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NEAMTIC July 2012

Tsunami Preparedness
Civil Protection - Good Practices Guide

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"Man masters nature not by force but by understanding."
Jacob Bronowski (1908–1974)

SC-2013/WS/7

Tsunami Preparedness Civil Protection

Good Practices Guide

NEAMTIC - July 2012

Contents

I. Foreword

1.1. Aims of report

"The development of a nation can be measured by its response to natural catastrophes."

The Mediterranean and the North-Eastern Atlantic and connected seas (NEAMTWS) are among the regions of the world with higher tsunami risk. This document is primarily developed for Civil Protection authorities in the NEAMTWS region. In the past several notable tsunamis, with high level of destructiveness, affected the shores of those areas. The apparent low-frequency of these events led to low preparedness among population and authorities. Recent events in the Pacific and Indian Ocean led to an increase awareness of the importance of tsunami hazard in coastal areas. A group of guidelines is summarized and proposed in this report to help civil protection authorities and coastal communities understand their exposure to tsunami hazards and to mitigate the resulting risk through awareness, preparedness information and land use planning. This report is essentially intended for Civil Protection authorities to facilitate/help in emergency and planning interventions in the case of major tsunami events which may require major responsive actions. These guidelines also provide critical elements associated with civil protection and emergency management. Timely and well-directed disaster prevention and management by the Civil Protection community is the key element for a successful operation; this is only possible if the civil protection agents are kept updated in terms awareness and risk perception. The role of Civil Protection is of the upmost importance due to the fact that they are the only official message providers to the general public.

Tsunamis are relatively rare phenomena compared to other natural events affecting coastlines around the world, such as hurricanes, typhoons, storms surges and floods. However, tsunamis often have a devastating impact on coastal populations, not only in terms of human lives but also economically. Thus, tsunami prevention (or the limitation of their impact) demands a dense system of instruments for monitoring tsunami sources and sea level, a fast and secure data-transmission system, and a pre-established, operational plan for alerting the concerned populations.

The effectiveness of any early-warning system ultimately depends upon an educated and trained population that are aware of the risks involved and must also be able to adopt the appropriate responses. In the recent tsunami events of 26th December 2004 (Indian Ocean) and the 11th of March 2011 (Japan) a strong contrasts in the consequences for different local communities was revealed. Although both events were considered almost apocalyptical, the consequences in terms of human lives were distinct mainly due to the preparedness of the local communities and the response of civil protection authorities.

In this work, individual, community awareness and preparedness policies are compiled and discussed. Strategic approaches and guidelines are proposed for a more effective development of tsunami risk awareness campaigns. The guidelines and best practices presented below are intended for the purpose of public education and outreach in order to support civil protection authorities in the goals of reduction of loss of life during a tsunami event. The report also aims to aid civil protection authorities, municipalities and land use planners to obtain qualitative and quantitative descriptions of what could be the impact of various tsunamis scenarios through the use of available data (geological, historical, inundation modelling, forecast and evacuation maps) and comparison with other locations and practices worldwide.

This report is a contribution to NEAMTIC (North-Eastern Atlantic and Mediterranean Tsunami Information Centre) - IOC/ UNESCO.

1.2. Structure of document

This document is organized in eight chapters. Chapter 1 introduces the scope of the report and the structure of the document. The following Chapter 2 discusses the sources and mechanisms associated with tsunamis. Briefly, its physics, behaviour, magnitude and intensity scales are presented. Chapters 3 and 4 were structured with a brief scientific component, a bullet point summary, examples of study cases and suggested references for more in depth analysis. Chapter 3 is sub-divided in four different aspects related with the collection of data to assess tsunami risk. The geological data, the historical data, the inundation modelling and warning systems are tools that are used by scientists and civil protection authorities to establish tsunami risk and hazard for local, regional or global areas. Chapter 4 addresses the pre-tsunami event strategy that is followed in a number of areas that have established strong awareness campaigns and legislation. The regulation regarding urban and coastal planning is mentioned concisely in section 4.1. Section 4.2 presents and discusses information campaigns aimed to increase the public awareness regarding tsunami risk and discusses education and training that has been implemented in regions usually affected by tsunami events. Section 4.3 presents a summary of the tsunami signage that is used worldwide to inform the general public. Finally, section 4.4 presents criteria that should be followed for building evacuation maps and some examples of evacuation maps are shown. Section 4.5 summarizes the recommended actions for Civil Protection authorities in the case of a tsunami. Chapter 5 and 6 have a similar structure. They address the sin and post event strategy from individual, community and local authority levels. Chapter 7 discusses and provides recommendations in terms of the strategic approaches that can be followed in terms of risk reduction, evacuation plans, etc. Finally, Chapter 8 summarizes the main recommendations of this report. Annex 1 presents details of ISO tsunami signage.

II. Tsunami sources

Extreme marine inundations caused by a tsunami have an important significance for coastal environments and their evolution. The impact of such events is a major concern for societies trying to understand and mitigate coastal flood hazards. Of these coastal hazards, undoubtedly the events with more destructive potential are tsunamis. In the recent cases of the 26th of December of 2004, 27th of February 2010 and the 11th of March 2011 tsunamis (Figure 2.1), in the Indian Ocean, in Chile and in Japan respectively, the world watched the profound consequences of those events in terms of human lives and damages.

Tsunami damage and casualties are usually caused by the impact of a fast-flowing mass of water (run-in and backwash), or by their effect on waterways and infrastructures. Run-in and backwash can also cause substantial erosion both of the coast and the sea-floor. They can damage roads and railways, land and associated vegetation. Debris impacts of material displaced by the tsunami waves can also cause many casualties and vast building damage arises from the high impulsive impacts of floating debris. In some cases, fire occurs when fuel installations are floated or breached by debris. Episodes of pollution can also be associated with tsunamis in cases where fuel tanks or other contaminants are spilled due to damage or destruction in infrastructures caused by the tsunami waves. Another frequent consequence of tsunamis is the strong saltwater-contamination of inland fields.

The word tsunami originates from the Japanese word that describes a "harbour wave". A tsunami can be generated by any disturbance that displaces a large water mass from its

Figure 2.1
Sendai Airport 11th March 2011 © AP/Kyoto News.
http://airceo.com/2011/03/japanese-aviation-in-disarray-after-tsunami/

equilibrium position. Although most tsunamis are triggered by submarine earthquakes involving vertical displacement of the water column, it is important to not underestimate tsunamis triggered by landslides or volcanic eruptions. Submarine landslide tsunamis often cause large run-up heights close to the source area but appear to propagate much less efficiently than earthquake tsunamis. Volcanic triggered tsunamis present similar features. In particular, volcanic tsunamis are typically generated within a very small geographic area on the flank of a volcano, and may even be modelled as a point source. The so-called meteo-tsunamis are tsunami-like events caused by differences in air pressure and are by many not considered a tsunami event but a meteorological event (i.e. similar to a surge). However, the most frequent cause of tsunamis is earthquakes capable of causing significant submarine surface rupture (Figure 2.2).

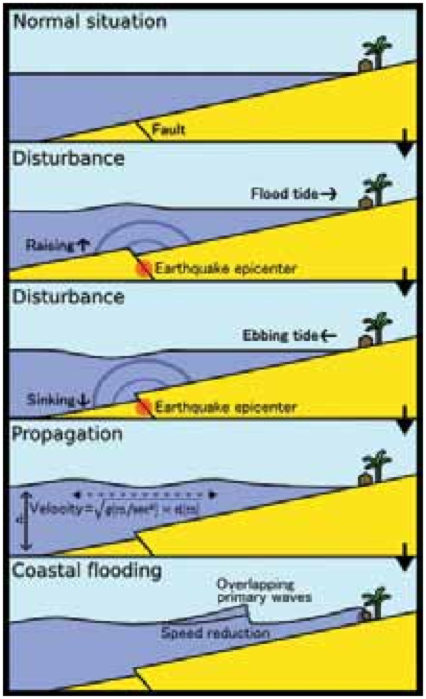


Figure 2.2
Schematic example of tsunami generation by abrupt vertical movement of the seafloor originated by earthquakes, propagation of the waves and flooding of coastal areas.
(http://en.wikipedia.org/wiki/File:Tsunami_comic_book_style.png)

The life span of a tsunami may be divided into four stages: the generation, the propagation to the coast, the run-up and run-in into the coastal fringe and backwash. The sea disturbance due to the tsunami may last for many hours and in certain circumstances (e.g. enclosed bays and harbours) resonance effects can be observed further away from tsunami source and after a long period of time has passed since the tsunami event started. As the waves approach the coastline, the wave amplitude increases while the tsunami energy flux, which is dependent on both the wave speed and wave height, remains nearly constant. Consequently, as the tsunami speed diminishes as it travels into shallower water, its height grows (Figure 2.3). Because of this shoaling effect, a tsunami, barely visible in the deep open ocean, may grow to be several meters in height near the coast. As the tsunami wave travels from deep-water to the nearshore zone, the corresponding run-up may exceed the nearshore elevation. Run-up can be

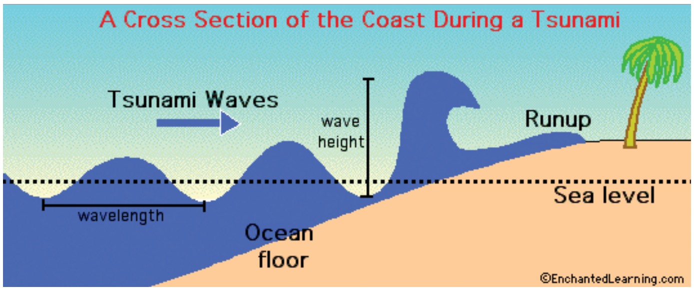


Figure 2.3
Physic characteristics of tsunami waves.
(http://trestlessurfcrowd.wordpress.com/2010/02/28/tsunami-physics-and-trestles/)

broadly defined as the maximum height reached by the tsunami at the coast. Because of the complicated behaviour of tsunami near the coast the first run-up and run-in of a tsunami is often not the largest. The arrival of a tsunami surge is sometimes preceded by extensive retreat of the sea, exposing the sea-bottom caused by a negative wave (trough) on the shoreward side of the bottom deformation (Figure 2.4).

Figure 2.4
Image of ocean retreat before tsunami run-in in Kalutana beach (Sri Lanka).
(NGDC_IOT_recedingwave.jpeg from meted.ucar.edu)

The two most important aspects that characterize tsunamis and that permit comparison between events are the magnitude and the intensity tsunami scales. The traditional magnitude scale is the so-called Imamura-Iida.

For tsunami intensity three different scales have been proposed. Soloviev (1970) pointed out that Imamura-Iida's scale is more like an earthquake intensity scale rather than a magnitude. The Sieberg tsunami intensity scale – a descriptive tsunami intensity scale which was later modified into the Sieberg-Ambraseys tsunami intensity scale (Ambraseys, 1962) - describes tsunamis from light tsunamis (Level 1) to disastrous tsunamis (Level 6) based on the physical destruction caused by their impacts. Furthermore, Papadopoulos and Imamura (2001) proposed a new intensity scale based in the effect on humans and on objects (of different sizes and nature) and the damage caused to buildings. This new scale varies from level I (Not felt) to level XII (Completely devastating). Civil protection authorities need to understand the different scales and apply one to their region.

Soloviev calculated the Tsunami intensity I according to the formula:

$$I = \frac{1}{2} + \log_2 H_{av}$$

where H_{av} is the average wave height along the nearest coast.

On the other hand, the Sieberg-Ambraseys Tsunami Intensity Scale is divided in:

1. Very light. Wave so weak as to be perceptible only on tide-gauge records.

2. Light. Wave noticed by those living along the shore and familiar with the sea. On very flat shores generally noticed.

3. Rather strong. Generally noticed. Flooding of gently sloping coasts. Light sailing vessels carried away on shore. Slight damage to light structures situated near the coasts. In estuaries reversal of the river flow some distance upstream.

4. Strong. Flooding of the shore to some depth. Light scouring on man-made ground. Embankments and dikes damaged. Light structures near the coasts damaged. Solid structures on the coast injured. Bid sailing vessels and small ships drifted inland or carried out to sea. Coasts littered with floating debris.

5. Very strong. General flooding of the shore to some depth. Quay-walls and solid structures near the sea damaged. Light structures destroyed. Severe scouring of cultivated land and littering of the coast with floating items and sea animals. With the exception of big ships all other type of vessels carried inland or out to sea. Big bores in estuary rivers. Harbor works damaged. People drowned. Wave accompanied by strong roar.

6. Disastrous. Partial or complete destruction of manmade structures for some distance from the shore. Flooding of coasts to great depths. Big ships severely damaged. Trees uprooted or broken. Many casualties.

Finally, Papadopoulos and Imamura (2001) proposed a new scale for tsunami intensity:

I. Not felt.

II. Scarcely felt.

- **a.** Felt by few people onboard small vessels. Not observed on the coast.
- **b.** No effect.
- **c.** No damage.

III. Weak.

- **a.** Felt by most people onboard small vessels. Observed by a few people on the coast.
- **b.** No effect.
- **c.** No damage.

IV. Largely observed.

- **a.** Felt by all onboard small vessels and by few people onboard large vessels. Observed by most people on the coast.

b. Few small vessels move slightly onshore.

c. No damage.

V. Strong. (wave height 1 meter)

a. Felt by all onboard large vessels and observed by all on the coast. Few people are fright ened and run to higher ground.

b. Many small vessels move strongly onshore, few of them crash into each other or overturn. Traces of sand layer are left behind on ground with favorable circumstances. Limited flooding of cultivated land.

c. Limited flooding of outdoor facilities (such as gardens) of near-shore structures.

