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Helping Coastal Communities at Risk from Tsunamis—The Role of U.S. Geological Survey Research

In 1946, 1960, and 1964, major tsunamis (giant sea waves usually caused by earthquakes or submarine landslides) struck coastal areas of the Pacific Ocean. In the U.S. alone, these tsunamis killed hundreds of people and caused many tens of millions of dollars in damage. Recent events in Papua New Guinea (1998) and elsewhere are reminders that a catastrophic tsunami could strike U.S. coasts at any time. The USGS, working closely with NOAA and other partners in the National Tsunami Hazard Mitigation Program, is helping to reduce losses from tsunamis through increased hazard assessment and improved real-time warning systems.

Population pressures in the coastal zones of the Pacific Ocean and the Caribbean are resulting in unprecedented shoreline development, putting residents, tourists, and property at increased risk from giant sea waves, called tsunamis. Tsunamis, often incorrectly referred to as "tidal waves," can be generated by distant earthquakes and by local seismic events, submarine landslides, and volcanic eruptions. For ocean-crossing tsunamis, there is often sufficient time to evacuate distant coastal areas, but more timely and accurate real-time tsunami forecasts are needed to avoid costly false alarms. Local tsunamis generated by quakes on active seismic zones in Alaska, the Pacific Northwest, the Caribbean, California, and Hawaii can arrive at nearby shorelines in minutes. In these cases, only better scientific understanding, informed disaster planning, and public education will save lives in future tsunamis.

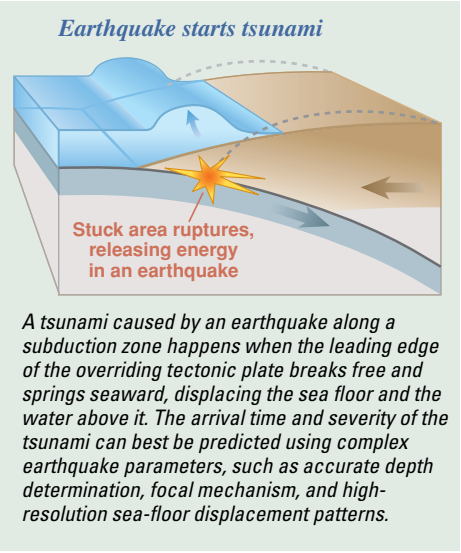
Aftermath of the 1960 Chilean tsunami in Hilo, Hawaii, where the tsunami caused 61 deaths (photo courtesy Pacific Tsunami Museum). Inset shows damage from a local tsunami that struck Okushiri Island, Japan, in 1993 (photo by Dennis Sigrist, International Tsunami Information Center). Floating debris, such as seen in these photographs, can cause significant destruction during tsunami runup.

Protecting lives and property from tsunamis demands a clear understanding of how tsunamis are generated, the identification of likely areas at risk, and mitigation efforts based on public education. The National Tsunami Hazard Mitigation Program (NTHMP), a partnership of the States of Alaska, California, Hawaii, Oregon, and Washington and the Federal Emergency Management Agency, National Oceanic and Atmospheric Administration (NOAA), and U.S. Geological Survey (USGS), is currently preparing tsunami inundation maps and implementing mitigation plans for states bordering the Pacific Ocean. The NTHMP is also providing tsunami early warnings for these states by means of deep-ocean tsunami detectors and new seismic stations on land. The cooperation of Federal and state agencies in the NTHMP is furthering scientific understanding of tsunami hazards and facilitating the development of plans to prepare coastal communities to better survive future tsunamis.

The mission of the USGS includes understanding the geologic mechanisms, frequency, magnitude, and physical consequences of natural hazards. In recent years, the USGS has upgraded its seismic networks to provide NOAA's tsunami warning centers with detailed earthquake information to aid in timely notification of the public. The USGS and NOAA are currently providing real-time seismic and tsunami information to state offices of emergency services in Alaska, Washington, Oregon, California, and Hawaii.

To ensure that its efforts to reduce the risk from tsunamis are focused where they will be most effective, the USGS convened a two-day workshop in Seattle, Washington, in January 2000. This workshop was attended by scientists and managers from the USGS, NOAA, state agencies, and academia. Based on needs identified by the workshop participants, the following recommendations on the role of the USGS in tsunami research were made:

Seismic networks—It is important that, as advances in technology and science allow, the USGS continue to enhance and improve the quality and quantity of seismic data supplied to tsunami warning



A tsunami caused by an earthquake along a subduction zone happens when the leading edge of the overriding tectonic plate breaks free and springs seaward, displacing the sea floor and the water above it. The arrival time and severity of the tsunami can best be predicted using complex earthquake parameters, such as accurate depth determination, focal mechanism, and high-resolution sea-floor displacement patterns.

centers. The USGS should also determine the need for additional strong-motion seismic stations along U.S. coasts. Further, the USGS should continue to develop software that supports tsunami warnings for local earthquakes, particularly in Hawaii, Alaska, the Pacific Northwest, and the Caribbean.

