United States Government Accountability Office

GAO

Report to Congressional Committees and Senator Dianne Feinstein

June 2006

U.S. TSUNAMI PREPAREDNESS

Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain

GAO-06-519

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Highlights

Highlights of GAO-06-519, a report to congressional committees and Senator Dianne Feinstein

Why GAO Did This Study

The 2004 Indian Ocean tsunami raised questions about U.S. preparedness for such an event. The National Oceanic and Atmospheric Administration (NOAA) leads U.S. detection and warning efforts and partners with federal and state agencies in the National Tsunami Hazard Mitigation Program (NTHMP) to reduce tsunami risks. In 2005, Congress appropriated $17.24 million in supplemental funding to enhance these efforts.

This report (1) identifies U.S. coastal areas facing the greatest tsunami hazard and the extent to which potential impacts have been assessed, (2) discusses the effectiveness of the existing federal tsunami warning system, (3) describes efforts to mitigate the potential impacts of tsunamis on coastal communities, and (4) assesses NOAA's efforts to develop long-range plans for federal tsunami programs.

What GAO Recommends

GAO recommends, among other things, that NOAA take steps to develop software for tsunami loss estimation, conduct periodic end-to-end warning system tests, increase high-risk community participation in its tsunami preparedness program and prepare risk-based strategic plans for its efforts.

NOAA reviewed a draft of this report and generally agreed with the findings and recommendations.

www.gao.gov/cgi-bin/getrpt?GAO-06-519.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Anu Mittal at (202) 512-3841or mittala@gao.gov.

What GAO Found

NOAA has determined that the Pacific coast states of Alaska, California, Hawaii, Oregon and Washington, as well as Puerto Rico and the U.S. Virgin Islands in the Caribbean Sea, face the greatest tsunami hazard. The east and Gulf coasts are relatively low-hazard areas. While high-hazard areas have been identified, limited information exists on the likely impacts of a tsunami in those areas. Some coastal areas lack inundation maps showing the potential extent of tsunami flooding in communities, and others have maps that may be unreliable. State assessments of likely tsunami impacts on people and infrastructure have been limited, in part, due to a lack of tsunami loss estimation software, as exists for floods and other hazards.
Although federal warning centers quickly detect potential tsunamis and issue warnings, false alarms and warning system limitations hamper their effectiveness. Some state and local emergency managers have raised concerns about false alarms—the 16 warnings issued since 1982 were not followed by destructive tsunamis on U.S. shores—potentially causing citizens to ignore future warnings. Furthermore, limitations in the Emergency Alert System and NOAA Weather Radio All Hazards may impede timely warnings to communities. For example, signal coverage for these two systems is insufficient to transmit warnings to some coastal areas and failure to properly activate them has resulted in warnings being delayed or not transmitted to some locations. NOAA has begun addressing false alarms but, according to agency officials, lacking the states' permission elsewhere, has only conducted "live" end-to-end testing of the warning systems in Alaska to identify problems.

The at-risk communities GAO visited have mitigated potential tsunami impacts through planning, warning system improvements, public education, and infrastructure protection, but the level of implementation varies considerably by location. Most of the states and some communities GAO visited have basic mitigation plans identifying tsunami hazards. While all of these locations have multiple warning mechanisms in place, disruptions to key infrastructure such as telephone lines may hamper timely warnings. Furthermore, key educational efforts, such as distributing evacuation maps and developing school curricula have not been consistently implemented. In addition, few states and communities protect critical infrastructure from tsunamis through land-use and building design restrictions. Emergency managers attributed variability in their efforts to the need to focus on more frequent hazards like wildfires and to funding limitations. Furthermore, few communities participate in NOAA's preparedness program, according to NOAA officials, because they perceive the threat of a tsunami to be low.
The nationwide expansion of NOAA's tsunami-related activities and NTHMP is under way; however, the future direction of these efforts is uncertain because they lack long-range strategic plans. NOAA has yet to identify long-range goals, establish risk-based priorities, and define performance measures to assess whether its tsunami-related efforts are achieving the desired results.

Contents

Abbreviations

DART	Deep-ocean Assessment and Reporting of Tsunamis
EAS	Emergency Alert System
FEMA	Federal Emergency Management Agency
HAZUS—MH	Hazards U.S.—Multi-Hazard
NOAA	National Oceanic and Atmospheric Administration
NTHMP	National Tsunami Hazard Mitigation Program
NWS	National Weather Service
USGS	U.S. Geological Survey

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United States Government Accountability Office
Washington, DC 20548

June 5, 2006

The Honorable Ted Stevens
Chairman
Committee on Commerce, Science and Transportation
United States Senate

The Honorable Daniel K. Inouye
Co-Chairman
Committee on Commerce, Science and Transportation
United States Senate

The Honorable Don Young
Chairman
Committee on Transportation and Infrastructure
House of Representatives

The Honorable James L. Oberstar
Ranking Democratic Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Dianne Feinstein
United States Senate

The Indian Ocean tsunami of December 2004 killed more than 200,000 people, displaced more than 1.5 million, and caused significant damage in 12 countries in Asia and East Africa. Although the earthquake that triggered the tsunami was immediately detected, the existence of a tsunami was not quickly confirmed, and a warning message was not delivered to most of those in the tsunami's path. As a result, casualties and damage occurred not only near the earthquake's source, where communities had little time to react, but also in distant coastal communities that were impacted by tsunami waves hours later. The devastation caused by the Indian Ocean tsunami has raised concerns about the vulnerability and preparedness of U.S. coastal communities and the ability of our detection and warning systems to help prevent a similarly destructive event.

A tsunami is a series of ocean waves typically generated by an underwater earthquake.[1] A tsunami wave may be very small in the deep ocean, but as it approaches land can increase to tens of feet in height and reach shore as a fast-moving wall of turbulent water. Tsunamis pose an inundation threat to low-lying coastal communities from multiple destructive waves that can penetrate far inland. Tsunamis are categorized as either distant or local. Distant tsunamis travel long distances from their triggering events to strike the coast hours later, allowing time to warn and evacuate threatened communities. Local tsunamis strike the coast minutes after their near-shore triggering event, allowing little time for warning and evacuation. However, the frequency of damaging tsunamis in the United States has been low, compared with other natural hazards, such as hurricanes, earthquakes, and floods.

The National Oceanic and Atmospheric Administration (NOAA) manages federal tsunami detection and warning efforts. NOAA's National Weather Service (NWS) operates two tsunami warning centers whose staff monitor seismic data and, based on the location and magnitude of earthquakes, issue warnings when tsunamis are likely. The warning centers transmit a tsunami warning message to NWS forecast offices and state emergency management centers, among others.[2] NWS forecast offices transmit the warning over NOAA Weather Radio All Hazards (NOAA Weather Radio) and the Emergency Alert System. NOAA Weather Radio is a nationwide network of radio stations broadcasting continuous weather information, including warnings, watches, forecasts and other hazard information, 24 hours a day directly from NWS weather forecast offices. The Federal Communication Commission's Emergency Alert System, designed to provide the President a means to communicate with the American people in the event of an emergency, can decode and retransmit NOAA Weather Radio warning messages over radio and television broadcast and cable systems.

Federal, state, and local government agencies are all involved in efforts to reduce the potential impacts of tsunamis through education, hazard assessment, mitigation planning, and other activities. For example, NOAA

[1]Landslides, volcanic activity, and meteor strikes may also generate a tsunami.

[2]NWS is the official U.S. source of warnings for life-threatening weather conditions, as well as tsunamis. NWS operates 122 weather forecast offices nationwide, providing weather, water and climate forecasts and warnings for the United States, its territories, adjacent waters and ocean areas to protect life and property and enhance the national economy.

operates a tsunami preparedness recognition program known as TsunamiReady that encourages communities to educate citizens on tsunami hazards, develop tsunami hazard plans, and establish local warning systems, among other things. In addition, NOAA provides leadership and funding for the National Tsunami Hazard Mitigation Program (NTHMP). This program, initiated in 1996, has been a partnership between NOAA; the U.S. Geological Survey (USGS); the Federal Emergency Management Agency (FEMA); and five states—Alaska, California, Hawaii, Oregon and Washington—to assess tsunami hazards, improve and coordinate tsunami warning systems, and develop state and local hazard mitigation programs.[3] For example, under the NTHMP, NOAA provides funding and technical support to help the states produce inundation maps showing the extent to which coastal areas may be flooded by a tsunami. Communities use these maps to help identify people and property at-risk and to develop strategies for mitigating the hazard. Furthermore, the Stafford Act, as amended by the Disaster Mitigation Act of 2000, requires all states and localities to develop FEMA-approved hazard mitigation plans to qualify for certain disaster relief funding.[4] These plans provide a framework for states and communities to assess their vulnerability to all hazards and, if a significant tsunami threat exists, develop approaches to reduce tsunami impacts on people and infrastructure within their jurisdictions.

In May 2005, the Congress appropriated $17.24 million in supplemental funds for NOAA to expand and improve its tsunami detection capabilities, enhance warning center operations and facilities, produce tsunami inundation forecast models, and expand the TsunamiReady program participation nationwide.[5] In fiscal year 2006, $9.82 million in appropriations were designated for tsunami-related activities, and NOAA requested $21.66 million for fiscal year 2007.[6] NOAA is initially spending these funds primarily on enhancing its tsunami detection capabilities, for

[3]As of March 2006, NOAA was expanding the NTHMP into a nationwide program open to participation by 28 coastal states and territories.

[4]42 U.S.C. § 5165.

[5]After a tsunami-generating event, inundation forecast models combine actual wave data with precomputed flooding scenarios to predict the size of the wave and the extent of potential flooding for specific locations.

[6]The $9.82 million designated for tsunami-related activities in fiscal year 2006 includes over $2.5 million for specific activities, such as $500,000 for warning sirens for the state of Washington.

example, by expanding its network of Deep-ocean Assessment and Reporting of Tsunamis (DART) detection stations in the Pacific Ocean to 39 stations covering the Pacific and Atlantic Oceans and the Caribbean Sea.

To address questions regarding the status of national tsunami preparedness, this report (1) identifies U.S. coastal areas facing the greatest tsunami hazard and the extent to which potential tsunami impacts on people and infrastructure have been assessed; (2) discusses the effectiveness of the existing federal tsunami warning system; (3) describes ongoing local, state, and federal agency efforts to mitigate the potential impacts of tsunamis on coastal communities; and (4) assesses NOAA's efforts to develop long-range plans for federal tsunami programs.

In conducting our work, we visited the states participating in the NTHMP—Alaska, California, Hawaii, Oregon, and Washington—as well as Puerto Rico and Florida. We met with federal, state, and local officials, reviewed documentation related to tsunami hazard assessment, warning and mitigation efforts, and analyzed plans for current and future tsunami preparedness activities. To identify the U.S. coastal areas facing the greatest tsunami hazard and the extent to which their vulnerability to tsunami impacts has been assessed, we reviewed historic and seismic data and analysis from NOAA and other federal and state sources. For the states facing the greatest tsunami hazards, we determined the extent to which tsunami inundation maps identifying the potential vulnerability of people and infrastructure have been prepared, and reviewed each state's FEMA-approved, all-hazard mitigation plan to determine how and to what extent tsunami impacts have been assessed.

To discuss the effectiveness of the current federal tsunami warning system, we visited both of NOAA's tsunami warning centers and met with officials to discuss how they conduct their detection and warning responsibilities and how they measure their effectiveness. In addition, we visited selected NOAA warning forecast offices, met with officials to determine how tsunami warnings are disseminated and tracked, and met with state emergency managers to determine how they receive warnings and to obtain their views regarding the effectiveness of the warnings. We also reviewed reports prepared by NOAA and by state emergency managers that evaluated the effectiveness of warnings issued by NOAA on June 14, 2005, due to a potentially tsunami-generating earthquake off the Northern California coastline.

To describe local, state, and federal agency efforts to mitigate the potential impacts of tsunamis on coastal communities, we initially met with state emergency managers and reviewed state mitigation documents. Because comprehensive statewide data on local mitigation activities does not exist, we next visited selected at-risk communities recommended by state emergency managers. The communities we visited are Seward and Kodiak, Alaska; San Mateo County and Crescent City, California; Hilo and Honolulu, Hawaii; Seaside and Gold Beach, Oregon; Mayaguez and Rincon, Puerto Rico; and Ocean Shores and Long Beach, Washington. We discussed tsunami preparedness efforts with the community emergency managers, such as planning, warning, education and outreach, infrastructure protection, and the TsunamiReady program and obtained documentation of their efforts and activities in these areas. We also met with NOAA officials involved with the TsunamiReady program and reviewed program documentation.

To assess NOAA's efforts to develop long-range plans for federal tsunami programs, we met with NOAA officials and reviewed plans for NOAA's ongoing tsunami activities, as well as schedules for the completion of NOAA's Tsunami Program expansion. We also met with National Tsunami Hazard Mitigation Program participants, including NOAA, USGS, FEMA, and state representatives and reviewed program documentation to determine how NOAA is planning for the future management and direction of its tsunami activities.

We conducted our work between April 2005 and March 2006 in accordance with generally accepted government auditing standards.

Results in Brief

The coastal areas of the five states bordering the Pacific Ocean and U.S. territories in the Caribbean face the greatest tsunami hazard, but reliable and comprehensive assessments of the potential impacts on people and infrastructure have not been completed for many of these areas. According to NOAA, the general areas most threatened by both distant and local tsunamis are Hawaii and the west coast states of California, Oregon, and Washington, whereas Alaska, Puerto Rico, and the U.S. Virgin Islands are threatened primarily by local tsunamis. Historically, the east coast and the Gulf coast tsunami hazards are relatively low. Because inundation maps are the foundation for evaluating potential tsunami impacts on communities, map production has been a high priority for NOAA and the threatened states. However, progress on this front has been slow—for example, Alaska has inundation maps for only 5 of 60 at-risk communities—primarily because accurate maps are complex and costly

for states to produce. To effectively prepare for a tsunami, states and localities also need to assess the potential impacts of a tsunami on people and infrastructure. While FEMA has standardized computer software for comprehensively estimating the likely human, structural, and economic damages from natural disasters such as floods, hurricanes and earthquakes, no such tool exists for tsunamis. For this and other reasons, California and Alaska have not specifically assessed potential tsunami losses, while the other at-risk areas have produced limited tsunami damage assessments. Consequently, emergency managers in the at-risk states and U.S. territories do not have comprehensive information on how many and what types of structures would be exposed and damaged, how many people could be injured or killed, or the extent of potential short and long-term economic impacts of a tsunami. We are recommending that NOAA work with FEMA and USGS to create standardized tsunami loss estimation software.

