Guidelines for Establishing Tsunami Inundation Zones for Evacuation Mapping and Planning in Regions without Tsunami Modeling

Original: U.S. National Tsunami Hazard Mitigation Program, 2011
Adapted for International use: ITIC, USA CTWP-PMEL, New Zealand, Philippines, Japan, August 2016

The purpose of this document is to provide guidance for establishing tsunami inundation zones to support tsunami evacuation mapping and planning in areas where any of the following conditions exist:

- The hazard is considered to be low based on historical occurrence of tsunamis, and no tsunami modeling exists or none is planned.
- The risk is considered to be low due to a small population and lower infrastructure vulnerability.
- Tsunami modeling does not exist but a community wishes to initiate planning and preparedness efforts.
- There is a high level of uncertainty in the model simulation results. Possible reasons include limited knowledge of the tsunami sources and/or topographic and bathymetric data with poor resolution (minimum 3 arc-sec data spacing (approx. 90 m at Equator)).

Guiding Principles

Tsunami impact (loss of life and property damage) can be reduced by building communities resilient to natural disasters, and especially tsunamis. Government Agencies worldwide have an important a responsibility to these coastal communities and an important role in facilitating this process by helping communities a process to aid in the assessment and mitigation of their risks.

Tsunami inundation modeling provides scientifically based guidance to enable communities to address their tsunami risk and develop products for planning, education, and training. One such product, the tsunami inundation map, provides the information necessary for making tsunami evacuation maps and plans. In some locations, the estimation of tsunami inundation is required, but modeling resources are not (yet) available. In this case, it is recommended that agencies use the guidance given in this document to develop their evacuation maps and plans now. Later, when required resources become available, the technical accuracy can be improved with modeling and their evacuation maps updated.

The guidelines in this document were adapted for global use from the 2011 United States (US) guidelines. The 2011 guidelines were prepared by the US National Tsunami Hazard Mitigation Program (NTHMP) Mapping and Modeling Subcommittee to assist at-risk communities, especially lower-risk states along the US East and Gulf Coasts, prepare for and mitigate tsunami impact.

Recommended Guidelines

As the first step, it is important to consult with scientists and emergency managers for advice on the community hazard and risk. The general guidelines and recommended process outlined below is considered best practice for estimating the most hazardous areas. When advised by experts, it is recommended to develop separate evacuation procedures for local (felt events with only minutes to evacuate) and distant (non-felt events with more time to evacuate) scenarios. The reference *Preparing*

Your Community for Tsunamis – A Guidebook for Local Advocates, Version 2.1, February 1, 2008, Laura Dwelley Samant, L. Thomas Tobin, Brian Tucker (see http://www.preventionweb.net/files/3984_PreparingYourCommunityforTsunamisV21.pdf) contains many of the recommendations below and can be further consulted.

General guidelines and recommended process:

1. Apply historical inundation information:
    a. Where information about historical tsunami events exist, use the maximum inundation evidence and add a safety buffer appropriate for the location. The inundation value can come from actual events, from geological evidence for past tsunami inundation, or from local experts. The National Centers for Environmental Information / World Data Service (NCEI/WDS) Global Historical Tsunami Database can be accessed at http://www.ngdc.noaa.gov/hazard/. An alternative database developed by the Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Tsunami Laboratory, Novosibirsk, Russia, is available at http://tsun.sscc.ru/tsunami-database/index.php. Regional tsunami catalogs are available in the literature as well.
    b. The safety buffer should take into account potential storm surge and maximum tide level that would add to the historic event source(s) inundation, other known sources for local tsunamis, and local topography. The US Guidelines recommended adding another 1/3 of the area corresponding to the historical maximum runup for safety.
    c. In situations where there is regional similarity in earthquake seismicity, source characteristics, tectonic regime, and off- and on-shore coastal morphology, using regional historical events as a proxy for country historical events is reasonable.
2. Choose an elevation and distance from the shoreline keeping in mind the following:
    a. Tectonic setting. Local tsunami sources typically generate larger tsunami waves along nearby coastlines than distant sources. Locations near subduction zones are more prone to large earthquakes, co-seismic subsidence, and thus larger tsunami waves. Establish the relative threat from local, distant, or both local and distant potential sources of tsunami.
    b. Local topography. The consensus among US tsunami modeling experts is that coastal morphologies (e.g. shorelines, areas along bays, inlets, rivers with direct ocean outflow) that are below 10 m (~33 ft) in elevation are at risk of tsunami impact. Therefore, in the absence of reference information, the "reasonable" safe elevation in these areas should be at least 10 m.
    c. Local tsunamis. It is possible for large local tsunamis to flood land that is above the "reasonable" safe elevation, so careful consideration is needed in deciding on the elevation for evacuation, particularly in regions where no local historical tsunamis have occurred. Maximum local runups of 30-40 m were measured in M9.1 2004 Indian Ocean tsunami in Sumatra, Indonesia (*Runup Measurements of the December 2004 Indian Ocean Tsunami, Synolakis and Kong, 2006*) and the 2011 Great East Japan tsunami in Tohoku, Japan (*National Field Survey of the 2011 Off the Pacific*