VI. Slightly damaging. (2 m)

a. Many people are frightened and run to higher ground.

b. Most small vessels move violently onshore, crash strongly into each other, or overturn.

c. Damage and flooding in a few wooden structures. Most masonry buildings withstand.

VII. Damaging. (4 m)

a. Many people are frightened and try to run to higher ground.

b. Many small vessels damaged. Few large vessels oscillate violently. Objects of variable size and stability overturn and drift. Sand layer and accumulations of pebbles are left behind. Few aquaculture rafts washed away.

c. Many wooden structures damaged, few are demolished or washed away. Damage of grade 1 and flooding in a few masonry buildings.

VIII. Heavily damaging. (4 m)

a. All people escape to higher ground, a few are washed away.

b. Most of the small vessels are damaged, many are washed away. Few large vessels are moved ashore or crash into each other. Big objects are drifted away. Erosion and littering of the beach. Extensive flooding. Slight damage in tsunami-control forests and stop drifts. Many aquaculture rafts washed away, few partially damaged.

c. Most wooden structures are washed away or demolished. Damage of grade 2 in a few ma sonry buildings. Most reinforced-concrete buildings sustain damage, in a few damage of grade 1 and flooding is observed.

IX. Destructive. (8 m)

a. Many people are washed away.

b. Most small vessels are destroyed or washed away. Many large vessels are moved violently ashore, few are destroyed. Extensive erosion and littering of the beach. Local ground subsid ence. Partial destruction in tsunami-control forests and stop drifts. Most aquaculture rafts washed away, many partially damaged.

c. Damage of grade 3 in many masonry buildings, few reinforced-concrete buildings suffer from damage grade 2.

X. Very destructive. (8 m)

a. General panic. Most people are washed away.

b. Most large vessels are moved violently ashore, many are destroyed or collide with build ings. Small boulders from the sea bottom are moved inland. Cars overturned and drifted. Oil spills, fires start. Extensive ground subsidence.

c. Damage of grade 4 in many masonry buildings, few reinforced-concrete buildings suffer from damage grade 3. Artificial embankments collapse, port breakwaters damaged.

XI. Devastating. (16 m)

a. Lifelines interrupted. Extensive fires. Water backwash drifts cars and other objects into the sea. Big boulders from sea bottom are moved inland.

b. Damage of grade 5 in many masonry buildings. Few reinforced-concrete buildings suffer from damage grade 4, many suffer from damage grade 3.

XII. Completely devastating. (32 m)

a. Practically all masonry buildings demolished. Most reinforced-concrete buildings suffer from at least damage grade 3.

Summary:

- Tsunamis are originated by earthquakes, volcanoes, landslides.
- Tsunami may be divided into four stages: generation, propagation to the coast, run-up and run-in into the coastal fringe and finally the backwash.
- Tsunamis waves are barely noticed at the surface in deep ocean areas but as tsunami travel into shallower water its speed diminishes and its height grows.
- Tsunami run-up is the maximum height reached at the coast.
- Tsunamis can be classified using magnitude and intensity scales.

Further reading:

- NEAMTIC (North-Eastern Atlantic and Mediterranean Tsunami Information Centre) webpage *http://neamtic.ioc-unesco.org/index.php*
- NOAA (National Oceanographic and Atmospheric Authority) webpage *http://www.tsunami.noaa.gov/*

III. Tsunami risk

There are many ways to determine tsunami risk. This chapter provides a brief summary of the tools and data that is gathered for an accurate determination of risk for any specific region.

3.1. Geological data

The geological record of extreme events (such as tsunamis) is of particular importance since it provides the potential for the identification of past extreme events in pre-history – thus enhancing a better understanding of past magnitude-frequency relationships, for the establishment of return periods risk and hazard maps.

The stratigraphy of any area is the product of geological phenomena that affected or impacted the studied region. Thus, a major event like a tsunami is capable of leaving sedimentological imprints that allow their separation and association with a specific event. The sedimentary recognition of tsunami deposits (also called tsunamiites) and their differentiation from other major marine inundations deposits in the stratigraphic column requires a multi-proxy approach involving the work of sedimentologists, palaeontologists, geochemists, geophysicists, etc. The nature of tsunami deposits varies greatly with coastal and nearshore morphology, the height of tsunami waves at the coast and run-up, and with the nature and amount of existing sediment in the coastal fringe. Tsunami deposition is commonly characterized by the re-deposition of coarse shallow marine or coastal sediments in terrestrial and/or transitional (estuarine) environments (Figure 3.1).

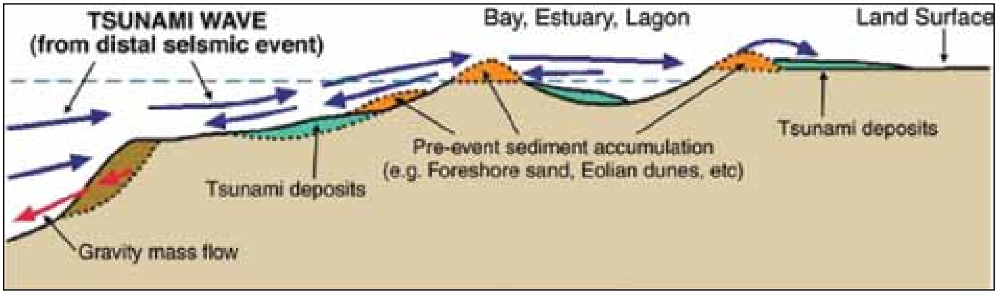


Figure 3.1
Schematic illustration of principal pathways of tsunami sediment transport and deposition (Dawson and Stewart, 2007).

Recognition of these deposits is the primary method for reconstructing tsunami minimum inundation distance, run-up and inland penetration, although patterns of erosion and deposition by both landward- and seaward-directed flows are complex, thus introducing uncertainties in those reconstructions. Tsunami deposits can be recognised not only onshore but also in the nearshore and offshore. However, the most common tsunamiites can be recognized in coastal stratigraphy as fine deposits (typically sand-sized – Figure 3.2) or boulder deposits in the coastal areas.

Figure 3.2
Trench excavated in Shetland Islands where a sandy tsunami deposit (app.10 cm thick – marked by the white arrow), under and overlies peat, can be observed. This layer has been associated with the Storegga Slide that affected the NE Atlantic coasts ca. 8000 years BP (i.e. England, Scotland, Norway and Faroe Islands). (Photo P. Costa, 2008).

Palaeotsunami datasets are frequently incomplete because many tsunamis do not leave an imprint in the geological record and, in some cases where the tsunami leaves sedimentary evidence it is extremely difficult to differentiate it from the background sedimentation or from other events (i.e. storm surges; hurricanes; typhoons). On top of all these difficulties, preservation of the palaeotsunami deposits is also threatened by sea-level changes, climatic conditions, anthropogenic actions and subsequent erosional events. Unfortunately, although the geological data is of vital importance because extends the time-window of observation, the reconstruction of the tsunamigenic inundation history of any region based solely on geological records will most probably produce an incomplete data-series.

Summary:

- Geological data can be used to extend range of return periods.
- Tsunamis waves transport sediment and deposit them inland.
- Tsunami deposits are also called tsunamiites.
- Not all tsunamis leave a sedimentary signature.
- There are two main types of tsunami deposits: boulders and sand-sized layers.

Study cases:

In the Figures below (Figure 3.3 and 3.4) two examples where tsunami deposits were described, along the shores of NE Atlantic, are presented. For the Mediterranean coasts, several deposits have also been described in Turkey, Greece or Italy.

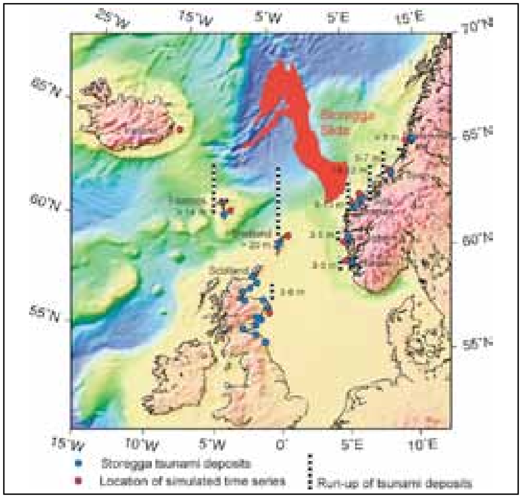


Figure 3.3
White dots show where tsunami deposits associated with the Storegga slide have been mapped (adapted from Bondevik et al., 2005).

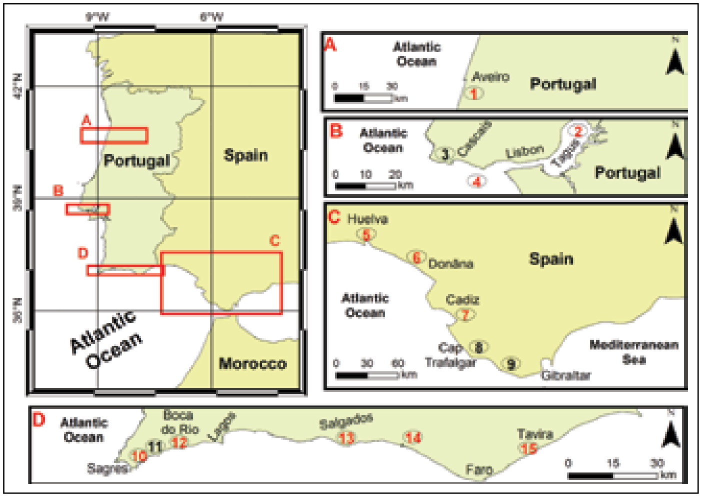


Figure 3.4
Locations where tsunami deposits have been described along the Atlantic Iberia coastline (sandy deposits numbered in red; boulder deposits numbered in black) (adapted from Costa et al., 2012)

Further reading:

- Prevention Web site *http://www.preventionweb.net/english/professional/maps/v.php?id=3831*
- Tsunamiites: Features and Implications. Edited by T. Shiki, Y. Tsuji, T. Yamazaki and K. Min oura. Elsevier, 2008, 411 pp.
- Dawson, A.G. and Stewart, I., 2007. Tsunami deposits in the geological record. Sedimentary Geology, 200(3-4): 166-183.
- Jaffe, B.E. and Gelfenbuam, G., 2007. A simple model for calculating tsunami flow speed from tsunami deposits. Sedimentary Geology, 200: 347–361.
- Morton, R.A., Gelfenbaum, G. and Jaffe, B.E., 2007. Physical criteria for distinguishing sandy tsunami and storm deposits using modern examples. Sedimentary Geology, 200: 184-207.
- Kortekaas, S. and Dawson, A.G., 2007. Distinguishing tsunami and storm deposits: An ex ample from Martinhal, SW Portugal. Sedimentary Geology, 200, 3-4: 208-221.

3.2. Historical data

The numerical calculation of tsunami hazard is a difficult task since much depends on what is known for a given coastal area of past tsunami occurrences. Historical data is commonly used to establish patterns of tsunami inundation in several tsunami-prone regions. The use of historical documentation has contributed to the establishment of worldwide tsunami catalogues. From those the NOAA (National Geophysical Data Center - *http://www.ngdc.noaa.gov/hazard/tsu_db.shtml)* stands out due to the global amount of information it contains. However, many other tsunami catalogues based on historical data are constrained, in some cases, by its association with earthquake events or other natural catastrophes and, in other cases, by the lack of inhabited locations affected by tsunami waves thus evidently explaining the absence of historical data. The creation of a catalogue of tsunamis covering all of Europe was first carried out in mid-1990 within an international project financed by the European Union called GITEC (Genesis and Impact of Tsunamis on the European Coasts). This catalogue was updated by Tinti et al. (2001) (Figure 3.5), who released an updated database and a reappraisal of European tsunami events. Since, the events that affected the Indian Ocean in 2004, several new catalogues have been produced or updated (e.g. Tinti et al., 2004).

Tsunamis with high run-ups in the Mediterranean are mainly associated with earthquake and volcanic activities, including submarine landslides. Tectonically induced tsunamis occur in Europe mainly in the Mediterranean and the Black Sea. Tsunamis caused by (submarine) landslides have mainly occurred in Norway and Scotland. Even though no devastating tsunamis have occurred in Europe in the last 100 years, the potential hazard is still high. Of those tsunamis that affect the Atlantic coasts of Europe the most relevant in historical times was the AD 1755 tsunami that strongly affected the Iberian coasts.

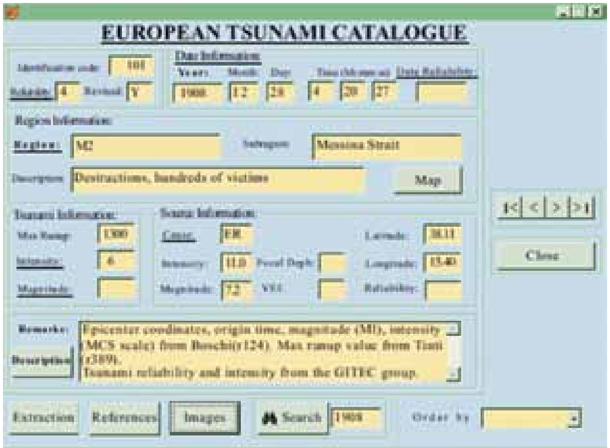


Figure 3.5
Main screen of the European tsunami catalogue (Tinti et al., 2001).

Summary:

- Historical descriptions of tsunamis are important for risk assessments.
- Tsunami catalogues have been built based in historical data.

