http://www.latimes.com/local/lanow/la-me-ln-tsunami-warning-20181002-story.html
Catastrophic Indonesia tsunami shows critical blind spot in warning system for California and beyond
Rong-Gong Lin II (9-12 minutes)
October 2, 2018

Along the California coast and across the world, dozens of deep-sea ocean sensors are a first line of defense that warns officials when a devastating tsunami is coming.

When an earthquake strikes, the sensors capture the movement of the ocean waters, giving authorities precious time to alert residents to move to higher ground.

But the destructive tsunami that hit Indonesia on Friday highlights a critical flaw in the systems.

If a big quake strikes too close to shore, it won't be detected by those deep-sea sensors, and the wave can arrive before major evacuations occur. That's what happened on the Indonesian island of Sulawesi, when a magnitude-7.5 earthquake hit just north of a narrow bay, sending waves as tall as 20 feet straight into Palu, a town where at least 1,200 people were killed.
Scientists said California faces similar vulnerabilities. Low-lying stretches of the coast are susceptible to damage from a tsunami, and there has been a push in recent years to improve safety protocols.

In Southern California, an earthquake could trigger an underwater avalanche in the Santa Monica Bay, producing a tsunami that could inundate low-lying areas of Santa Monica and the South Bay towns of Manhattan Beach, Hermosa Beach and Redondo Beach, said Costas Synolakis, a USC civil and environmental engineering professor and tsunami expert.

"This is exactly the scenario we are afraid of in Southern California," Synolakis said, "where we are going to get an on-land earthquake … and the biggest shaking triggers a submarine landslide. … This is kind of a nightmare ... that's hard to prepare against."

In Los Angeles County, a locally generated tsunami could bring water as high as 11 feet in Redondo Beach, 8 feet at the ports of Los Angeles and Long Beach, 7 feet in Manhattan Beach and 5 feet in Marina del Rey. There is evidence that a 20-foot-high tsunami was generated 7,500 years ago when a magnitude-7 earthquake triggered an underwater landslide off the Palos Verdes peninsula.

With only minutes between the shaking and the tsunami, it's possible no official early warning may come. It was only about 10 minutes between the earthquake and the first wave that washed across Palu, said Caltech seismology professor Pablo Ampuero. When a quake hits further out in the ocean, officials can have hours to evacuate before the waves hit land. But on Friday, they had only minutes.

And when a tsunami warning was issued by the Indonesian government, the public may not have received the alert, Ampuero said, because the quake knocked out electricity and communications systems.

It is a scenario that could be repeated in Southern California.

During the great 2011 Japan tsunami, some of the first detailed alerts underestimated the size of the tsunami to be lower than the protective sea walls on the coast. Then the communications were cut off, leaving the public with a false sense of security.

While tsunamis get less attention than earthquakes in California, officials have warned the state needs to be better prepared — and to better understand the deadly risks. In 1964, 11 people died when waves slammed into Crescent City, inundating the downtown area. In 2011, hours of warning enabled an effective evacuation of Crescent City, although one man, taking photographs of the tsunami at the mouth of Klamath River, died after being swept to sea.

Tsunami science has improved considerably since the 1980s, thanks to a new generation of detection equipment. Nations rallied to fill in gaps in the global network after the 2004 Sumatra tsunami exposed shortfalls, including the lack of a network in the Indian Ocean.

Some news reports after Friday's quake initially focused on the state of disrepair of Indonesia's network of nearly two dozen deep-sea sensors as a possible factor in the loss of life. The German-funded effort never produced a working system, Synolakis said.

Synolakis and others, however, noted that even having a working deep-sea sensor network of the kind used by the United States and other nations — known as DART — may not have helped. Deep sea sensors are more intended to detect tsunamis that are farther from its destination, not a matter of minutes away from the shoreline.

"The DARTs are really wonderful for judging a tsunami and figuring out how it's going to be on the far side of the ocean," said Gerard Fryer, former geophysicist at the Pacific Tsunami Warning Center in Hawaii. "But for warning of a local tsunami, they're just not enough. They might help if you're lucky if you've got one in just the right place. But they probably won't."