Coast of Tohoku Earthquake Tsunami, 2011 Tohoku Earthquake Tsunami Joint Survey Group, 2011). For the 2011 Great East Japan tsunami (see summary at end), runups and inundation averaged 10-20 m, and up to 30 m at locations nearest the earthquake epicenter.

   d. Distance from the shoreline. Low-lying areas along rivers or channels that connect to the ocean should be designated as tsunami inundation zones. For large, flat coastal rivers, the zone should be at least three kilometers inland and up to ten kilometers inland (Sendai plain inundation was 8 km in the 2011 Great East Japan tsunami). The US Guidelines noted that most local tsunamis would no longer be destructive by 3 km (~ 2 miles) inland, and most distant tsunamis generally affected beaches and waterfront areas within ~1.6 km (1 mile) of the open coast.
   e. Once the elevation or distance from shoreline is reached, this will determine the potential inundation/evacuation zone.

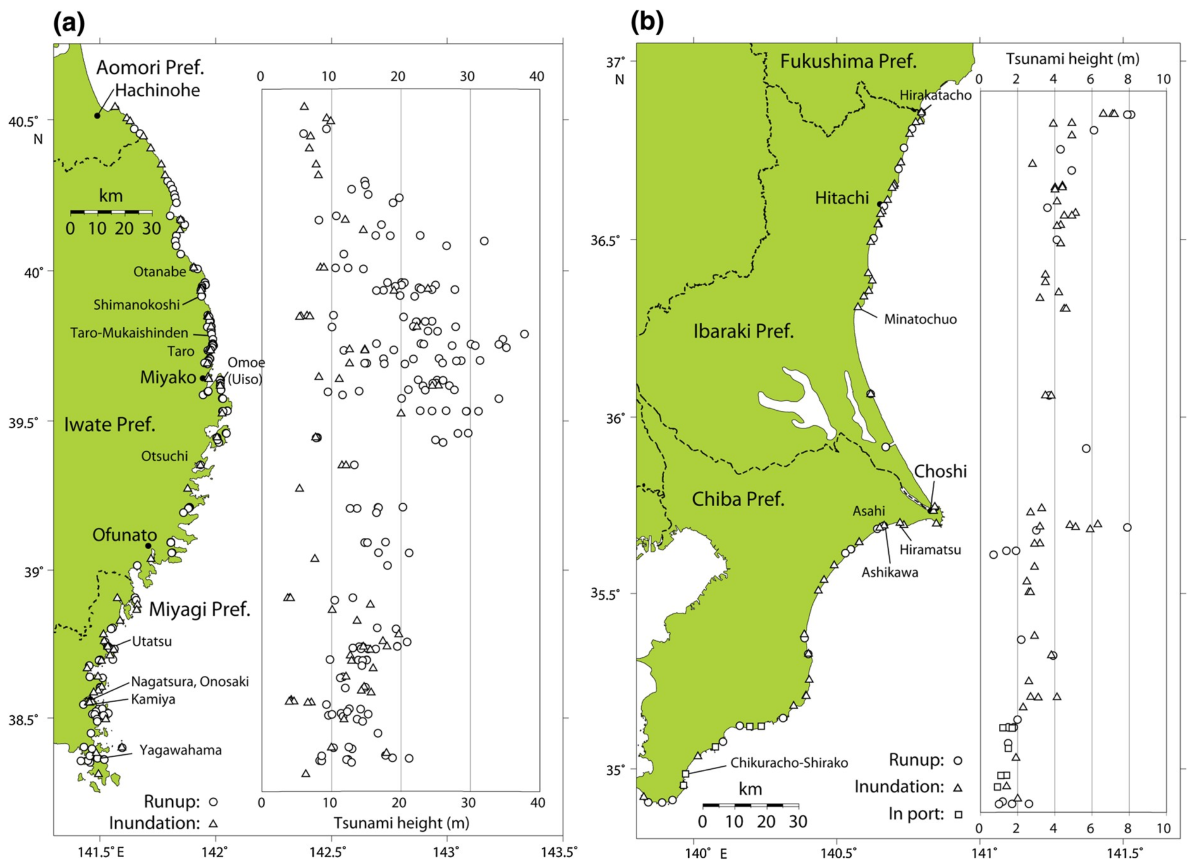
3. Use tsunami modeling for nearby areas. In situations where there are regionally-similar earthquake, tectonic, and coastal regimes, and numerically-acceptable inundation modeling has been conducted for other nearby locations, define inundation based on maximum modeled inundation in nearby / bounding areas.
   a. If available, use low resolution, regional simulations to estimate the relative amplification of tsunamis by offshore bathymetric effects.
   b. Consideration should be given to the behavior of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.
4. Take a conservative approach if using lower-resolution tsunami model results by adding a safety buffer to estimates of both inundation and evacuation zones.
   a. US Guidelines for require a minimum grid resolution of 3 arc-sec (90 m at latitude of Equator) for inundation modeling and 10 m for determination of tsunami currents. If modeling has been completed at a lower resolution, it is advisable to apply a safety factor to both inundation and runup.
   b. Account for the behavior of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.
5. In the absence of other tsunami hazard information, and where Hurricane Storm Surge Maps are available, storm surge inundation may be considered as a proxy, in consultation with scientists, for tsunami evacuation planning.
6. If inundation modeling shows that inland areas will not be affected, but strong offshore currents are possible, consider developing safety and response procedures for recreational areas (e.g., ‘clear the beaches’) and port facilities.