Earthquake source characterization— In order to provide accurate warnings and hazard assessments, better characterizations of critical earthquake source parameters are needed. Modern methods of analyzing seismic data developed by the USGS can be used by tsunami warning centers in an overall effort to improve the accuracy and timeliness of tsunami warnings. Further research is also recommended into using rapid seismic inversion algorithms to estimate sea-floor displacement, an indicator of likely tsunami size, which could be automated as part of local tsunami warning systems.

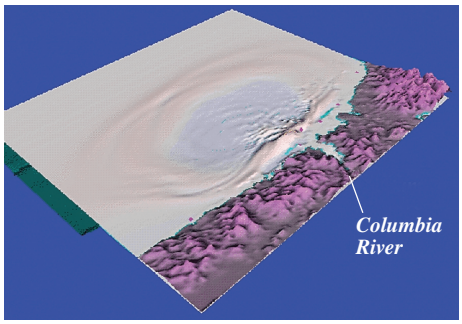
Hazard assessments—The NTHMP is coordinating the preparation of tsunami inundation maps for high-risk coastal communities in Alaska, California, Hawaii, Oregon, and Washington. The USGS can provide valuable guidance in the preparation of these maps by analyzing and interpreting deposits from historic and prehistoric tsunamis to estimate inundation limits, flow velocities, and recurrence intervals.

Coastal bathymetry and topography— Producing reliable and useful inundation maps for hazard assessment partially depends on accurate bathymetry and topography of coastal regions. The USGS, along with NOAA, NASA, and the Army Corps of Engineers, have proven capability to survey coastal and nearshore bathymetry and topography using modern techniques. It is recommended that the USGS coordinate with other Federal agencies to provide such information for hazard mitigation planning in high priority areas of the Pacific Northwest, Alaska, Hawaii, California, and the Caribbean.

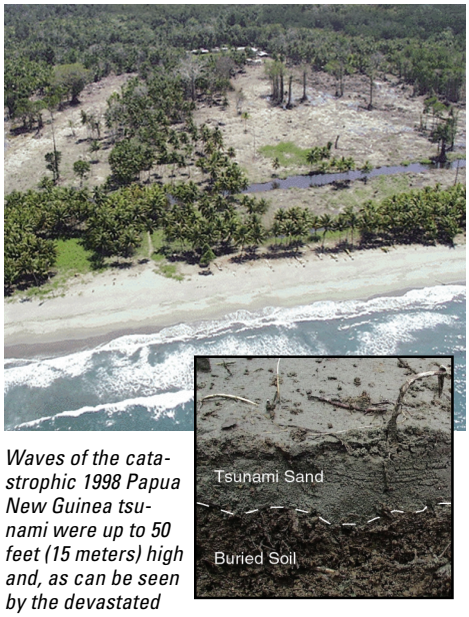
Sedimentary deposits as keys to tsunami character—Identification and interpretation of sedimentary deposits left behind by prehistoric tsunamis will improve our ability to assess the magnitude of tsunami risk in areas with an insufficient historical record. The USGS will provide expertise and leadership in sediment transport modeling to increase understanding of the mechanics of sediment transport in tsunamis and of the deposits they leave behind. Research would occur in field settings by integrating predictive modeling with laboratory and post-event studies.

Post-event rapid response—The visible effects of tsunamis are short-lived and may be lost after a single subsequent storm or during clean-up efforts employing earth-moving equipment. To determine the effects of tsunami inundation on land, the run-up elevation and distance, flow-speed and direction indicators, and patterns of sedimentary deposition must be mapped and quantified immediately following an event. USGS scientists should join the International Tsunami Survey Team, when warranted, to gather information about tsunami deposits and to calibrate sediment transport models.

Tsunamis generated by landslides and volcanic events—Landslides and volcano flank failures in coastal and island settings have also initiated large tsunamis. The accumulated knowledge of USGS scientists about submarine and coastal landslides and active volcanic processes should be focused on improving understanding of how and where these catastrophic mass failures may occur. This information then can be used in regional hazard assessments by Federal, state, and local authorities.



Computer simulation of a major nearshore earthquake along the Cascadia Subduction Zone off the Pacific Northwest shows the advancing wave fronts of the resultant tsunami.



Waves of the catastrophic 1998 Papua New Guinea tsunami were up to 50 feet (15 meters) high and, as can be seen by the devastated forest in this photograph, inundated areas as much as half a mile (800 meters) inland. This locally generated tsunami, caused by a magnitude 7.1 earthquake just offshore, killed at least 2,000 people and left more than 10,000 others homeless. Inset shows sand and debris left behind by this tsunami. Sand deposits from recent and prehistoric tsunamis yield information about the magnitude, extent, and frequency of past tsunamis, which can in turn be used to estimate the hazard posed to an area by future tsunamis.

The efforts of USGS and other cooperators in the NTHMP are leading to a better understanding of tsunamis and how coastal populations can be prepared to survive their onslaught. The work of USGS scientists in tsunami research is only part of the ongoing efforts of the USGS to protect people's lives and property from geologic and environmental hazards in the coastal zones of the United States.

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See also *Surviving a Tsunami—Lessons from Chile, Hawaii, and Japan* (USGS Circular 1187)
This Fact Sheet and any updates to it are available on line at
http://geopubs.wr.usgs.gov/fact-sheet/fs150-00/