Giving warning of a nearby tsunami would probably require a new technological solution. One idea, Fryer said, is blanketing the seafloor of an area particularly at risk of tsunamis with underwater microphones, and then develop a computer program to send out the alerts. But, he said, "that's not something we can do off the shelf right now."

But there are things that could have been done to better prepare Palu for what happened. For one, Palu has had a history of dealing with damaging tsunamis. A magnitude-7.8 earthquake led to a tsunami that killed 200 people in 1968, Fryer said, and there were deaths from tsunamis generated by a magnitude-7.6 earthquake in 1938 and a magnitude-6.3 earthquake in 1927.

A key reason lies in Palu's geography. Sitting at the end of a narrow, finger-shaped bay is one of the worst locations to be in if a tsunami enters the inlet. Water rushing into a bay that gets progressively shallower can allow it to push on to land.

In fact, tsunami translates from Japanese literally as "harbor wave," as the towns known to be clobbered by tsunamis were at the long end of narrow harbors on the northeastern coast of Japan's Honshu island, Fryer said. The same dynamic led to significant damage in Port

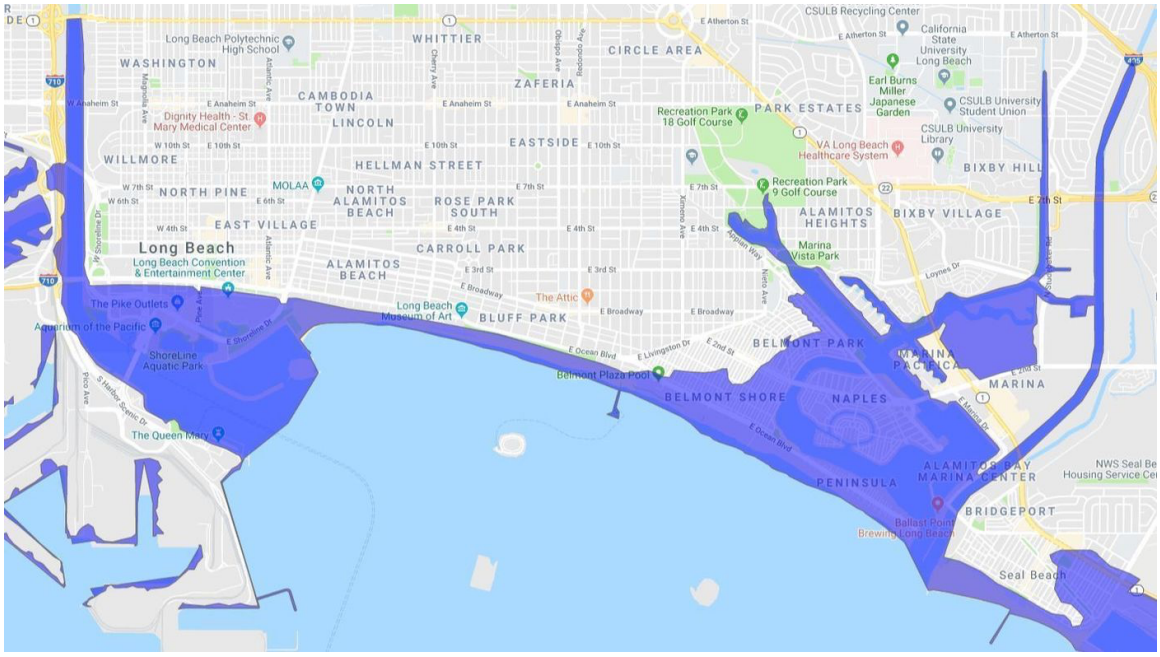
Alberni, at the end of the Alberni Inlet, on Vancouver Island in the great 1964 Alaska earthquake.

“These bays, they tend to funnel the energy. It’s almost like a bull’s-eye is where the city is,” Synolakis said.

Experts say it makes sense for people along the coast to seek higher ground in the event of any major quake.

“If you feel strong ground shaking and it lasts for 10 to 15 seconds or so, or maybe even less — don’t take any chances. If you’re in a coastal area or along the beach, move uphill and inland as quickly as possible,” said Stuart Weinstein, deputy director of the Pacific Tsunami Warning Center in Hawaii. “You can self-evacuate. The worst case is you take a fast walk for nothing; on the other hand, it could save your life.”

