Communications

Tsunami warning systems have unique and extensive communications requirements. Seismic and water level signals must be sent from remote sites often without power or telephone lines, and warning messages must be transmitted quickly and reliably to subscribers having different means of access. Distances to be covered range from less than a kilometer to tens of thousands of kilometers. Meeting these needs requires a variety of communication methods.

Geostationary satellite antennas (left, partially hidden behind tree) and VHF radio antennas (right, at top of tower) make up part of PTWC's many communications

Real Time Access to Data

Seismic and water level data used by warning centers must be reliably received in real or very near real time to be useful. Many communications techniques are used for this purpose including VHF radio, microwave, dedicated landlines, telephone dialup, continuous satellite links, scheduled satellite transmissions, and packet networks. In certain cases, more than one technique may be needed for access to a data collection site. Although a communications circuit may be commercially provided, specialized equipment is often needed to convert the data into a form transmittable on the circuit. Complicating the data communications problem is that collection sites may be located in remote places without power or access to telephone lines. Also, in the case of a local tsunami, power and telephone service may be lost due to the earthquake. For water level gauges, which have very low data rates, solar powered data collection platforms that transmit on a regular schedule through the USA's Geostationary Operational Environmental Satellite (GOES) or Japan's Geostationary Meteorological Satellite (GMS) have provided a solution. Smart seismic stations that detect large earthquakes and only need to transmit a few bytes of parametric data, in contrast with standard seismic stations having a continuous data transmission requirement, are also under development.

Warning centers need to receive essential seismic and water level data reliably in real or very near real time. Current methods and channels for sending data from seismic and water level instruments to warning centers are often complex and costly, and their limitations can sometimes prevent the deployment of needed sensors, particularly in remote locations. Many new kinds of communication methods are now becoming available through satellites, fiber optic networks, and cellular telephone technologies. These new methods need to be continually evaluated for their applicability to data communication problems faced by the TWSP, and adopted when appropriate. In addition, instrumentation with less demanding communications requirements should be developed.

Dissemination of Messages

Just as important as communications for real time access to data are communications methods to get a center's warning and informational messages out quickly to its users. Short text messages may be securely transmitted to offices worldwide through dedicated circuits such as the Global Telecommunications System (GTS) or the Aeronautical Fixed Telecommunications Network (AFTN). Messages can also be transmitted worldwide through commercial circuits such as Telex. Electronic mail provides another way to quickly reach persons and offices worldwide, although this method can be less reliable because it depends on links over which centers have no control. On local or national levels, tsunami messages can also be sent over text or voice circuits designed for national defense or other emergencies. Messages can also be sent by telephone or fax, although these methods are less efficient because a connection must be established separately to each recipient.

Warning centers need to distribute their tsunami warning messages and other related information quickly and reliably to appropriate authorities within the warning center's AOR. An

ideal message communications system would provide for affordable rapid dissemination and receipt of text as well as graphics (for example, a tsunami travel time map) to any location in the Pacific region, with one message going simultaneously to many locations, with the capability to alarm critical messages so recipients are alerted that immediate action may be required, and with confirmation sent back to the warning center that the message was successfully received by each key recipient. Current methods and channels for sending messages have these characteristics only in varying amounts, and none are ideal. Many new kinds of communication methods are now becoming available through satellites, fiber optic networks, and cellular telephone technologies. These new methods need to be continually evaluated for their applicability to message communication problems faced by the TWSP, and adopted when appropriate.

Preparedness

Activities in this category take place in response to both the hazard assessment and warnings. The appropriate preparedness for a warning of impending danger from a tsunami requires knowledge of areas that could be flooded (tsunami inundation maps) and knowledge of the warning system to know when to evacuate and when it is safe to return. Without both pieces of information the response could be inappropriate and fail to mitigate the impact of the tsunami. A level of public awareness and understanding of tsunamis is also essential. Except in cases where there is time, resources, and procedures to carry out a mandatory forced evacuation, getting persons quickly and safely out of a potential inundation zone requires some knowledge of the hazard on their part. This is particularly true in the case of a locally generated tsunami where the only warning will be the shaking from the earthquake. Another type of preparedness is land use planning to locate essential facilities such as schools, police and fire departments, and hospitals outside of inundation zones. Engineering efforts to build tsunami-resistant structures, protect existing buildings, and create defensive tsunami barriers such as dikes or breakwaters are also a form of preparedness.

