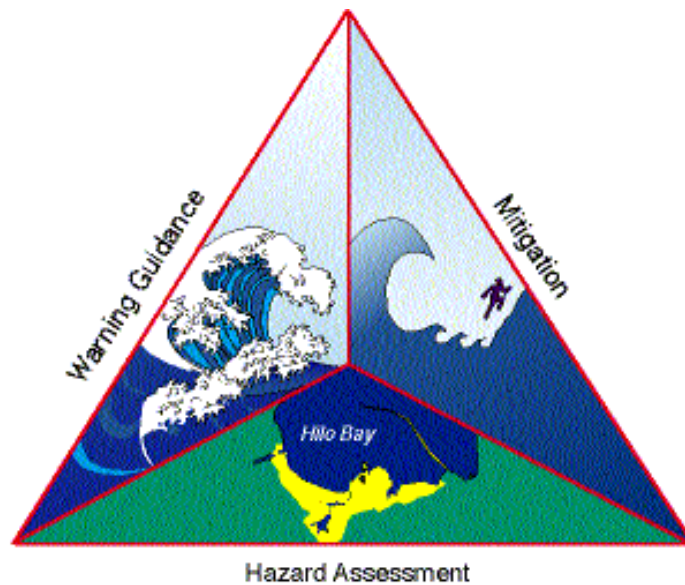


National Tsunami Hazard Mitigation Program  
2009 – 2013 Strategic Plan  
June 21, 2010



## PARTICIPANTS

David Oppenheimer, USGS

Jenifer Rhoades, NOAA

Mark Roberts, Alaska Division of Homeland Security Emergency Management

Christa von Hillebrandt-Andrade, Puerto Rico Seismic Network, UPRM

Paul Whitmore, NOAA

Charles Williams, Alabama Emergency Management Agency

## EXECUTIVE SUMMARY

The National Tsunami Hazard Mitigation Program (NTHMP) is a partnership between Federal and State agency representatives designed to reduce the impact of tsunamis on U.S. coastal communities. Led by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS), the NTHMP is the nation's community-focused program to improve tsunami mitigation and preparedness of at-risk areas within the United States and its territories (33 U.S.C. 3201 et seq).

The NTHMP includes all 28 U.S. coastal States, Territories and Commonwealths, the United States Geological Survey, the Federal Emergency Management Agency and NOAA. This strong and active partnership enables all levels of government to work toward the common goal of saving the lives of all people at risk for a tsunami at our nation's coastlines, and reducing damage to property and the economy.

The NTHMP was originally formed in 1995 by Congressional action which directed NOAA to form and lead a Federal/State working group. This action was based on increased recognition of the Cascadia tsunami threat, the April 1992 earthquake and tsunami on the Cascadia subduction zone in northern California, and the loss of life and property in Japan due to the 1993 Hokkaido Nansei-Oki tsunami that devastated the island of Okushiri. These events, together with the historic Alaska tsunamis of 1946 and 1964, brought to light the general lack of tsunami preparedness and hazard assessment for the U.S. coasts and the need for significant improvement in tsunami detection and forecasting.

This Strategic Plan describes how, over the next five years (2009 – 2013), the NTHMP will help U.S. coastal communities threatened by tsunamis improve their preparedness and mitigation efforts. The successful implementation of this strategic plan will result in the following outcomes:

- ❖ Reduction of loss of life and property damage from tsunami
- ❖ Successful execution of NTHMP tsunami mapping, modeling, mitigation, planning and education efforts
- ❖ Tsunami inundation maps that support informed decision making in tsunami-threatened communities
- ❖ Tsunami evacuation maps that support effective preparedness and response
- ❖ A culture of tsunami preparedness and response
- ❖ Establishment of more tsunami resilient communities
- ❖ Effective and reliable warning dissemination to people at risk
- ❖ Understandable and effective Tsunami Warning Center products

The NTHMP's Mission is to reduce loss of life and property damage from tsunamis.

Our Vision is resilient coastal communities that are highly informed and prepared for all tsunami hazards, that loss of life is negligible, and loss of property is minimized should a tsunami strike any U.S. state, commonwealth, or territorial coastline.

## INTRODUCTION

The National Tsunami Hazard Mitigation Program (NTHMP) is the nation's community-focused program to improve tsunami mitigation and preparedness of at-risk areas within the United States and its territories. While the United States is not subject to frequent tsunamis, the impact of just one tsunami can be truly catastrophic – as shown by the December 2004 Indian Ocean tsunami. To lessen the cultural and economic effects of a tsunami, the NTHMP takes actions to improve preparedness and response of U.S. coastal communities.

Since 1995, the NTHMP has improved U.S. tsunami preparedness through actions such as:

- Preparing tsunami inundation maps for at-risk communities;
- Supporting community efforts to create evacuation maps and tsunami response plans;
- Providing resources to enhance public education about the tsunami threat,
- Funding community warning systems;
- Providing guidance to NOAA's Tsunami Warning System (TWS) and TsunamiReady program;
- Expanding and maintaining seismic networks along the west coast, Alaska, and Hawaii;
- Funding the first deep-ocean pressure sensor network (DART); and
- Supporting development of tsunami forecast models.

With the passage of the Tsunami Warning and Education Act in December 2006, the mission of the NTHMP has been further focused on:

- Improving the quality and extent of inundation mapping,
- Promoting and improving community outreach and education networks and programs to ensure community readiness,
- Integrating tsunami preparedness and mitigation programs, and
- Promoting the adoption of tsunami warning and mitigation measures by Federal, State, tribal, and local governments and non-governmental entities.

To plan and organize the NTHMP in accordance with the Tsunami Warning and Education Act, this strategic plan sets 5-year strategies, performance measures, and milestones for the Program. It takes into account recommendations from the 2007 Independent 5-Year Review of the NTHMP, the 2006 Government Accountability Office (GAO) Report on U.S. Tsunami Preparedness, and the 2005 National Science and Technology Council Report on Tsunami Risk Reduction for the U.S.

In 2007, an external review of the NTHMP was conducted by five experts on tsunami hazard and mitigation (John Aho, Professional Engineer; Lori Dengler, Humboldt State U. Geophysics Professor; Michael Lindell, Texas A&M U. Urban Planning Professor; Richard McCarthy, Executive Director of the California Seismic Safety Commission; and

Jay Raskin, City Council Member from Cannon Beach, Oregon). The panel issued a consensus statement which summarized the NTHMP as:

*“A unique partnership among multiple states and federal agencies that has been developed over the past decade, has set challenging goals, and met many of them. This program has institutionalized a partnership between federal and state members that is unmatched by other hazard and risk management programs.”*

To continue to build on the past success of the Program, this strategic plan utilizes suggestions put forth in the external review. Some of these include:

- Establishing performance standards and standardized assessment tools for evaluating its effectiveness,
- Continuing to expand focus to include community resiliency,
- Transferring lessons learned in the program to the new 24 members of the Program,
- Establishing an information clearinghouse where local officials can obtain the information they need for community tsunami hazard management,
- Establishing a long-term plan for developing and disseminating tsunami inundation maps - recognizing that planners can do much with approximate maps produced from low resolution data, and
- Producing consistent evacuation maps among all state partners while allowing for necessary state and local variations.