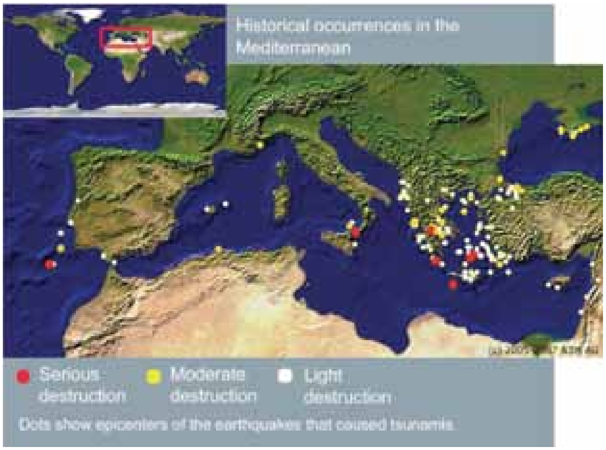


Figure 3.6
Historical occurrences of Tsunamis in the Mediterranean Sea Image Source: (Tsunami Institute 2009) (Groen et al., 2010).

Study cases:

Although not located in an area with high frequency tsunamis, the European coasts are not immune to such events triggered by earthquakes, volcanic eruptions or landslides occurring on the Atlantic seaboard or in Mediterranean coast (Figure 3.8).

Tsunami catalogues for the region of the Mediterranean Sea have been compiled by Papadopoulos (2002, 2003) for Greece and surrounding regions, including the Marmara Sea, and Tinti and Maramai (1996) and Tinti et al. (2004) for the Italian region and the Côte d' Azur. The westernmost and easternmost parts of the basin, that is the Alboran Sea and the region of Cyprus and Levantine Sea, are covered by the catalogues of Soloviev et al. (2000) and Fokaefs and Papadopoulos (2006), respectively.In Mainland Portugal, historical data associated with description of tsunami inundations was compiled as a tsunami catalogue by Baptista and Miranda (2009) and is summarized in Figure 3.6 and 3.7.

Date	Time hh mm ss	Reliability	Cause	Sub-region	Source location			TI Sieberg Ambraseys	K – Imamura Papadopoulos	R – Run-up (m)	A – Max Amplitude (m)
					N Latitude	E Longitude	H – depth (km)				
60 BC	Un	3	ER	SWIT	36.00	−10.70	-	4	VII	-	-
382 AD	Un	3	ER	SWIT	36.00	−09.50	-	4	VI	-	-
26 Jan 1531	04:30:00	4	ER	TE	38.90	−09.00	-	4	VII	-	-
27 Dec 1722	17:30:00	4	ER	SWIT	37.02	−07.48	-	3	VI	-	-
26 Dec 1746	-	0	-	-	-	-	-	-	-	-	-
28 Apr 1752	-	0	-	-	-	-	-	-	-	-	-
1 Nov 1755	09:40:00	4	ER	SWIT	36.70	−09.80	-	6	XI	>10	-
2 Nov 1755	-	0	-	-	-	-	-	-	-	-	-
16 Nov 1755	15:30:00	2	ER	SWIT	43.40	−11.00	-	2	III	-	-
21 Dec 1755	-	0	-	-	-	-	-	-	-	-	-
31 Jan 1756	-	0	-	-	-	-	-	-	-	-	-
29 Mar 1756	Un	2	ER	TE	38.70	−9.20	-	2	III	-	-
31 Mar 1761	12:01:00	4	ER	GFD	34.50	−13.00	-	3	VI	2.4	-
4 Jul 1809	-	0	-	-	-	-	-	-	-	-	-
18 Dec 1926	14:45:00	4	ES	TE	38.70	−9.20	-	2	IV	-	-
18 Nov 1929	20:32:00	4	ES	GB	44.50	−56.30	-	1	II	-	0.19 (Leixões)
4 Mar 1930	18:03:00	4	GL	MAD	32.65	−16.97	-	4	VIII	>5	-
25 Nov 1941	18:04:00	4	ER	GFD	37.42	−19.01	25	1	II	-	0.10 (Lagos)
28 Feb 1969	02:40:32	4	ER	SWIT	36.01	−10.57	22	2	III	-	0.30
17 Jul 1969	05:00:00	4	Un	Un	Un	Un	-	1	II	-	0.13 (Lagos)
26 May 1975	09:11:51	4	ER	GFD	35.90	−17.50	15	1	II	-	0.30 (Lagos)

Figure 3.7
Date – date of the event; Time – time of the event; Reliability – reliability of the event; Cause: ER (Earthquake); RF (Rock Fall) or LS (Landslide). The time attributed to the 17 July 1969 tsunami is approximate. Sub-regions of Atlantic (AT) region are coded as: SWIT – Southwest Iberian Transpressive zone; TE – Tagus Estuary; GFD – Gloria Fault Domain; GB – Grand Banks; MAD – Madeira. Lat and Lon – Latitude and Longitude in degrees; H – focal depth in km; TI – tsunami intensity; K – tsunami intensity; R – run-up height in (m); A – Max Amplitude – maximum amplitude observed in the Portuguese tide gauge network (m); in all case Un means "unknown" (Baptista and Miranda, 2009).

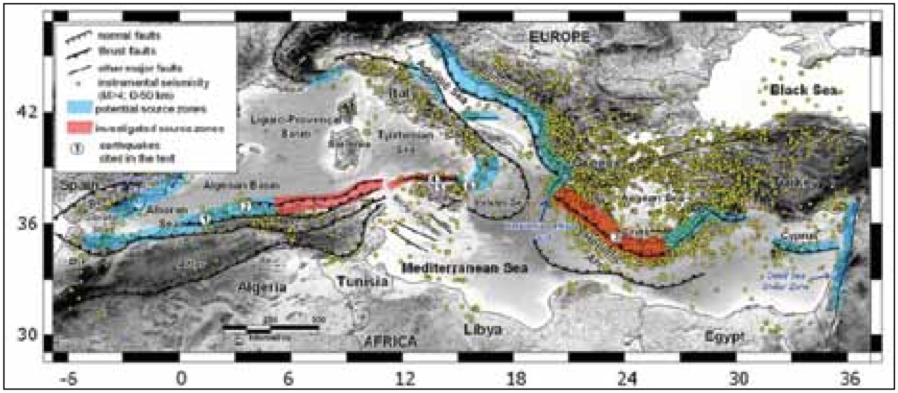


Figure 3.8
Tectonic sketch map of the Mediterranean basin. Instrumental seismicity (yellow dots; M > 4; depth 0–50 km) is taken from the ISC Catalogue (ISC, 2004). Color-shaded ribbons highlight the main structures capable of generating tsunamis that pose significant hazard to Mediterranean shore-facing settlements (shown in blue or red. Those shown in red have been investigated in this work). Selected earthquakes are shown with circles: 1) El Asnam, 1980; 2) Boumerdes, 2003; 3) Crete, 365 AD; 4) Palermo, 2002; 5) Northern Sicily, 1823; 6) Messina Straits, 1908. (Lorito et al., 2008)

Further reading:

- National Geographic Data Center – Tsunami Data and Information
http://www.ngdc.noaa.gov/seg/hazard/tsevsrch_idb.shtml
- Tsunami Risk and Strategies for the European Region (TRANSFER project)
http://www.istanbul.edu.tr/eng2/jfm/transfer/research.html
- British Geological Survey - Tsunami page
http://www.bgs.ac.uk/research/earthquakes/BritishTsunami.html
- Tinti, S., A. Maramai and L. Grazziani, 2001. A new version of the European tsunami cata logue: updating and revision. Nat. Hazards Earth Syst. Sci. 1, 255-262.
- Baptista, M.A. and Miranda, J.M., 2009. Revision of the Portuguese catalogue of tsunamis. Nat. Hazards Earth Syst. Sci., 9: 25-42.
- Andrade, C.; Borges, P. and Freitas, M. C., 2006. Historical Tsunami in the Azores archipela go. Journal of Volcanology and Geothermal Research, 156: 172-185.
- Haslett, S. K. and Bryant, E., 2008. Historic tsunami in Britain since AD 1000: a review. Nat. Hazards Earth Syst. Sci., 8, 587–601.
- Tinti, S., Maramai, A. and Graziani, L., 2004. The new catalogue of the Italian tsunamis. Natural Hazards, 439-465.
- Altinok, Y., Ersoy, S., Yalciner, A.C., Alpar, B. and Kuran, U. (2001). Historical tsunamis in the Sea of Marmara. Proceedings of the International Tsunami Symposium 2001, Seattle, Wash ington, August 7-10, 2001, 527-534.

3.3. Inundation modelling

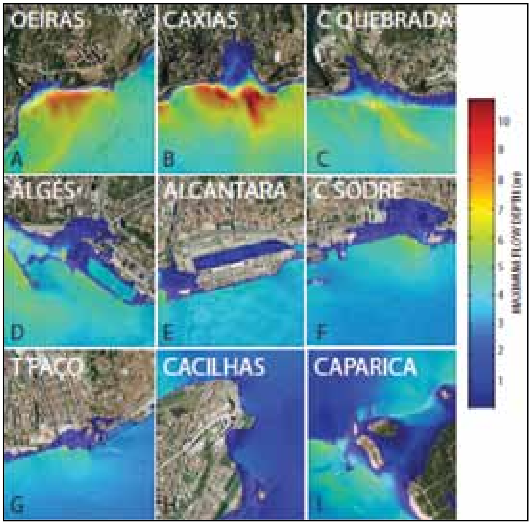
In order to produce evacuation maps it is useful to carry out simulation studies for the extent of coastal inundation. The inherent variability of tsunami events and tsunami waves require that, at the present state of knowledge, inundation models should also be corroborated with geological, historical or instrumental data. Furthermore, the number, height and wavelength of future tsunami waves will be highly variable depending on source, propagation, and shoaling effects. This variability is combined with the flow of water across rough surface topography. Features such as dunes and coastal vegetation, buildings, topographic irregularities and rivers all significantly affect where, and to what depth, inundation will occur (Berryman, K., Review of Tsunami Hazard New Zealand report, 2006). Several physical models are currently applied and have been summarized by Synolakis and Bernard (2006). Examples of those limitations are that most propagation models assume that coastlines behave as perfect reflectors of tsunami waves, but this omits the natural dissipation of tsunami energy which occurs when they run up against the shore, leading to a gradual reduction of the accuracy of the model. This is a particular problem for modelling the effect of tsunami from distant sources, as incoming waves may arrive over the course of several hours and interact with earlier waves, especially in locations where tsunami waves may become ‘trapped’ within bays and inlets. However, presently far field tsunamis, in deep waters, can be predicted quite accurately. In contrast, nearshore events are more difficult to access exactly although 3D models (e.g. Delft3D or MOST) which allow description of the behaviour of the wave, how it propagates in the oceans, together with the height, try to provide a correct prediction of timing and entity of the wave. One very important point for these models is the initial condition - where and how to model the initial disturbance is extremely important for modelling the behaviour of the wave.

Summary:

- Based on geological, historical and instrumental records, numerical models can be devel oped to predict inundation paths and areas in coastal regions.
- Inundation varies with geomorphological setting and construction patterns.
- Constrains in tsunami modelling are often associated with lack of topographic, bathymetric or ground roughness data with sufficient spatial resolution.

Study cases:

There are many examples worldwide of detailed tsunami inundation models. For instance, in Lisbon, Baptista et al. (2011) presented a 10m resolution tsunami flooding map for Lisbon downtown (including



the Tagus estuary). The inundation maps were computed using the present bathymetry and topographic maps and a reasonable estimate for the maximum credible tsunami scenario. Tsunami modelling was made with a non-linear shallow water model using four levels of nested grids (Baptista et al., 2011). The results showed that, even today, in spite of the significant morphologic changes in the city river front after the AD 1755 earthquake and tsunami, a similar event would cause tsunami flow depths larger than one meter in a large area along the Tagus estuary and Lisbon downtown (Baptista et al., 2011) (Figure 3.9).

Figure 3.9
Inundation areas along the Lisbon riverfront. Offshore, colors represent wave height (Baptista et al., 2011).

In Setúbal (south of Lisbon), a number of high resolution wave propagation simulations, considering different potential earthquake sources with different magnitudes, was made. As a result, detailed inundation maps combined with the available information of the local infrastructures were able to produce high scale vulnerability maps, escape routes and emergency routes maps for that region of Portugal (Ribeiro et al., 2011).

In the Algarve, with the support of national and local entities (municipalities, regional directorates, etc.) the Portuguese National Authority of Civil Protection has ordered a GIS-based seismic (and tsunami) simulator for the Algarve region. Called the Estudo do Risco Sísmico e de Tsunamis para o Algarve (Seismic Risk Study for the Algarve – ERSA), it was aimed to produce a comprehensive assessment of risk and create a detailed emergency plan for each county in the Algarve region. In 2010, this project produced a detailed report compiling all the available information. Tsunami inundation modelling was conducted for several areas of central and western Algarve.

Figure 3.10 shows tsunami wave modelling for a tsunami in the Hellenic Arc (Tinti et al., 2005). In the tsunami field computed 15 minutes after the tsunami initiation, it can be observed that all Ionian Greece coasts, the entire West Crete and almost all South Crete is already affected by the tsunami, and that a front is travelling in south-west direction towards the Libyan sea. Thirty minutes after the earthquake, the leading front has hit North-East Libya, the largest part of Crete and the South-West Aegean islands. Furthermore, the tsunami propagates north-west towards southern Italy and south-east towards Egypt with a characteristic sequence of two successive crests. The image describing the tsunami propagation after 45 minutes indicates that waves have already hit southern Apulia and

Calabria, are approaching eastern Sicily, and are slowly propagating inside the Aegean Sea, with a pattern that is strongly influenced by the very complex morphology. One hour after the tsunami has hit eastern Sicily to the west it is approaching with smaller but still considerable energy towards Egypt and south-eastern Turkey, and continues its propagation towards the central portion of Libya and the Sidra Gulf to the south, and towards Tunisia to the west.