Evacuation

Evacuation plans and procedures are usually developed and carried out at a local level, since they require detailed knowledge of the coastal populations and facilities at risk, and the local resources that can be applied to the problem. Local tsunamis provide little or no time for a formal warning and may be accompanied by earthquake damage, while distant tsunamis may give several hours time to get ready before the first waves arrive. For these reasons, evacuation preparations and procedures are different for the two cases.

Evacuations for Local Tsunamis

When a local tsunami is imminent, the only warning may be shaking from the earthquake, or an unusual behavior of the ocean. Persons at risk must recognize the danger signs, then move immediately and quickly inland and/or towards high ground, since destructive waves may strike within minutes or even less. Evacuees also face potential earthquake effects such as landslides and collapsed buildings and bridges that may hinder their efforts to escape. For this kind of rapid, undirected evacuation to be effective a high level of public awareness and education about the tsunami hazard is required. It also requires advance planning by public officials to map out and make known tsunami evacuation zones and safe evacuation routes. The key elements for motivating sufficient public education and the production of evacuation maps and procedures is a clear understanding of the tsunami risk and where tsunami inundation is likely to occur.

Most Pacific coastal communities are unprepared to immediately evacuate low-lying coastal areas following a tsunamigenic local earthquake. Further efforts are needed to produce potential inundation maps for all populated coastal areas threatened by local tsunamis and to educate populations at risk about local tsunamis, the danger they pose, and steps to take immediately to protect their lives should one occur.

Evacuations for Distant Tsunamis

In the case of a distant tsunami, there is more time for authorities to carry out an organized evacuation. Following notification from a warning center that a tsunami has been generated, and the expected arrival time of the

first wave, local emergency officials make a decision about whether an evacuation is warranted. This decision is based on knowledge from historical or model data about the threat to local coasts from the tsunami source region, and on further guidance received from the warning center about the severity of the tsunami as it moves closer. The public is informed about the impending hazard, and instructed about how, where, and when to evacuate. Designated local forces, such as the police, fire, and civil defense, help carry out the evacuation orders. Certain procedures to save property may also be carried out including moving boats and ships out to deep water and securing industrial facilities located near the water. Effective preparation is based on estimates of the potential inundation and other effects that may occur from a distant tsunami. Evacuation zones and routes to safety must be defined, and the public must be educated about the tsunami hazard and evacuation procedures so they won't choose to remain in dangerous areas, enter them out of curiosity, or return before the threat has completely passed. Unnecessary evacuations must be minimized to retain public confidence in the system.

Educational material about tsunamis and the TWSP produced and published by ICG/ITSU Member States and the IOC.

Effective evacuation procedures for distant tsunamis are not in place in many regions of the Pacific. In some cases, warnings do not reach potentially affected communities. But even armed with warnings, emergency managers often have limited knowledge of, or access to, information about past or model tsunamis or the characteristics of the tsunami hazard on which to base their evacuation decision. Potential inundation maps for distant tsunamis are needed for all threatened coastal areas, particularly centers of population, industry, or tourism, in order to develop evacuation plans. Educational programs are also generally insufficient, and past unnecessary evacuations may have eroded confidence in the system. All of these deficiencies need to be addressed in order to carry out effective evacuations that will prevent unnecessary loss of life the next time a major Pacific-wide or other distant tsunami occurs.