Although NWS's warning centers can quickly detect potential tsunamis and issue warnings, the effectiveness of these warnings is hampered by false alarms and limitations in the federal systems that transmit warnings to the local level. NWS's warning centers have rapidly analyzed seismic data to detect potential tsunamis, and if the location and magnitude of an earthquake indicated that a tsunami was likely, the centers generally issued a warning within 5 to 10 minutes for local tsunamis. However, some state and local emergency management officials have raised concerns about false alarms, because the warnings proved to be unnecessary—no damaging waves actually reached U.S. shores following the 16 warnings issued since 1982—or were overly broad and included communities that were not imminently threatened. Such warnings can cause unnecessary and costly evacuations and, experts warn, may cause people to ignore future warnings. NWS has begun addressing false alarm concerns, for example, by expanding the network of DART stations that help warning centers confirm whether a tsunami has been generated, but it has not set specific performance targets for reducing the number, scope, and duration of false alarms. We are recommending that NOAA take specific steps, such as reexamining its rules for when a warning will be issued and to which areas, to reduce false alarms. Furthermore, although NWS warning centers effectively transmit tsunami warnings to NWS forecast offices, these offices do not always send timely warnings to affected local areas because the two primary federal warning alert systems—the Emergency Alert System and NOAA Weather Radio—have significant limitations. For example, signal coverage for these two systems is insufficient to transmit warnings to some coastal areas. This shortcoming was highlighted in June 2005, when an actual tsunami warning for the west coast was issued but

signal problems prevented the warning from reaching portions of the coasts of Washington and Oregon. Also, to properly activate these warning systems, NWS forecast office staff must enter a tsunami-specific code into a computer. During the June 2005 event, failure to do so in a timely manner or at all resulted in warnings being delayed or not transmitted to some locations. NOAA has only conducted end-to-end tests of the tsunami warning system using actual "live" warning codes, rather than test codes, in Alaska to identify problems before actual events occur. In commenting on a draft of this report, NOAA said that it conducts such end-to-end testing where allowed and uses test codes in other states. We are recommending that NOAA continue to work with the states to conduct end-to-end testing that ensures the system will function as intended during an emergency.

The at-risk communities we visited have taken actions to mitigate tsunami impacts through planning, warning system improvements, public education, and infrastructure protection; however, the level of implementation among these locations varies considerably. Each of the six states we visited have FEMA-approved, all-hazard mitigation plans that identify tsunami hazards; and most have taken the additional step of identifying actions to mitigate those hazards, such as relocating critical facilities out of inundation zones. However, only 4 of the 12 communities we visited have developed FEMA-approved plans that include tsunami mitigation projects. Further, while all of the states and communities we visited have developed some mechanisms for warning people about a tsunami threat, communications problems may hamper some communities' ability to receive and disseminate warnings in a timely manner. For example, during the west coast tsunami warning in June 2005, many 911 dispatch centers and telephone lines were overloaded, in some cases, preventing local emergency managers from quickly disseminating the warning to other local officials and preventing telephone-based warning systems from reaching residents. Moreover, while state and local officials recognize the need to educate the public, key efforts identified by tsunami preparedness experts—such as distributing evacuation maps and developing school curricula—have not been consistently implemented across the states and communities we visited. For example, only two of the six at-risk states we visited have developed and implemented tsunami preparedness curricula in schools. In addition, few states and localities have implemented long-term mitigation efforts such as land-use restrictions and building design codes to prevent loss of life and reduce economic damage. Overall, state and local emergency managers attributed the variability in tsunami preparedness efforts to a variety of factors, including their focus on other higher priority natural hazards and a lack of

funding. Furthermore, only a few communities in coastal areas have chosen to participate in NOAA's voluntary TsunamiReady program, which is designed to help them take the initial steps in tsunami mitigation. NOAA officials believe that TsunamiReady participation is limited because of community perceptions of a low tsunami threat and perceived high cost versus benefit. We are recommending that NOAA evaluate the TsunamiReady program to determine how to increase participation by high-risk communities.

Efforts are under way to significantly expand federal tsunami detection and related activities as well as the NTHMP; however, the future direction of these efforts is uncertain because NOAA has not established long-range strategic plans to guide them. Strategic plans are important because they help agencies set specific program goals and objectives, define performance measures for assessing program effectiveness, ensure coordination of existing activities and establish risk-based priorities. Prior to the Indian Ocean tsunami in December 2004, NOAA's various tsunami-related activities, such as warning center operations, the TsunamiReady program, and tsunami-related research, were not managed as a formal, integrated program. NOAA combined the activities in 2005 into a single program and is currently strengthening and expanding certain elements of the program. However, NOAA has not yet adopted a comprehensive, risk-based strategic plan to guide its expanded tsunami program into the future. NOAA officials told us they expect to finalize such a plan during 2006. In addition, the plan that NOAA is using to guide the NTHMP activities has not been updated since 1996, and the program's performance has not been formally assessed since 2001. As a result, some issues raised in the 2001 assessment, such as lack of performance measures, remain concerns of state NTHMP members today. Representatives of the five original high-hazard NTHMP states are also concerned that the program's funding decisions and strategic direction may become less risk-based as states that face relatively low hazards join the program. Without an updated, risk-based strategic plan for the expanded NTHMP, NOAA will have difficulty ensuring that the most threatened states get the resources they need to continue and complete key mitigation activities. We are recommending that NOAA evaluate the NTHMP to determine what has worked well and what high-priority activities remain to be completed and develop comprehensive risk-based strategic plans for the Tsunami Program and NTHMP.

In commenting on a draft of this report, the Department of Commerce representing NOAA agreed with all of our recommendations and indicated that steps will be taken to implement them. The Department of Homeland

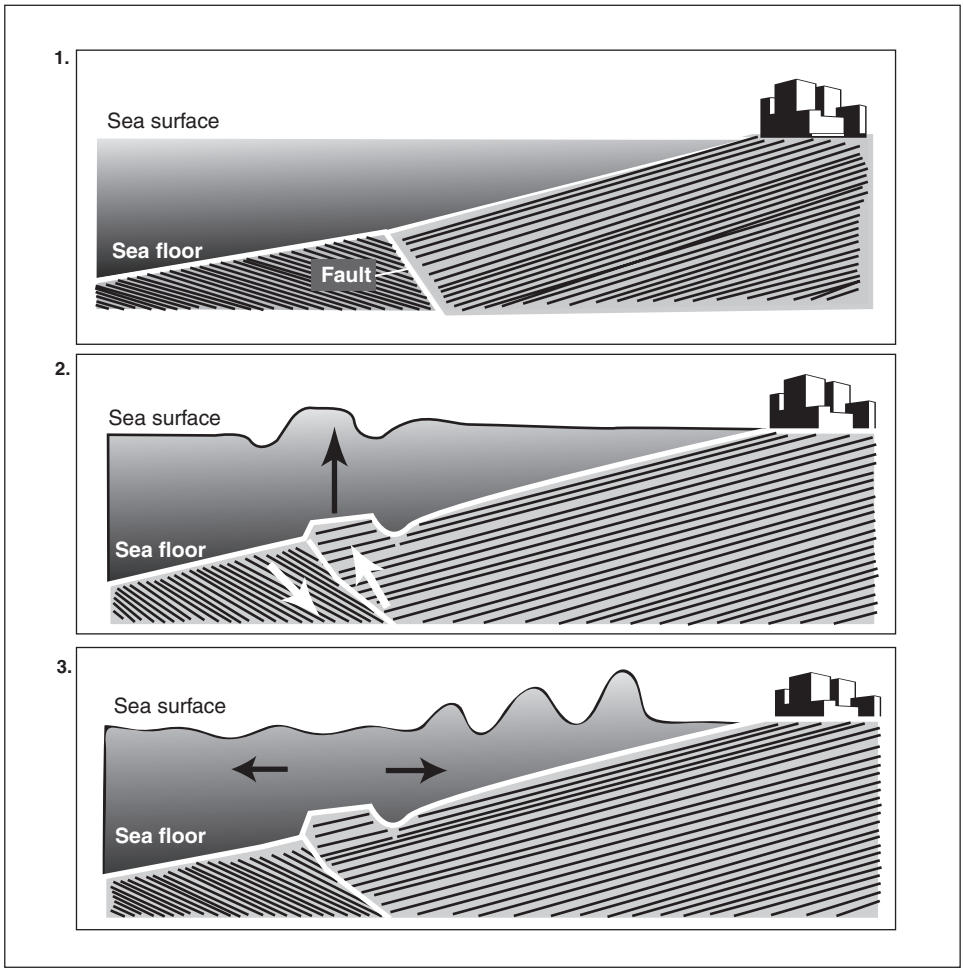
Security representing FEMA concurred with our recommendation that NOAA should work with FEMA and USGS to create standardized tsunami loss estimation software. However the department noted that FEMA does not have the resources to pursue such a request; and therefore, any request of assistance on this issue from NOAA would have to address these resource constraints. The Department of the Interior did not comment on our recommendations. The comments from the Departments of Commerce, Homeland Security, and the Interior appear in appendixes I, II and III.

Background

Tsunamis are typically generated by underwater earthquakes—landslides, volcanic activity, and meteor strikes are other known, but less common, tsunami sources. Tsunami generating earthquakes usually occur in subduction zones, such as those found in the Pacific Ocean off the U.S. western and Alaskan coasts, as well as in the Caribbean. Marked by deep trenches in the seafloor, subduction zones are formed where one of the earth's outer shell of tectonic plates plunges underneath another.[7] Usually the plates are gradually moving past each other, but friction may temporarily lock them together, causing stress to build up between the plates. Sometimes the stress is relieved suddenly in the form of a large earthquake. As shown in figure 1, the bottom plate dives farther down, snapping the top plate violently upward, disturbing the overlying seawater. The size of the resulting tsunami depends on a complex set of factors, including the size of the earthquake, its depth below the ocean floor, the depth of the water, the type and amount of seafloor movement and the energy released.

[7]Tectonic plates are the large plates of rock that compose the earth's outermost layer and move in relation to each other as they ride atop the hot, mobile material below them.

Figure 1: Subduction Zone Earthquakes Generate Tsunamis



Source: NOAA.

Once generated, some tsunami waves move quickly inland while other waves head toward the open ocean, often at speeds up to 600 miles per hour. Therefore, a tsunami generated by an earthquake off the coast of Alaska would be a local tsunami for that state's coastal areas, and could strike within minutes of the event, while the same event is considered a distant tsunami for the coast of Washington state, which would not likely be hit until 3 or more hours later.

While tsunamis can be a high impact natural hazard, the frequency of damaging tsunamis in the United States has been low, compared with other natural hazards. According to NOAA's records, the last tsunami

causing significant impacts was at Skagway, Alaska, in November 1994, where the landslide and associated tsunami caused one death and $25 million in damages. According to FEMA, flooding, severe storms, and hurricanes are the most common and costly causes of disaster declarations in the United States; at least 10 such events since 1989 have each required FEMA relief expenditures in excess of a billion dollars. Although damaging tsunamis are relatively rare, the devastation caused by the Indian Ocean tsunami demonstrates the need for assessing the threat, and for monitoring and preparing for an event in at-risk areas, particularly low-lying, seismically active coastal areas.

The West Coast/Alaska Tsunami Warning Center in Palmer, Alaska, is responsible for warning Alaska, the west coast and east coast states, and states along the Gulf of Mexico, while the Richard H. Hagemeyer, Pacific Tsunami Warning Center in Ewa Beach, Hawaii, is responsible for warning Hawaii and U.S. territories in the Pacific Ocean and Caribbean Sea.[8] These warning centers use two types of data for determining when to issue a tsunami warning. First, they receive and analyze earthquake data from seismic networks operated by NOAA, USGS, the states, and universities to determine whether to issue a warning.[9] If the seismic data indicate that a local tsunami may be generated, the responsible warning center issues a warning based on the earthquake data alone. Second, the warning centers analyze sea-level data to determine whether a tsunami has actually been generated, and if not, cancel the warning. The centers receive sea-level data through a network of DART stations and sea-level gauges, as shown in figure 2. DART stations consist of a seafloor bottom-pressure recording system that is capable of detecting tsunamis smaller than 1 inch and is connected to a surface buoy that transmits the data by satellite to NOAA. Scientists at the warning centers incorporate the data from the DART stations into tsunami forecast models to estimate the size of the expected waves and the potential impact on coastal areas. The tsunami warning centers have used forecast models they developed, as well as models

[8]The warning center in Alaska is also responsible for providing warnings to Canada, and the warning center in Hawaii is responsible for warning 27 countries in the Pacific. In addition, each warning center provides operational backup for the other center.

[9]In May 2005, the Congress appropriated $8.1 million in supplemental funds for USGS to, among other things, begin expanding the Global Seismographic Network.

developed by NOAA's Pacific Marine Environmental Laboratory, which produce expected tsunami inundations at nine high-risk locations.[10]

Figure 2: Sea-Level Tsunami Detection Methods

Source: NOAA.

DART station

Source: NOAA.

Tide gauge

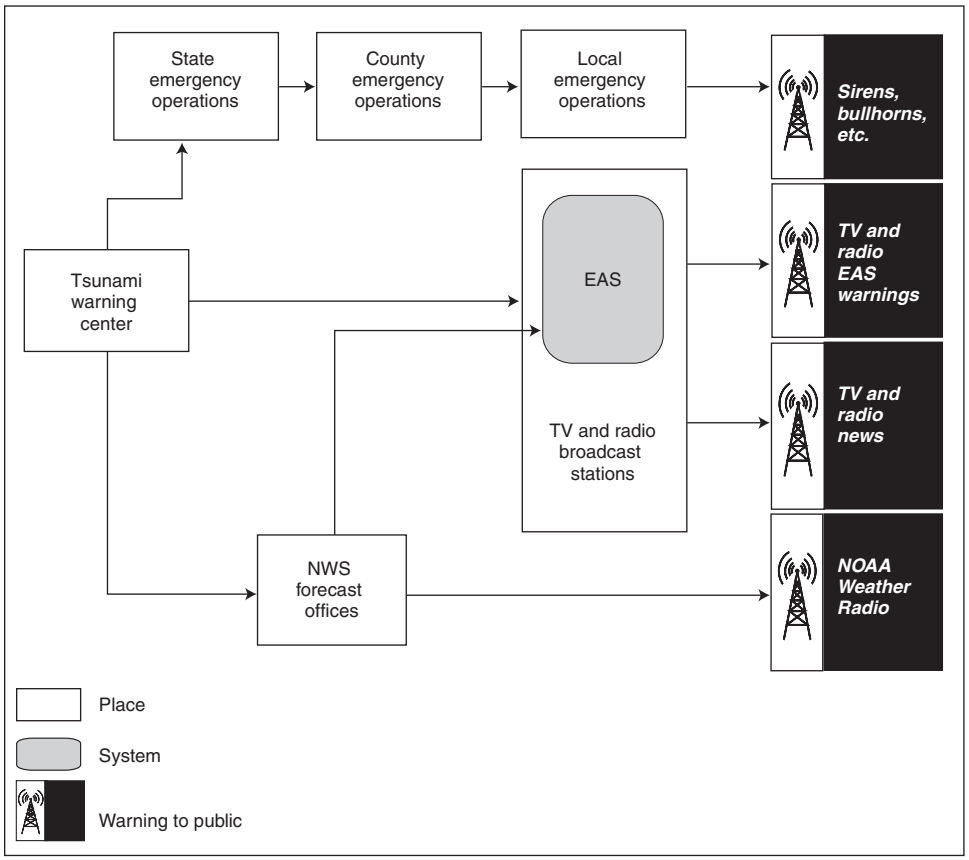
A network of federal, state, and local government agencies are responsible for ensuring that a tsunami warning reaches the public. Figure 3 provides an overview of the key components of this process. The federal tsunami warning centers send a warning to NWS forecast offices and state emergency management centers by multiple means, such as FEMA's National Warning System, a dedicated telephone hotline, and NWS's satellite-based National Weather Wire Service.[11] The forecast offices, in turn, transmit the warning over NOAA Weather Radio and the Emergency Alert System (EAS). State emergency managers receive tsunami warnings from NWS and then warn counties and local communities using multiple methods, including a dedicated telephone network for state and local emergency management officials. Finally, county and local officials are

[10]The nine completed tsunami forecast models are for Kodiak, AK; Crescent City, CA; Hilo, HI; Newport, OR; Seaside, OR; San Francisco, CA; Willapa Bay, WA; Neah Bay, WA; and Port Angeles, WA.

