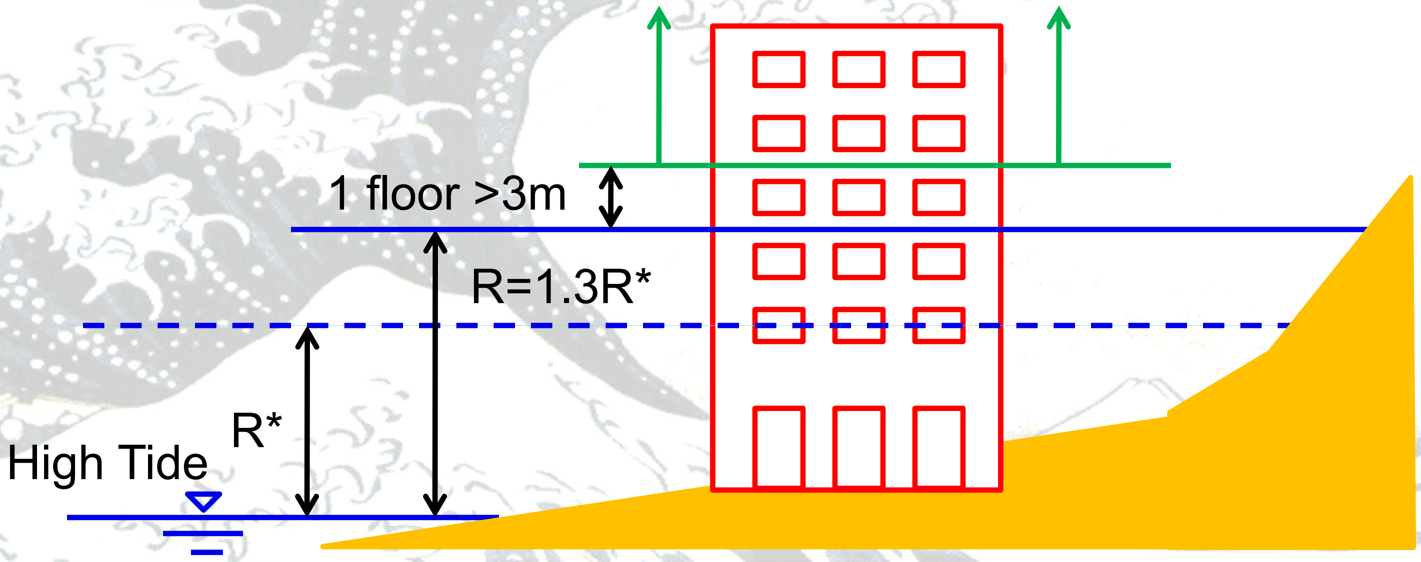
- **Do not ignore seismic sources that have never failed historically**
  - Geological time much longer than historical human time
  - Look at every seismic source and estimate largest possible earthquake, then model subsequent tsunami
  - For example: 2004 Indian Ocean was especially deadly due to a lack of tsunami-warning infrastructure.
    - Subduction zone had not subducted in human time scale, contributing to a lack of tsunami-warning infrastructure in the area.
    - Subduction zone will most likely subduct in the future, even if not recorded in human historical data.

# Recommendations

- **Adopt IBC 2018, referencing ASCE 7-16 Standard Chapter 6 "Tsunami Loads and Effects," for the design of vertical evacuation structures. Ensure compliance with local building codes.**
  - Design for Maximum Considered Tsunami, with a 2% probability of being exceeded in a 50-year period, or a 2500 year average return period. source: link
  - Do not rely only on historical records to estimate tsunami wave height
- **Dedicate funding to generate new maps based on probabilistic tsunami hazard analysis that are required by IBC 2018 / ASCE 7-116**
- **Expand tsunami education in school and include tsunami response and vertical evacuation in lesson plans.**
  - Ensure children understand what vertical evacuation is
    - When to select a natural versus man-made vertical evacuation building refuge,e.g., minimum total building stories, which floor to evacuate to, ideal building material, etc.
    - Example: Waikiki, Oahu permits evacuation to the fourth floor or higher in structural steel or reinforced concrete buildings that are 10 stories or higher

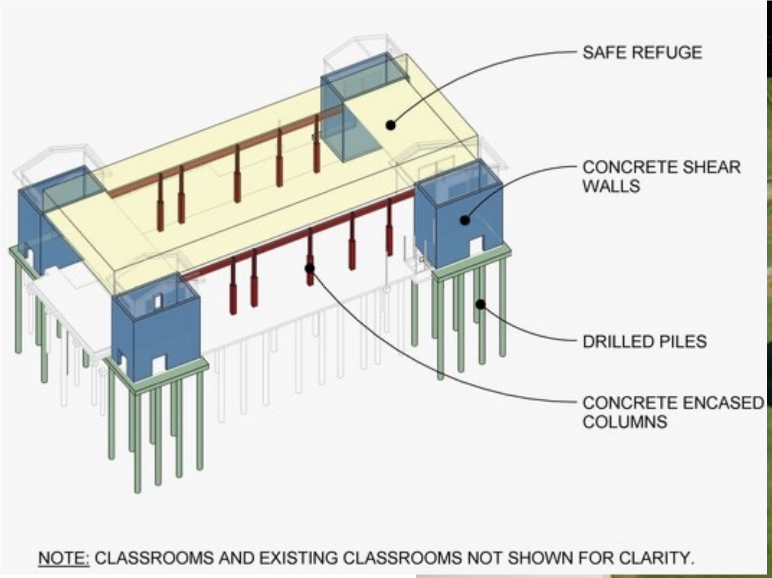
# Minimum Refuge Elevation

- **Recommends refuge elevation be 1 story (3m, 10ft) above predicted inundation (with 1.3 factor)**



# Vertical Evacuation Structures – Ocosta, WA, USA


Ocosta Elementary School – 1st vertical evacuation structure in NA (2019)





*WTAD 2019, UNDRR*

International Tsunami Information Center
A UNESCO IOC – NOAA – SHOA Partnership
April 2026

# Good Practices

# Vertical Evacuation Tsunami Guidance

ITIC Vertical Evacuation Website:
https://www.weather.gov/itic-car/vertical_evacucation_guidance

Dr. Laura Kong
Director, ITIC, USA NOAA