The 2006 GAO report addressed NTHMP management. Regarding the NTHMP, the report suggested that NOAA create loss estimation software with FEMA and USGS, conduct end-to-end tests of the system, evaluate the TsunamiReady program, and evaluate the NTHMP and create a risk-based strategic plan. This plan addresses these suggestions.

The strategic plan first lists the NTHMP customers and partners. This section is followed by an overview of the 5-year outcomes, and then discusses specific strategies organized under four main themes:

- Over-arching outcomes and strategies
- Mapping and modeling outcomes and strategies
- Mitigation and education outcomes and strategies
- Warning coordination outcomes and strategies

An implementation section then addresses how the NTHMP will execute the strategies. Performance measures and milestones are listed in Appendix A.

## CUSTOMERS

The NTHMP activities impact, either directly or indirectly, all people of the United States. The following are the primary beneficiaries of NTHMP efforts.

- Coastal residents and visitors
- Business and government organizations
- Elected officials
- State, local and tribal emergency responders
- State, local, and tribal land use planning authorities
- Insurance industry
- Tourism industry
- Educators
- U.S. Coast Guard and maritime industry
- International tsunami warning systems
- News media
- Private weather providers

## PARTNERS

NTHMP partners are agencies whose actions help accomplish the mission of the Program. These include:

- Academia
- Emergency management/response associations
- National Earthquake Hazard Reduction agencies (USGS, NIST, NSF)
- Regional Seismic Networks
- Building code developers
- Land use planners
- Other local, state, and federal agencies
- National Weather Service/Warning Forecast Office management
- Regional tsunami and earthquake working groups (e.g., Cascade Regional Earthquake Working Group)
- United Nation's Educational, Scientific, and Cultural Organization (UNESCO)
- Intergovernmental Oceanographic Commission (IOC) Intergovernmental Coordination Groups (ICGs) for Tsunamis.
- Professional/scientific organizations
- News media

## 5-YEAR STRATEGY

This strategic plan describes the long-term vision and outcomes of the National Tsunami Hazard Mitigation Program (NTHMP). The NTHMP will execute this plan during the next five years (2009-2013) to support its mission to provide scientifically accurate assessments of the tsunami hazard, mitigate the threat through public outreach, local dissemination, planning and education, and lend guidance to optimize real-time warnings to communities on all U.S. Coastlines.

### **NTHMP Outcomes**

- ❖ Reduction of loss of life and property damage from tsunami
- ❖ Successful execution of NTHMP tsunami mapping, modeling, mitigation, planning and education efforts
- ❖ Tsunami inundation maps that support informed decision making in tsunami-threatened communities
- ❖ Tsunami evacuation maps that support effective preparedness and response
- ❖ A culture of tsunami preparedness and response
- ❖ Establishment of more tsunami resilient communities
- ❖ Effective and reliable warning dissemination to people at risk
- ❖ Understandable and effective Tsunami Warning Center products

This plan defines ambitious strategies that will strengthen the program and enable it to meet the outcomes stated above. These strategies are consistent with the requirements of the Tsunami Warning and Education Act, and will need to be balanced against funding constraints to ensure the program improves overall tsunami preparedness for all communities in the United States that are at-risk for a tsunami.

Important drivers and issues that face the NTHMP are considered. These items include state of knowledge constraints, recommendations to develop a risk-based strategic plan, and the need to balance the immediate requirement for community readiness over long-term research including hazard and risk assessments (Appendix B provides an overview of these issues).

This strategic plan recommends that over the next 5 years that NTHMP program resources be weighted appropriately between activities that improve the level of community preparedness and the state of tsunami science. This balance will be achieved through the many activities including: the development of inundation models and evacuation maps; establishing guidelines to establish areas of inundation for non-mapped areas; support of vulnerability analyses; developing quantitative tsunami hazard analysis techniques including source determination and probability of occurrence; improved information sharing and coordination; mitigation, education and outreach; and improved community warning dissemination systems.

## **OVER-ARCHING OUTCOME and STRATEGIES**

The effective execution of this strategic plan requires the NTHMP Coordinating Committee (CC) to be responsible for the overall implementation of the plan. Most strategies will be executed through the NTHMP Sub-Committees; however, there are four key strategies identified in this section which will support the NTHMP in its entirety. The NTHMP Chair or designee will take the lead and actions necessary to complete the strategies, measures, and milestones related to the outcome listed below.

**Outcome:** Successful Execution of NTHMP Tsunami Mapping, Modeling, Mitigation, Planning and Education Efforts

The Tsunami Warning and Education Act authorizes the NTHMP CC to recommend how funds within the NTHMP (under Section 5) are appropriated, recommend improvements to the National Weather Service's TsunamiReady Program, and ensure all components of the program are integrated with on-going hazard warning and risk management activities, emergency response plans, and mitigation programs in affected areas. The NTHMP Chair or designee is responsible for the overall achievement of this outcome, which will predominantly be achieved through the NTHMP Sub-Committees. The strategies below are directly tied to this outcome and benefit the overall NTHMP.

### **Strategies:**

- Establish an accessible web-based repository for NTHMP-related products
  - The NTHMP has and is continuing to develop a wealth of products and information that can be used by local officials and NTHMP Members to develop and improve local community tsunami hazard management. An accessible web-based repository for NTHMP-developed and related products is necessary to promote information sharing of NTHMP developed products. This repository will contain all products funded by the NTHMP including but not limited to: inundation maps and models, non-proprietary digital elevation models, evacuation maps, K-12 curriculum and lesson plans, mitigation and preparedness materials, and peer reviewed documents.
  
- Strengthen Sub-Committees to execute this strategic plan
  - The NTHMP's three Sub-Committees: Mapping and Modeling, Mitigation and Education, and Warning Coordination are in the unique position to achieve the activities described within the Tsunami Warning and Education Act and the strategies outlined in this Strategic Plan. The NTHMP's Sub-Committees will be strengthened and supported by the NTHMP CC to execute the activities contained within this plan. Sub-committees will meet periodically to address assigned actions as other Coordinating Committee actions as required.
  - An assessment to determine the number of the tsunami threatened communities in the U.S. will be conducted.