[11]The National Weather Wire Service transmits text-based weather forecasts and warnings to an array of subscribers, including the media.

responsible for warning the public and issuing evacuation orders, using a variety of methods including bullhorns, sirens, and telephone systems.

Figure 3: Overview of Tsunami Warning Flow



Source: GAO analysis.

Federal, state, and local government agencies also conduct hazard mitigation activities to reduce the potential impacts of tsunamis. At the federal level, NWS operates the TsunamiReady community recognition program. Initiated in 2000, TsunamiReady is modeled after NWS's StormReady program for hurricanes and tornados. NWS meteorologists in regional forecast offices are responsible for reviewing applications from coastal communities and ensuring that they meet program requirements in conjunction with state emergency management officials. NOAA also provides a chairperson and funding for the NTHMP. From 1998 through 2001, NOAA provided $2.3 million annually for the NTHMP, increasing to $4.3 million annually in 2002 through 2005, and returning to $2.3 million in

2006. Initially, the five participating states each received less than $100,000 annually from the NTHMP, but in recent years they have each received approximately $275,000 annually to directly supplement their individual mitigation efforts, while NOAA and the other federal partners used the remaining funds to support their own activities under the program. NOAA estimates that since the program's inception the states have matched the NTHMP funding by a ratio of six state in-kind or dollar contributions for every program dollar.

The Tsunami Hazard Is Greatest in the Pacific States and Caribbean Territories, but the Potential Impacts Have Not Been Comprehensively Assessed

Tsunamis pose the greatest hazard to the coastal areas of the five states bordering the Pacific Ocean and U.S. territories in the Caribbean, but for many of these areas reliable, comprehensive assessments of potential tsunami impacts on people and infrastructure have not been completed. Some high-hazard coastal areas do not have tsunami inundation maps—the foundation for evaluating potential tsunami impacts on communities—showing the extent to which a tsunami would penetrate inland and flood communities, while others have maps that may not be reliable. Progress in developing these maps has been slow, primarily because accurate maps are complex and costly for states to produce. Furthermore, states and communities do not have comprehensive information on the potential human, structural, and economic impacts of a tsunami. While FEMA has standardized computer software for estimating losses resulting from natural disasters such as floods, hurricanes, and earthquakes, no such tool exists for assessing tsunamis.

The Coastal Areas of the Pacific United States, Puerto Rico, and the U.S. Virgin Islands Face the Greatest Tsunami Hazards

According to NOAA, the general areas most threatened by both distant and local tsunami hazards are Hawaii and the west coast states of California, Oregon, and Washington, whereas Alaska and the Caribbean Islands of Puerto Rico and the U.S. Virgin Islands are threatened primarily by local tsunamis, as shown in table 1. The hazard levels are primarily based on tsunami source, height, and frequency information since 1900—the most reliable and accurate information available—from NOAA's National Geophysical Data Center tsunami database.

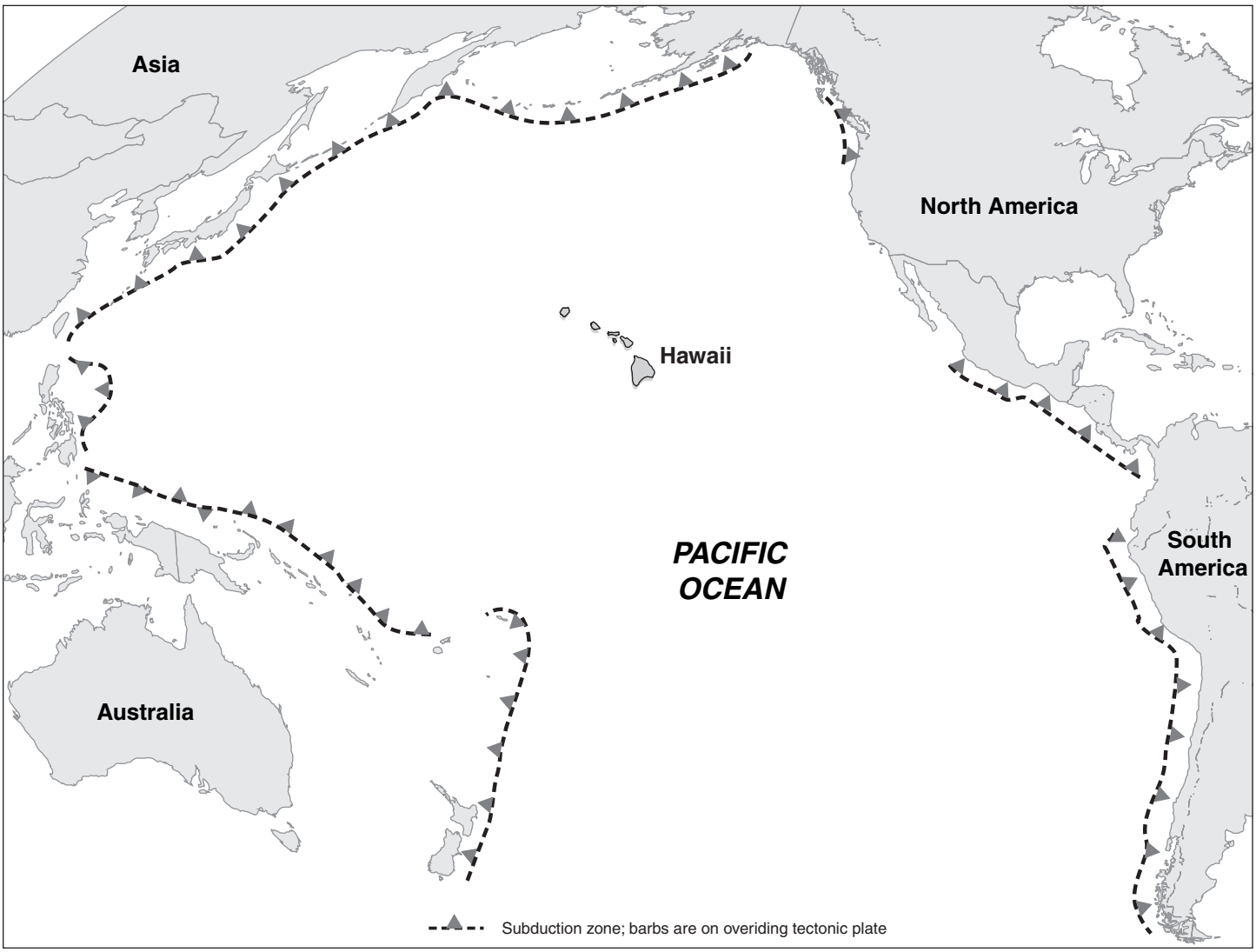
Table 1: Relative Tsunami Hazard for Distant and Local Tsunamis in U.S. Coastal Areas

Coastal area	Distant tsunami hazard	Local tsunami hazard
Hawaiian	High	High
Western	High	Medium
Alaskan	Low	High
Caribbean	Low	High
Eastern	Low	Low
Gulf	Low	Low

Source: NOAA.

According to NOAA, Hawaii is a high-hazard area for distant and local tsunamis. Hawaii has experienced many destructive tsunamis because of its location in the Pacific Ocean, as shown in figure 4, where about 80 percent of all recorded tsunamis have occurred. More than one-half of all tsunamis recorded in the Hawaiian Islands were generated in the distant Aleutian regions of the northern and northwestern Pacific Ocean, and about one-fourth were generated along the western coast of South America. Hawaii's local tsunami threat stems from earthquake and volcanic activity, which cause underwater landslides off the coast. Hawaii suffered its greatest tsunami death and destruction in 1946, when an earthquake in the Aleutian Islands generated a tsunami that reportedly killed 159 people. Hilo, Hawaii suffered the greatest loss—96 deaths and the destruction of its waterfront area. Since 1946, an additional five tsunamis—four distant and one local—have caused a reported 63 deaths and widespread destruction.

Figure 4: Pacific Ocean Subduction Zones Surround Hawaii

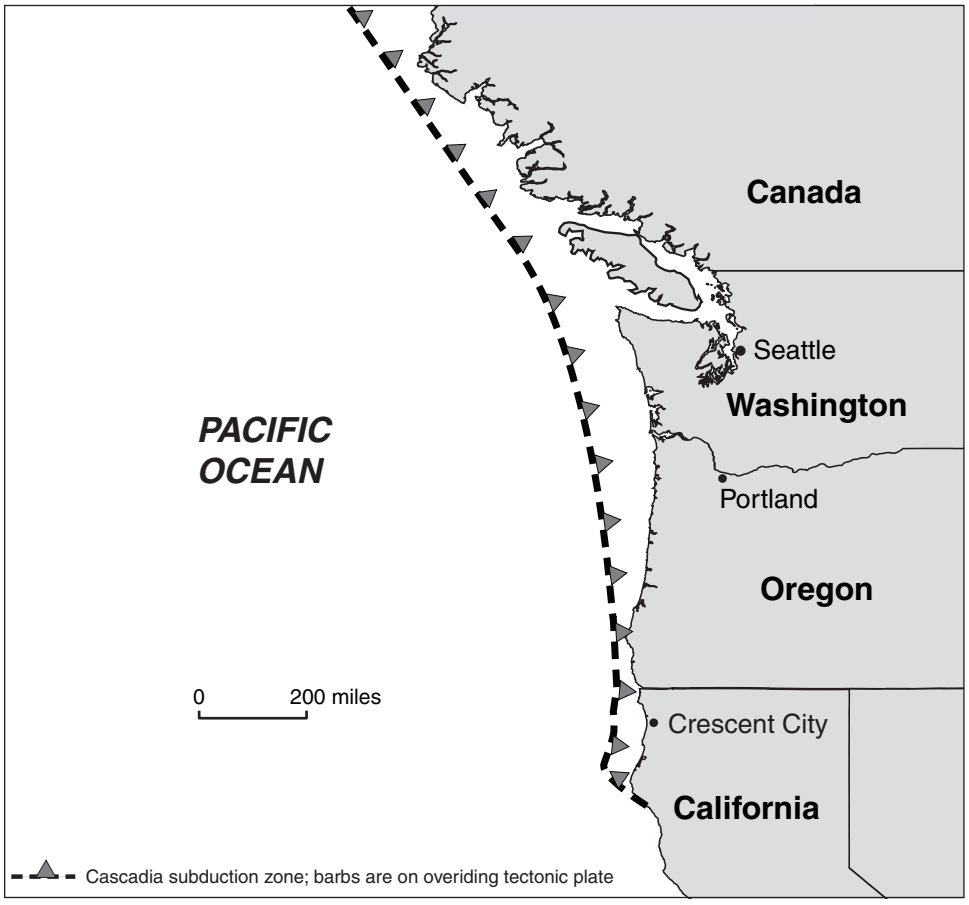


Sources: USGS and MapArt.

NOAA considers the west coast a high-hazard area for distant tsunamis and medium-hazard area for local tsunamis. Like Hawaii, the west coast historically has suffered the most destruction from tsunamis generated by Pacific earthquakes in the distant South America and Aleutian regions. In California, two tsunamis have caused significant damage. The 1960 Chilean earthquake caused estimated tsunami damages of over $1 million, and the tsunami generated by the 1964 Alaskan event killed 12 in Northern

California and caused an estimated $15 million in destruction, including damages inside San Francisco Bay. Oregon and Washington both have sustained damages in coastal areas from distant tsunamis over the years. Although distant tsunamis historically have been most common, a local tsunami generated by the 750 mile long Cascadia subduction zone, lying just 50 to 100 miles off the coasts of Washington, Oregon, and Northern California, is considered a major threat. (See fig. 5.) Geologic and other records from a Cascadia earthquake in 1700 suggest that the fault could generate a tsunami wave of up to 30 feet that would likely reach the Oregon coast in 15 to 30 minutes, raising concerns of a catastrophic future event.

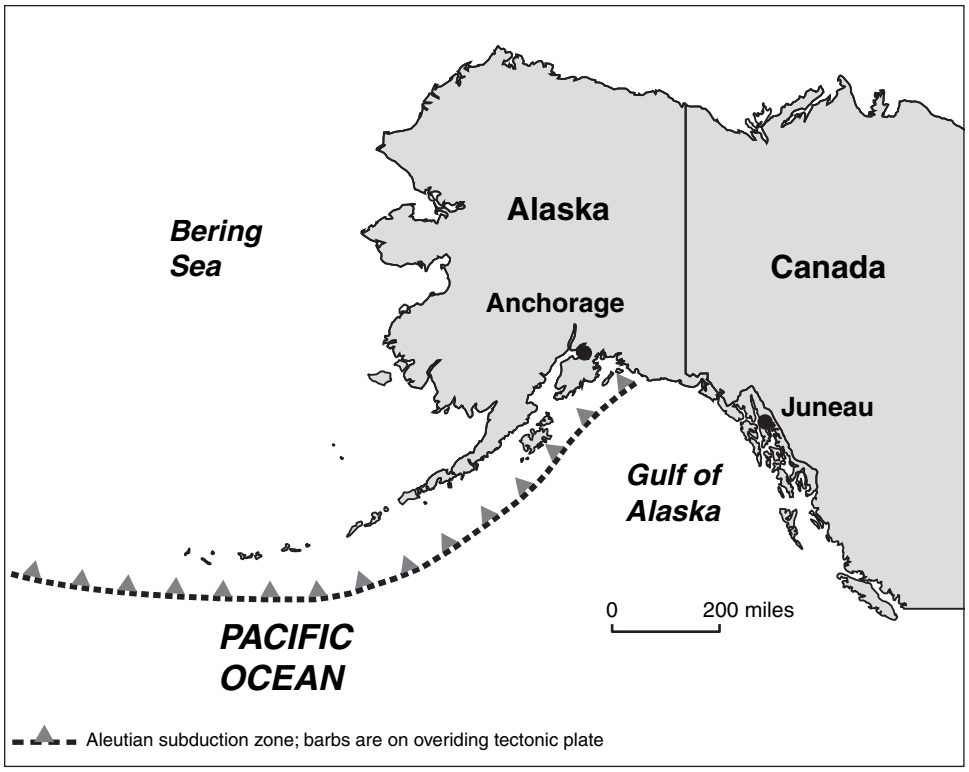
Figure 5: The Cascadia Subduction Zone



Sources: USGS and MapArt.

Alaska is a high-hazard area for local tsunamis, but a low-hazard area for distant tsunamis, according to NOAA. The local tsunami threat to Alaska is caused by seismic activity in the Aleutian subduction zone where the Pacific and North-American tectonic plates collide, as shown in figure 6. Tsunamis generated by earthquake induced landslides occurring inside bays have been responsible for most death and damage in Alaska. The 1964 Alaskan earthquake triggered several tsunamis that in some cases struck land within 2 minutes of being generated. The tsunamis caused 106 deaths in Alaska and caused significant damage in the towns of Kodiak, Seward, Whittier, and Valdez. Only once has a distant tsunami caused damage in Alaska; the 1960 Chilean earthquake caused relatively minor tsunami impacts on Alaskan harbors.