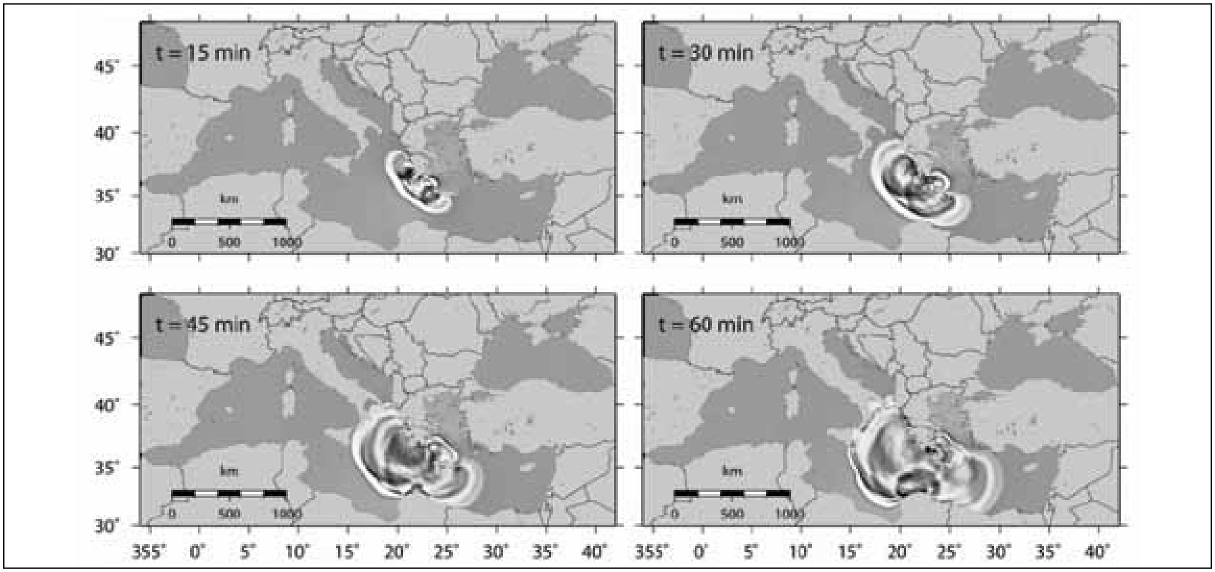
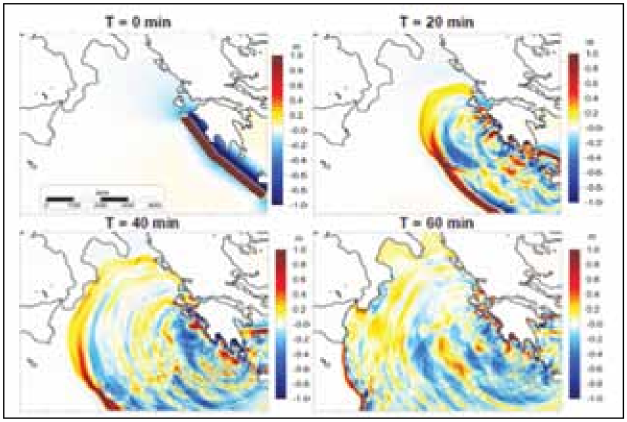


Figure 3.10
Snapshots of the tsunami elevation fields computed for the western Hellenic Arc tsunamigenic scenario (Tinti et al., 2005).



An example from Catania (Italy) is provided and displays the field obtained by combining the maximum sea elevation computed for the five scenarios examined for this site (Figure 3.11) (SCHEMA Report, 2011). The inundation line is the boundary of the maximum extent of flooding.

Figure 3.11
Tsunami propagation snapshots for one of the scenarios considered for a tsunami affecting Catania, based on the AD 365 event that occurred off western Crete, Greece and computed by UNIBOL (SCHEMA Report, 2011).

Notice that often the aggregated map is dominated by one individual case, which in each point of the map attains the maximum (minimum) value. Tsunami damage scenarios describe at the local scale the possible damaging consequences of the tsunami as given in the tsunami hazard scenarios (SCHEMA Report, 2011).

Further reading:

- SCenarios for tsunami Hazard-induced Emergencies Management (SCHEMA) Report, 2011. *http://publications.jrc.ec.europa.eu/repository/handle/111111111/16149*
- Berryman, K. Review of Tsunami Hazard – New Zealand, 2006. *http://www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tsunami-Risk-and-Preparedness-in-New-Zealand?OpenDocument*
- Synolakis, C.E. and Bernard, E. N. 2006. Tsunami Science Before and after 2004. Philosophical Transactions of the Royal Society A 364: 2231–2265.
- Baptista MA, Miranda JM, Omira R, Antunes C., 2011. Potential inundation of Lisbon downtown by a 1755-like tsunami. Natural Hazards and Earth System Science (in press).
- Ribeiro, J., Silva, A. and Leitão, P., 2011. High resolution tsunami modelling for the evaluation of potential risk areas in Setúbal (Portugal), 2371-2380. In Natural Hazards and Earth System Science 11 (8).
- Tonini, R., Armigliato, A., Pagnoni, G. and Tinti, S., 2010. Tsunami inundation scenarios of the city of Catania, Eastern Sicily, Italy. Geophysical Research Abstracts, Vol. 12, EGU2010-7000-1.

3.4. Early Warning Systems

After the 2004 Indian Ocean tsunami, the IOC, Intergovernmental Oceanographic Commission of UNESCO (United Nations Educational, Scientific, and Cultural Organization) received the mandate to coordinate the UNESCO member states plans aimed at the implementation of Tsunami Warning Systems in the world ocean basins. In 2005 the 23rd IOC Assembly formed four Intergovernmental Coordination Groups, with the common goal of coordinating the development of tsunami warning systems in the Pacific Ocean, in the Indian Ocean, in the Caribbean Sea and in the NE Atlantic, Mediterranean and connected seas region.

Tsunami predictions should provide site-specific data (i.e. arrival time and wave characteristics) about tsunamis in advance of the arrival of the first wave to a coastal area. These predictions are based on observations collected at measuring stations (i.e. buoys, tide gauges, seismic stations, accelerometers, GPS, etc.), use of complex numerical models, and also pre-calculated seismic and tsunami scenarios. To build any consistent real-time forecast of tsunami inundation it is important to assess in great detail aspects such as the source, the propagation, inundation, the fragility of the flooded areas and with all this data, establish risk, determine arrival time and wave features for a given coastal area (Figure 3.12 and 3.13). Potential impacted areas are established based in region that bear earthquake, landslide or volcano hazards. Tsunami Warning Systems have been developed for the Pacific Ocean and the Indian Ocean, and they are also under development in the Mediterranean and Caribbean. These Warning Systems are fundamental in the inundation forecast and are crucial in the dissemination of information and in issuing alerts for threatened areas. It is expected that warning systems will be developed in order to provide reliable and accurate forecast to regions that are located in the vicinity of the tsunami source – near field tsunamis. Undoubtedly, tsunami forecast contributes decisively to mitigation of effects in coastal areas.

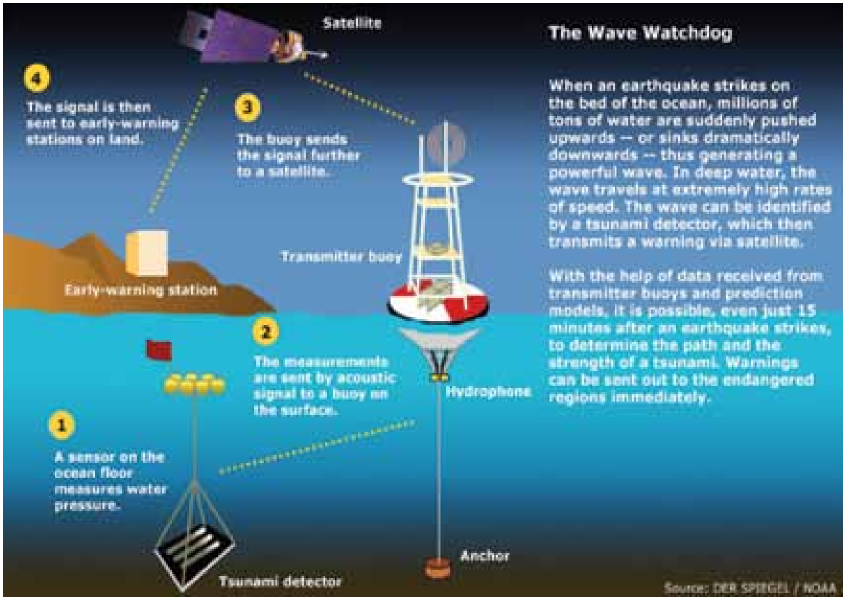


Figure 3.12
Conceptual tsunami warning system.

Summary:

- Tsunamis warning system are fundamental for tsunami forecast and for mitigation.
- Tsunami warning systems exist in the Pacific and are being developed in the Mediterranean, Caribbeaa and Indian Oceans.

Study cases:

“The Pacific Tsunami Warning System (PTWS) comprises 30 member states that are watered by the Pacific Ocean. The PTWC is operated by US NOAA (National Oceanographic and Atmospheric Administration) and has the responsibility to issue tsunami warning to all the states of the PTWS. Beyond USA, the Pacific states that have a longest tradition in TWS are Russia and Japan.

In Russia the system is currently structured in three “regional” services, located on the Pacific Russian coasts, i.e. in the Sakhalin Island, in Kamchatka and in Primorsky Krai.
In Japan the responsibility of tsunami monitoring and warning is covered by the Japanese Meteorological Agency, which concentrates forecast and warning national responsibilities for weather, climate, earthquakes, tsunamis and volcanic eruptions.
Considering the large number of tsunami sources around the Pacific rim and the consequent large number of countries exposed, there is tendency in the Pacific area to integrate the PTWS activities by means of sub-regional Groups, such as for instance the Central America Pacific Coast, the Southwest Pacific, and the Northwest Pacific and South China Sea, aiming at a better service to local specific needs.
The Indian Ocean Tsunami Warning System (IOTWS) was developed in the aftermath of the 2004 tsunami. Since October 11 2011, several states in the region have announced the completion of the basic infrastructure for national systems, among which are India, Indonesia, Thailand and Australia.
The ICG of the Caribbean region (ICG/CARIBE-EWS) was established in 2005. Unlike other regions, the system has been conceived since the beginning with a multi-hazards approach, with main focus on hurricanes and tsunamis.
In Europe the Tsunami Warning System was established, in 2005, for Euro-Mediterranean region covers the North-East Atlantic, the Mediterranean and the Connected Seas.

Further reading:

- http://ptwc.weather.gov/

- http://nctr.pmel.noaa.gov/tsunami-forecast.html

- http://www.tsunami.noaa.gov/warning_system_works.html

- http://soundwaves.usgs.gov/2010/04/research2.html

- SCenarios for tsunami Hazard-induced Emergencies Management (SCHEMA) Report, 2011. *http://publications.jrc.ec.europa.eu/repository/handle/111111111/16149*

- Baptista M. A., Omira R., Matias L., Miranda J. M., Annunziato A., Carrilho F. and Kaabouben F., 2011. On the Need for a Tsunami Warning System in the North East Atlantic Area (Gulf of Cadiz). The Tsunami Threat - Research and Technology, Book edited by: Nils-Axel Mörner, ISBN: 978-953-307-552-5, Publisher: INTECH.

- Sørensen, M. B., Spada, M., Babeyko, A. Y., Wiemer, S., Grünthal, G., 2012: Probabilistic tsunami hazard in the Mediterranean Sea. - Journal of Geophysical Research, 117, B01305. DOI: 10.1029/2010JB008169