- Advocate tsunami research as applicable to NTHMP
  - The Tsunami Education and Warning Act instructs NOAA to work in consultation with other agencies, academic institutions and the NTHMP CC to establish or maintain a tsunami research program to develop detection, forecast, communication, and mitigation science and technology. The NTHMP CC will work with NOAA to develop a process to improve coordination of the Tsunami Research Program among all necessary parties to achieve the requirements of the Act and support NTHMP-related research.
  
- Conduct periodic external review of the NTHMP
  - The Tsunami Warning and Education Act directs the NTHMP to conduct periodic reviews of the program. The NTHMP supports external 5-Year Reviews of the Program. Two external programmatic reviews, one in 2001 and the other in 2007, were conducted to determine program strengths and address weaknesses. The NTHMP will support another external 5-Year review of the program in 2012.

## **MAPPING and MODELING OUTCOMES and STRATEGIES**

Mapping and modeling outcomes concern efforts to define potential tsunami inundation zones along threatened coastal regions. Historically, the NTHMP has provided states funds to develop inundation maps. These maps provide emergency management agencies the necessary input to create evacuation maps. Throughout the 12 years of the Program, many threatened communities were provided inundation maps. Those that have not received funding have mainly been communities with either lower threat levels or those for which little bathymetric or elevation data exists. A recurring theme from the 2007 NTHMP review was that maps made with lower resolution input data provide emergency management with valuable input to create evacuation maps even if it is not as accurate as those made with high resolution data. As the program moves forward, this point must be addressed so that all coastal communities are provided evacuation zone guidance.

NTHMP will accomplish mapping and modeling goals through the Mapping and Modeling Sub-Committee (MMS). This Sub-Committee will take the lead and actions necessary to complete the strategies, measures, and milestones related to the outcome listed below.

### **Outcome: Tsunami Inundation Maps that Support Informed Decision Making in Tsunami-Threatened Communities**

Tsunami inundation maps provide information necessary to create evacuation maps. Where potential maximum sources and coastal bathymetry/elevation are known, maps can be created by modeling expected inundation using one of many numerical techniques. To accurately represent actual inundation through a model, high resolution bathymetric and elevation data are necessary. Where either the source or bathymetric /elevation data are not well known, other techniques can be used to estimate maximum inundation. As the Program extends to areas with less defined sources and poorer bathymetric control, these other techniques must be used.

### **Strategies:**

- Develop approval procedures for tsunami inundation models to meet NOAA modeling standards.
  - The Tsunami Warning and Education Act requires NTHMP inundation models to meet a standard of accuracy defined by NOAA. NOAA has defined the standards in the NOAA Technical Memorandum OAR PMEL-135. The next step is for the MMS to establish a benchmarking procedure based on the standards.
- Develop guidelines for tsunami inundation maps.
  - A recommendation from the 2007 NTHMP review was for the different inundation modeling efforts supported by the NTHMP to follow the same basic guidelines when creating inundation maps. For example, common

output formats will enable the NTHMP to set up a web-based repository for all community inundation maps that is easily accessible by the public. Common use of legends and symbols will support easier map comprehension. Bathymetric/elevation data resolution guidelines should be set and consistent tsunami sources used as appropriate between neighboring states. Best practices developed by state efforts should be shared through annual modeler meetings.

- Prioritize inundation map development.
  - Each NTHMP partner must determine which of its coastal communities requires an inundation map. Those which do not have maps completed must be prioritized.

Digital elevation maps (DEMs) are necessary input to create inundation maps. NOAA has an ongoing project to create DEMs for the PMEL forecasting project. These DEMs can also be used in NTHMP inundation mapping projects. However, some communities for which inundation maps need to be created will not be used as forecasting points. These community's DEMs will need to be prioritized and created through actions of the MMS.

- Develop inundation maps for all communities with high tsunami hazard.
  - Based on the NOAA/USGS National Tsunami Hazards Assessment (Dunbar and Weaver, 2007), U.S. regions are characterized by tsunami hazard ranked from very low to very high. Inundation maps should be developed for all threatened communities in regions with tsunami hazard ranked high or very high. Regions ranked high or very high are Alaska, Hawaii, U.S. west coast, Puerto Rico, U.S. Virgin Islands, and U.S. Pacific Island territories.
- Provide guidance to regions for which no inundation maps exist concerning tsunami threatened areas.
  - As discussed above, many communities do not have either well known potential tsunami sources or DEMs. New techniques must be developed to provide appropriate guidance to these communities.
- Ensure any NTHMP funded model code is shared.
  - To improve coordination between the different mapping efforts funded by the NTHMP, source code used to compute expected runup should be shared.

## **MITIGATION and EDUCATION OUTCOMES and STRATEGIES**

Mitigation and Education refer to the activities through which the agencies and people in the potentially impacted zone are educated and take the appropriate actions to save lives and minimize property loss. It is important to assure the integration of the ongoing hazard warning and risk management activities, emergency response plans and mitigation programs in affected areas. Since the program was created, the NTHMP has funded state and multi-state projects to improve tsunami awareness and mitigation, and the TsunamiReady program was established. In the wake of the 2004 Indian Ocean Tsunami and the following assessments of the US Tsunami Program, much emphasis has been placed on the importance of educating the public, preparing for evacuation and emergency response, and modifying land use planning and development approval practices. Even small efforts to plan for tsunamis can significantly increase community safety.

NTHMP will accomplish Mitigation and Education Outcomes and Strategies through the Mitigation and Education Sub-Committee (MES). This Sub-Committee will take the lead and actions necessary, except where noted, to complete the strategies, measures and milestones related to the outcomes listed below.

### **Outcome: Reduction of Loss of Life and Property Damage from Tsunamis**

Tsunamis are infrequent events, but their impacts on coastal communities can be devastating. To reduce the loss of life and property, communities need to prepare for evacuation and emergency response and also modify their land use planning and development approval practices. Given the challenge to maintain mitigation and preparedness programs when the threat is perceived as remote, it is important that the measures adopted be integrated into existing community plans and that they be reviewed and revised regularly. NTHMP will provide support for periodic exercises and educational material development and distribution.

### **Strategies:**

- Develop guidelines for mitigation, preparedness and education programs
  - Educational guidelines will be developed to ensure quality educational programs are delivered by the NTHMP. These guidelines will be based on expertise developed within the program, and will provide direction to partners carrying out NTHMP education goals. These guidelines will be consistent with previous NTHMP work documented in the Strategic Implementation Plan for Mitigation Projects (Dengler, 1998). Consideration will be given to using the guidelines in the TsunamiReady program educational requirement.