Figure 6: The Aleutian Subduction Zone

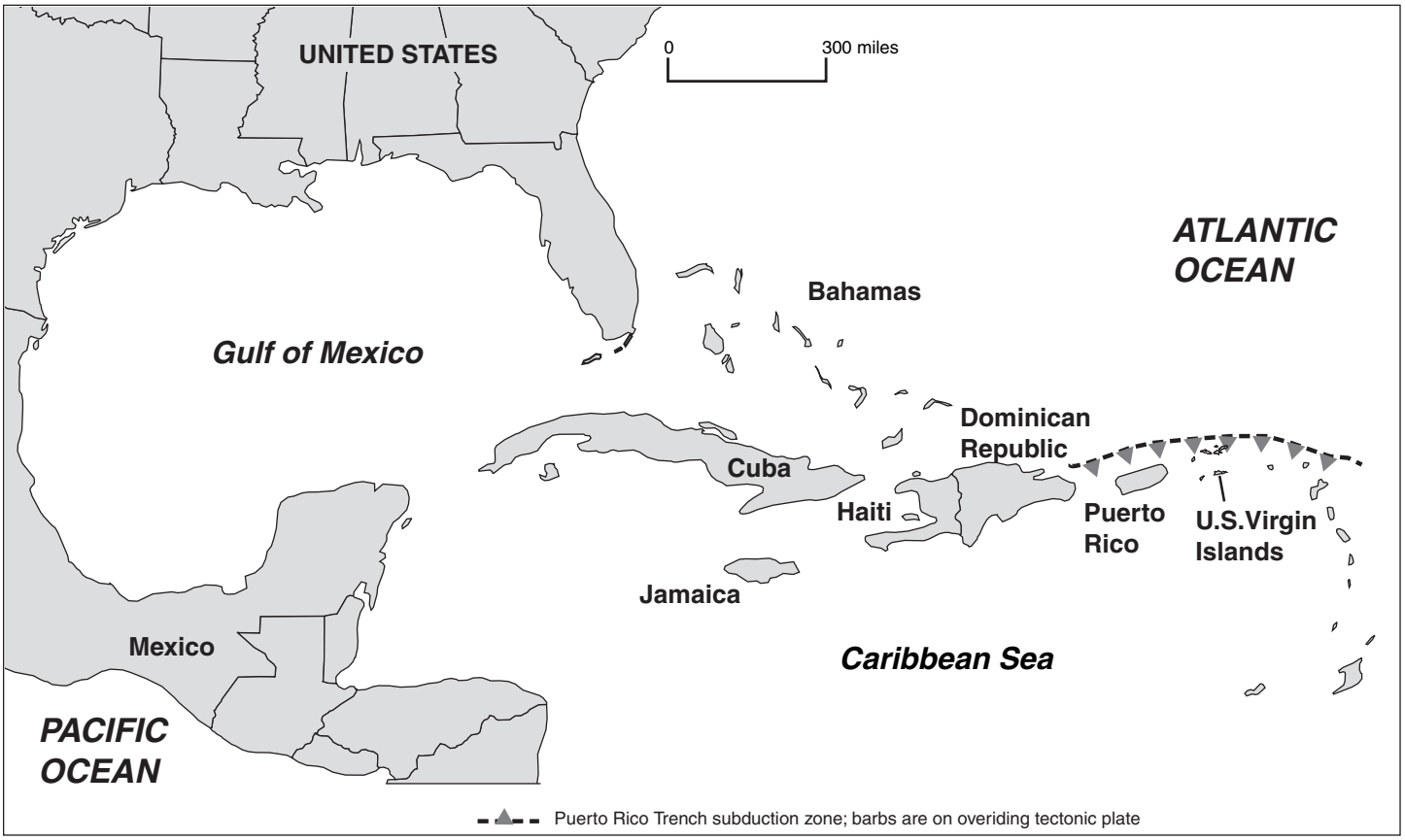


Sources: USGS and MapArt.

The Caribbean area, including the U.S. territories of Puerto Rico and the U.S. Virgin Islands, is a high-hazard area for local tsunamis but a low-hazard area for distant tsunamis, according to NOAA. The local tsunami threat posed to the islands comes primarily from the potential for

earthquakes and underwater landslides in the Puerto Rico Trench subduction zone that lies to the north of both Puerto Rico and the U.S. Virgin Islands, as shown in figure 7. Puerto Rico's most devastating event of the last century occurred in 1918, when an earthquake off the northwest coast generated a tsunami of more than 15 feet, causing an estimated 140 deaths and about $4 million in property damages. In the town of Aguadilla, nearly 300 homes were destroyed. In the U.S. Virgin Islands, an 1867 earthquake in the Anegada Trench sent destructive waves into the harbor of Charlotte Amelie on the island of Saint Thomas, destroying boats, the wharf, and the waterfront.

Figure 7: The Puerto Rico Trench Subduction Zone



Sources: USGS and MapArt.

According to NOAA, the Atlantic and Gulf state coasts are relatively low-hazard areas for distant or local tsunamis, with few reliable reports of tsunami waves of any size ever reaching either coast. This is a

consequence of the low level of tsunami generating seismic activity nearby—the nearest subduction zones are in the Caribbean. Historically, none of the tsunamis generated in the Atlantic Ocean region has significantly affected the east coast of the United States. For example, the 1929 Grand Banks earthquake-induced landslide caused a tsunami which killed 29 in Newfoundland but only resulted in a wave height of 1 foot on the U.S. coast, and a distant tsunami generated by a massive earthquake near Lisbon, Portugal in 1755 had no observed impact on the U.S. coast. The potential distant threat from the collapse of a volcanic island off the coast of Africa is the subject of scientific debate, and the potential for a local tsunami-generating collapse of the continental shelf off of the east coast is being investigated but is unconfirmed. Regarding the Gulf coast, an earthquake in the Caribbean is considered the most likely source of a tsunami; however, scientists believe that Florida and Cuba protect the Gulf from Caribbean tsunamis and that the Gulf is unlikely to propagate a large, destructive tsunami wave.

Potential Tsunami Impacts on People and Infrastructure Have Not Been Comprehensively or Reliably Assessed

Because inundation maps are the foundation for evaluating the potential impacts of tsunami events, producing such maps has been a high priority since 1996 for NOAA and the five states participating in the NTHMP. To optimize time and resources, the NTHMP partners agreed that (1) the states would identify the high-priority communities to be mapped; (2) NOAA, state, and university tsunami modeling scientists would use models to produce inundation information for high-priority areas identified by the states; and (3) state and local officials would produce and publish official inundation maps. NOAA's Center for Tsunami Inundation Mapping Efforts at its Pacific Marine Environmental Laboratory assists the modelers and the states in their efforts.

Although the NTHMP planned to complete mapping for all at-risk U.S. coastal communities by 1999, progress has been slowed, primarily because more accurate—but also more complex and costly—mapping techniques have been adopted by the states. Initially, the NTHMP planned to use relatively simple modeling technology because this approach would require fewer resources than the more advanced technique, known as two-dimensional modeling, which requires detailed seafloor and coastal terrain data to accurately model wave action and impact. Upon comparison of these two technologies, the NTHMP decided in December 1996 to use two-dimensional modeling techniques for all mapping. While the NTHMP members recognized that adopting two-dimensional modeling would reduce the pace of modeling and mapping, they agreed that the decision would result in products of improved detail, quality, and reliability.

Consequently, in the five states participating in the NTHMP, some coastal areas currently do not have two-dimensional tsunami inundation maps, while other coastal areas have inundation maps that predate current modeling standards and therefore may not be reliable.[12] Specifically:

- Alaska has produced two-dimensional inundation maps for 5 communities, while 60 additional communities are prioritized, but have yet to be mapped;
- California has produced two-dimensional inundation maps for 11 coastal counties, excluding some areas such as harbors, while maps are being produced for the remaining 4 counties;
- Hawaii has 66 maps covering the entire coastline that predate current modeling standards; because the existing maps may underestimate inundation areas, the state initiated a two-dimensional mapping program in 2005 that has produced one map;
- Oregon has 52 maps covering the entire coastline that predate current modeling standards; since 1996 the state has produced two-dimensional maps for 9 communities, and 17 additional communities are prioritized but have not yet been mapped; and
- Washington has two-dimensional maps for its southern coast as well as many northern areas, while eight additional maps have been prioritized but remain incomplete for certain coastal bay and Puget Sound communities.

To effectively prepare for a tsunami, states and localities also need to assess potential impacts on people and infrastructure. According to FEMA risk assessment guidance, after mapping how and where hazards will impact an area, planners should determine what elements of the population, infrastructure, and economy will be impacted by the hazards and estimate the potential losses that could occur. According to FEMA, estimating losses is essential for decision making at all levels of government, including providing a basis for developing mitigation plans

[12]Separate from the NTHMP, Puerto Rico has produced two-dimensional tsunami inundation maps for its entire coastline, and the U.S. Virgin Islands has produced maps for St. Croix, St. John, and St. Thomas that roughly estimate tsunami inundation based on the wave that struck the islands in 1867.

and policies, emergency preparedness, and response and recovery planning.

Each of the five Pacific region states, as well as Puerto Rico and the U.S. Virgin Islands, have identified tsunamis as a hazard in their FEMA-approved, all-hazard mitigation plans.[13] To obtain FEMA approval, states are required to describe and estimate losses—based on their own and local jurisdiction assessments—for state-owned or -operated buildings, infrastructure, and critical facilities in areas subject to hazards. According to FEMA, the agency deliberately took the approach of not being highly prescriptive regarding the development of the plans—focusing its requirements more on what should be done rather than how it should be done—in recognition of the inherent differences among states in terms of size, resources, capabilities, and vulnerability. For example, states are highly encouraged, but not required, to consider impacts on vulnerable populations, in particular elderly, disabled, and low-income persons, and to analyze the potential economic and human impact that each hazard would have statewide. FEMA also encourages the use of several tools in preparing damage assessments, such as HAZUS-MH (Hazards U.S.—Multi-Hazard), which is standardized computer software for comprehensively estimating the likely human, structural, and economic damages from earthquakes, floods, and hurricane winds. However, HAZUS-MH does not include a tsunami loss estimation module; and according to FEMA, there is no similarly reliable tool for estimating tsunami losses.

The National Science and Technology Council's December 2005 report on tsunami risk reduction specifically called for FEMA, NOAA, and USGS to take responsibility for developing a coordinated risk-assessment tool—e.g., HAZUS—for effective use in tsunami risk assessments.[14] The National Institute of Building Sciences—which produced the existing HAZUS-MH software for other hazards in partnership with FEMA—has estimated that developing tsunami loss estimation methods and software would take about 3 years, at a cost of up to $10 million. A standardized tsunami loss estimation tool would not only help the existing five NTHMP-member states conduct risk assessments, but it would also be useful to any additional states joining the NTHMP as it expands into a national program;

[13]In addition, the Atlantic coast states of Connecticut, Delaware, Florida, New Hampshire, New Jersey, Maine, and North Carolina have also identified tsunamis as a hazard.

[14]"Tsunami Risk Reduction for the United States: A Framework for Action." National Science and Technology Council, December 2005.

and it could also help the NTHMP and NOAA prioritize tsunami activities to focus on the areas most vulnerable to tsunami losses.

Because of the lack of tsunami inundation maps, the variability in approaches that was allowed in the all-hazard plans, and the lack of a standardized tsunami loss estimation tool, some at-risk states have not specifically assessed potential tsunami impacts, while other at-risk states or territories have produced assessments that do not provide complete loss information for all areas. Consequently, emergency managers in the at-risk states and territories do not have comprehensive information on how many and what types of structures would be exposed and damaged, how many people would likely be injured or killed, or the extent of likely short- and long-term economic impacts in the event of a tsunami.[15] For example:

- Alaska has not assessed tsunami impacts because the state lacks detailed inundation information for many at-risk coastal communities;
- California assessed impacts from its high-risk earthquake hazard where tsunamis are identified as a subhazard, but the state has not specifically assessed tsunami impacts; and
- Hawaii assessed tsunami impacts on the state's critical infrastructure and estimated the average annualized property loss; but the state did not estimate injuries, deaths or the overall economic impacts due to tsunamis.

According to NOAA officials, risk assessments for coastal areas requires the careful analysis of information such as tsunami frequency, site-specific tsunami inundation levels, and population density; but they acknowledge that such information is not available for many at-risk areas. Nevertheless, in March 2006, NOAA developed a preliminary estimate of the tsunami risk to people on beaches in various areas, including the Pacific region, Florida's east coast, and the Caribbean region. Based on historical tsunami frequency information from the 1700's to the present, and estimates of current daily beach attendance, NOAA's analysis suggests that while large tsunamis occur more often in the Pacific region, over a 100-year time frame, the potential loss of life in the Caribbean and Florida regions could be greater due to higher beach attendance in these warm water locations.

[15]The seven Atlantic coast states that identified tsunamis as a hazard did not assess tsunami impacts either because they concluded that the tsunami risk was low or because they lacked adequate information on the hazard to permit assessment of tsunami impacts.

Federal Warning Centers Quickly Detect Potential Tsunamis, but Warning Systems Have Limitations

NWS's two tsunami warning centers quickly detect potential tsunamis and issue warnings, but the effectiveness of these warnings has been hampered by frequent false alarms and limitations in the federal systems that transmit warnings to the local level. Experts warn that false alarms may generate unnecessary and costly evacuations and cause people to ignore future warnings. NWS is working to reduce the number and duration of false alarms, but it has not established any specific performance targets for reducing them. Furthermore, although the warning centers quickly transmit tsunami warnings to NWS forecast offices, the forecast offices do not always send timely warnings to affected local areas because the two primary federal warning systems—the Emergency Alert System and NOAA Weather Radio—have significant limitations.

NWS Quickly Detects Potential Tsunamis and Issues Warnings, but False Alarms Are a Concern

NWS's tsunami warning centers' goal is to issue "timely, accurate, reliable, and effective" warnings to protect coastal populations from tsunamis. Based on warning center data, the centers issued timely warning bulletins, generally within 5 to 10 minutes for local events.[16] The tsunami warning centers have consistently reduced their average annual time to issue bulletins—from 11 minutes in 1996 to 6.4 minutes in 2005 for the center in Alaska, and from 16 minutes in 1996 to 4.5 minutes in 2005 for the center in Hawaii. According to tsunami warning center officials, more and better quality seismic data, as well as improved analysis techniques and computer equipment over the last decade, have enabled faster bulletin issuance.

While the warning centers are able to detect potential tsunamis and issue timely warnings, some state and local officials have raised concerns about their accuracy and reliability due to false alarms. No destructive tsunami has reached U.S. shores following any of the 16 warnings—primarily for local tsunamis—issued to states by the warning centers since 1982. According to warning center officials, their responsibility to provide timely warnings requires them to broadcast warnings based on limited, preliminary earthquake information before any resulting tsunami wave is actually observed. However, according to emergency response experts, such false alarms can generate costly, potentially dangerous evacuations

[16]Warning bulletins include "tsunami warnings" to inform areas where a tsunami is likely, "tsunami watches" that alert areas outside of a warned area, and "tsunami information bulletins" that inform areas that an earthquake has occurred but a tsunami is unlikely.

and may cause people to ignore critical warnings in the future. For example, according to the state of Hawaii's most recent estimate, an evacuation from a tsunami false alarm in 1996 would have cost the state $58.2 million in economic losses, or—adjusted for inflation—about $71 million in 2006 dollars.