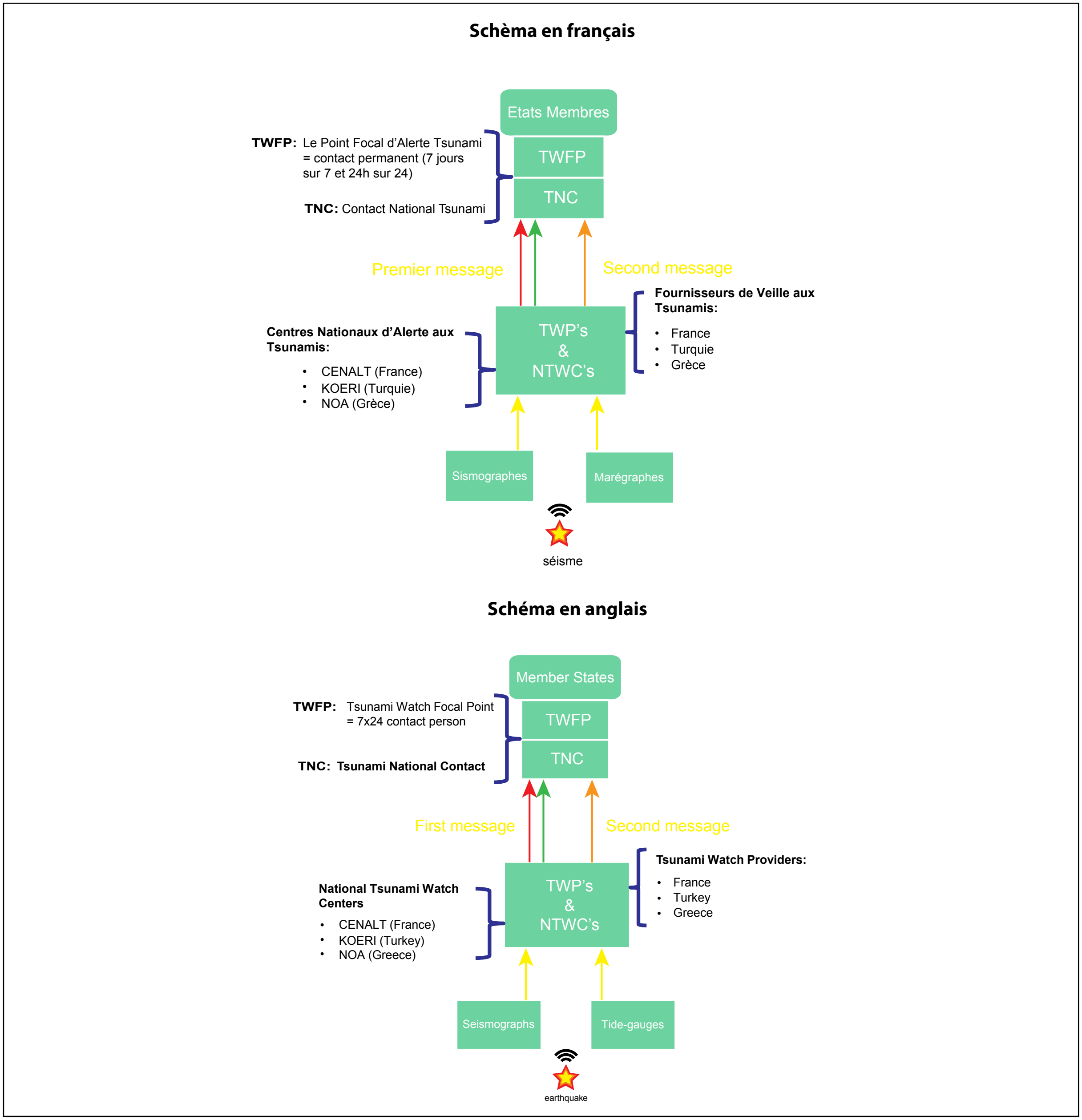


Figure 3.13
Schematic Diagram of a Tsunami Warning System - *(http://www.tsunami.noaa.gov/warning_system_works.html).*

IV. Pre-tsunami strategy Preparedness and Awareness

4.1. Urban and coastal planning

In order to develop a strategy of urban and coastal planning it is important to primarily evaluate the geographic and geomorphological characteristics of a given coastal area. Tsunami wave penetration (run-in) is strongly conditioned not only by the height of the wave but also by the geomorphological features against which it collides. The detailed knowledge of the geomorphological characteristics of a given coastline allows a better planning in terms of creation of infrastructures, evacuation routes and mitigation strategies. For instance, of the 697 km in the Portuguese coastline 28.3% are beaches, 6% are estuaries, 7.8% are coastal lagoons and 57.9% are cliffs. This simple characterization immediately allows the establishment of zones with higher risk of tsunami inundation (i.e. beaches, estuaries and coastal lagoons) because of their flat and low-lying configuration thus offering less resistance to wave invasion (in contrast with cliff areas).

On top of the knowledge of physical environment is important to legislate in order to avoid or constrain possible damages in case of a tsunami event. With that frame of mind it is important that:

- The coastal areas with higher tsunami inundation vulnerability should be identified in local maps (according to the level of vulnerability).
- Specific legislation should be applied to each different level of vulnerability and risk.
- In areas where tsunami risk is higher it should be constrained/forbidden the construction of hospitals, schools, emergency facilities, major road or rail networks and buildings that can favour a great population concentration.
- In areas where the risk is moderate, developers while planning the structural details of each building should have in consideration the maximum wave height and flow velocity expected in case of tsunami. If the plans do not follow the standard legislation, construction should be suspended.

There exist several guidelines developed by international group of experts working under the auspices of the IOC (Intergovernmental Oceanographic Commission of UNESCO) *(http://ioc-unesco.org/)* that address coastal hazards and coastal zone management and planning. These guidelines aim to assist policy makers and managers in the reduction of the risks to coastal communities, their infrastructure and service-providing ecosystems from tsunamis, storm surges and other coastal hazards within the framework of Integrated Coastal Area Management (ICAM). The assessment of coastal hazards and the mitigation of the risks can be embedded within the four phases of ICAM, each with its respective procedural steps: preliminary identification; preparation; implementation; consolidation, replication and expansion. The guidance in the management of the assessed risks within the framework of ICAM aims to enhance public awareness of the risks and to improve the resilience of coastal communities for coping in emergency situations of the threat or impact of a hazard event. Finally, the guidelines describe the options for structural and non-structural responses within the framework of ICAM for the mitigation of the assessed risks by strategic management.

In urban areas, where it is not possible to plan or to construct new infrastructures, it is important to improve the existing physical structures in order to prepare them to face tsunami waves.

A key aspect of resilience to climate-related hazards lies in the way the governance of risk is undertaken at the national and local level through well-planned policies and projects. Effective land-use management and well-designed structures allow communities to recover more quickly after a disaster event. In addition, the existence of land-use plans and policies that address critical vulnerabilities identified through hazard risk assessments can expedite recovery.

Summary:

- Knowledge of the physical environment is an important factor in coastal planning.
- Coastal areas with different tsunami inundation risks should be identified.
- Legislation should be established and be applied in accordance with the degree of vulner ability and risk of coastal regions.
- In zones with higher risk legislation should forbid/constrain construction of critical infra-structure such as schools, hospitals, emergency services, power plants, industrial facilities and road or train networks.

Study cases:

There are several successful examples worldwide of land planning against tsunamis. Most are based on the Coastal Plans that involve a (holistic?) approach regarding definition of hazardous zone, building codes and legislation, urban development restrictions, natural preservation and hazard mitigation infrastructures. For example, in Australia, building restrictions were specified in the Coastal Plan for Queensland where it was stated that: the policy of the Coastal Plan is to restrict the development footprint in the coastal zone by limiting development to infill and redevelopment of existing urban areas, and allowing only coastal-dependent development in other areas. Bearing in mind that the coastal zone can extend more than 5 km inland from the coast where the level of the land is 10 m below mean sea level.

Figure 4.1
Sea wall with stairway evacuation route used to protect a coastal town against tsunami inundation in Japan. Photo courtesy of River Bureau, Ministry of Land, Infrastructure and Transport, Japan.

Several countries produced similar legislation and many already contain specific reference to tsunami hazard and ruling legislation accordingly.

In Japan, coastal protective infrastructures (sea walls, breakwaters) have been built over the years to protect the coastal areas from tsunamis. Of those a few deserve special notice:

- Sea walls are curved coastal barriers that block waves from inundating coastal areas and redirect wave energy back towards the sea (Figure 4.1). However, during the 2011 Tsunami these did not prove to be sufficient to limit the advance of tsunami waves.
- Tsunami breakwaters (are offshore structures that restrict the inflow of tsunami and storm waves into a harbour by narrowing the entrance (Figure 4.2). Example: Ofunato Bay on Sanriku Coast.
- Elevated shelter (Figure 4.3).
- Tsunami refuge built in reinforced concrete (Figure 4.4).

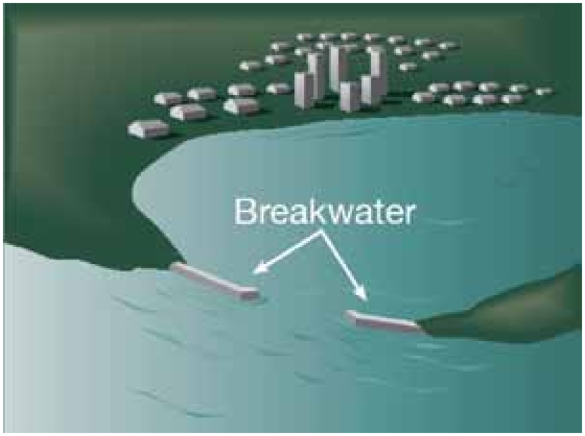


Figure 4.2
Schematic drawing representing a breakwater in a coastal embayments.

Figure 4.3
Example of an elevated shelter at Shirahama, Tokushima Prefecture, Japan.

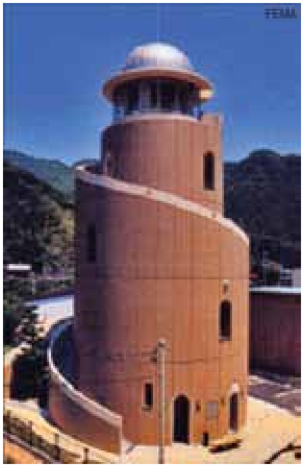


Figure 4.4
Example the Nishiki Tower in the town of Nishiki, Mie Prefecture, Japan

- Water gates – The gate begins to automatically close within seconds after earthquake shaking triggers its seismic sensors (Figure 4.5).
- Artificial berms with high elevations. Example: Aonae on Okushiri Island.
- Zoning- Cities can zone low-lying high-risk tsunami areas for open space use or if necessary, for large lots. This may decrease the amount of people in a high-risk area and/or decrease the amount of potential damage or floating debris from a tsunami.

Following the tsunami of 2004, Indonesia adopted tsunami mitigation measures such as the construction of hard structures (seawall or break-water) and evacuation of population who lived in areas with higher risk of tsunami impact and using soft structures, such as mangrove green belt, coastal forest, and land use arrangement.

Since 2005, in order to protect the Tamil Nadu, India developed a protection against tsunami that involved, for instance, the construction of sea walls or beach protection measures. As well as the development of shelter belts, mangrove plantations along the coastline to protect the coastal areas from the tsunami attack. Furthermore, new regulation/legislation involving Coastal Reserve Zones was implemented and enlarged its area of influence to coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action (on the landward side) up to 500 metres from the high tide line, and the land between the low and high tide line.

Figure 4.5
Example of water gates from Okushiri Island, Japan.

In Thailand, site-specific integrated coastal zone management was designed to suit the needs of coastal communities. Natural bioshields served to mitigate tsunami impact and protect people and property.

In Sri Lanka, with the help of Australian experts, a coastal development plan was created with a range of tasks and activities has been specified which focus largely on strategic planning at the national, regional and local level, settlement planning, urban design and coastal planning for areas affected by the 2004 Indian Ocean tsunami.

Further reading:

- IOC Manuals and Guides, 50 (ICAM Dossier 5) Hazards Awareness and Mitigation in Integrated Coastal Area Management
http://ioc-unesco.org/index.php?option=com_oe&task=viewDocumentRecord&docID=3947
- DEFRA. 2006. Shoreline Management Plan Guidance. Volume 1: Aims and requirements. Department of Environment, Farming and Rural Affairs (DEFRA), HMSO, London, 48 pages.
http://www.defra.gov.uk/environ/fcd/guidance/smpgvol1.pdf
- National Oceanic and Atmospheric Administration (NOAA). Shoreline Management Toolbox: Policy, Planning and Regulatory Tools.
http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_overview.html
- SCenarios for tsunami Hazard-induced Emergencies Management (SCHEMA) Report, 2011.
http://publications.jrc.ec.europa.eu/repository/handle/111111111/16149

4.2. Public awareness – Education and training

Even the most reliable warning is ineffective if people do not respond appropriately. Individual and community education programs are thus the most important aspect of a tsunami mitigation program. Although there has been vast technological developments in the recent years (more reliable geological and historical data, development of wave models, implementation of warning systems, more real time seismic and sea level observations etc.) improving early detection of tsunami and facilitating mitigation of effects of tsunami, educating communities to ensure an appropriate response when a tsunami strikes is of high importance.

Individuals should seek information to understand if their every-day visited locations (i.e. home, workplace, school, etc.) are or are not in a tsunami high or moderate risk area. Every person should look for site-specific information regarding return periods, wave height, evacuation routes, and evacuation buildings and warning systems that cover their area. Individuals/families/work groups should have a detailed knowledge of the evacuation plan that should be followed during a tsunami warning. Moreover, after gathering information each individual can more wisely select secure areas in terms of height and distance from the coastline which will protect them from the incoming waves. This of course, should be supported by preventive actions and signage placement by Local Authorities and Emergency and Protection services. The use of cars is not recommended as roads may become blocked. Uphill and inland footpaths, preferably clearly signed as evacuation routes, should be used instead. Local emergency management officials should advise on the best route to safety and likely shelter locations.

Furthermore practicing evacuation plans makes the appropriate response more of a reaction, requiring less thinking during an actual emergency situation. Each individual or family should organize an evacuation/survival kit (Figure 4.6). It is also important that an access to media/information providers is secured during the period while the warning is on.

Public awareness can be raised through the use of media, advertising campaigns and simulation exercises. This should be directed not only to specific groups (i.e. schools) but also to the general public. As a recommendation, it can be suggested that the dissemination of on tsunami and tsunami preparedness should be promoted by the government bodies, local authorities or by emergency services the following actions:

- Disaster education at the school level.
- Implement community-level public awareness programs.
- Enhance information management systems.
- Improve coordination mechanisms within the disaster management system.

Growing recognition that public education programs based on the dissemination (e.g., using mass media, pamphlets, etc.) of general information are ineffective has called attention to a need for alternative approaches to hazard education (Paton et al., 2008). In some cases people decide not to prepare themselves for a calamity having the belief that tsunami consequences are too catastrophic for personal action to make any difference to people's safety. The only way to do it is by stressing the importance of individual and educated reaction to such events. Furthermore, providing information to these persons will increase the understanding of such events and with proliferation of knowledge it will be easier for those initially sceptic to comprehend the hazard risks and to develop a conscience of the behaviour they should have in a tsunami event.