Educational guidelines will consist of items such as: education of the teacher, curriculum content, frequency of offerings, and testing/follow-up

- procedures. Consideration will be given to the fact that many tsunami threatened regions receive visitors from other areas.
- NTHMP partners already participate in FEMA and other state and local mitigation and preparedness programs. The Tsunami Warning and Education Act has very specific program components that need to be addressed. The NTHMP definitions of “mitigation” and “preparedness” will be established.
  - Critical facilities represent the lifelines of communities. If they are heavily impacted and can’t recuperate, the recovery of the communities will also be delayed. Therefore, it is very important to assure that critical facilities include tsunamis in their emergency response plan. The NTHMP will define the term critical facilities for its program.
  - In order to measure the increase in the number of the tsunami threatened communities and critical facilities with tsunami response plans, a baseline of tsunami-threatened communities and critical facilities with such plans need to be increased.
  - Through mitigation, future impacts from tsunamis can be minimized. NTHMP proposes to increase the number of tsunami threatened communities which include tsunamis in their hazard mitigation plan. To measure this increase, the baseline of communities which include tsunamis in their hazard mitigation plan a baseline has to be established.
  - Promote the integration of tsunami inundation research into building codes and land use planning.
    - The use of adequate construction materials, building configuration and tsunami specific design features can reduce loss of life and property damage. Most local building codes are based on the International Building Code (IBC) prepared by the International Conference of Building Officials (ICBO). The IBC does not contain requirements for tsunami resistant design, although measures to resist earthquake shaking, can also help reduce tsunami damages. Given the advances in tsunami research, discussions need to be held with building officials to integrating tsunami resistant design; this will be done at both the ICBO and the local level.
    - The Tsunami Warning and Education Act requires the NTHMP to promote measures by Federal, State, Tribal and Local governments to discourage development in high-risk areas. Although the 1972 Coastal Zone Management Act and the FEMA National Flood Insurance Program are particularly important for land use planning in coastal areas, there are no federal requirements for statewide or local land use planning for tsunamis. Land use planning for tsunamis, regulation and permitting take place at the state and local level. NTHMP partners will seek ways to incorporate tsunami loss-prevention measures to help make communities less vulnerable in the future.
  - Support coordination of NTHMP mitigation programs with other state, local and federal mitigation programs.
    - PL-109-424 states that NTHMP shall integrate tsunami preparedness and mitigation programs into ongoing hazard warning and risk management

activities, emergency response plans and mitigation programs in affected areas. FEMA is the Federal government agency responsible for the promotion and support of mitigation of all natural hazards. FEMA's Pre-Disaster Mitigation (PDM) program provides funds to States, Territories, Tribes and communities for hazard mitigation planning and for the implementation of mitigation activities. NTHMP partners also have their own state and local mitigation programs. To maximize resources, an inventory will be prepared by each NTHMP state and federal partner mitigation activities.

### **Outcome: Tsunami evacuation maps that support effective preparedness and response**

The primary strategy for saving lives immediately before tsunami waves arrive is to evacuate people from the hazard zone. Tsunami evacuation maps need to be prepared and distributed before an event to maintain awareness and instill effective response behavior when the tsunami strikes. The evacuation maps include the area at risk, the evacuation routes and the safety zones, as well as the evacuation sites. Consideration can also be given to using tall buildings for vertical evacuation. Some uniformity in these maps will aid in their clearer interpretation as people travel between the different states, territories and commonwealths. Nevertheless it is important to note that the maps all need to be tailored for special facilities and populations.

#### **Strategies:**

- Develop guidelines for tsunami evacuation maps
  - The guidelines for the evacuation maps will include scale, colors, symbols, critical infrastructure and specialized institutions to be included as well as the text. The needs of large non-English speaking communities will also need to be addressed. Criteria for defining the evacuation routes, evacuation sites and vertical evacuation exercises would help the local communities develop effective maps.
  - Guidelines will also address the base inundation maps that will be used to develop the evacuation maps.
  - Guidelines for the approval and distribution of these maps will also be developed.
  - NTHMP will assess the number of tsunami threatened communities that require tsunami evacuation maps.

### **Outcome: A Culture of Tsunami Preparedness and Response**

The Tsunami Warning and Education Act mandated that the NTHMP shall "improve and increase education and outreach". This is a challenging mandate, possibly the NTHMP's most important, considering there are over 500 coastal counties within the ten NTHMP regions. To approach this challenge, a national tsunami education plan must be

developed to eliminate duplication of efforts and provide the necessary support to NTHMP partners implementing the plan. The plan starts with the previously mentioned goal of developing educational guidelines. The end result of the plan will be an educated populace ready to take the appropriate actions in the event of a tsunami. To reach this objective, the following strategies will be pursued.

**Strategies:**

- Facilitate educational events.
  - A national education plan will be developed which will focus and provide guidance to the NTHMP education program. The plan will leverage existing educational materials produced by the NTHMP and elsewhere. The public education provided by this program may serve a double purpose as it also could be utilized by the TsunamiReady program in their recognition criteria. The plan will help eliminate duplication of effort between NTHMP partners by consolidating educational materials and curriculum in the NTHMP web-based repository.
- Explore the feasibility of integrating tsunamis more into K-12 education.
  - Tsunami preparedness should be mainstreamed into educational curricula in zones that are at risk. Outreach to schools, including post-secondary institutions, reinforces a learned response, educates the next generation of decision makers and is a natural way to involve parents in tsunami education. Approaches can be made at the corresponding levels including the teachers and text book editors for new and improved educational materials and resources. NTHMP will support educational efforts at learning institutions including tsunami exercises, especially in at-risk communities through at least one state pilot project
- Promote development of tsunami emergency response procedures including collaboration among federal, state, and local agencies.
  - In the wake of a tsunami, emergency management personnel must be ready to respond in many different localities. These response efforts will be coordinated between national, regional and local governments through close cooperation with security officers, Coast Guard, medical personnel and engineers. Cooperation of the general public is also critical for proper tsunami response. Response procedures must be tested for their appropriateness.
  - Response procedures will include rapid and safe evacuation of people at risk, establishment of evacuation routes, evacuation areas, dissemination of information, and attention for people with special needs and visitors. The response procedures need to address both local earthquake and tsunami events, as well as regional and distant tsunamis. Clear procedures will be developed for evacuation, holding and returning to the at-risk areas once the danger has passed.
  - In preparing and responding to disasters, it is indispensable that the characteristics of the population at risk be identified. A clear understanding of the population composition and distribution in the areas at risk provide responders with the capacity to attend, manage and channel

aid more easily and effectively. The decision support tools mandated by Tsunami Warning and Education Act will help emergency officials and a wide range of decision makers to better visualize the potential impacts of a particular event.