According to some state and local emergency management officials, a false alarm occurred in June 2005, when they received a tsunami warning from NWS that they felt was too broad. On June 14, 2005, the warning center in Alaska detected a 7.2 magnitude earthquake 90 miles off the Northern California coast. The center quickly issued a warning for all coastal areas that were within two hours of the tsunami's forecasted travel time, including areas from the northern tip of Canada's Vancouver Island to the California-Mexico border. Knowing that it would take hours for the tsunami to reach his community, a Southern California emergency management official who received the warning sought to confirm the tsunami's existence by contacting his Northern California counterparts closer to the source. He learned that a destructive tsunami had not been generated and determined that his community should not evacuate. According to this official, because his area was not imminently threatened by a tsunami, it should not have been included in the initial warning. As a result of the feedback received after the June 14, 2005 event, the warning center in Alaska has changed its warning protocols so that it will issue a tsunami warning for only about half of the area that received a warning during the June event, if a similar situation should occur in the future.

Seismologists outside of NOAA have suggested that the tsunami warning centers could reduce the duration—and perhaps the number—of false alarms by relying more on seismic analyses that assess the type and direction of an earthquake. For example, according to some state and USGS seismologists, the June 14, 2005, earthquake's horizontal motion should have indicated that the generation of a tsunami was highly unlikely, enabling the warning center to cancel the warning within minutes, rather than over an hour later. However, a NWS review of the event noted that horizontal-motion earthquakes can trigger submarine landslides that can in turn produce tsunamis, so the warning center should not cancel a warning solely based on seismic analysis. According to warning center officials, they receive feedback from outside seismologists regarding warning procedures through organizations such as the NTHMP. However, some outside seismologists are concerned that warning center seismologists are reluctant to seek feedback or adopt new analytical procedures for issuing and canceling warnings.

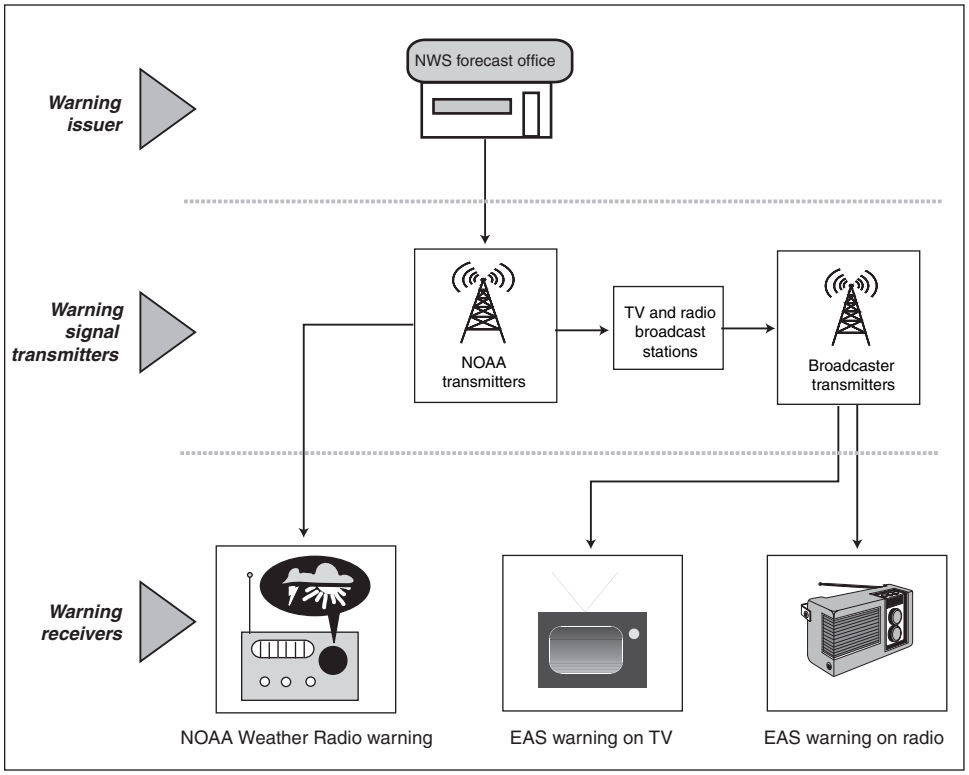
NOAA expects that false alarms will be reduced with the expansion of the sea-level data network and through an upgrade of its forecasting tools. DART stations help reduce false alarms for distant tsunamis because the stations detect slight changes in deep-ocean waves far from shore that help forecast how these waves will grow as they approach the coast. In addition to expanding the DART network, NOAA is upgrading the models that use DART data to forecast tsunami flooding and is also expanding and upgrading its network of sea-level gauges that the warning centers use to confirm or cancel tsunami warnings. The tide gauge expansion plan calls for deploying a total of 16 new gauges and upgrading 33 gauges by November 2006.

NOAA acknowledges the importance of reducing tsunami false alarms but has not yet established performance goals or related metrics for identifying progress toward this goal, such as tracking the number and duration of warnings to areas that do not experience destructive tsunamis. According to NWS officials, they are currently evaluating outcome goals and performance measures for warnings and other tsunami-related activities and expect to finalize these goals and measures in 2006.

Limitations in Federal Emergency Warning Systems Impede Rapid and Comprehensive Tsunami Warning Transmission

Technical gaps and procedural limitations have impeded federal emergency warning systems from broadcasting rapid and comprehensive tsunami warnings to affected local areas. For example, technical gaps such as weak signals and transmitter failures have prevented comprehensive warning transmission over the EAS and NOAA Weather Radio. Broadcasting tsunami warnings over EAS and NOAA Weather Radio requires NOAA-owned transmitters to relay a signal from the NWS forecast offices to the broadcast stations and NOAA Weather Radio, as shown in figure 8.

Figure 8: Tsunami Warning Signal Transmission for EAS and NOAA Weather Radio



Source: GAO analysis and Art Explosion.

According to NOAA officials, NOAA transmitters provide signal coverage for 97 percent of the nation's population; however, some coastal locations including portions of Hawaii receive such weak signals that NOAA Weather Radio is unlikely to function. Transmitter failure has also prevented warnings from being sent over EAS and NOAA Weather Radio. For example, on June 14, 2005, some coastal communities in Washington and Oregon did not receive the warning over EAS or NOAA Weather Radio because transmitters failed to send a signal. A September 2005 test of the federal tsunami warning systems in California, Oregon, and Washington found improvements in problematic transmission areas identified during the June event but uncovered new signal transmission issues in other areas. NWS is adding new transmitters to improve signal coverage and refurbishing old transmitters to improve their reliability.

In addition, procedural limitations such as the NWS forecast offices' inconsistent activation of EAS and NOAA Weather Radio can impede rapid and comprehensive transmission of tsunami warnings. On June 14, 2005,

the forecast offices responded to the tsunami warning in a variety of ways, some of which caused delays or nontransmission of EAS or NOAA Weather Radio warnings to affected local areas. For example, staff in some NWS forecast offices did not enter a tsunami-specific warning code into a computer, resulting in EAS and NOAA Weather Radio not activating rapidly, if at all. According to a subsequent NWS assessment of the event, guidance to forecast office staff on tsunami warning procedures was inadequate. Since the June 2005 event, coastal NWS forecast offices in Washington, Oregon, and California have received guidance that, for example, lists EAS activation as the proper first step when a tsunami warning is received.

Although the warning centers conduct monthly tests of their communication systems to ensure that NWS forecast offices and state emergency management centers receive the warnings, NWS does not routinely conduct periodic end-to-end tests of the tsunami warning system using the actual "live" computer codes rather than test codes. Such an end-to-end test would check the systems and procedures used to transmit an actual tsunami warning from the tsunami warning center to the public and identify technical gaps and procedural shortcomings. NWS conducted the first such end-to-end test of the tsunami warning system in Alaska, including activation of EAS and NOAA Weather Radio in March 2005. The test uncovered breakdowns in EAS warning transmission at television and radio stations whose EAS systems were not set up to use the tsunami warning code. NWS is working with emergency managers and broadcasters in Alaska to take corrective actions and retest the system. In commenting on a draft of this report, NOAA stated that while it supports broadening end-to-end testing in at-risk states it can conduct end-to end testing using "live" warning codes for the EAS system only in those states that permit it to do so. In other states, end-to-end testing is conducted by using test codes for the EAS system. NOAA said it will continue to encourage state participation in the end-to-end testing of the tsunami warning system.

State and Local Tsunami Hazard Mitigation Activities Are Under Way, although Implementation Varies Considerably among Locations

The 12 coastal communities in the six at-risk states and territories that we visited are taking actions to mitigate tsunami impacts through planning, warning system improvements, public education, and some infrastructure protection efforts, although the level of implementation varies considerably among locations.[17] While state and local tsunami mitigation plans and warning systems have largely been developed, limitations exist that have raised concerns about their effectiveness. In addition, key public education efforts have not been consistently implemented in all coastal communities we visited, and only a few communities have taken steps to protect critical infrastructure from potential tsunami damage. Overall, tsunami mitigation efforts have been mixed due to a number of challenges, including competing priorities, funding constraints, and lack of authority to implement legislative or policy changes. Finally, while 7 of the 12 communities we visited participate in NOAA's TsunamiReady preparedness program, nationwide few coastal communities have chosen to participate in the program.

State and Local Tsunami Mitigation Plans and Warning Systems Have Been Largely Developed, but Concerns Exist about Warning System Effectiveness

According to FEMA guidance, the purpose of mitigation planning is to identify natural hazards, consider actions and activities to reduce potential losses from those hazards, and coordinate the implementation of a hazard mitigation plan. All six of the states and territories we visited have developed FEMA-approved, all-hazard mitigation plans, a requirement to qualify for certain disaster-related grant funds under the Stafford Act, as amended by the Disaster Mitigation Act of 2000.[18] These plans identify tsunami hazards and describe in general terms the vulnerability of people and property to tsunami threats. Most of the state level plans we reviewed take the additional step of identifying specific actions to mitigate the risks identified, such as relocating critical facilities out of tsunami inundation zones. While only 4 of the 12 communities we visited have FEMA-approved plans, each of the four has identified projects to mitigate tsunami hazards. State and local emergency managers whom we spoke

[17]The six at-risk states and territories are Alaska, California, Hawaii, Oregon, Puerto Rico, and Washington. The 12 communities are Seward and Kodiak, Alaska; Crescent City and San Mateo County, California; Hilo and Honolulu, Hawaii; Seaside and Gold Beach, Oregon; Mayaguez and Rincon, Puerto Rico; and Ocean Shores and Long Beach, Washington.

[18]According to FEMA, the states used FEMA Pre-disaster Mitigation Program grant funds to develop their all-hazard mitigation plans. In addition, FEMA's Hazard Mitigation Grant Program has funded tsunami mitigation projects in Alaska and Puerto Rico.

with cited resource and time constraints as significant barriers to improving mitigation planning.

All of the states and communities we visited have developed warning systems, but they have various limitations that may impact their effectiveness. State and local tsunami warning systems help ensure that all at-risk residents and tourists are warned about a potential tsunami in a timely manner. Most of the coastal communities we visited employ some technologically sophisticated methods to warn residents. For example, 8 of the 12 communities we visited had at least one tsunami warning siren and three alerted residents by an automated telephone system. However, local emergency managers told us that inadequate warning siren coverage was a significant issue in many locations, such as Ocean Shores, Washington, and on Alaska's Kenai Peninsula. In addition, many of the warning methods used by communities—such as sirens and internet-based messaging systems—are dependent on telephone lines and other infrastructure that would likely be disrupted by a strong earthquake. During the June 2005 tsunami warning on the west coast, officials in several communities noted that telephone lines were overloaded by a surge of incoming 911 calls from concerned residents, in some cases, preventing emergency managers from contacting other local officials and preventing telephone-based warning systems from reaching all residents. Some emergency managers expressed concern that they do not have adequate backup systems to receive and disseminate warning messages if telephone lines fail. Finally, three of the communities we visited rely on warning methods such as verbal notifications by bullhorns or radio broadcasts.

State and local emergency managers are aware of the limitations of existing tsunami warning systems and are involved in a number of projects to address them. For example, some of the communities we visited have attempted to obtain additional sirens and replace unreliable ones to provide better coverage to residents. For Crescent City, California, and Gold Beach, Oregon, county officials obtained a number of used civil defense sirens for a nominal cost but reported that installation and maintenance costs pose additional challenges. Washington state has provided seven at-risk communities with advanced All Hazard Alert Broadcasting sirens, but their high cost—approximately $50,000, twice as much as a new, conventional siren—may be prohibitive for other

communities.[19] In addition, communities have taken actions to ensure more effective communications between emergency management officials and first responders. For example, some have purchased satellite phones and digital communications systems that are not vulnerable to earthquake damages or interoperable radios that ensure that first responders can talk to each other if telephone lines are disrupted. In coastal areas with high population and building densities—where roads, bridges, and other horizontal evacuation methods are limited or where warning time is short—vertical evacuation to the upper floors of buildings that are capable of withstanding the initial earthquake and subsequent tsunami can be an alternative or supplement to horizontal evacuation.[20]

Most of the states and communities we visited have made efforts to test their evacuation plans and warning systems, but few comprehensive drills have been conducted. Recent events, such as Hurricanes Katrina and Rita, have illustrated that robust training and testing are important to identify problems in advance of an actual event.[21] However, only Seaside, Oregon, has conducted comprehensive tsunami exercises involving multiple agencies and full public participation. Five of the communities we visited have conducted exercises involving multiple agencies in mock tsunami scenarios to discuss plans and procedures involved in responding to a real event. While these efforts are useful, their limited scope may not adequately identify all of the issues that would emerge in an actual event. For example, in an actual emergency, traffic control and public evacuations may take substantially longer than estimated. Local officials told us that more comprehensive drills would be beneficial, but they have limited funding and staff to plan and conduct them and getting community involvement is very difficult due to the disruption to the local economy.

[19]The All Hazard Alert Broadcasting Radio is an outdoor system that provides both tone and voice alert and notification to residents/visitors by federal, state, and local emergency authorities; an intense blue light is also activated at each location to further indicate the area is in a hazardous situation.

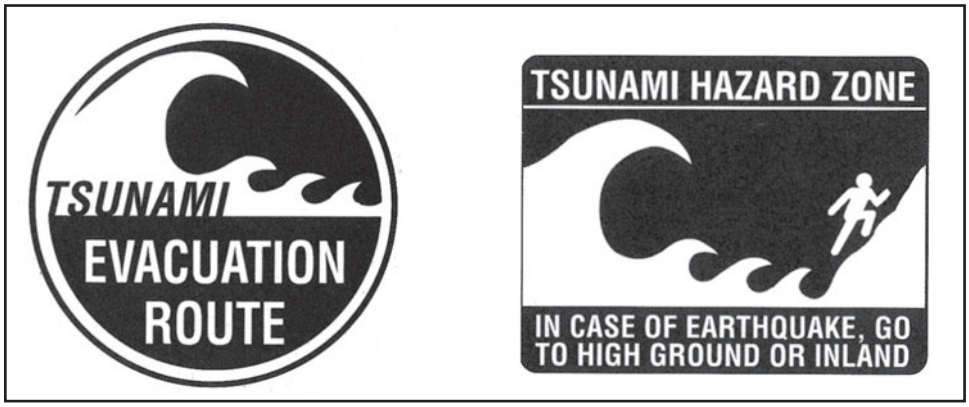
[20]FEMA and NOAA, with a grant from the NTHMP and the National Earthquake Hazards Reduction Program, are currently developing guidance for constructing vertical evacuation shelters.

