

Our Ocean Backyard — *Santa Cruz Sentinel* columns by Gary Griggs, Director, Institute of Marine Sciences, UC Santa Cruz.

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Tsunamis in California



Crescent City was heavily damaged by a tsunami from a large Alaskan earthquake in 1964, which led to the deaths of 11 people.

The earthquake and tsunami in Japan two weeks ago, combined with the fascination many have with giant waves, has led me to pursue the topic of large waves a bit further. Tsunamis are created by large displacements of water, either big ocean floor earthquakes, submarine volcanic eruptions, or massive landslides. There are good historic examples of each of these scattered across the globe, but to date, the tsunamis we have experienced historically along the California coast have all been driven by distant earthquakes.

The world has experienced some devastating earthquakes over the past several years; three of the six largest recorded since 1900 all happened within the last five years: Sumatra 9.1 magnitude in 2006, Chile 8.8 in 2010, and Japan 9.0 in 2011. Rounding out the top six are Chile 9.5 magnitude in 1960, Alaska 9.2 in 1964, and Kamchatka 9.0 in 1952. Interestingly, the world's greatest earthquakes all occurred

at subduction zones or trenches – most of which are located around the margins of the Pacific Ocean – and all of these have the potential to generate tsunamis that could impact the California.

The size or magnitude of an earthquake is directly related to the surface area of the plates or slabs that rupture; the larger the rupture area, the greater the energy released. While the 6.9 magnitude Loma Prieta earthquake was devastating locally and seemed large to all of us here in 1989, it was actually a moderate shock in the big picture of things seismic. Loma Prieta only ruptured 25 miles of the San Andreas Fault. The 9.1 magnitude Sumatra earthquake of December 26, 2004 took place at a subduction zone in the Indian Ocean and ruptured 900 miles of fault, the greatest ever recorded.

The energy released during an earthquake is proportional its magnitude, which is based on a logarithmic scale. Each unit increase in magnitude corresponds to a release of about 30 times more energy. The Sumatra earthquake and the massive 9.0 shock two weeks ago, therefore, released 30 times 30, or about 900 times more energy than Loma Prieta. In addition, both the Sumatra and Japan earthquakes displaced huge areas of seafloor producing large pulses that propagated across the Indian and Pacific oceans, respectively. Waves along the coast of Indonesia in 2004 reached elevations 100 feet above sea level and led to the loss of about 250,000 lives. Along the coast of Japan, waves reached 30 feet in elevation, and while the total number of casualties is not yet known, estimates are already approaching 20,000.

Five of the six largest earthquakes ever recorded on seismographs have occurred around the margins of the Pacific Basin, and these have been about as large as seismologists can imagine. We might reasonably conclude that we have already experienced the worst that can be expected in terms of tsunami impacts here in California, but there are some worse case conditions that might produce even greater impacts. The tsunami from Japan two weeks ago, for example, arrived at a low tide; if it had been a high tide, the situation would have been even worse.

Over the past nearly 200 years of historic record in California there have only been seven destructive tsunamis. Over this period, 17 lives have been reported lost due to tsunamis, far less than the number of people killed by dog bites or bee stings. The earliest reported event was in 1812, when a tsunami caused by an earthquake in the Santa Barbara Channel generated large waves that washed ashore at Santa Barbara, and further west at Gaviota and Refugio canyons. A tsunami that appears to have been generated by an offshore earthquake hit the coast of southern

California in August 1930. Maximum wave heights appear to have been about ten feet. Many swimmers were rescued and one person is reported to have drowned along the Santa Monica shoreline.

Until two weeks ago, the tsunamis that have been the most damaging to the California coast were both generated by large earthquakes in the Aleutian Trench off of Alaska, one on April Fool's Day in 1946 and the other on Good Friday in 1964. A man walking along the shoreline in Santa Cruz was drowned in the 1946 tsunami when the water level rose quickly to 10 feet above normal.

The most destructive historic tsunami to batter California's coast accompanied the magnitude 9.2 1964 Alaskan earthquake. Crescent City was the hardest hit, being inundated by a series of waves that pushed buildings off their foundations and swept vehicles and buildings into the ocean. Wave run-up extended 2,000 feet inland in the commercial and residential areas of the city with water depths of up to 8 feet in city streets and 13 feet along the shoreline. The worst waves struck the waterfront area at 1:45 A.M., drowning 12 people, demolishing 150 stores, and littering the streets with huge redwood logs from a nearby sawmill.

In Half Moon Bay, Santa Cruz, Avila and Morro Bay harbors, boats broke loose, were damaged and sunk. Boats and harbor facilities were also damaged in Santa Monica and Los Angeles harbors. There is a pattern here, where nearly all of the significant tsunami damage in California has been in or adjacent to ports or harbors, where the wave energy can be concentrated or focused.

The size of a tsunami and its impact can vary widely depending on the magnitude and location of the earthquake, the nature of the offshore seafloor, and the coastal topography. Although destructive tsunamis are not everyday events in California, they do occur and will occur in the future. Seven destructive tsunamis have reached the California coast over the past 200 years and about 17 lives have been lost. The tsunamis of 1946, 1964 and now 2011 have caused the most damage and are good indicators of what may again happen in the future.