- NTHMP state/territory/commonwealth partners lead the effort within their jurisdictions to prepare state, county, and community tsunami response. Working groups which coordinate between the different levels of government help information flow and planning throughout the jurisdiction. NTHMP will support these groups' organization and execution.
- The NTHMP will promote annual table top exercises and drills which will ensure smoother and more effective operations in the case of an event. These exercises reveal flaws or weaknesses in current systems. They also provide important feedback as to whether current evacuation measures, emergency response and mobilization procedures are appropriate.
- Support tsunami outreach efforts to coastal residents, media, coastal businesses, and tourism.
  - Before, during and after a tsunami event the media is a critical sector to reach the public. Media kits provide the tools to deliver an effective message. The number of state media toolkits will increase and a national tsunami media toolkit will also be developed. The national tsunami media kit will be designed to supplement the state toolkits.
  - The cooperation of the coastal businesses and tourism is intrinsic to proper tsunami response. Tsunami outreach products need to be developed that meet the special needs of these groups within their corresponding states and jurisdictions. Tsunami education products will be developed for the tourist (cruises, hotels and vacation rental homes) and business communities.
  - To enhance tsunami education in the schools, educational toolkits and curricula for educators will be made available electronically and in a non-proprietary format.
  - Evaluations and surveys will be conducted to determine the effectiveness of tsunami education products and the level of preparedness.
  - Promote innovative outreach events to help inform local public and reach broad audiences (e.g., fairs, mall kiosks, and community workshops).
  - Develop and distribute outreach materials as needed while attempting to utilize existing materials developed within the NTHMP and elsewhere (e.g., posters, brochures, etc.).
- Propose a National Tsunami Awareness week.
  - The establishment of a National Tsunami Awareness week will increase the awareness of tsunamis and related preparedness activities and help focus the timing of communications testing and exercise.



## **Outcome:** Establishment of more Tsunami Resilient Communities

Resilience is the capacity to cope with unanticipated danger after they have become manifest, learning to bounce back (Wildavsky, 1991). The Tsunami Warning and Education Act directs the NTHMP to seek ways to make communities more tsunami resilient through the use of inundation maps and other mitigation practices. Tsunami resilient communities are not only prepared to respond to tsunamis, but also protect existing development from tsunami losses, take special precautions in locating and designing infrastructure and have plans in place to recover if a tsunami should strike.

### **Strategies:**

- Provide funding through NTHMP grant program to provide communities resources necessary to obtain TsunamiReady recognition.
  - NOAA's TsunamiReady Program is designed to help cities, towns, counties, universities and other large sites in coastal areas reduce the potential for disastrous tsunami-related consequences. TsunamiReady helps community leaders and emergency managers strengthen their local operations. No community is tsunami proof, but TsunamiReady can help minimize loss. The TsunamiReady program recognizes communities that meet the criteria. Over 50 communities have been recognized in the US as TsunamiReady. NTHMP will support a greater number of communities to become TsunamiReady.
- Support reviews of the TsunamiReady program.
  - The NTHMP recognizes that this critical program will need periodic review and improvement to continue to enhance local community preparedness efforts. To that end, the NTHMP will support and convene meetings to discuss improvements that can be made to the TsunamiReady Program.
- Support a research effort to develop U.S. tsunami risk assessment methodologies.
  - In 2007, the NTHMP conducted a U.S. States and Territories National Tsunami Hazard Assessment: Historic Record and Sources of Waves, Prepared for the NTHMP. This report was seen as an initial step towards a national tsunami risk assessment which would include determining the harm or the potential exposure of a population, infrastructure, resources and other assets to tsunamis. The NTHMP will develop quantitative tsunami risk analysis techniques, including the source determination and probability of occurrence.
  - The NTHMP will determine the applicability of economic and loss estimation tools (eg. HAZUS) to gain a better understanding of the potential impact of tsunamis in the US

## **WARNING COORDINATION OUTCOMES and STRATEGIES**

Warning Coordination outcomes relate to the content and delivery of the operational Tsunami Warning System's (TWS) products. The NTHMP is a guidance body to the NOAA-operated U.S. TWS and provides recommendations on the format and content of Tsunami Warning Center (TWC) domestic messages. The NTHMP also takes an active role in assuring the local delivery of TWC products. The NTHMP supports community warning point reception and dissemination equipment and provides for coordination of TWS exercises and tests.

NTHMP will accomplish warning coordination goals through the Warning Coordination Sub-Committee (WCS). This Sub-Committee will take the lead and actions necessary to complete the strategies, measures, and milestones related to the outcomes listed below.

### **Outcome: Understandable and effective Tsunami Warning Center Products**

Tsunami warnings, watches, and advisories are relatively rare products for any given U.S. location. For example, U.S. west coast locations have only experienced three warnings in the last 40 years while the state of Hawaii has experienced two warnings in the same time period. U.S. east, Gulf of Mexico, and Puerto Rico/Virgin Islands coasts have never been put in tsunami warning, watch, or advisory status. Since these products are received so rarely, they must be clear and concise in content. Graphical products must support textual content and provide straight-forward information.

#### **Strategies:**

- Provide guidance to refine TWC products.
  - Product guidance will be provided to the TWCs through the WCS. TWCs will implement minor changes proposed by the WCS after necessary coordination. Major changes will be made using the NWS Service Change procedures. Special attention will be made to enhance TWC graphical products.

### **Outcome: Effective and Reliable Warning Dissemination to people at risk.**

One of the biggest challenges facing the TWS is tsunami message delivery to those at risk. TWCs utilize standard NWS message dissemination routes such as NOAA Weather Radio, NOAA Weather Wire, Emergency Managers Weather Information Network, and others. Products issued over these routes provide local emergency management guidance when making decisions regarding evacuation. It is critical for proper operation of the TWS that local emergency management have reliable TWC product reception and the capability to distribute the message to those at risk.