[21]See GAO, Statement by Comptroller General David Walker on GAO's *Preliminary Observations Regarding Preparedness and Response to Hurricanes Katrina and Rita*, GAO-06-365R (Washington, D.C.: Feb. 1, 2006).

Tsunami Education and Outreach Efforts Have Not Been Consistently Implemented

Education and outreach efforts are important because plans and warning systems may do little to save lives if the public does not know what to do when it receives a warning. Two such efforts, distributing evacuation maps and posting tsunami evacuation signs, raise awareness of tsunami threats and educate the public on appropriate escape routes. Ten of the 12 communities we visited have either received evacuation maps from the state or developed their own maps identifying appropriate evacuation routes. However, only five of the communities reported distributing evacuation maps to all residents, either by mailing them to all registered utility customers, publishing them in the local telephone book, or in one case distributing them door-to-door.[22] A few communities have taken other actions to reach the public such as posting evacuation maps in police stations and on grocery store reader boards. Several communities have made efforts to reach tourists by providing evacuation maps at areas they frequent, such as the local visitor's center and distributing tsunami hazard information and evacuation maps to hotels. Regarding tsunami signs, 9 of the 12 communities reported posting tsunami hazard or evacuation route signs in their communities, such as those shown in figure 9, although in a few locations, local emergency managers reported that the signs are frequently stolen.

Figure 9: Tsunami Hazard Zone Signs



Source: Oregon Emergency Management.

According to emergency management officials and other emergency preparedness experts, focusing on educating youth—the adults of tomorrow—has considerable promise for increasing tsunami

[22]In Hawaii, evacuation maps are printed in each county's telephone book.

preparedness. Specifically, two key efforts—developing and implementing school curricula and conducting tsunami evacuation drills in schools—may help improve tsunami preparedness now and in the future. Of the six at-risk states and territories we visited, only two—Oregon and Washington—have developed tsunami specific curricula and are teaching them in schools, according to state emergency managers.[23] The Washington state curriculum is targeted at two age groups—grades K through 6 and grades 7 through 12—and provides various lessons to help students plan ahead for a tsunami and protect themselves and their families when a tsunami occurs. In addition, Hawaii has developed a tsunami specific curriculum that will be tailored to each of its counties. Oregon and Hawaii also require schools in tsunami inundation areas to conduct tsunami drills at least once a year, often in conjunction with Tsunami Awareness month activities. For example, in Hilo, Hawaii, an elementary school located in a known tsunami inundation area conducts an annual evacuation drill in which students practice responding to a tsunami warning by walking from the school to a safe location. Three of the communities we visited in Washington, Puerto Rico, and Alaska also reported conducting tsunami evacuation drills in schools at least once a year, even though the states do not require them.

All six of the at-risk states and territories we visited have conducted a variety of education and outreach activities to distribute tsunami hazard information to communities. For example, the states we visited have developed a variety of print materials, produced videos, made tsunami information available on the Internet, and conducted forums and other workshops to educate citizens on tsunami risks and preparedness. At the community level, 11 of the 12 emergency managers we visited stated that forums and workshops have been conducted to educate residents and tourists about tsunami hazards.[24] However, only two local emergency managers reported meeting with special needs populations, such as

[23]In 1995, the Oregon legislature passed Senate Bill 378, requiring that at least 30 minutes of earthquake, tsunami, and other disaster-related education be taught in schools each month, among other things. Or. Rev. Stat. § 336.071 (2003).

[24]One comprehensive education effort was funded by the NTHMP. In September 2004, the city of Seaside, Oregon, launched a 9-month Tsunami Awareness Program to determine the feasibility of educating the public on tsunami hazards and preparedness practices. The community implemented five outreach strategies to reach target audiences, including a neighborhood educator project, business workshop, school outreach program, public workshop, and a tsunami evacuation drill that included Seaside residents, businesses, and visitors.

community hospitals and senior centers, to distribute tsunami hazard information and encourage them to develop tsunami evacuation plans.

All of the at-risk states and territories acknowledged the need for additional education and outreach but cited two primary challenges to increasing and sustaining such efforts. First, many of the state emergency managers whom we spoke with noted that they are responsible for other, higher priority hazards—such as floods and wildland fires—that occur more frequently than tsunamis. Second, the states have limited funding dedicated to tsunami preparedness activities. Of the approximately $275,000 in NTHMP funds provided annually to each state, the states have chosen to use most of it to develop or upgrade existing tsunami inundation maps rather than for education or outreach efforts. Local emergency managers echoed these challenges. Moreover, in many areas that depend on tourism, local emergency managers said that businesses are reluctant to post tsunami hazard information because it may scare tourists and negatively impact the economy. Many noted, however, that since the December 2004 Indian Ocean tsunami and the subsequent June 2005 tsunami warning on the west coast, community interest in workshops and forums has increased. Local businesses—in particular hotels and motels—have become increasingly interested in receiving tsunami hazard information to distribute to patrons.

States and Localities Have Undertaken Few Efforts to Protect Infrastructure from Potential Tsunami Damage

According to tsunami experts, land-use planning and zoning strategies—for example, designating tsunami hazard areas for open-space uses, such as parks, and locating new infrastructure and critical facilities (i.e., police stations, hospitals, and potable water systems) out of tsunami hazard areas—can mitigate loss of life and property from a devastating tsunami.[25] However, many of the at-risk states we visited have not adopted any land-use planning strategies to address the tsunami threat. Oregon is the only at-risk state we visited that has passed a land-use statute placing limits on the construction of certain high occupancy structures within tsunami inundation areas.[26] Alaska also places restrictions on development in certain designated "natural hazard" areas, including coastal areas potentially affected by tsunamis.[27] One at-risk community also has been

[25]*Designing for Tsunamis: Seven Principles for Planning and Designing for Tsunami Hazards.* NTHMP, March 2001.

[26]Or. Rev. Stat. §§ 455.446-447 (2003).

[27]Alaska Admin. Code tit. 11, § 112.210 (2006).

successful in implementing a land-use strategy to mitigate future tsunami losses. The city of Hilo, Hawaii, developed an Urban Renewal Plan—based on the devastation from the 1960 tsunami—that set aside certain "open areas" for limited use in order to minimize the danger of loss of life or damage to property in areas potentially subject to inundation from tsunamis.[28]

Tsunami experts believe that constructing new buildings in a tsunami inundation area to better withstand tsunami forces can reduce loss of life and property damage in cases where land-use planning and zoning are not feasible. Building design and construction in the United States is governed at the local level by building codes that establish minimum acceptable requirements for preserving public safety. Although the Uniform Building Code contains design requirements and standards for fire, wind, floods, and earthquakes, it does not include requirements for tsunami-resilient design.[29] Nonetheless, two communities we visited, Hilo and Honolulu, Hawaii, have developed guidelines for constructing tsunami-resilient structures. For example, a 2000 Honolulu building ordinance requires, among other things, that the inhabitable space in buildings at-risk from tsunamis must be elevated above the regulatory flood elevation through the use of posts, piles, piers or shear walls parallel to the expected flow of a tsunami wave.[30] None of the at-risk states we visited have developed guidelines for constructing tsunami-resilient structures although legislation establishing tax incentives for such construction is pending in Washington.[31] Hawaii's state legislature is currently considering a bill to develop a state building code based on the International Building Code, which, according to state emergency management officials, would strengthen buildings against tsunamis and other hazards.[32] In commenting on a draft of this report, FEMA noted that, the International Building Code, which has replaced the Uniform Building Code as the national model code, also does not contain specific requirements addressing the tsunami

[28]*Urban Renewal Plan for the Kaiko'o Project*, Hawaii Redevelopment Agency, County of Hawaii, Hilo, Hawaii, June 1965.

[29]Most local building codes in the Pacific states are based on the Uniform Building Code prepared by the International Conference of Building Officials.

[30]Revised ordinances of Honolulu, Ch. 16-11, available at http://www.co.honolulu.hi.us/refs/roh/16a11.htm.

[31]H.B. 1022, 59th Leg., Reg. Sess. (Wa. 2006).

[32]H.B. 3230, 23rd Leg. Reg. Sess. (Hi. 2005).

hazard. However, structures built in conformance with the International Building Code are likely to perform better during a tsunami because of other code provisions, particularly seismic requirements.

Several states, including California and Oregon, have adopted laws and ordinances for retrofitting existing buildings to reduce losses from future earthquakes.[33] For existing infrastructure, earthquake retrofits may improve tsunami resistance, or help minimize floating debris that can damage nearby buildings.[34] Earthquake retrofits could be particularly important in the case of a locally generated tsunami off the west coast of the United States, where a magnitude 9.0 or greater earthquake is likely to precede a tsunami. FEMA has developed guidance for rehabilitating buildings to resist earthquake forces.[35]

Most of the states and coastal communities we visited have not attempted to mitigate tsunami risk through land-use planning and infrastructure requirements for several reasons. First, state and local emergency managers said that although they recognize the need for additional infrastructure protections, such decisions typically reside with a community's city council or other governing body. Second, many coastal communities rely on coastal-dependent development such as ports and harbors that, by their nature, must be situated on the coast; and in other cases, communities have already built to capacity in tsunami hazard areas, and relocation is not a practical or cost-effective option. Finally, few states or coastal communities have adopted tsunami building codes because model codes generally have not included requirements for designing tsunami-resilient structures and few have implemented retrofitting projects because of their high costs.

[33]See e.g., Cal. Gov. Code § 8875 (2006); S.B. 2-5, 73rd Leg., Reg. Sess. (Or. 2005).

[34]Retrofitting is making changes to an existing building to protect it from flooding, or other hazards such as high winds and earthquakes.

[35]FEMA-172, National Earthquake Hazards Reduction Program, *Handbook of Techniques for the Seismic Rehabilitation of Existing Buildings.*

Community Participation in NOAA's TsunamiReady Hazard Preparedness Program Is Limited

Of the approximately 500 coastal communities at-risk from a tsunami in five Pacific states and Puerto Rico, only 25 communities—including 7 of the 12 we visited—have been recognized by NWS as TsunamiReady, the primary federal effort to encourage communities to prepare for tsunami hazards.[36] According to NWS, the program was developed to provide minimum standard guidelines for communities to follow and to enhance tsunami readiness by increasing public awareness and understanding of the tsunami hazard, among other things.[37] Communities that meet program standards are provided signs such as those shown in figure 10.

[36]In January 2006, FEMA developed a proposal that encourages communities to map and manage tsunami hazards by providing credits in the Community Rating System that reduce their flood insurance rates. The Community Rating System, part of the National Flood Insurance Program, is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum program requirements. Communities that participate in the National Flood Insurance Program receive federally subsidized flood insurance.

[37]As of March 2006, there were a total of 27 TsunamiReady recognized communities in the United States, including 2 on the East Coast – Indian Harbour Beach, Florida, and Norfolk, Virginia. All counties in the state of Hawaii are also recognized as TsunamiReady.

Figure 10: TsunamiReady Sign for Communities

Source: NWS.

While the majority of at-risk coastal communities have not joined the TsunamiReady program, we found that four of the five at-risk communities we visited that are not yet recognized as TsunamiReady do plan to pursue recognition in the future. Two of the four communities are currently taking steps to meet program requirements by installing additional warning infrastructure, such as NOAA Weather Radios. Emergency management officials generally agreed that the TsunamiReady program is a good first step toward helping communities mitigate the potential impact of a tsunami. Specifically, in the TsunamiReady communities we visited, most officials stated that they sought recognition to increase community tsunami awareness, and officials noted that the TsunamiReady signs had helped them move toward that goal. One emergency manager whom we spoke with stated that the TsunamiReady recognition had "opened doors" to conduct outreach with hotels and that hotel managers had begun seeking tsunami hazard information. However, some of the state emergency managers with whom we spoke expressed three concerns about the TsunamiReady program: (1) it is too limited in scope—for

example, emphasizing warning infrastructure but not requiring tsunami specific evacuation and mitigation plans; (2) it should be more focused on education, particularly regarding the local tsunami threat; and (3) the name "TsunamiReady" promotes a false perception of readiness, since preparedness is a continuous process.

NOAA officials believe that the lack of program participation may be due to community perceptions of a low tsunami threat and perceived high cost versus benefit, but the agency has not formally assessed the program to identify barriers to participation or potential program modifications to encourage participation. The agency's 2005 Report to Congress on the Tsunami Community Preparedness Implementation Plan, identifies achieving tsunami preparedness recognition for at-risk communities in the United States as a vital part of its tsunami activities.[38] To that end, according to the report, the agency has committed to work with each at-risk coastal community across the nation to ensure that community and emergency management officials fully understand the tsunami hazard and take action to prepare.

Significant Expansion of National Tsunami Preparedness Activities Is Occurring in the Absence of Long-Term Strategic Planning

A significant expansion of federal tsunami detection, warning, and related activities, as well as the NTHMP, is under way; however, the future direction of these efforts is unclear because NOAA has not developed long-range strategic plans to guide them. In 2005, NOAA combined its various tsunami-related activities into a single program and is currently strengthening and expanding certain elements of the program. However, NOAA has not yet adopted a comprehensive strategic plan that sets specific program goals and objectives, defines performance measures, ensures coordination of existing activities, and establishes risk-based priorities to guide the expansion of the warning program into the future. Furthermore, with the likely expansion of the NTHMP from 5 state participants to potentially 28 state and territorial participants in 2006, it will be difficult for NOAA to ensure that the most threatened states receive the resources they need to continue and to complete key mitigation activities without an updated, risk-based strategic plan.

[38]NOAA, FY 2005 Emergency Supplemental Appropriations Act (P.L. 109-13), Report to Congress on NOAA's Tsunami Community Preparedness Implementation Plan.

NOAA Is Expanding Elements of Its Tsunami Program, but the Program Lacks a Long-Range Strategic Plan

Prior to the Indian Ocean tsunami, NOAA's various tsunami-related activities, such as warning center operations, the TsunamiReady program, and tsunami-related research were not managed as a formal, integrated program within the agency. The administration's initiative to expand NOAA's tsunami activities—and the receipt of supplemental funding from the Congress for that purpose—led NOAA in April 2005, to establish an integrated national Tsunami Program. NOAA is strengthening the Tsunami Program by (1) expanding the Pacific warning center and National Data Buoy Center facilities by the end of 2005;[39] (2) expanding tsunami warning center operating hours to 24 hours, 7 days a week in April 2006; (3) upgrading and expanding water level observation capabilities by November 2006; (4) expanding and upgrading the earthquake detection network by the end of 2006; (5) establishing a long-term tsunami data archive by late 2007; (6) increasing DART tsunami detection stations in the Pacific, Atlantic, and Caribbean by early 2008; (7) expanding TsunamiReady participation nationwide through 2012; and (8) developing a tsunami forecast system, including 75 inundation forecast models by 2013.