A general rule of thumb is to climb 50 feet to 100 feet above sea level. Sometimes, it may be better to evacuate vertically up a tall concrete or steel-frame building. A two-story wood-frame home is not high or sturdy enough, experts say.



A hypothetical tsunami flood map shows areas of Long Beach and Seal Beach inundated by water. (California Department of Conservation / U.S. Geological Survey's Science Application for Risk Reduction Tsunami Scenario)

Friday’s tsunami was seen as unusual. The largest tsunamis in the world are generated from what’s known as subduction zones, in which one tectonic plate slides underneath another. Earthquakes on subduction zones can generate vertical motion that propel tsunamis to land.

But this tsunami was generated after a quake began on land on a strike-slip fault — the same kind of fault like the San Andreas, where one block of land slides past the other

horizontally. This produces horizontal movement not typically associated with large tsunamis, yet is still possible, as Friday's disaster showed.

There are other possible explanations for why a tsunami hit Palu so hard. One is that the bay starting moving back and forth, like someone shaking a mug filled with coffee, leaving the liquid to slosh onto land, Synolakis said.

Another possibility is that the fault movement caused just one side of the bay to move, pushing water toward the other side, Synolakis said.

One thing is clear: Technology cannot be the only answer to tsunami warnings, especially in Indonesia, with its 17,000 islands.

"The shaking is your natural warning," Ampuero said.

Eddie Bernard, a former director of the Pacific Tsunami Warning Center, expressed sympathy for his tsunami scientist colleagues in Indonesia.

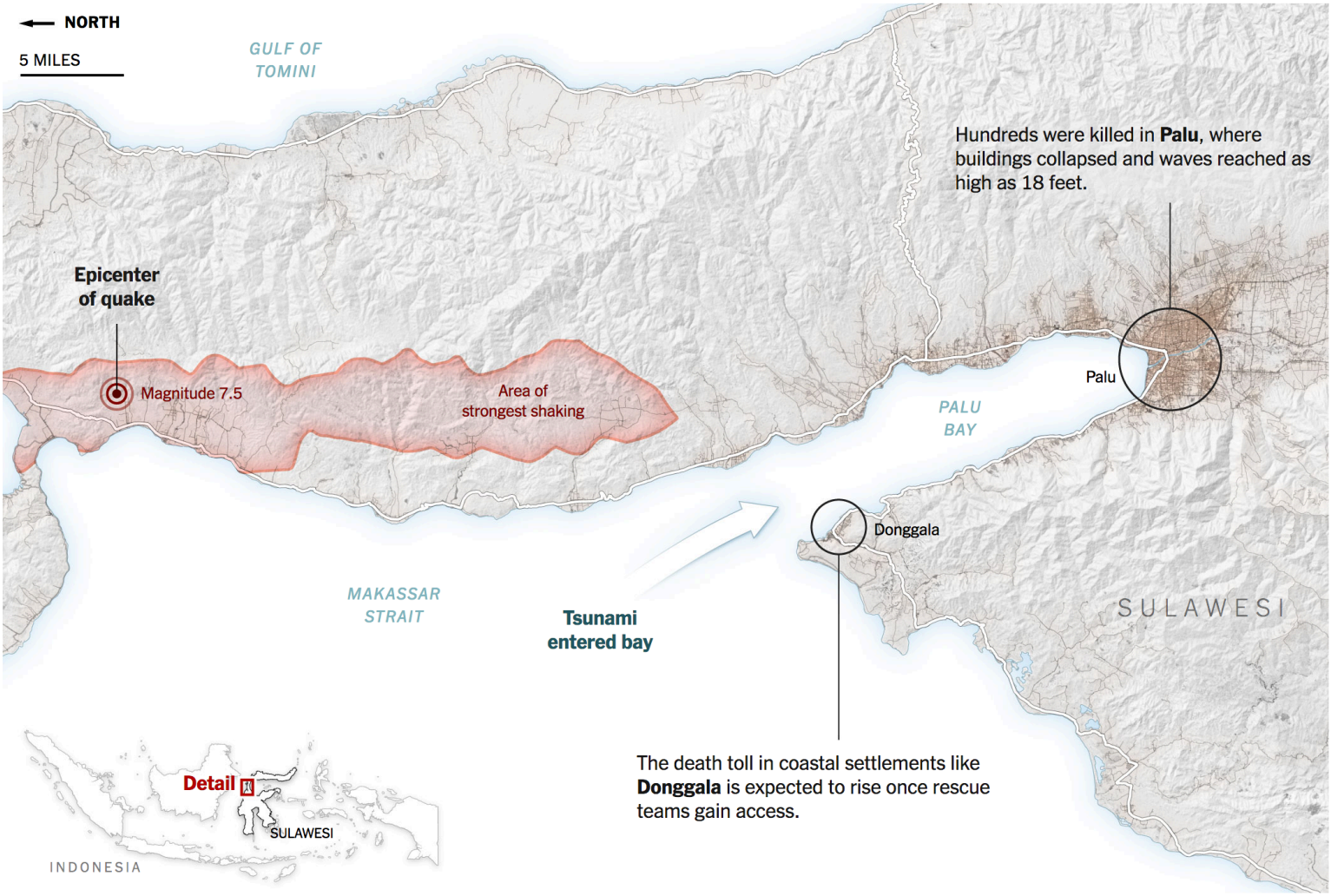
"They did the best they could with the information they had available," Bernard said. "A tragedy like this, everybody feels sad. But in time, more information will become available and maybe from this we'll learn more about what to do next."