Tsunami information should frequently and regularly be provided at different levels from primary school to general public

EMERGENCY PREPAREDNESS CHECKLIST

Around the home:

- Assemble emergency supply kits for your home, car and work
- Know your community's emergency and evacuation plans
- Install latches on cupboards and secure water tanks, top-heavy furniture, appliances or computers and other items against movement
- Know the location of your gas shut off, electricity panel and water valves
- Know ahead of time where the safest spots are at home, school or work and in the case of a tsunami, know how to get to higher ground (above 10 metre safe zone)
- Decide in advance on a family meeting place, in case you are separated
- Identify an out-of area phone contact person to call
- Keep sturdy shoes beside all household members' beds, and
- Take an approved first aid course.

Emergency supply kit:

- A three-day supply of food and water (choose non-perishable foods that are easy to carry, nutritious and ready-to-eat)
- Cutlery, plastic plates, large plastic bags
- Prescription medicines
- First aid kit
- Portable radio, flashlights and extra batteries
- Whistle
- Important papers
- Personal toiletries
- Money and matches in a waterproof container
- Blankets (aluminum foil ones take less space)
- Infant and small children's needs (if appropriate)
- Manual can opener
- Pet needs (leash, food); and
- Shovel and other useful tools.

Suggested places to store emergency supply kits at home are: under a bed, in a closet, behind drapes, in a garage or in a garbage can - any place that is cool, dry and dark, but easily accessible.

Figure 4.6
Emergency preparedness checklist (Earthquake and Tsunami Smart Manual – British Columbia, Canada).

in awareness campaigns and also belonging to educational programs involving different modules and grades. On top of common awareness campaign the use of art and media can also be used to highlight the tsunami risk. For example, screening of short-films, theatrical plays, music and innovative approach using internet (even social networks) are more readily accepted by younger generations that more easily will assimilate the information delivered. Another suggestion is the creation of permanent (or mobile) centres for tsunami awareness and preparedness that are dedicated to disseminate information to the general public and can be used in articulation with science and civil protection authorities. Furthermore, the creation of Museums of Natural Catastrophes or the pledge of sectors/part of existing museums to this subject can also help raise the tsunami risk awareness by providing further information to the general public.

Positive outcome expectancy (the belief that preparation can increase personal safety) can motivate people to prepare. Faced with complex and uncertain events, when the population do not possess all the information they need themselves, population perception of risk and how they might mitigate it, is influenced by information from others who share their interests and values. So, participating in community activities provides access to information from people that share one's interests, values and expectations, information from this source can assist understanding one's circumstances and deciding what to do.

Summary:

- Individual and community education programs and awareness are the most important aspect of a tsunami mitigation program.
- Educating individuals to an appropriate tsunami response saves lives.
- Disaster education at the school level and public awareness programs for communities should be implemented.
- Tsunami information should be available at every educational program.
- It is important to raised awareness of risk, preventing behaviour and adequate event response.
- Community dissemination of information is crucial for influence individuals.
- Museums, films, leaflets, advertising campaigns, internet and media should be used to broadcast information on tsunami education.
- The public should seek information and be informed of its tsunami risk, inundation maps, evacuation routes and warning system,
- Evacuation exercises should be conducted periodically in schools and workplaces.
- Each individual or family should prepare an evacuation/survival kit.

Study cases:

"In the United States, the National Tsunami Hazard Mitigation Program (NTHMP) was designed to reduce the impact of tsunamis through hazard assessment, warning guidance, and mitigation. The NTHMP works towards the production of tsunami inundation maps, based on long-term tsunami forecasts, for use in community planning, standardized data archives, and the understanding of historical tsunami events. Warning Guidance, through the NTHMP Warning Coordination Subcommittee, addresses improving tsunami warnings and associated information, seismic data acquisition and processing, and warning communications. Mitigation, through the NTHMP Mitigation Subcommittee, works toward improving: outreach activities; hazard mitigation planning; evacuation planning; educational material development; NOAA's Tsunami Ready program; public education; tsunami workshops; tsunami evacuation exercises; and land-use planning. These components of NTHMP are a part of a strong and active partnership between federal, state and territorial agencies. This partnership enables all levels of government to quickly assess potential problems with the U.S. Tsunami Warning System (including response at the state and local levels) and work toward giving the greatest benefit to tax payers and our partners with the goal of saving lives and reducing damage to property and the economy.
Primary goals of NTHMP are to: 1) raise awareness of the affected population; 2) develop integrated tsunami maps and models that can be used to develop improved warning guidance and evacuation maps; 3) improve tsunami warning systems; 4) incorporate tsunami planning into state and federal multi-hazard programs. Because tsunami mitigation is applicable beyond tsunamis and is integral to the nation's overall effort to reduce coastal losses and improve resilience, the mitigation capability takes a multi-hazards physical, commercial and ecological approach that responds to socio-economic and disaster management priorities" (Adapted from National Tsunami Hazard Mitigation Program *http://nthmp.tsunami.gov/about_program_links.html).*

Further reading:

- US National Tsunami Hazard Mitigation Program - *http://nthmp.tsunami.gov/about_program_links.html*
- Tsunami Ready Program US National Weather Service - *http://www.tsunamiready.noaa.gov/*
- UNESCO - Intergovermental Oceanographic Comission – Tsunami Program *http://www.ioc-tsunami.org/*
- Town of Sidney (Canada) - Tsunami Awareness webpage *http://www.sidney.ca/Municipal_Hall/Departments/Emergency_Services/Fire_Department/Tsunami_Information/Tsunami_Awareness.htm*
- United Nations Development Program – Mozambique - Tsunami hazard awareness campaign *http://www.undp.org.mz/en/Newsroom/News-and-press-releases/News-2011/Tsunami-hazard-awareness-campaign-conducted*

4.3. Tsunami signage

Tsunami signage is a crucial component of all tsunami risk management systems and of an effective tsunami warning system. Tsunami signs play a crucial role in tsunami hazard zones; they provide guidance to the population in the case of a tsunami and they indicate: tsunami evacuation zones, tsunami evacuation routes and tsunami safe areas. There are several tsunami signs available in tsunami hazard regions around the world. Tsunami signs should be easily read and be identifiable by the general public and should be placed in areas that can be easily seen and accessed. However, only three are recognized by the International Organization for Standardization (ISO). There are two main elements in tsunami signage: Information boards and tsunami signs. Tsunami Information Boards provide the public with information related to tsunamis. Tsunami information boards are used to assist the community to understand the risk and helping them to respond effectively to tsunami warnings. These boards are more effective if accompanied by tsunami educational programs and if the same information is made available in brochures and distributed by the population. Tsunami information boards contain information on tsunami characteristics and how the public should respond, escape routes, etc. These boards should be placed at visible locations of public access to the beach or to the waterfront. As a standard protocol it is suggested that each sign should contain a title, a symbol (i.e. tsunami hazard zone/evacuation zone/evacuation route or other) and an identification of the Local Authority. Regarding location of the signage, one should consider:

- any signs do not obscure any traffic signs.
- Impact/interpretation – Select a location and orientation that will be noticed and which will give the right impression of the location of the hazard and of safety.
- Location - Will the majority of beach users notice the sign?
- Ground Conditions – Is the ground firm enough to support the sign?
- Access – Is the location easy to get to when installing and maintaining the sign?
- Shelter – Is the location sheltered? Will people want to stop and read the sign on a windy day?
- Visual pollution – Achieve optimum balance of effectiveness without adverse impact.
- Vandalism – Is the location prone to being vandalised due to isolation?

Summary:

- Tsunami signage should be available at every area with considerable tsunami risk.
- Tsunami signage provides guidance to the population in the case of an event.
- Tsunami signage should be located in areas visible for the majority of coastal-goers.
- Tsunami signage includes: evacuation area, evacuation building and hazard zone.

Study cases:

Figures 4.7 to 4.20 present examples of Tsunami signage.

Figure 4.7
Signage used for
“Tsunami evacuation area”.

Figure 4.8
Signage used to indicate a
“Tsunami evacuation building”.

Figure 4.9
Signage used to indicate
“Tsunami hazard zone”.

Figure 4.10
Signage used to indicate
“High surf or large breaking waves”.

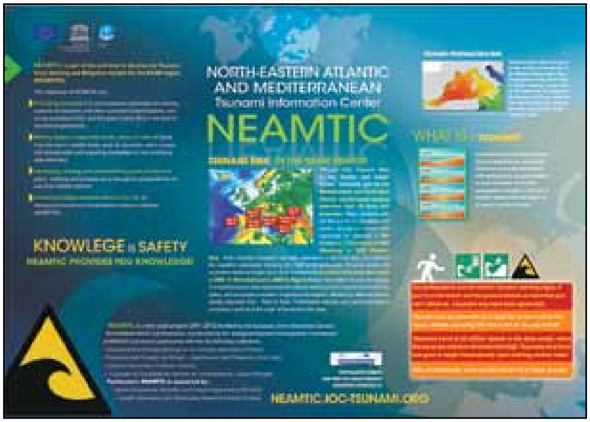


Figure 4.11
NEAMTIC TSUNAMI INFORMATION POSTER
(available:http://neamtic.iocunesco.org/images/documents/neamtic%20english%20poster%20printer.pdf)

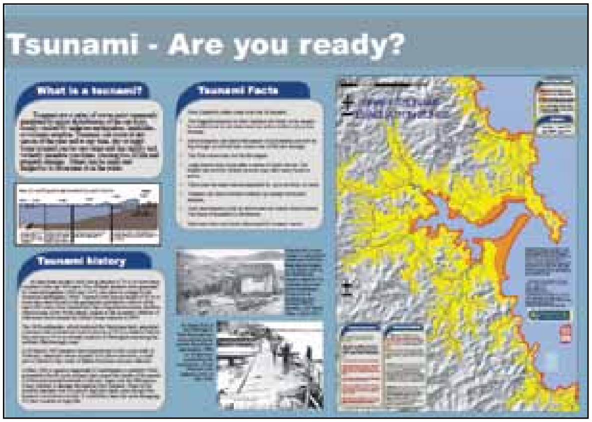


Figure 4.12
Information board
New Zealand National
Tsunami Signage Committee (2007).

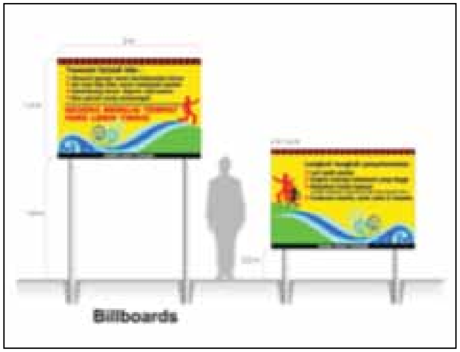


Figure 4.13
Information board (Indonesia).

Figure 4.14
Tsunami hazard zone signage (USA).

Figure 4.15
Tsunami hazard zone signage (Chile) *(http://itic.ioc-unesco.org).*

Figure 4.16
Tsunami hazard zone signage (US) – entering and leaving zone.

Figure 4.17
Tsunami evacuation route (a) – Chile; (b) – Indonesia; (c) – USA.

Figure 4.18
Tsunami evacuation route (New Zealand) (a) – General sign; (b) – Driving evacuation route; (c) – Walking evacuation route.

Figure 4.19
Tsunami safe área signage. Left image from New Zealand and Righ image from Japan (evacuation building).

Figure 4.20
Tsunami safe áreas (a) – Japan; (b) – New Zealand; (c) – Alaska *(from itic-unesco.org).*

Further reading:

- USInternational Organization for Standardization *http://www.iso.org/iso/home.html*
- Darienzo, M., 2003. Tsunami Sign Placement Guidelines. Oregon Department of Geology and Mineral Industries OFR-03-06. 11 pp.

4.4. Evacuation maps

According to the IOC – Tsunami Glossary (2008) a tsunami evacuation map is a drawing or representation that outlines danger zones and designates limits beyond which people must be evacuated to avoid harm from tsunami waves (Figure 4.21 and 4.22). Tsunami evacuation maps depict three different types of features: Evacuation Zones, Evacuation Routes and Safe areas. These maps should exhibit predictions for the maximum extent of inundation for local and distant tsunamis. Evacuation routes are sometimes designated to ensure the efficient movement of people out of the evacuation zone to evacuation shelters. Evacuation zones are the areas that must be evacuated in the event of a tsunami. These zones correspond to the areas that will most probably be flooded in case of tsunami. Evacuation zones should be defined through tsunami worst case scenario for each area.

Tsunami evacuation map products may be based on printed maps, digital map files, or interactive web-based maps. They should also include a title, scale, geographic location (coordinates), intended use, and appropriate explanatory information. Evacuation maps should also demarcate zones that should be evacuated in the event of a tsunami and also differentiate the different risk zones. These maps should include as much information (i.e. street names, landmarks, etc.) as possible/necessary to facilitate identification by the general public. Furthermore, it is important that evacuation maps indicate not only mode of evacuation but also identify terrain obstacles or structure failures. All evacuation maps should be available through the use of well visible coastal boards, printed and distributed through mail and also available in digital form (through a city council or civil defence authority).

Evacuation maps should according to Samant et al. (2008) be based on historical inundation information, geological evidences of past tsunamis (using the maximum run-up and adding a safety buffer – consider source and local topography) and in inundation modelling from nearby regions or distant regions presenting the same geomorphological context. Furthermore, it is important to consider that local sources of tsunami have additional challenges from the limited time to evacuate after the warning is cancelled/lifted.

Evacuation zones location and limits are determined using tsunami hazard models. The evacuation zones, depicted in the maps, must be able to represent a set of possible inundation areas due to different tsunami scenarios from different source areas. Due to the high degree of uncertainty in tsunami source models tsunami evacuation maps should be dynamic and be updated whenever our knowledge progresses.

Summary:

- Tsunami evacuation maps depict: Evacuation Zones, Evacuation Routes and Safe areas.
- Evacuation maps should exhibit predictions for the maximum extent of inundation for local and distant tsunamis.
- Evacuation zones location and limits are determined using tsunami hazard models.