While NOAA has developed a schedule for strengthening elements of the Tsunami Program, it has not developed a long-range strategic plan that includes specific detection, warning and mitigation outcome goals, and performance measures to evaluate progress in achieving them. For example, NOAA does not have program outcome goals and performance measures for reducing false alarms or other critical tsunami-related activities such as mapping, modeling, research, education, and outreach. Although strategic planning is required for the major functions and operations of agencies by the Government Performance and Results Act of 1993, it is not specifically required for individual programs within agencies. However, our work related to the act and the experience of leading organizations have shown the importance of identifying long-term goals and establishing performance measures to guide program operations and help policy makers determine if program activities are achieving the desired results. In addition, the Department of Commerce's Inspector General has identified improving strategic planning as a top priority and

[39]The National Data Buoy Center, under the NWS, designs, develops, operates, and maintains a network of data collecting buoys and coastal stations.

reported on the need for NOAA's programs to improve how they report and measure performance toward achieving specific outcomes.[40]

In this context, a strategic plan would provide NOAA a framework for ensuring that its tsunami-related activities are planned and implemented in a risk-based manner. Our recent reports have emphasized the importance of federal agencies using risk-based planning. For example, in a June 2005 testimony on the Department of Homeland Security's resource allocation, we reported that the department must carefully weigh the benefit of activities and allocate resources where the benefit of reducing risks is worth the additional cost.[41] Any actions taken by NOAA absent risk-based analysis have the potential to divert funds away from locations, such as the Pacific and Caribbean regions, where the tsunami hazard—particularly from local tsunamis—is well documented. Some of NOAA's activities designed to strengthen the tsunami program are scheduled in a manner that raises questions about the extent to which they are risk-based. For example, there is little historical evidence of tsunamis on the Atlantic coast or Gulf coast, yet expansion activities already implemented or scheduled in 2006 include the placement of DART stations in the Atlantic Ocean, tsunami forecast modeling of an east coast community, and recognition of new TsunamiReady communities on the east coast. In addition, NOAA's initial strengthening efforts emphasize detection and warning for distant tsunamis, while the greater risk to most locations in the United States—according to NOAA data as well as the National Science and Technology Council's December 2005 report on tsunami risk reduction—are likely to be posed by local tsunamis. For example, the deployment of DART stations and warning center enhancements will not reduce the local tsunami risk as directly as other strategies such as educating vulnerable populations to immediately head for high ground when the earth shakes near the coast. According to NWS officials, they are

[40]*National Oceanic and Atmospheric Administration: Improvements Needed in the Reporting for NOAA GOALS—Build Sustainable Fisheries, Recover Protected Species, and Predict and Assess Decadel to Centennial Climate Change*, Final Audit Report No. FSD-15989-4-0001, September 2004; *National Oceanic and Atmospheric Administration: Improvements Needed in the Reporting of Performance Measures Related to Promoting Safe Navigation and Sustaining Healthy Coasts*, Audit Report No. FSD-14998-3-0001, February 2003; and *National Oceanic and Atmospheric Administration: Improvements Needed in the Reporting of Performance Measures Related to Goals for Advancing Short-term Warnings and Implementing Seasonal to Interannual Climate Forecasts*, Audit Report No. FSD-15643-3-0001, September 2003.

[41]GAO, *Strategic Budgeting: Risk Management Principles Can Help DHS Allocate Resources to Highest Priorities*, GAO-05-824T (Washington, D.C.: June 29, 2005).

in the process of evaluating outcome goals and performance measures for the Tsunami Program, and expect to finalize a strategic plan in 2006. In commenting on a draft of this report, NOAA stated that it will work with its partners to begin a risk assessment following the completion of a tsunami hazard assessment in November 2006, which will improve its future ability to allocate funds in a manner consistent with established risk management practices.

Concerns Exist about the Management and Direction of the Expanded National Tsunami Hazard Mitigation Program

Since its inception in 1996, NOAA has used the Tsunami Hazard Mitigation Implementation Plan to guide NTMHP activities. The plan has four specific goals: (1) raise awareness of affected populations, (2) supply tsunami inundation and evacuation maps, (3) improve tsunami warning systems, and (4) incorporate tsunami planning into state and federal all-hazards mitigation programs. In August 2001, an expert panel reviewed the NTHMP's progress and performance under the plan and provided a number of suggestions for improving the program. While the then-chairman of the NTHMP drafted some goals based on the suggestions, NOAA did not update or revise the plan to incorporate the experts' suggestions or the proposed goals because, according to the subsequent chairman, the plan's four original goals had not yet been achieved.

Five years later, two key issues raised by the expert panel review remain concerns of the state NTHMP participants. First, the positive impacts of the program were being largely assumed and not effectively measured. State members of the NTHMP still believe that more needs to be done to measure the effectiveness of tsunami mitigation activities—such as surveys to measure the effectiveness of public education programs. Second, the NTHMP was "seriously out of balance," in terms of focusing on detection and risk assessment at the expense of working with communities to educate and modify behaviors in ways that could save lives. State members of the NTHMP remain concerned about the focus on detection and warning systems improvements, which are perceived as "federal solutions," rather than state and local educational and behavioral activities, such as conducting tsunami preparedness drills, which they see as key to community preparedness, particularly for local tsunamis.

The NTHMP had planned to conduct another program review and develop an updated implementation plan in 2006. These plans have been placed on hold, according to the chairman of the NTHMP, because the decision to make the NTHMP a nationwide program—likely including representatives of the 23 states on the Pacific, Atlantic, and Gulf coasts as well as the two commonwealths and three U.S. territories in the Pacific Ocean and

Caribbean Sea—raised significant issues that needed to be settled before any revisions to the program's goals and objectives could be considered.[42] However, failing to conduct a program review now means that the program will not have vital information regarding (1) what has worked or not worked in implementing the program since 2001 and (2) what tsunami mitigation activities remain incomplete in the five original Pacific area states with high tsunami hazards. A program review could contribute to the development of a risk-based strategic plan that ensures that the activities that remain uncompleted in areas with the greatest threat get the highest priority for funding.

According to NOAA officials, the agency expects to implement the nine recommended actions for the NTHMP and the Tsunami Program contained in the National Science and Technology Council's December 2005 report on tsunami risk reduction. The report, developed by NOAA, USGS, FEMA, and other federal agencies, recommends actions such as developing standardized and coordinated tsunami hazard and risk assessments for all U.S. coastal areas, improving tsunami detection and warning data and infrastructure, enhancing tsunami forecast and warning capabilities, promoting the development of model mitigation measures, and increasing outreach to communities. However, because the report and recommendations were developed without the participation of the NTHMP members, they question whether the recommendations and priorities represent the best strategic direction for the NTHMP. All of the state NTHMP members agree that full participation in program decision making by individuals with state and local level knowledge of tsunami mitigation activities is key to the efficiency and success of the NTHMP.

In addition, state NTHMP members are particularly concerned that the program's funding decisions and strategic direction may become less risk-based with the inclusion of numerous eastern and southern coastal states with lower known tsunami hazards. These members want to ensure that communities facing the greatest threat obtain the greatest benefits from the program, particularly since many tsunami preparedness activities remain incomplete and unfunded in the original five at-risk states. For example, in 2005, the Director of the California Governor's Office of Emergency Services estimated that in California alone over the next five years about $19.5 million was needed for state preparedness activities and

[42]The commonwealths are Puerto Rico and the Northern Mariana Islands, and the territories are American Samoa, Guam, and the U.S. Virgin Islands.

about $7.5 million for local government activities. As such, state NTHMP members were surprised to learn that some eastern states have already submitted proposals for NTHMP funding.

Conclusions

In the hazardous Pacific region, NOAA and its federal and state partners are working to help prepare communities for tsunamis. However, much is left to be done to improve tsunami hazard assessment, detection, warning, and mitigation for these areas and other at-risk areas of the United States. It is particularly important that when at-risk states complete their inundation mapping, they then conduct comprehensive assessments of the expected damage from a tsunami. Without this basic information, emergency managers will not be able to effectively formulate plans to mitigate potential tsunami impacts on people and infrastructure. In addition, improved technical capabilities to detect tsunamis will be of limited value if the warning systems and processes that NOAA depends on to disseminate this information cannot reliably ensure that all threatened individuals and communities will receive an accurate and timely warning.

Because tsunamis are an infrequent hazard that may be overlooked due to higher priority reoccurring natural hazards such as hurricanes and flooding, NOAA and its federal and state partners face a significant challenge ensuring that communities are sufficiently engaged in preparedness activities. The Indian Ocean tsunami, however, has created a window of opportunity by spotlighting the devastation and destruction that can result from a lack of planning, preparedness, and education for such an event—no matter how rare. We believe that federal and state partners can take advantage of this current sense of urgency and develop a strategic approach that will ensure that the significantly increased resources that have been made available to expand U.S. tsunami detection and preparedness programs are being effectively targeted. As part of this effort, all federal tsunami-related activities, including the TsunamiReady program and the NTHMP, should be reassessed to determine how to increase their effectiveness. Moreover, NOAA needs to address the lack of long-range, risk-based strategic planning for these activities. Without strategic planning and performance measures to guide these efforts, the Congress and the public will lack important information about the extent to which resources are being directed to activities that are of the greatest benefit to the most vulnerable communities and to what extent measurable progress is being made toward the desired results. We believe U.S. tsunami programs guided by long-term strategic plans with demonstrable achievements will be better able to sustain their efforts for vulnerable coastal communities into the future.

Recommendations for Executive Action

To help improve national tsunami preparedness, we are recommending that the Secretary of Commerce direct the NOAA Administrator to take the following six actions:

- work with the FEMA Director and the USGS Director to create standardized tsunami loss estimation software to help communities determine the potential impact of tsunamis and identify appropriate mitigation actions;
- reduce the number of tsunami warning false alarms by (1) completing the planned expansion of tsunami detection stations, (2) reexamining NWS's rules dictating when a warning will be issued and to which areas, (3) establishing a routine process for other federal and state experts to formally review and comment on the centers' use of seismic data, and (4) setting performance goals to guide improvements;
- work with the states to conduct periodic end-to-end tests of the tsunami warning system, including NOAA Weather Radio and the Emergency Alert System, to ensure the system will function as intended during a tsunami emergency;
- evaluate the TsunamiReady program to determine what barriers, if any, exist to participation and what modifications are needed to encourage more high-risk communities to participate;
- evaluate the NTHMP to determine what has worked well in the past and what high priority activities remain to be completed and to help inform strategic planning efforts, and;
- develop comprehensive risk-based strategic plans for the Tsunami Program and National Tsunami Hazard Mitigation Program that consider input from states and federal partners and include metrics for measuring progress toward achieving program goals.

Agency Comments and Our Evaluation

We provided copies of a draft of this report to the Departments of Commerce, Homeland Security and the Interior for their review and comment. Commerce, representing NOAA, concurred with all six recommendations and generally agreed with our findings, although it provided technical and factual clarifications, which we have incorporated into the report as appropriate. However, in its comments, NOAA suggested a revision to one of the recommendations with which we disagree. In response to our recommendation that NOAA evaluate the TsunamiReady program to determine what barriers, if any, exist to participation and what

modifications are needed to encourage more high-risk communities to participate, NOAA suggested changing the recommendation's focus from "high-risk" to "at-risk" communities. According to NOAA all U.S. coastal communities should be prepared for a tsunami no matter how rare. While we agree that preparing all U.S. coastal communities for a tsunami may be a laudable long-term goal, given the agency's limited resources, it may be an unrealistic goal in the short-term. Therefore, we believe that NOAA should use a risk-based approach and target initial participation in the TsunamiReady program to those communities that face the greatest risk. Commerce's specific comments and our detailed responses are presented in appendix I.

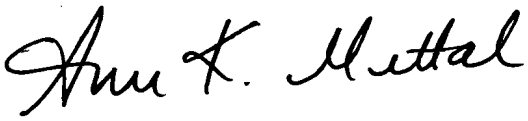
Homeland Security, representing FEMA, commented on one of the six recommendations and indicated that while it concurred with the recommendation that NOAA work with FEMA and USGS to create standardized tsunami loss estimation software, it was concerned that FEMA did not have the funding or the staff resources to pursue such a request and that such a request from NOAA would have to address these resource needs. Homeland Security also noted that the report did not mention other programs such as FEMA's Pre-disaster Mitigation Program and the Hazard Mitigation Grant Program, which can be used by states and communities to fund tsunami mitigation projects. We revised the report to mention that these programs have funded tsunami mitigation projects. Finally, Homeland Security stated that the report's description of the TsunamiReady program as it relates to response, preparedness, and mitigation activities is unclear. We believe that we have clearly characterized the program as providing minimum guidelines that communities can use to enhance tsunami readiness and therefore have not revised the report in response to this comment. Homeland Security's specific comments and our detailed responses are presented in appendix II.

The Department of the Interior commented that the report was a thorough well-researched examination of the nation's tsunami warning system and that it correctly recognizes the need for close collaboration at the federal, state, and local levels to have an effective tsunami warning system. Interior also said that it supports the need for a risk-based approach to prioritizing federal investments in this system and is actively collaborating with NOAA to provide the hazard assessments necessary for such an approach. In addition, Interior said that one area it felt was inadequately addressed in the report was the importance of a long-term federal role in research to improve tsunami warnings and mitigate tsunami risks and noted that none of our recommendations involved improving or expanding

research. While we agree that tsunami-related research is an important issue, it was not included in the scope of our review, and consequently, this report does not cover issues related to tsunami research or offer any recommendations in this area. Interior's specific comments and our detailed responses are presented in appendix III.

We are sending copies of this report to the Secretaries of Commerce, Homeland Security, and the Interior; appropriate congressional committees; and other interested Members of Congress. We also will make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or mittala@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix IV.



Anu K. Mittal
Director, Natural Resources
and Environment

Appendix I: Comments from the Department of Commerce

Note: GAO comment supplementing those in the report text appear at the end of this appendix.

THE DEPUTY SECRETARY OF COMMERCE
Washington, D.C. 20230

May 8, 2006

Ms. Anu K. Mittal
Director
Natural Resources and
Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, D.C. 20548

Dear Ms. Mittal:

Thank you for the opportunity to review and comment on the Government Accountability Office's draft report entitled *U.S. Tsunami Preparedness: Federal and State Partners Collaborate To Help Communities Reduce Potential Impacts, But Significant Challenges Remain* (GAO-06-519). I enclose the Department of Commerce's comments to the draft report.

Sincerely,

David A. Sampson

Enclosure

Department of Commerce's Comments on the GAO Draft Report Entitled "U.S. Tsunami Preparedness: Federal and State Partners Collaborate To Help Communities Reduce Potential Impacts, But Significant Challenges Remain" (GAO-06-519/May 2006)

General Comments

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review this report. The report captures and addresses the major elements of the tsunami program and acknowledges the involvement and roles of all levels of government. The U.S. Tsunami Warning System depends on multi-agency coordination where all parts must be working for optimal operation. While the Federal Government is the integrator of the program, the states play a key role in disseminating tsunami warning messages. The Nation's Tsunami Warning System's biggest challenge in most U.S. coastal areas is getting warning messages to those in the potentially hazardous area. The report acknowledges this issue, focusing primarily on NOAA Weather Radio All Hazards (NWR) and the Emergency Alert System dissemination systems. While these are important systems, individuals are more likely to rely on local and state emergency management for their warnings.