Rong-Gong Lin II is a metro reporter for the Los Angeles Times, specializing in covering statewide earthquake safety issues and Northern California. He won the California Newspaper Publishers Assn.'s Freedom of Information Award and the University of Florida's Joseph L. Brechner Freedom of Information Award. He was a finalist for the Ursula and Gilbert Farfel Prize for Excellence in Investigative Reporting and the Knight Award for Public Service. A San Francisco area native, he graduated from UC Berkeley in 2004.

Indonesia Tsunami's Power After Earthquake Surprises Scientists
By Henry Fountain, Sept. 30, 2018

Scientists expressed surprise at the size of the tsunami that devastated the Indonesian city of Palu on Friday, saying an earthquake like the one that preceded it would not necessarily spawn such destructive waves.

By Derek Watkins and Bedel Saget | Source: U.S. Geological Survey ShakeMap



"We expected it might cause a tsunami, just not one that big," said Jason Patton, a geophysicist who works for a consulting firm, Temblor, and teaches at Humboldt State University in California.

But he added, "When events like this happen, we are more likely to discover things that we haven't observed before."

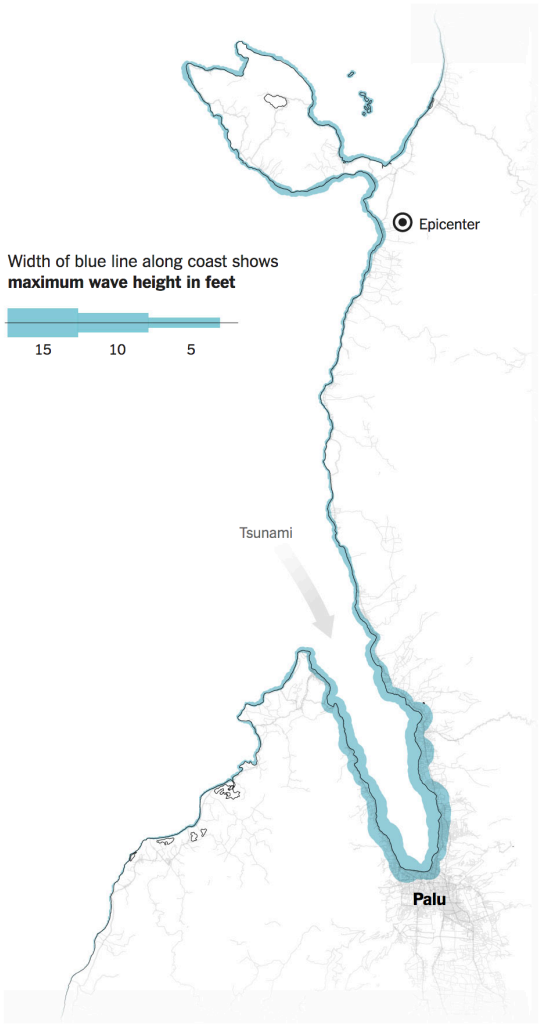
The 7.5-magnitude quake, which struck in the early evening, was centered along the coast of the island of Sulawesi about 50 miles north of Palu. Shortly afterward — within 30 minutes by some accounts — waves as high as 18 feet crashed ashore in the city, destroying buildings, smashing vehicles and killing hundreds of people.