11 March 2011 - Tsunami Runup and Inundation Measurements - Extracted Summary

Field Surveys of Tsunami Heights from the 2011 off the Pacific Coast of Tohoku, Japan Earthquake, *Y. Tsuji, K. Satake, T. Ishibe, S. Kusumoto, T. Harada, A. Nishiyama, H. Y. Kim, T. Ueno, S. Murotani, S. Oki, M. Sugimoto, J. Tomari, M. Heidarzadeh, S. Watada, K. Imai, B. H. Choi, S. B. Yoon, J. S. Bae, K. O. Kim, and H. W. Kim,* Bull. Earthq. Res. Inst. Univ. Tokyo Vol. 86 (2011) pp. 29-279

We report the results of field surveys conducted by the Earthquake Research Institute, to measure tsunami heights from the 2011 off the Pacific coast of Tohoku, Japan Earthquake (M 9.0), on March 11. Measurements were taken at 296 points on the Sanriku coasts of Aomori, Iwate, and Miyagi Prefectures, and the Pacific coasts of Ibaraki and Chiba Prefectures. The data are included in the results of the 2011 Tohoku Earthquake Tsunami Joint Survey Group … Along the northern Sanriku coast (Aomori and Iwate), most of the 141 heights range between 10 m and 30 m. Runup heights exceeding 30 m were measured at one location in Noda Village and nine locations in Miyako City. On the southern Sanriku coast in Miyagi, most of the 76 measurements range between 4 and 20m. On the Ibaraki coast, 36 measurements range from 2.8 to 8.1m, and the heights generally decease toward the south. On the Chiba coast, 43 measurements range from 0.7 to 7.9 m, with the maximum height near Iioka, Asahi City.

Tsunami Heights along the Pacific Coast of Northern Honshu Recorded from the 2011 Tohoku and Previous Great Earthquakes, Y. Tsuji, K. Satake, T. Ishibe, T. Harada, A. Nishiyama, and S. Kusumoto, Pure Appl. Geophys. 171 (2014), 3183–3215



a Distribution of tsunami heights in Aomori, Iwate, and Miyagi prefectures (TSUJI *et al*. 2011). *Circles* and *triangles* indicate runup and inundation heights, respectively. The *dashed lines* indicate prefectural boundaries. b Distribution of tsunami heights in Ibaraki and Chiba prefectures. *Circles*, *triangles*, and *squares* indicate runup heights, inundation heights, and tsunami heights in ports, respectively