Tsunamis are a hazard because of the damage and casualties that they can cause when they strike shore. In the best of cases, a tsunami may come onshore like a series of quickly rising and falling tides and only cause a gentle repetitive flooding of low-lying coastal areas. Even this can be dangerous to persons who are caught unaware or are immobile and may be unable to escape. In the worst of cases, a tsunami can come onshore as a bore — a wall of turbulent water carrying rocks and debris that can be likened to the leading edge of a flash flood. This type of tsunami can be extremely destructive and may sweep away all but the most sturdy of structures. Large tsunamis can flood inland many hundreds of meters from the coast and run onshore to a height of 30 meters or more above normal sea-level. In addition, the danger can continue for many hours after the initial wave as following and sometimes-larger waves flood onshore and then drain offshore. Persons caught in a large tsunami have a much smaller chance to survive than in many other natural hazards. Aside from the danger of drowning, they face a significant possibility of being crushed by objects carried in the water. Children and the elderly are particularly at risk since they may have less strength, endurance and mobility.

A few tsunamis occur each year, most of them non-destructive and observed only on sea-level gauges (Figure 3). When they are destructive, tsunamis are often categorized as local, regional, or Pacific-wide, depending upon the distance they travel from the area of generation to the coasts along which they are observed or cause damage. Tsunamis that strike the closest shorelines within minutes of their generation, and whose damage is confined only to those shorelines, are categorized as local (Figure 4). Tsunamis that only cause damage within a few hundred kilometres of their source, or just within a well-defined geographic area such as a marginal sea, are categorized as regional. The largest tsunamis cross entire ocean basins and can cause damage thousands of kilometres from their source. They are known as teletsunamis, or in the Pacific where most of them occur as Pacific-wide tsunamis. A few of these occur each century (Figure 5). Destructive local, regional, and teletsunamis also occur outside the Pacific, for example in the Atlantic, Mediterranean, and Indian Oceans, but on a much less frequent basis.

During the 1990s, eleven destructive tsunamis occurred causing more than 4 000 casualties and at least several hundred million US dollars in property damage (Table 1). These tsunamis were all local or regional tsunamis. There has not been a destructive Pacific-wide tsunami since 1964 (Figure 6).

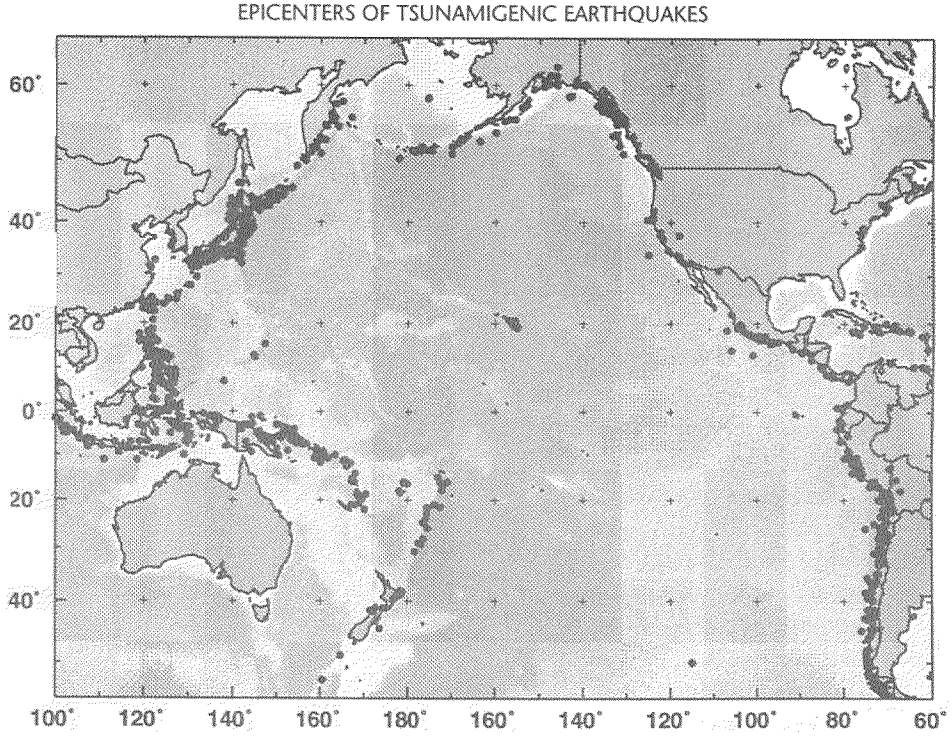

Figure 3. Tsunamigenic earthquakes (dots) occur all along the margins of the Pacific basin at the boundaries between tectonic plates. Most of the resulting tsunamis are not destructive and are often observed only on sensitive sea-level gauges. A few tsunamis occur each year in the Pacific (Data from the historical tsunami database of the World Data Center - A.)