NOAA Response to GAO Recommendations

The draft GAO report states, "To help improve national tsunami preparedness, we are recommending that the Secretary of Commerce direct the NOAA Administrator to take the following six actions:"

Recommendation 1: "…work with the FEMA Administrator and the USGS Director to create standardized tsunami loss estimation software to help communities determine the potential impact of tsunamis and identify appropriate mitigation actions;…"

NOAA Response: NOAA agrees with this recommendation and will work with the Federal Emergency Management Agency (FEMA), the agency responsible for creating loss-estimation software and the U.S. Geological Survey (USGS) to identify required modules and the state of research, prior to creating standardized tsunami loss estimation software.

Recommendation 2: "…reduce the number of tsunami warning false alarms by (1) completing the planned expansion of tsunami detection stations, (2) reexamining NWS's rules dictating when a warning will be issued and to which areas, (3) establishing a routine process for other federal and state experts to formally review and comment on the centers' use of seismic data, and (4) setting performance goals to guide improvements;…"

NOAA Response: NOAA agrees with this recommendation and provides the following comments:

(1) NOAA expects to complete the planned expansion of the tsunami Deep-ocean Assessment and Reporting of Tsunami (DART) detection stations by mid-fiscal year 2008.

(2) The Tsunami Warning Centers will continue to re-evaluate their rules specifying when a warning will be issued and for which areas, incorporating new technologies and modeling efforts as they become available.

1

(3) NOAA will continue to solicit feedback on warning procedures through the National Tsunami Hazard Mitigation Program (NTHMP) and the International Coordination Group/Pacific Tsunami Warning System. In addition, NOAA will consider the establishment of an ad hoc advisory committee under the NTHMP that would review warning center procedures and propose changes.

(4) NOAA is reviewing and updating its performance measures (e.g., response time and false alarm rates). The review will be completed by the end of fiscal year 2006, and the performance measures will continue to be used to guide program improvements.

Recommendation 3: "…conduct periodic end-to-end tests of the tsunami warning system, including NOAA Weather Radio and the Emergency Alert System, to ensure the system will function as intended during a tsunami emergency;…"

NOAA Response: NOAA agrees with the recommendation for end-to-end testing and will continue to perform these tests where permitted. NOAA can only conduct tests with live warning codes with permission from state emergency management agencies. To date, only Alaska has approved EAS tests with live warning codes. In states where tests with live warning codes are not permitted, NOAA conducts periodic tests fully exercising the NOAA Weather Radio All Hazards, but only activates EAS with test codes. NOAA will continue to encourage state participation in end-to-end testing of the tsunami warning system.

Recommendation 4: "…evaluate the TsunamiReady program to determine what barriers, if any, exist to participation and what modifications are needed to encourage more high-risk communities to participate;…"

See comment 1.

NOAA Response: NOAA believes all of the Nation's coastal areas should be prepared for a tsunami – no matter how rare. As such, NOAA recommends changing the wording of this recommendation from "…evaluate the TsunamiReady program to determine what barriers, if any, exist to participation and what modifications are needed to encourage more high-risk communities to participate;…" to "…evaluate the TsunamiReady program to determine what barriers, if any, exist to participation and what modifications are needed to encourage more at-risk communities to participate;…"

NOAA agrees with this recommendation to encourage more "at-risk" communities to participate in the TsunamiReady Program. NOAA will review the program at its annual Storm/TsunamiReady National Board meeting during summer 2006 and will coordinate any changes with members of the NTHMP.

Recommendation 5: "evaluate the NTHMP to determine what has worked well in the past and what high priority activities remain to be completed and to help inform strategic planning efforts;"

NOAA Response: NOAA agrees with this recommendation and will coordinate with NTHMP members during the next year to identify successes, areas for improvement, and high priority activity gaps. This information, along with existing planning documentation from the NTHMP subcommittee, will be used to inform strategic planning efforts, which acknowledge the

expansion of the program to other states and territories, as well as the types of projects the program funds.

Recommendation 6: "...develop comprehensive risk-based strategic plans for the Tsunami Program and National Tsunami Hazard Mitigation Program that consider input from states and federal partners and include metrics for measuring progress towards achieving program goals."

NOAA Response: NOAA agrees with this recommendation; however, it is important to note that the necessary risk assessments cannot be begun until the tsunami hazard assessment is completed in November of 2006. NOAA will then work with its partners to begin the risk assessments, which require detailed information including inundation maps, land-use, and population. NOAA will incorporate risk assessments, once available, into the strategic plans for the Tsunami Program and the NTHMP.

NOAA has developed a draft Tsunami Program Strategic Plan and will coordinate with state and federal partners. A final Tsunami Program Strategic Plan is expected to be released by January 2007.

The NOAA will begin to develop an NTHMP Strategic Plan during Fiscal Year 2006. The success of the strategic plan depends heavily on the participation and commitment from state and federal NTHMP members. NOAA will work with its partners to complete an NTHMP Strategic Plan.

The following is GAO's comment on the Department of Commerce's letter dated May 8, 2006.

GAO Comment

1. Having all coastal communities be prepared for a tsunami may be a worthwhile long-term goal; however, given limited resources, in the short-term we believe that it is important to prioritize the efforts of the TsunamiReady program to encourage higher-risk communities to participate.

Appendix II: Comments from the Department of Homeland Security

Note: GAO comments supplementing those in the report text appear at the end of this appendix.

U.S. Department of Homeland Security
Washington, DC 20528

Homeland Security

May 12, 2006

Ms. Anu K. Mittal, Director
Natural Resource and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Ms. Mittal:

Re: Draft Report GAO Report 06-519 "U.S. Tsunami Preparedness: Federal and State Partners Collaborate To Help Communities Reduce Potential Impacts, But Significant Challenges Remain.

Thank you for the opportunity to review the draft report. Although none of the recommendations are directed to DHS/FEMA, the following represents our response to the content of the report and the recommendations made to the Department of Commerce National Oceanic and Atmospheric Administration (NOAA). The GAO report does a very good job of introducing the hazard and the issues, and of describing the role of NOAA and the National Tsunami Hazard Mitigation Program (NTHMP); however FEMA continues to have some significant concerns. These concerns are as follows:

The first recommendation for Executive Action is that the "Secretary of Commerce direct the NOAA Administrator to … work with the FEMA Administrator and the USGS Director to create standardized tsunami loss estimation software to help communities determine the potential impact of tsunamis and identify appropriate mitigation actions." FEMA agrees that this need exists and that the existing FEMA HAZUS-MH (Hazards U.S. – Multi-Hazard) standardized loss estimation software program would be the most appropriate vehicle for such a tool. However, while FEMA work currently underway includes funding for the development and maintenance of modules that address earthquake, hurricane winds, coastal storm surge, and coastal and riverine flooding, we do not have or anticipate funding for additional modules to the HAZUS-MH package. While there are several additional hazards that could be added to the HAZUS-MH package, including wildfire and tornado as well as tsunami, FEMA does not have the funding or staff resources to pursue this. Any request from NOAA in this regard would need to address these needs. As a technical point, FEMA is led by a Director, not an Administrator.

See comment 1.

Page numbers in draft report may differ from those in this report.

www.dhs.gov

See comment 2.

The GAO report makes no mention of other federal agency's programs that address the tsunami hazard and encourage the States and local communities to take preparedness and mitigation action. One example of this would be FEMA's Community Rating System (CRS) in the National Flood Insurance Program (NFIP). The NFIP is a federally-backed flood insurance program administered by FEMA that makes flood insurance available for citizens of communities that adopt and enforce certain flood loss reduction ordinances. The NFIP also covers flooding due to tsunami. The CRS provides incentives to reward communities that take actions above and beyond the minimum requirements of the NFIP to help their citizens prevent or reduce flood losses or to initiate new flood protection activities, including "special" flood hazards like tsunami. The benefit for communities that undertake these CRS activities is lower flood insurance premiums for their citizens. Under the CRS, FEMA has worked over many years to develop tsunami credits in order to provide incentives for communities to implement special tsunami loss reduction activities. These activities range from direct acquisition and relocation projects to zoning to prohibit future development in high risk areas.

See comment 3.

FEMA programs that could be used to fund tsunami mitigation projects that have been identified as part of a State or communities mitigation plan should also be described in the report. These include FEMA's Pre-Disaster Mitigation Program, which is a competitive grant program available to all States, and FEMA's Hazard Mitigation Grant Program, which is a grant program that is made available after a Presidentially-declared disaster. These programs should be described as another federal activity under the section entitled "State and Local Tsunami Hazard Mitigation Activities are Underway, Although Implementation Varies Considerably Among Locations", probably in the subsection that ends on page 37.

See comment 4.

FEMA continues to be concerned that the report's description of the NOAA TsunamiReady Program and how it relates to response, preparedness and mitigation is confusing. "Response" is immediate action taken to save lives, including responding to a warning. "Mitigation" is sustained actions taken to reduce or eliminate long-term risk to people and property from natural hazards and their effects. Mitigation actions often involve safer land use measures and building practices, and the improvement of existing structures and supporting infrastructure. The NOAA TsunamiReady Program is an important program, but is limited in scope to identifying and improving a local community's tsunami warning system and how it would be used, which the report covers very well. The program "encourages" and "rewards" preparedness, but does not include preparedness and mitigation activities such as developing school plans and curriculum, facilitating community workshops or campaigns, working with various community target groups such as policy decision makers or businesses, or helping with planning beyond warning systems.

See comment 5.

Further, the report does not adequately describe the role of emergency management organizations at the local, State and Federal levels and how they deal with mitigation and preparedness issues. These government organizations work together in the NTHMP Mitigation Subcommittee, which is made up of State emergency managers and geoscientists and led by FEMA. This subcommittee developed and has been

implementing a strategic plan for mitigation and preparedness, and has been producing outreach products since the NTHMP began in 1996. Under the subcommittee, community needs are prioritized and gaps reviewed and addressed, State program activities are shared and several multi-State products have been developed and disseminated.

GAO may wish to include recent program discussions suggesting staff from the TsunamiReady Program could work more closely with or as part of the NTHMP Mitigation Subcommittee. This action would bring community preparedness, mitigation and outreach components together in a comprehensive and mutually supportive partnership between the emergency management members and National Weather Service (NWS) TsunamiReady Program staff that can build together on past successes as the NTHMP expands.

See comment 6.

The last sentence of the first paragraph on page 31 states "vertical evacuation to the upper floors of a building can be an alternative or supplement to horizontal evacuation" and then includes a reference to the FEMA/NOAA Tsunami Vertical Evacuation Shelter Guide currently under development. While vertical evacuation in a structure is certainly a feasible option, and in some cases the only option, the report needs to be careful to state that this should only be planned and promoted for buildings that are capable of withstanding the initial earthquake loads as well as the subsequent tsunami loads. Such a determination will be a key component of the FEMA/NOAA document.

See comment 7.

The first paragraph on page 36 references the Uniform Building Code (UBC). While this model building code may still be used in some areas, it is obsolete and has been replaced by the International Building Code (IBC). The last sentence in that paragraph states that the IBC "would strengthen buildings against tsunamis and other hazards." This statement needs to clarify that, like the UBC, the IBC does not contain specific requirements addressing the tsunami hazard, but that structures built in conformance with the IBC will overall tend to perform better due to other code provisions, particularly seismic requirements.

Thank you for the opportunity to review the GAO report. We would be happy to answer any questions or address any information needs you or your staff may have.

Sincerely,

Steven J. Pecinovsky

Steven J. Pecinovsky
Director
Departmental GAO/OIG Liaison Office

The following are GAO's comments on the Department of Homeland Security's letter dated May 12, 2006.

GAO Comments

1. We revised the text to show the correct title for the FEMA Director.

2. We describe FEMA's Community Rating System in a report footnote. For this reason, we did not revise the report.

3. We revised the report to indicate that FEMA's Pre-disaster Mitigation Program and Hazard Mitigation Grant Program have funded tsunami mitigation activities.

4. We believe that the report clearly describes the TsunamiReady program as providing minimum guidelines for communities to use to enhance tsunami preparedness, not as a program that requires all of the activities that could be taken to maximize community protection. For this reason, we did not revise the report.

5. We believe that the report adequately describes the NTHMP's federal and state partnership as well as the roles of emergency management organizations at the federal, state, and local levels, not only for warning systems, but also for planning, education and outreach, and infrastructure protection mitigation activities. For this reason, we did not revise the report.

6. We revised the report to clarify that vertical evacuation should only occur in buildings that are capable of withstanding the initial earthquake and subsequent tsunami.

7. We revised the report to clarify the extent to which building codes address the tsunami hazard.

Appendix III: Comments from the Department of the Interior

Note: GAO comment supplementing those in the report text appear at the end of this appendix.

United States Department of the Interior

OFFICE OF THE ASSISTANT SECRETARY
POLICY, MANAGEMENT AND BUDGET
Washington, DC 20240

MAY 04 2006

TAKE PRIDE IN AMERICA

Ms. Anu K. Mittal
Director, Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, N.W.
Washington, D.C. 20548

Dear Ms. Mittal:

Thank you for providing the Department of the Interior (DOI) the opportunity to review the U.S. Government Accountability Office (GAO) draft report entitled, "U.S. TSUNAMI PREPAREDNESS: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, But Significant Challenges Remain" (Report Number GAO-06-519).

The GAO staff is to be commended for conducting a thorough, well-researched examination of the Nation's tsunami warning system. The report correctly recognizes the need for close collaboration at the Federal, State, and local levels to have an effective end-to-end system. The report also acknowledges the unique challenge of providing adequate warning to coasts vulnerable to locally generated tsunamis, but the agencies could benefit from more specific recommendations in this regard.

The DOI supports the need for a risk-based approach to prioritizing Federal investments in this system and is actively collaborating with the National Oceanic and Atmospheric Administration to provide the hazard assessments that necessarily underpin such an approach.

See comment 1.

One area that we feel is inadequately addressed is the importance of a long-term Federal role in research to improve tsunami warnings and mitigate tsunami risks. None of the recommendations involve improving or expanding research. Yet because tsunamis are rare and tsunami risk reduction is a multi-decadal undertaking, major improvements to tsunami warning and risk reduction will come as a result of research. Multiple agencies support research programs in the geological and ocean sciences and in monitoring and observing systems, including satellite systems. Such research spanning fundamental investigations to applications will provide opportunities to apply new technologies such as the Global Positioning System and hydro-acoustic monitoring methods developed in other fields for other uses to advance tsunami warning and preparedness.

We hope our comments will assist you in preparing the final report.

Sincerely,

R. Thomas Weimer

R. Thomas Weimer
Assistant Secretary

cc: Secretary Surname
ES
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AS/PMB
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USGS/DO/bbageant:cr/4/17/06:ext703-648-4328:2006332-DO

The following is GAO's comment on the Department of the Interior's letter dated May 4, 2006.

GAO Comment

1. The analysis of the federal role in research on tsunami warnings and mitigation was not included in the scope of this report. Consequently, we did not examine issues related to tsunami research or offer any recommendations.

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Anu K. Mittal, (202) 512-3841

Staff Acknowledgments

In addition to those named above, Stephen D. Secrist, Assistant Director; Brad C. Dobbins; Joel A. Green; Ryan S. Lambert; and Susan M. Zimmerman made key contributions to this report. Also contributing to the report were Claudia K. Becker; John W. Delicath; Gregory A. Marchand; John G. Smale, Jr.; Anne O. Stevens; and Randall B. Williamson.

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