#### **Strategies:**

- Encourage authorities to receive and respond to Tsunami Warning Center products.
  - The WCS will provide the coordination mechanism for system-wide communication tests as well as set up a review process to determine TWS effectiveness during events which prompt tsunami warnings. Monthly or quarterly communication tests will be conducted by the TWCs to ensure message receipt by primary recipients. Annual end-to-end tests will be conducted using the live tsunami warning Emergency Alert System code and over NOAA Weather Radio when approved by the state.
  - NTHMP will encourage an increase in the number of states participating in the annual end-to-end testing of the Tsunami Warning System.
- Advocate for continual tsunami detection and warning system improvements.
  - While the NTHMP's main purpose is to enhance tsunami mitigation and education efforts, it is in a unique position to also advocate for improvements to the operational TWS. This advocacy will take the form of joint state letters to congressional members, CC recommendations to NOAA leadership, and/or interaction with the Congressional Hazards Caucus.
- Improve local warning dissemination capabilities to people at risk.
  - The WCS will conduct an inventory of dissemination capabilities at threatened communities throughout the coastal U.S. Local dissemination techniques include, but are not limited to, NOAA Weather Radio, cable TV overrides, automatic phone call systems, Emergency Alert System, sirens/loudspeakers, local SMS, etc. Based on this inventory, the WCS will take the actions necessary to improve dissemination capabilities at threatened communities nation-wide.
- Improve community warning point reception capabilities.
  - Before communities can disseminate tsunami information to people at risk, they first must be able to reliably receive tsunami information from the TWCs. Some of the methods used to receive tsunami warnings are FEMA's National Warning System, NOAA Weather Wire, the NWS Family of Services, and the Emergency Managers Weather Information Network. As above, the WCS will conduct an inventory of community warning reception capabilities. Based on this inventory the WCS will take actions necessary to improve warning information reception in threatened communities nation-wide.

## IMPLEMENTATION

Outcomes and strategies of the plan naturally fall into one of four categories: Over-arching outcomes and strategies which impact the entire program; Inundation Mapping outcomes and strategies which relate to the NTHMP's modeling effort, Mitigation and Education outcomes and strategies which relate to planning, public education and preparedness activities; and Warning Guidance outcomes and strategies which relate to warning products and dissemination. Structurally, these categories mesh well with the NTHMP's Sub-Committee structure. The over-arching outcomes and strategies will be executed by the NTHMP Chair or designee while the other three categories will be executed by the appropriate Sub-Committee. The responsibilities of the Sub-Committees must be strengthened and their Terms of Reference reviewed, adjusted and followed to ensure the successful implementation of this plan.

Implementing the strategies and achieving the performance measures will require significant amounts of time from the NTHMP Chair or designee and the Sub-Committee Chairs. Sub-Committee Chairs must be in a position in which the responsibilities of executing the plan align with their existing responsibilities, have the extra time necessary, and have sufficient financial support from their respective agency or from the NTHMP to accomplish the tasks.

Sub-Committees will need to compile, track, and complete actions and performance measures generated directly and indirectly through this plan. Action item status will be provided to the CC quarterly. Performance Measure status will be provided to the CC annually.

Grants and Contracts provided through the NTHMP must complete and support strategies and measures within this plan. Each Sub-Committee will track the success of Grantee and Contractor completion of funded tasks in relation to their respective Sub-Committee performance metrics. Sub-Committees will provide an annual report to the CC on the status of their respective performance metrics. This report will include a detailing of Grantee and Contractor impacts on the performance metrics.

## ACKNOWLEDGEMENTS

The developers of this plan would like to acknowledge the following parties and individuals for their support:

The National Tsunami Hazard Mitigation Coordination Committee for their support and guidance to develop this strategic plan.

Richard May (NOAA) for his contribution to document our Working Group Meeting discussions.

The 2007 5-Year Review Panel whose recommendations guided the development of this document.

## APPENDICIES

### Appendix A – Performance Measure Chart

<b>Outcome</b>	<b>Strategy</b>	<b>Measure</b>	<b>Milestone</b>	<b>Execution</b>
Successful execution of NTHMP tsunami mapping, modeling, mitigation, and education efforts.	Establish an accessible web-based repository for NTHMP-related products.	Percentage of NTHMP-related products available through web-based repository from 0% in 2008 to 90% by 2012.	Evaluate and centralize existing NTHMP-related products by 2009.	NTHMP Chair
			Web-based repository operational by 2012.	
	Strengthen NTHMP Sub-Committees to execute this strategic plan	90% of action items from Sub-Committee meetings will be completed within one year of being assigned.	Conduct at least one in-person meeting per year for each subcommittee.	All Sub-Committees
			All Sub-Committees revise Terms of Reference to implement strategic plan measures and milestones by 2009.	
			Assess the number of tsunami threatened communities by 2012.	
	Advocate Tsunami Research as applicable to the NTHMP		TBD	TBD
Conduct periodic external review of the NTHMP.		Conduct External Review of program in 2012.	NTHMP Chair	
Tsunami inundation maps that	Develop approval procedures for	All NTHMP-funded models will meet established	Establish a benchmark procedure for	MMS

support informed decision making in tsunami-threatened communities.	tsunami inundation models to meet NOAA tsunami modeling standards.	standards by 2012.	models by 2010.		
	Develop guidelines for tsunami inundation maps	New NTHMP-funded maps will meet established guidelines by 2012.	Establish inundation map guidelines by 2009.	MMS	
			Develop process to assess applicability of previously produced maps by 2012.		
	Prioritize inundation map development.		By 2009, establish a prioritized list of communities for which to develop inundation maps	MMS	
	Develop inundation maps for all communities with high tsunami hazard	Complete inundation maps for all threatened communities in Washington, Oregon, California, Hawaii, Puerto Rico, and the U.S. Virgin Islands by 2013			MMS
		Complete inundation maps for 33% of highly- threatened communities in Alaska and the U.S. Pacific Island Territories by 2013			
	Provide guidance to regions for which no inundation maps exist concerning tsunami threatened areas.			Develop guidelines to establish areas of inundation for non-mapped and low hazard areas by 2010.	MMS
All NTHMP-funded model code shall be open					

			source by 2010.	
	Ensure NTHMP-funded model code is shared.		Determine the potential inundation zones for non-mapped coastal regions using the established guidelines by 2012.	MMS
Reduction of Loss of life property damage from tsunamis	Develop guidelines for mitigation, preparedness, and education programs.		Establish NTHMP definitions of “mitigation” and “preparedness” by 2009.	MES
			Develop educational guidelines by 2010.	
		By 2012, increase percentages of the critical facilities in tsunami-threatened communities which include tsunamis in their emergency response plan by 30%.	Define the term “critical facilities” for NTHMP use by 2009.	
			Determine baseline percentages of tsunami-threatened critical facilities and communities which include tsunami response in their emergency response plan by 2010.	
		By 2012, increase percentages of tsunami-threatened communities which include tsunamis in their emergency response plan by 30%.	Determine baseline percentages of tsunami-threatened critical facilities and communities which include tsunami response	