Study cases:

Examples from evacuation maps from Oregon and Washington states (Figure 4.21 and 4.21).

Figure 4.21
Evacuation map in a brochure of Aberdeen and Hoquiam counties along the Washington coast (SCHEMA Report, 2011).

Further reading:

- SCenarios for tsunami Hazard-induced Emergencies Management (SCHEMA) Report, 2011.
http://publications.jrc.ec.europa.eu/repository/handle/111111111/16149
- Pacific Disaster Center
http://www.pdc.org/iweb/tsunami_zones.jsp
- Department of Geology and Mineral Industries, State of Oregon, United States
http://www.oregon.gov/DOGAMI/earthquakes/Coastal/Tsubrochures.shtml

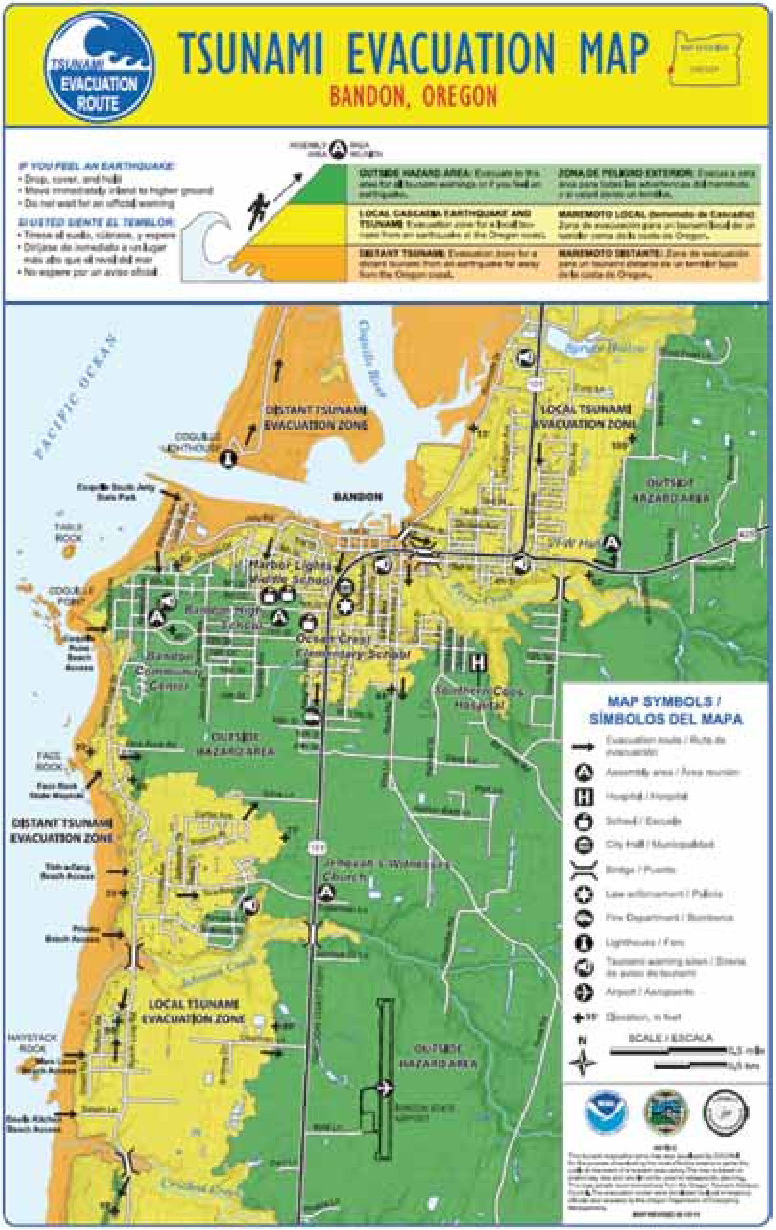


Figure 4.22
Bandon (Oregon, USA) region tsunami evacuation map.

4.5. Civil Protection

Due to the fact that tsunamis were considered a low frequency and risk event, the preparedness of Civil Protection Authorities has not been fully developed and enhanced over the years. This has changed since the Indian Ocean tsunami of 2004 and major efforts with regard to the establishment of proper conducts for mitigation and swift catastrophe responses have been developed in some countries.

Some civil protection authorities have started to develop awareness programs, emergency management plans (SCHEMA Report, 2011) that addresses aspects such as:

- Where to rescue those who have survived? Following a tsunami people may need to be rescued from open waters, from flooded areas, from inside houses where they can be trapped after a structural collapse; it was even reported that people had to be rescued from trees where they had been swept by the wave.
- Debris: Following a tsunami, masses of debris can be found and this debris carries and ac cumulates what can be swept away by the waves.
- Remaining water: Following a tsunami formerly inhabited areas can remain flooded; the same can happen with agricultural land eventually leaving salt on the soil.
- People missing: Following a tsunami there can be considerable number of people missing.

The size and impact of tsunami will have an effect on the number of casualties and structural damages. In case of a large tsunami impact some major issues typically arise for Civil Protection authorities, (SCHEMA Report, 2011):

- Casualty numbers may be uncertain (for instance in areas with many tourists);
- Locating injured people that may have been swept inland;
- Missing people;
- Lack of morgues.

Coastal inundation can cause saltwater intrusion in coastal aquifers and impact drinking water. Salt water intrusion as such can also create long-term problems because it will affect agriculture and potentially food supply. Supply of food and water for an extended period can be needed for the tsunami-affected areas (SCHEMA Report, 2011). The fishing industry can also be affected due to the destruction of boats, harbours and other facilities. Other tsunami-related long-term response measures for the civil protection authorities may be (SCHEMA Report (2011) to provide psychosocial support to survivors.

Preventive action is required not only the placement of accurate warning systems (which depend of funding sources and political decisions) but also, as recommend by SCHEMA Report (2011) the application of policies concerning:

- Education: people should know about the risk even if a tsunami may rarely happen; people should know about the initial retreat of the sea and take it as an additional warning signal; all non-permanent residents like tourists should be informed about the risk as well;
- Signage for and maintenance of evacuation routes;
- Enforcement and control of building standards;
- Protective actions (e.g. construction of sea walls in front of crowded beaches).

Summary:

- Civil protection authorities should develop public awareness (education and training) fore cast, mitigation and emergency plans.
- Emergency plans should include evacuation plans. Contact between scientific community and civil protection authorities should be encouraged.
- Preventive measures should also include coastal planning.
- Tsunami warning systems should provide detailed information to Civil Protection Authorities.

Study cases:

Within the scope of the project SCHEMA, selected areas from several countries (Italy, France, Morocco, Portugal and Bulgaria) were studied to determine the level of preparedness of the general public and authorities in case of a tsunami event. It was concluded that the level varied for each city studied depending on their knowledge and past experience about tsunamis. Among the studied sites, Catania (Italy) was established as the most prepared city to manage a crisis due to a tsunami. Evacuation plans and alert systems were prepared for an occurrence of a tsunami. This also included the conduction of periodic evacuation exercises (including residential buildings). In Cannes-Mandelieu (France) there is low preparedness for tsunamis mainly because of the tsunami risk is disregarded for this region. Nevertheless, it was observed that awareness is real since the 2004 Indian Ocean tsunami and some information has been broadcasted by the media. There are also several existing alert and crisis communication systems which can be used or serve as a base for a possible tsunami warning system. In the Rabat-Salé region (Morocco) it was observed that the region is well-prepared for other hazards. There are crisis management plans under development (including evacuation plans) for several hazards but not for potential tsunamis. In Setúbal (Portugal) there is no preparedness for the case of a tsunami event mainly because of the lack of knowledge about the tsunami risk in the region. In the Balchik region (Bulgaria) the tsunami risk is not considered as major threat when compared with other hazards. The region has emergency plans in case of earthquakes and floods but not in case of tsunamis.

As a conclusion the SCHEMA Report, 2011 stated that the most important information required by civil protection authorities is: (i) the intensity and severity of the phenomenon, (ii) the extent and accessibility of the affected area, the location and damage level of critical infrastructures, (iii) the possible contaminations and induced hazards.

In terms of operational use of "scenario" (a notion that needs to be defined precisely) very little is done at local level for preparedness against tsunami hazard. At national level, interesting work has been done by the U.S. National Tsunami Hazard Mitigation Program (NTHMP). The mapping efforts are based on credible worst-case scenarios. In their turn, credible worst-case scenario maps are based on a geophysical tsunami source and a tsunami inundation model simulation for that scenario. These maps are considered essential for effective disaster planning and development of emergency management products and programs. They guide the development of evacuation maps, educational and training materials, and tsunami mitigation plans. At higher decision making level of civil protection and for international organisations, some exercises have been organised in the framework of EC projects. For instance, in 2007, the Euromed exercise was conducted involving the co-operation of several European civil protections authorities, used scenarios of joint earthquake/tsunami events on five regions of the Mediterranean basin (SCHEMA Report, 2011).

Further reading:

- SCenarios for tsunami Hazard-induced Emergencies Management (SCHEMA) Report, 2011.
http://publications.jrc.ec.europa.eu/repository/handle/111111111/16149
- National Tsunami Hazard Mitigation Program
http://nthmp.tsunami.gov/
- Department of Geology and Mineral Industries, State of Oregon, United States
http://www.oregongeology.org/tsuclearinghouse/thmp.htm
- Alaska Division of Homeland Security and Emergency Management – Tsunami Mitigation
http://ready.alaska.gov/plans/mitigation/tsunami.htm
- Berryman, K. Review of Tsunami Hazard – New Zealand, 2006.
http://www.civildefence.govt.nz/memwebsite.nsf/wpg_URL/For-the-CDEM-Sector-Publications-Tsunami-Risk-and-Preparedness-in-New-Zealand?OpenDocument

V. Recommended strategy during a tsunami

5.1. Individual and Community response

In a tsunami warning situation, it is important that people are familiar with the location of all evacuation exits, evacuation routes and well-informed about the procedure they should follow.

The people most vulnerable to tsunamis around the world include the elderly and the infants, although those that are within or in the vicinity of poor or minimal coastal infrastructures are also at higher risk than the general public. The main steps to an effective individual response to a tsunami event are to remain calm, move to a higher ground (following evacuation routes) and avoid the return to the coastal fringe until the "all clear" signal is provided by the Local Authorities or Emergency Services. One should monitor media sources for updated information. If a person is near the ocean and feels a large earthquake, they should immediately go inland or to higher ground. Other recommendations include:

- If you are camping on a beach or near the ocean, you may have to abandon your belongings in order to save your life.
- Know your local community suggested evacuation routes to safe areas, and proceed immediately.
- Be aware that damaged roads and bridges and debris caused by the earthquake may prevent driving.
- Take your emergency supplies kit with you.
- If you are on a boat when a tsunami is coming, you should leave the harbour for the open water. Tsunamis are scarcely noticed when they pass under a boat in deep water

If a tsunami event occurs, people's survival will be influenced by the degree to which they are prepared to respond. The population will react according to the awareness and preparedness to which they have been trained and informed. Once a community is alerted that the arrival of a distant tsunami is (or may be) expected; residents should be warned in a number of different ways (e.g. a siren; sms; radio; other media; door-to-door; loud speaker system).

Summary:

- In case a tsunami occurs: maintain calm, move to a higher ground (following evacuation routes) and avoid the return to the coastal fringe.
- People's survival is influenced by the degree of preparedness and awareness.

5.2. Local authorities response

Local authorities should activate emergency plans and emergency services should be promptly called to participate in the dissemination of information, warning and guiding population into evacuation routes and safer locations.

Immediately after receiving accurate confirmation of the tsunami warning, local authorities should develop the following efforts:

- Coordinate the Tsunami warning with their areas.
- Coordinate the evacuation of people from the area.
- Arrange all logistic requirements for evacuees from the area.
- Work with community response structures within the areas to ensure that all are aware of danger.
- Request assistance from Emergency Services for medical support.
- Provide initial and follow-up reports to media and other local authorities.

However, time plays a decisive role in catastrophes like tsunamis. The time can be controlled by distance to source. The time it takes tsunamis to reach coastal locations farther away increase the chance that warnings and evacuation notices could be issued—but the accuracy and timing of these warnings are critical, as is ensuring that all individuals in the affected area receive the message and that the evacuations are well planned and managed. Because communities threatened by distant tsunamis will probably be too far from the triggering event to detect the natural signals of a tsunami, official messages are likely to be the only indicator that a tsunami is coming. Adequate public education is essential to ensure that people understand how to respond to warning messages.

Summary:

- Local authorities should coordinate the Tsunami warning with their areas and the evacuation of people.
- Local authorities should ensure that all are aware of danger.
- Local authorities should request assistance from Emergency Services for medical support.
- Local authorities should provide initial and follow-up reports to media and other authorities.

VI. Recommended post-tsunami strategy

6.1. Individual and Community response

Following a tsunami that reaches a given coastline, it is important that the population do not return to the area after the first wave. Tsunamis generally involve several powerful waves. The general public should wait for emergency management officials to give the “all clear” signal before they return home or to the coastal fringe. Bulletins should be issued by emergency officials providing updates on the situation using radio and any other media available. It is important that every person searches for information and stay tuned to a media provider. Population should stay away from buildings, damaged areas and unstable infrastructures.

Some approaches that communities should use to keep disaster preparedness activities on-going include:

- Create an organization to focus on disaster preparedness issues. The structure of an organi zation spreads the momentum for preparedness activities away from individuals or temporary groups to a permanent entity.
- Integrate tsunami preparedness into government programs. Government officials can incorporate activities such as distributing evacuation maps, testing warning systems, or mak ing sure development is tsunami-resistant into their on-going work.
- Integrate tsunami preparedness into programs of other institutions, such as schools and businesses. Schools can add tsunami preparedness to their curricula. Schools or businesses can involve the community in planning for emergency evacuations on a regular basis.