Table 1. Destructive tsunamis since 1990

Date	*Source Region*	*Estimated Casualties*
2 September 1992	Nicaragua	168
12 December 1992	Flores Island, Indonesia	1 000
12 July 1993	Okushiri Island, Japan	230
3 June 1994	Java Island, Indonesia	222
4 October 1994	Shikotan Island, Russia	11
14 November 1994	Philippines	74
9 October 1995	Manzanillo, Mexico	1
1 January 1996	Sulawesi, Indonesia	9
17 February 1996	Irian Jaya, Indonesia	110
23 February 1996	Peru	12
17 July 1998	Papua New Guinea	2 500

TSUNAMI MITIGATION

The great tsunami of 22 May 1960 was generated off the coast of Chile by the largest earthquake this century. It struck nearly every coastline in the Pacific and caused 61 casualties in Hawaii and nearly 200 in Japan — more than halfway around the globe. Following that event, countries around the Pacific recognized the need for a coordinated international effort to more effectively mitigate tsunamis. Consequently, in 1965, the Tsunami Warning System in the Pacific (TWSP) was formed under the auspices of the Intergovernmental Oceanographic Commission of UNESCO. It is guided by its International Coordination Group (ITSU), and now has 25 Member States. At the same time, the US National Tsunami Warning Center became the operational center for the TWSP and changed its name to the Pacific Tsunami Warning Center.

There are four key areas that have been the focus of most tsunami mitigation activities carried out by ITSU, its Member States, and other organizations. They are: 1) hazard assessment; 2) warning systems; 3) preparedness including education, and 4) research.

HAZARD ASSESSMENT

Tsunami hazard assessment is an evaluation of how often a tsunami may impact some particular coastline, and what the possible characteristics of that impact might be. Accurate hazard assessment is a very important first step to provide guidance for and help motivate the other mitigation activities needed to help protect a coastline. Data useful for hazard assessment are: 1) historical data; 2) paleotsunami data; 3) data from post-tsunami surveys; and 4) numerical model outputs.

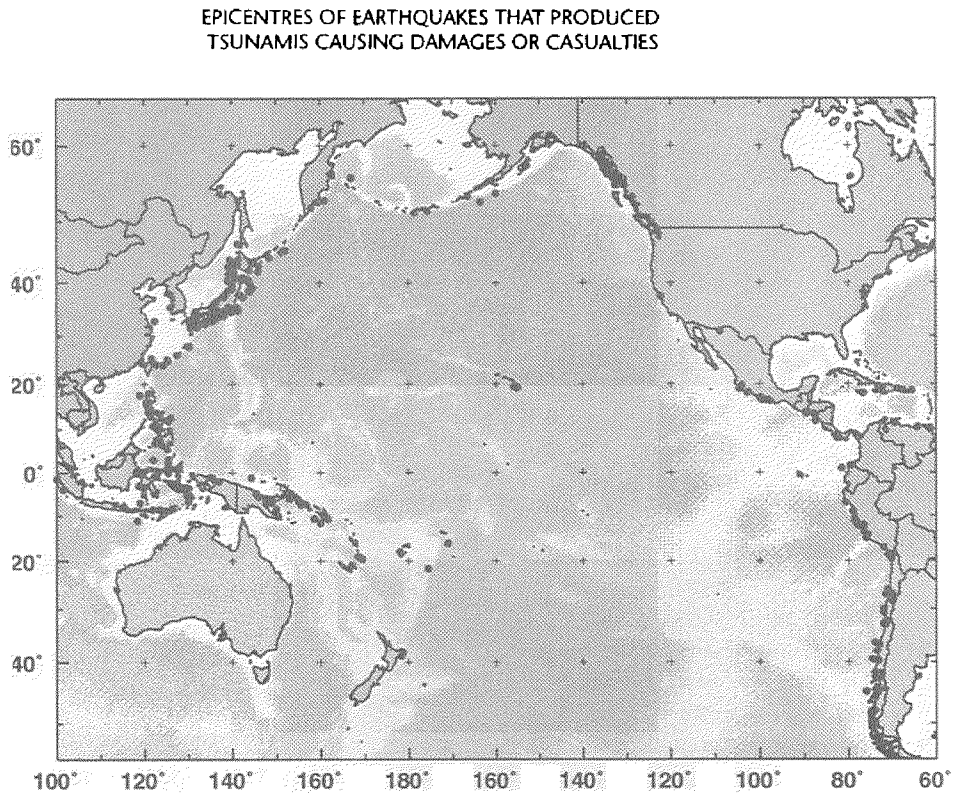

Figure 4. Destructive tsunamigenic earthquakes in the Pacific (dots) occur primarily along convergent plate boundaries associated with major subduction zones. Most destructive tsunamis are local or regional, only causing damage or casualties along coasts near the generating earthquake. (Data from the historical tsunami database of the World Data Center - A.)