			in their emergency response plan by 2010.	
		By 2012, increase percentages of tsunami-threatened communities which include tsunamis in their hazard mitigation plan by 30%.	Determine baseline percentages of tsunami-threatened communities which include tsunamis in their hazard mitigation plan by 2010.	
	Promote the integration of tsunami inundation research into building codes and land use planning.	10% of tsunami-threatened communities include tsunami in their community planning, zoning and building code deliberations by 2012.	Integrate tsunami building standards into the International Building Code by 2015.	MES
	Support coordination of NTHMP mitigation programs with other state, local, and federal mitigation programs.		Inventory each NTHMP state and federal partner mitigation activities (include non-NTHMP funded activities) by 2009	MES
Tsunami evacuation maps that support effective preparedness and response	Develop guidelines for tsunami evacuation maps.	100% of tsunami evacuation maps posted to NTHMP web-based repository by 2012.	Establish guidelines for evacuation maps by 2010.	MES
		Annually increase the number of tsunami evacuation maps by 10% annually (based on the baseline established in 2010.)	Establish baseline of existing tsunami evacuation maps by 2010	MES.
A culture of	Facilitate		Develop an	MES

tsunami preparedness and response.	educational events		NTHMP education implementation plan by 2009.	
	Explore the feasibility of integrating tsunami education into K-12 curriculum		Integrate tsunami information into K-12 education through at least one state pilot project by 2011.	MES
	Promote development of tsunami emergency response procedures including collaboration among federal, state, and local agencies.		<p>Conduct annual tsunami table-top exercise to ensure response plans to tsunamis are integrated and effective by 2010</p> <p>Develop decision support tools for emergency responders to better visualize and plan for potential impacts by 2013.</p> <p>All states with a high or very high level of tsunami hazard (as defined by Dunbar and Weaver, 2007) create and utilize a high-level structure to address tsunami response at the state level by 2012. (For example, state/local working group, tsunami technical review committees, etc.)</p>	WCS

	Support tsunami outreach efforts to coastal residents, media, coastal businesses, and tourism	Increase the number of state tsunami media toolkits from 1 in 2008 to 7 by 2012.	Publish a national tsunami media toolkit by 2010.	MES
			Education toolkits and curricula for educators electronically accessible by 2012.	
			Conduct evaluations to determine the effectiveness of tsunami education products and programs in 10 selected communities by 2010. Repeat every 3 years with goal of improving the percentage of informed citizens by 30%.	
			Establish baseline (percentage) of states and local community conducted educational tsunami events by 2010.	
			Increase percentage of states and local community conducted educational tsunami events by 10% annually. (Events can include	

			workshops, town-hall meetings, and outreach in schools) starting in 2011	
			Support outreach efforts with the use of educational materials such as brochures, posters, etc.	
			Develop and distribute tsunami education products for the tourist community (e.g., hotels, cruises, and vacation rental homes) by 2011.	
	Propose a national tsunami awareness week.		Determine the recommended week for national tsunami awareness week by 2009.	NTHMP Chair
			Establish a national tsunami awareness week by 2012.	
			Develop educational guidelines by 2010.	
Establishment of more Tsunami resilient communities	Provide funding through NTHMP grant program to provide communities resources necessary to obtain TsunamiReady	Increase the number of recognized TsunamiReady communities from 57 in 2008 to 105 by FY2013.		MES

	recognition.			
	Support a research effort to develop U.S. tsunami risk assessment methodologies.		Determine applicability of economic and loss estimation tools (e.g. HAZUS) by 2010.	MMS
			Develop quantitative tsunami hazard analysis technique including source determination and probability of occurrence by 2013.	
	Support reviews of the Tsunami Ready program.		Complete TR program review using external reviewers and provide recommendations by 2009.	MES
Understandable and effective Tsunami Warning Center Products	Provide guidance to refine TWC products		Conduct an annual review of TWC products at the annual WCS meeting and update products accordingly.	WCS
Effective and reliable Warning dissemination to people at risk.	Encourage authorities to receive and respond to Tsunami Warning Center products.	Increase percentage of response from primary recipients to monthly Tsunami Warning Center communications tests from 82% in 2008 to 90% by 2013.	Conduct an annual end-to-end communications test of the U.S. Tsunami Warning System	WCS

			Develop a post-event review process with performance measures to determine the effectiveness of tsunami warning products with corrective action plan by 2009.	
			Conduct post-event reviews and compile report within one year of a tsunami warning.	
	Improve local warning dissemination capabilities to people at risk.	Annually increase local warning dissemination capabilities by 10%, based on the baseline established in 2010.	Develop a needs inventory of local warning dissemination capabilities by 2010.	
	Improve community warning point reception capabilities.	Annually increase local warning reception capabilities by 10%, based on the baseline established by 2010.	Develop a needs inventory of local warning reception capabilities by 2010.	

## Appendix B – State of Knowledge and Risk versus Hazard

### Current State of Knowledge

A comprehensive overview of the current state of knowledge and research needs for reducing tsunami risk can be found in the *National Tsunami Research Plan* by Bernard et al. (2007). The *Plan* contains 15 recommendations in the areas of technology, geosciences, oceanography, engineering, and social sciences to “develop, promote, and institutionalize tsunami-resilient communities in the United States”. While efforts are now underway to address some of these needs, many of the recommendations will take years, if not decades to fully implement. This strategic plan addresses the efforts of the NTHMP over the next 5 years, and consequently we

must allocate resources and prioritize efforts based on the present state of knowledge in tsunami science.

### **Risk versus Hazard**

A rational basis for allocating NTHMP resources could be predicated on tsunami risk, where risk is defined as the product of the probability of the occurrence of a tsunami (i.e., the “hazard”) times the loss of property and life due to the tsunami. The determination of tsunami risk is a relatively new field, and there are only a few case examples to follow, such as the assessment conducted for Seaside, OR (Tsunami Pilot Study Working Group, 2006). Until now, NTHMP resources have been implicitly been allocated based on tsunami hazard, as the program was restricted to the 5 states of Hawaii, Alaska, Washington, Oregon, and California where there was a historical basis for estimating tsunami hazard. Under the expanded scope of the Tsunami Warning and Education Act, the NTHMP is now charged with mitigating the effects of tsunamis for all U.S. coastal communities. However, our understanding of tsunami risk for all coastal communities is currently unknown for the following reasons.

Establishing a community’s risk requires, as a first step, an understanding of the tsunami hazards specific to each community. Dunbar and Weaver (2007) performed a comprehensive assessment of tsunami hazards for the United States but were hampered by the limited historical time period over which to assess long-term hazards. Because of the limited or absence of seismological data for historical tsunamigenic earthquakes, it was impossible for them to make rigorous determinations of the probability of a tsunami source over 50-2500 year time intervals, as is commonly done for earthquake hazard probability studies.