During the aftermath of the event and also while the rebuilding process occurs communities and individuals can do much to raise awareness with local authorities in order to secure a safer future for their coastal locations.

Summary:

- Individuals should wait for “all clear”signal from civil defence authorities before returning to coastal areas.
- Individuals should seek updated information and should avoid damaged structures.
- While the rebuilding process occurs preparedness and coastal planning should be included in the process.

6.2. Local authorities response

After a disaster one of the first tasks is to find survivors and bring them to safety. It is time for the so called search and rescue. A few days later, depending on circumstances, the chance of finding more people alive becomes very remote. At some point, this search and rescue effort will become recovery work.

After the recovery phase is complete and before reconstruction starts local authorities should reinforce the implementation of a series of rules and regulation in order to incorporate hazard information into short- and long-term planning processes, to improve evacuation routes and building evacuation sites and to support the resilience of coastal natural systems through the maintenance or restoration of vegetation and landscape.

In order to improve the increase of scientific knowledge, tsunami survey teams should also be deployed and conduct research, gathering data that will allow a better understanding of the catastrophe. This might provide further grounds for adjusting strategic options and improve emergency and local authorities' response in a future event.

Improved characterization of vulnerability and risk can benefit all phases of the disaster management process where human exposure has to be considered, namely in emergency planning, risk mitigation, preparedness and response to an event. In any scenario the application of tsunami hazard programs should be pursue following the idealized organization below (Figure 6.1).

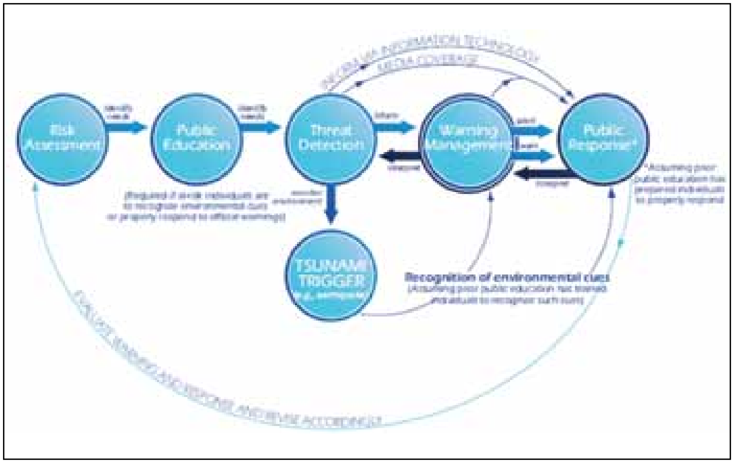


Figure 6.1
The idealized tsunami program includes risk assessment, public education, threat detection, and warning management, to elicit the appropriate public response to a tsunami *(http://dels.nas.edu/osb)*.

Summary:

- After search and rescue, recovery and rebuilding works should start.
- A series of rules and regulation in order to incorporate hazard informa tion into short- and long-term planning processes should be implemented.
- Evacuation routes and building evacu ation sites should be developed.
- Resilience of coastal natural sys tems through the maintenance or res toration of vegetation and landscape should be supported.
- Characterization of vulnerability and risk should be improved.

VII. Recommended strategic approaches to risk reduction

Minimizing future losses from tsunamis requires persistent progress across risk assessment, public education, government coordination, detection and forecasting, and warning-centre operations. Sustained efforts in all these areas will be needed for communities to prepare for an event that may occur years to decades in the future but affords only minutes or hours for people to respond.

An effort should be made to encourage the development of tsunami-resilient communities essentially through educative actions. To be efficient, this education must be adapted to local cultural, age, social and geographical characteristics.

It is important that, as advances in technology and science allow, the continued enhancement and improvement of the quality of seismic data is supplied to tsunami warning centres. The arrival time and severity of the tsunami can best be predicted using complex earthquake parameters, such as accurate depth determination, focal mechanism, and high resolution sea-floor displacement patterns. Furthermore, it is also recommended the improvement of hazard assessments by analysing and interpreting deposits from historic and pre-historic tsunamis to estimate inundation limits, flow velocities, and recurrence intervals, thus producing reliable and useful inundation maps. The latter are also dependent on detailed bathymetry and topography of coastal regions. Another aspect that must be considered by authorities concerns the mapping and detailed study of tsunami imprints immediately after the event, allowing the measurement of tsunami inundation on land, the run-up elevation and distance, flow-speed and direction indicators, and patterns of sedimentary deposition.

Actions for tsunami risk reduction should also involve:

- Development of tsunami hazard and risk assessments for all coastal regions.
- Improvement of tsunami warning systems through the progress in tsunami and seismic data collection.
- Enhance tsunami forecast and warning capability along coastlines.
- Providing scientific and technical know-how to facilitate development of international tsunami hazard.
- Promoting the development of model mitigation measures and encourages communities to adopt land-use planning practices to reduce the impact of future tsunamis.
- Raise awareness, improve preparedness, and encourage the development of tsunami re sponse, mitigation and evacuation plans.

VIII. Conclusion

This report addressed several issues that constitute the basis to develop an awareness and preparedness program at local and national scales. The information provided can contribute to inform individuals and authorities of the present-day scientific knowledge as well as an extensive summary of good practices to implement in any coastal region with existing tsunami hazard. The main aim of this report was to make citizens aware of risks of tsunamis, to acquire knowledge on safe behaviour, and to provide guidelines for Civil Protection authorities in order to the development of a group of actions that can prepare coastal regions and their populations for the likelihood of a tsunami event. These good practices are summarized as:

- Disseminate accurate information (based in scientific knowledge) through individuals, com munities and general population.
- Be aware of risks, inundation models, evacuation and emergency plans that concern your area.
- Civil Protection authorities should develop and update emergency plans for tsunami scenarios.
- Development of warning systems will allow improvement in the mitigation of tsunami effects.
- Urban and coastal planning can avoid large number of fatalities and economic damages.
- Awareness, education and training individuals and communities is vital and should be en couraged and implemented at a global scale.
- Civil Protection authorities and emergency services should have plans of actions for pre-event awareness and signage campaigns, also during the duration of the event, for the search and rescue operation and for the reconstruction phase.
- Only through the integration of knowledge, participation of citizens and communities, dedica tion of Civil Protection authorities and governments can a strategy to moderate tsunamigenic catastrophes aim to be successful.

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Annex 1
Details of tsunami signage

Figure 0.41
Signage used for “Tsunami evacuation area”.

Signage: Tsunami evacuation area

Standard: ISO 20712-1:2008 — Water safety signs and beach safety flags -- Part 1: Specifications for water safety signs used in workplaces and public areas

Committee: ISO/TC 145/SC 2; Edition: 1; ICS: 01.080.10 - Public information symbols

Reference number: WSE002; Registration date: 2008-06; Status: Active; Category: Safe condition

Function/description: To indicate the location of a safe place/uphill area for evacuation to in the event of a tsunami.

Additional information: This water safety sign has been the subject of extensive research by the Japanese government and has also been requested by UNESCO as part of an overall approach to a management strategy designed to mitigate the disastrous effects of a tsunami wave. The design selected has received the best comprehension results and is specific to the special circumstances of the tsunami hazard. Supplementary text shall be used to increase comprehension except when the safety sign is supplemented by manuals, instructions or training.

Main field of application: Workplaces and Public areas

Hazard: Tsunami wave originating from an ocean-floor seismic event in which people could be caught if they have not reached the tsunami evacuation area.

Application rules: This safety sign contains a specific safety colour that shall conform with ISO 3864-1 and ISO 3868-4.

Human behaviour intended to be prevented: Evacuation from coastal/beach zone towards higher place/hill in the event of an earthquake or when a tsunami warning has been issued.

Need: Although tsunami mitigation plans have been prepared and are available to civil protection agencies, they shall be complemented by signs that advise the population on directions to take to tsunami evacuation areas. People can be injured or drowned if they are not given indication of location of tsunami evacuation areas and directions to them.

Format of application: Multiple signs in relevant coastal/beach zones and evacuation routes, notices, safety manuals.

Context of use: In tsunami hazard zones, signing of evacuation routes to tsunami evacuation areas should consist of WSE002 supplemented by the appropriate direction arrow ISO 7010-E005 or ISO 7010-E006. WSE002 shall be used to indicate the location of a tsunami evacuation area.

Figure 0.42
Signage used to indicate a "Tsunami evacuation building".

Signage: Tsunami evacuation building

Standard: ISO 20712-1:2008 — Water safety signs and beach safety flags -- Part 1: Specifications for water safety signs used in workplaces and public areas

Committee: ISO/TC 145/SC 2; Edition: 1; ICS: 01.080.10 - Public information symbols

Reference number: WSE003; Registration date: 2008-06; Status: Active; Category: Safe condition

Function/description: To indicate the location of a safe building for evacuation in the event of a tsunami.

Additional information: This water safety sign has been the subject of extensive research by the Japanese government and has also been requested by UNESCO as part of an overall approach to a management strategy designed to mitigate the disastrous effects of a tsunami wave. The design selected has received the best comprehension results and is specific to the special circumstances of the tsunami hazard. Supplementary text shall be used to increase comprehension except when the safety sign is supplemented by manuals, instructions or training.

Main field of application: Workplaces and Public areas

Hazard: Tsunami wave originating from an ocean-floor seismic event in which people could be caught if they have not reached.

Application rules: This safety sign contains a specific safety colour that shall conform with ISO 3864-1 and ISO 3868-4.

Human behaviour intended to be prevented: Evacuation from coastal/beach zone towards a tsunami evacuation building in the event of an earthquake or when a tsunami warning has been issued.

Need: Although tsunami mitigation plans have been prepared and are available to civil protection agencies, they shall be complemented by signs that advise the population on directions to take to tsunami evacuation buildings. People can be injured or drowned if they are not given indication of location of tsunami evacuation buildings and directions to them.

Format of application: Multiple signs in relevant coastal/beach zones and evacuation routes, notices, safety manuals.

Context of use: In tsunami hazard zones, signing of evacuation routes to tsunami evacuation buildings should consist of WSE003 supplemented by the appropriate direction arrow ISO 7010-E005 or ISO 7010-E006. WSE003 shall be used to indicate the location of a tsunami evacuation building.

Figure 0.43
Signage used to indicate "Tsunami hazard zone".

Signage: Warning; Tsunami hazard zone

Standard: ISO 20712-1:2008 — Water safety signs and beach safety flags -- Part 1: Specifications for water safety signs used in workplaces and public areas

Committee: ISO/TC 145/SC 2; Edition: 1; ICS: 01.080.10 - Public information symbols

Reference number: WSW014; Registration date: 2008-06; Status: Active; Category: Warning

Function/description: To warn of a hazard from tsunami waves.

Additional information: This water safety sign has been the subject of extensive research by the Japanese Government and has also been requested by UNESCO as part of an overall approach to a management strategy designed to mitigate the disastrous effects of a tsunami wave. The design selected has received the best comprehension results and is specific to the special circumstances of the tsunami hazard. Supplementary text shall be used to increase comprehension except when the safety sign is supplemented by manuals, instructions or training. The particular circumstances of the tsunami wave and its nature as a vast volume of water indicated that, for exceptional reasons, the "exclusion zone" (as specified in ISO 3864-3) should be entered to gain the best comprehension test results.

Main field of application: Workplaces and Public areas.

Hazard: Tsunami wave originating from an ocean floor seismic event in which people could be caught.

Application rules: This safety sign contains a specific safety colour that shall conform with ISO 3864-1 and ISO 3868-4.

Human behaviour intended to be prevented: Evacuation from coastal/beach zone towards higher ground inland in the event of an earthquake or when a tsunami warning has been issued.

Need: Although tsunami mitigation plans have been prepared and are available to civil protection agencies, they shall be complemented by signs that warn the population in zones that will be specifically affected in the case of a tsunami event (inundation areas). The population should immediately leave this zone in case of an earthquake. People can be injured or drowned and they need to be warned of potential danger.

Format of application: Multiple signs in relevant coastal/beach zones and evacuation routes, notices, safety manuals.

Context of use: In tsunami hazard zones. The tsunami hazard zone sign should be complemented by WSE002 or WSE003 that provide directions towards a safe area/evacuation area or tsunami evacuation building, respectively.

Figure 0.43
Signage used to indicate
“High surf or large breaking waves”.

Signage: Warning; High surf or large breaking waves

Standard: ISO 20712-1:2008 — Water safety signs and beach safety flags -- Part 1: Specifications for water safety signs used in workplaces and public areas

Committee: ISO/TC 145/SC 2; Edition: 1; ICS: 01.080.10 - Public information symbols

Reference number: WSW023; Registration date: 2008-06; Status: Active; Category: Warning

Function/description: To warn of the hazard of high surf or large breaking waves.

Additional information: Test data obtained according to ISO 9186-1 are not available from more than one country. Findings from national testing, however, showed that in one country the graphical symbol did not reach the criteria of acceptability. Consequently, a supplementary text sign shall be used to increase comprehension except when the safety sign is supplemented by manuals, instructions or training.

Main field of application: Workplaces and Public areas.

Hazard: Large, rapidly moving mass of water in which people could be caught.

Application rules: This safety sign contains a specific safety colour that shall conform with ISO 3864-1 and ISO 3868-4.

Human behaviour intended to be prevented: Taking care when entering the water or being near the water’s edge, when there are large breaking waves.

Need: People can be injured or drowned if they are caught by large breaking waves.

Format of application: Safety signing, notices, safety manuals.

Context of use: In areas of aquatic activity, water safety, aquatic safety

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