The high casualty toll may also reflect Indonesia's lack of advanced systems for tsunami detection and warning, tsunami experts said.

Other communities on Sulawesi, including the city of Donggala, were also hit by the tsunami, although there are as yet few details of the destruction or death toll outside of Palu.

Catastrophic tsunamis are often the result of so-called megathrust earthquakes, when huge sections of the Earth's crust are deformed, moving vertically along a fault.

This suddenly displaces enormous amounts of water, creating waves that can travel at high speed across ocean basins and cause destruction thousands of miles from the quake's origin.



Source: Center for Disaster Management at the Karlsruhe Institute of Technology

The 2004 Indian Ocean tsunami, which had waves as high as 100 feet and killed nearly a quarter of a million people from Indonesia to South Africa, resulted from a 9.1-magnitude megathrust quake in Sumatra.

By contrast, the fault that ruptured on Friday was a so-called strike-slip fault, in which the earth movement is largely horizontal. That kind of movement would not ordinarily create a tsunami.

But under certain circumstances it can, Dr. Patton said.

A strike-slip fault might have some amount of vertical motion that could displace seawater. Or the fault's rupture zone, which in this case was estimated to be about 70 miles long, may pass through an area where the seafloor rises or drops off, so that when the fault moves during the quake, it pushes seawater in front of it.

Another possibility is that the tsunami was created indirectly. The violent shaking during the quake may have caused an undersea landslide that would have displaced water and created waves. Such events are not uncommon; several occurred during the 1964 9.2-magnitude Alaska earthquake, for example.

Dr. Patton said a combination of factors may have contributed to the tsunami. Studies of the seafloor will be crucial to understanding the event. "We won't know what caused it until that's done," he said.

The tsunami could also have been affected by Palu's location at the end of a narrow bay. The coastline and the contours of the bottom of the bay could have focused the wave energy and guided it up the bay, increasing the wave height as it approached shore.

Such effects have also been seen before. Crescent City, Calif., has been hit by over 30 tsunamis, including one after the 1964 Alaska quake in which 11 people were killed, because of the contours of the seafloor in the region and the city's topography and location.

Whatever the genesis of the waves, a 7.5-magnitude quake would not be expected to create an ocean-wide event, but rather a more localized one, as was the case on Friday.
With the tsunami generated so close to Palu, there was little time for people to escape. A tsunami warning was issued by the government and was lifted about half an hour after the quake, apparently after the tsunami hit Palu.
Indonesia currently uses only seismographs, global positioning system devices and tide gauges to detect tsunamis, which are of limited effectiveness, said Louise Comfort, a professor at the University of Pittsburgh graduate school. She has been involved in a project to bring new tsunami sensors to Indonesia.

In the United States, the National Oceanic and Atmospheric Administration has a sophisticated network of 39 sensors on the ocean bottom that can detect extremely small pressure changes indicating the passage of a tsunami.

The data are then relayed via satellite and analyzed, and an alert is issued if required.

Dr. Comfort said that Indonesia had a similar network of 22 sensors but that they were no longer in use because they were not being maintained or had been vandalized.

The project she is working on would bring a new system to Indonesia that would use undersea communication to avoid the use of surface buoys that could be vandalized or hit by ships.

Dr. Comfort said she had been discussing the project with three Indonesian government agencies. Plans to install a prototype of the system in western Sumatra were delayed this month. “They couldn’t find a way to work together,” she said.

“It’s heartbreaking when you know the technology is there,” she added. “Indonesia is on the Ring of Fire — tsunamis will happen again.”

A version of this article appears in print on Sept. 30, 2018, on Page A6 of the New York edition with the headline: Tsunami’s Power Takes Scientists by Surprise