Dunbar and Weaver (2007) also note that offshore earthquakes as small as magnitude (M) 6.5 are too small to displace sufficient volumes of water to directly generate a tsunami, but the dynamic shaking from the earthquake can trigger a submarine slide that can generate a tsunami (Lockridge et al., 2002; Tuttle et al., 2004). The state of geologic knowledge does not permit the calculation of meaningful probabilities of occurrence for U.S. offshore  $M > 6.5$  earthquakes because seismologists cannot identify the location and areal extent of most active offshore faults, estimate the rupture recurrence interval or date of last rupture, or establish the likelihood that shaking would trigger a submarine slide. Similarly, scientists cannot establish meaningful probabilities for the likelihood of tsunamis caused by the collapse of volcanic edifices (Ward and Day, 2001), failures of the continental slope, asteroid impacts, and submarine volcanic eruptions.

Were we to have meaningful tsunami hazard assessments for all U.S. communities at risk for tsunamis in the U.S., we would then attempt to calculate inundation models for each of the tsunami hazard sources. To obtain accurate inundation models, high resolution bathymetric and onshore digital elevation models are needed. This information is expensive to obtain and currently not available for all U.S. communities at risk from tsunamis. Even were it possible to compute accurate

models of inundation and current velocities in each community for all likely tsunami sources, our understanding of the fragility of structures subjected to tsunami currents and entrained debris in a tsunami is poor. In addition, it would take substantial resources to develop the inventory of structures in each community. This strategic plan recommends that over the next 5-year the NTHMP program resources be allocated to develop U.S. tsunami risk assessment methodologies that will contribute to the future development of a U.S. Tsunami Risk Assessment.



## Appendix C – Glossary of Acronyms and Terms

CC:	Coordinating Committee of the NTHMP
CREW:	Cascadia Regional Earthquake Working Group
CZMA:	Coastal-zone Management Act
DART:	Deep-ocean Assessment and Reporting of Tsunami Network
DEM:	Digital Elevation Model
FEMA:	Federal Emergency Management Agency
GAO:	Government Accountability Office
IBC:	International Building Code
ICBO:	International Conference of Building Officials
ICG:	Intergovernmental Coordination Groups
IOC:	Intergovernmental Oceanographic Commission
MES:	Mitigation and Education Sub-Committee
Mitigation*:	Any action taken to reduce or eliminate the long-term danger to human life and property from a tsunami.
MMS:	Mapping and Modeling Sub-Committee
NIST:	National Institutes of Standards and Technology
NOAA:	National Oceanic and Atmospheric Administration
NSTC:	National Science and Technology Council
NTHMP:	National Tsunami Hazard Mitigation Program
NTHMP Regions:	Gulf Coast States, Eastern States, Pacific Islands, Hawaii, Alaska, Oregon, Washington, California, Puerto Rico, and U.S. Virgin Islands
NWS:	National Weather Service
OAR/PMEL:	Office of Atmospheric Research/Pacific Marine Environmental Laboratory
PDM:	Post-Disaster Management Program (FEMA)
SMS:	Short Message Service (Text Messaging format)
TWC:	Tsunami Warning Center
TWS:	Tsunami Warning System
UNESCO:	United Nation’s Educational, Scientific, and Cultural Organization
USGS:	United States Geological Survey
WCS:	Warning Coordination Sub-Committee
WFO:	Weather Forecast Office

\* The definition for mitigation will be modified as necessary once the NTHMP CC determines the formal definition of the term.

## Appendix D - References

Bernard, B., Dengler, L., and Yim, S. (editors), 2007, National Tsunami Research Plan: Report of a Workshop Sponsored by NSF/NOAA. NOAA Technical Memorandum OAR PMEL-133, 135p. <http://www.pmel.noaa.gov/pubs/PDF/bern3043/bern3043.pdf>

Dengler, L., 1998. Strategic Implementation Plan for Tsunami Mitigation Projects, approved by the Mitigation Subcommittee of the National Tsunami Hazard Mitigation Program, April 14, 1998. NOAA Technical Memo. ERL PMEL-113, NTIS: PB99-115552, NOAA/Pacific Marine Environmental Laboratory, Seattle, WA, 133 pp.

Dunbar, P. K. and Weaver, C. S., 2007. U. S. States and Territories National Tsunami Hazard Assessment: Historic Record and Sources of Waves, Prepared for the National Tsunami Hazard Mitigation Program.

FEMA, NOAA and ATC, 2008. Guidelines for Design of Structures for Vertical Evacuation from Tsunamis, FEMA P646, 158 pp.

Government Accountability Office. U.S. Tsunami Preparedness. 2006.  
<http://www.gao.gov/new.items/d06519.pdf>

Lockridge, P.A., Whiteside, L.S., and Lander, J.F., 2002, Tsunamis and tsunami-like waves of the eastern United States, Science of Tsunami Hazards, the International Journal of the Tsunami Society, v. 20, no. 3, p. 120–144. <http://epubs.lanl.gov/tsunami/ts203.pdf>

National Tsunami Hazard Mitigation Program, 2001. Designing for Tsunamis Seven Principles for Planning and Designing for Tsunami Hazards, 60 pp.

National Tsunami Hazard Mitigation Program 5-Year Review Recommendations, January 2008.  
[http://nthmp.tsunami.gov/documents/NTHMP\\_5yr\\_Recommendations.doc](http://nthmp.tsunami.gov/documents/NTHMP_5yr_Recommendations.doc)

National Tsunami Hazard Mitigation Program: Tsunami Risk Reduction for the United States Implementation Plan (Draft), 2007

Santos-Hernández, J. M., Rodriguez, H., Diaz, W., 2008. Disaster Decision Support Tool (DDST): An Additional step towards community resilience, UPR Sea Grant, Mayagüez, 23 pp,

Tsunami Warning and Education Act, approved December 2006.  
[http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109\\_cong\\_public\\_laws&docid=f:publ424.109.pdf](http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=109_cong_public_laws&docid=f:publ424.109.pdf)

Tsunami Pilot Study Working Group, 2006, Seaside, Oregon Tsunami Pilot Study - Modernization of FEMA Flood Hazard Maps, Joint NOAA/USGS/FEMA Special Report, 94 p., 7 appendices. <http://pubs.usgs.gov/of/2006/1234/>

Tuttle, M.P., Ruffman, A., Anderson, T., and Jeter, H., 2004, Distinguishing tsunami from storm deposits in eastern North America: The 1929 Grand Banks tsunami versus the 1991 Halloween storm, *Seismological Research Letters*, v. 75, p. 117–131.

Ward, S.N. and Day, S., 2001, Cumbre Vieja volcano—Potential collapse and tsunami Canary Islands, *Geophysical Research Letters*, v. 28, no. 17, p. 3397–3400.

Wildavksu, A., 1991. *Searching for Safety*: Transaction Books.