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Japan Faces Up to Failure of Its Earthquake Preparations

Systems for forecasting, early warning and tsunami protection all fell short on 11 March.

Tuesday, March 29, 2011

By David Cyranoski of *Nature* magazine

TOKYO

Japan has the world's densest seismometer network, the biggest tsunami barriers and the most extensive earthquake early-warning system. Its population is drilled more rigorously than any other on what to do in case of earthquakes and tsunamis. Yet this month's magnitude-9 earthquake surprised the country's forecasters. The grossly underestimated tsunami destroyed the world's deepest tsunami barrier and caught people by surprise. And the early-warning system for earthquakes largely failed. What went wrong?

The first problem was the earthquake forecast. Japan's seismic hazard map, the latest version of which was released in March 2009, breaks the offshore area of northeastern Japan into five seismic zones and envisages seven different earthquake scenarios. Each is assigned a probability based on the historical record of earthquakes. The southern Sanriku offshore region, which included the origin of this month's earthquake, was given a 30-40% chance of rupturing in the next 10 years and a 60-70% chance in the next 20 years.

As earthquake forecasting goes, these are very high numbers. "That basically means it could happen any day," says Yoshinori Suzuki of the Earthquake Disaster Reduction Research Division within the science ministry, which coordinates the map-making. But the fault was expected to unleash an earthquake of around magnitude 7.7 -- about as large as any in the historical record for the area (see *Nature* 471, 274; 2011).

For a separate fault segment offshore from the Fukushima Daiichi nuclear plant, the same forecasting approach postulated only a magnitude-7.4 earthquake, with a less than 2% chance of occurring over the next 10 years and less than 10% over the next 50 years. The government of Fukushima prefecture even refers to the seismic hazard map to boast on its website: "With firm geological foundations and major earthquakes rare, Fukushima is a safe and secure place to do business." What the risk maps didn't allow for, however, was the coupling of segments that allowed the rupture to propagate for some 500 kilometres, unleashing an earthquake of magnitude 9.0 (see ▪False comfort;).

Japan's earthquake forecasting has had its successes. In 2003, the magnitude-8.3 Tokachi-oki earthquake occurred right in the middle of a forecasted hotspot. But for the most part, earthquake forecasting, which really took off in Japan in the 1980s and 1990s, has had mixed results, with many devastating quakes hitting outside the expected zones. "We would like to see more hit the marks," says Kyoto University's James Mori.

Despite the surprisingly powerful earthquake, Japan's earthquake-resistant buildings seemed to hold up well. "There was shaking damage but not much considering how strong the earthquake was," says Mori. It was the tsunami that did most of the damage, overwhelming barriers and years of preparation.

The world's deepest tsunami barrier, a 2-kilo- metre-long edifice at the mouth of Kamaishi Bay on the northeast coast, was completed in 2008 after 30 years, at a cost of more than ¥120 billion (US$ 1.4 billion). Anchored to the sea floor 63 metres down and rising 8 metres above the water, the 20-metre-thick break- water was designed to withstand the impact of a tsunami like the one from the 1896 Sanriku earthquake, which produced waves rising to nearly 40 metres in some areas.

Koji Fujima, a specialist in tsunami wave propagation at the National Defence Academy in Yokosuka, says that this and other structures along the coast gave people a false sense of security. "The region probably gets 2- or 3-metre tsunamis more than once a decade, and people know that the breakwaters will protect them from those," says Fujima. With the hazard map forecasting earthquakes in the magnitude-7.5 range, people would have anticipated a maximum tsunami of 4-5 metres.

Tsunami risk underestimated

Faith in the barriers seems to have undermined Japan's legendary tsunami-preparedness drills. In northeastern Japan as elsewhere, university professors, research institutes, non-governmental organizations and local civic groups carried out several drills each year to train people in how and where to evacuate. "We were working as hard as we could to educate people," says Fujima.

Yet people apparently became relaxed about tsunami risks, says Yoshiaki Kawata, a disaster-management expert at Kansai University. A tsunami originating in Chile last year triggered an evacuation warning to 1.68 million people in northeastern Japan. Only 62,000 sought shelter, says Kawata.

"People thought the breakwater was enough," says Fujima. But he adds that "there was no way it could protect them" against the tsunami on 11 March, although it did diminish the wave. Rising an estimated 15-20 metres at sea and 50 metres at some points after hitting the shore, even higher than the 1896 wave, it destroyed the tsunami barriers at Kamaishi and elsewhere and has killed an estimated 20,000 people who had failed to find safe, higher ground. It also swamped emergency generators at the Fukushima Daiichi plant, disabling the cooling system. Built in the 1960s, the plant was designed to withstand a tsunami of no more than 5.7 metres.

The early-warning system operated by the Japan Meteorological Agency, designed to alert people when an earthquake will create shaking at or above level 5 on Japan's energy intensity scale (severe enough to crack walls), fell short as well. Based on a seismic reading taken a few seconds after an earthquake hits, the system provides up to tens of seconds of warning before the major shaking begins. On 11 March it delivered accurate warnings to areas near the epicentre. But the greater Tokyo region, where many areas experienced level-6 shaking, received no warning. Bullet trains and nuclear reactors, which have their own warning systems, shut

down promptly, as designed.

The problem, according to Kyoto University's Masumi Yamada, was that the system assumes a "point source" for an earthquake. In this case, the point source led to an estimate of a magnitude-7.2 quake. But as the Sanriku rupture ripped hundreds of kilometres of fault line parallel to the coast, unleashing ever more energy and causing slips of 20 metres or more near the Tokyo region, the system didn't correct itself. The frequent aftershocks also confounded the system, which generated several false alarms and missed large aftershocks.

"The system seems to break down around a magnitude-8 quake," says Yamada. In April, she will start a three-year collaborative project with the Japan Meteorological Agency to convert the point-source warning system to a dynamic one that works in two dimensions.

Japan's disaster defences can certainly be improved, says Fujima, but he thinks that people should recognize that there are limits to what can be done against a "once in a thousand or two thousand years earthquake". Sturdier breakwaters could be built in areas where the tsunamis hit hardest, but they are expensive and could never fully protect against the biggest waves. "People probably should just stop building in the areas where large tsunamis will come," he says.

Kawata, however, puts his faith in better engineering. He agrees that the most effective way to avoid damage is to have people live out of reach of tsunamis. But he envisages houses (and nuclear plants) built on an artificial coastline supported by 10-metre-high concrete pillars. "There are a lot of things we have to do urgently. If we have a vision and we pool our energies, we can do it."

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