Education

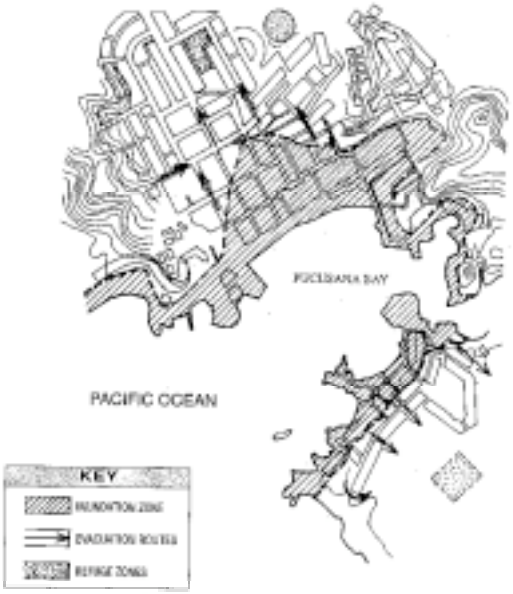
Any advance in the mitigation of the tsunami threat must contain plans for a better understanding by the general public, by local authorities, and by policy makers of the characteristics of tsunami waves, the damage and destruction they can cause, and appropriate actions to be taken to reduce the tsunami risk.

Public Education

The educational requirements of the general public are addressed most effectively by individual Member States and localities that take into account language, culture, local customs, religious practices, relationships to authority, and past tsunami experiences.

ITSU has developed and distributed certain educational materials to assist and guide the local efforts. A color brochure entitled *Tsunami: The Great Waves* contains general information about the tsunami phenomenon and the hazard it presents, tsunami warning systems, tsunami research, and what to do in case of a tsunami. A cartoon book entitled *Tsunami Warning* contains similar information but is aimed at young children. It is accompanied by a supplemental workbook for teachers and students that provides certain key information in more depth. Although both the brochure and the cartoon book are in English, they are now being put into a format that will facilitate easy translation and publication in other languages. Chile recently produced a set of

four Spanish-language textbooks with teachers' guides on the subject of earthquakes and tsunamis that cover grades K-12. They were subsequently translated into English by Canada. Each set has now been published and distributed with support from the IOC. In addition, ITIC is routinely involved in public education efforts such as: answering inquiries from students and concerned individuals; providing information to the news media, producers of television and film documentaries, and book writers; giving public lectures; and assisting other organizations with programs that educate the public about tsunamis. ITIC is also developing a website that will contain a wide variety of tsunami-related information of interest to the general public as



Inundation and Evacuation Map created for the coastal town of Pucusana, Peru.

well as the tsunami mitigation community. Some Member States also carry out their own public tsunami education programs.

Education for Warning System Operators, Emergency Managers, and Policy Makers

Warning system operators, emergency managers, and policy makers also have an educational need to be met. Because tsunamis, either distant or local, occur so infrequently on any particular coast, these key people often have little or no prior personal experience with the phenomenon on which to base their decisions concerning preparations or actions to be taken when one strikes. They may depend almost entirely upon training programs and/or convenient access to information about tsunamis in general, the particular threat to their areas of responsibility, warning systems, and mitigation measures.

ITSU has developed several programs to help meet these needs. The Visiting Experts Program conducted annually by ITIC with IOC support and assistance from PTWC and other organizations, trains scientists and engineers from all over the Pacific about the tsunami threat, warning systems, and mitigation efforts. Some Member States also conduct training programs for natural hazards that include tsunamis. A *Tsunami Newsletter,* with information about recent tsunami events and mitigation activities is published by ITIC and distributed internationally to about a thousand persons and offices having some kind of responsibility with respect to tsunamis. ITIC also responds to frequent information requests from emergency managers and policy makers. The ITIC tsunami website will soon provide another kind of worldwide access to pertinent tsunami information. The Expert Tsunami Database is also an excellent tool that can provide quick access to historical tsunami data across the Pacific.

Much of the population at risk, as well as their emergency managers and policy makers, remain poorly educated about tsunamis, the risk they pose, and mitigation strategies. In view of the general weakness of educational programs, and their high level of importance for mitigation efforts, they should continue to receive special attention. Educational programs should be directed towards coastal residents, coastal visitors (tourists), school teachers, mass media representatives, warning system operators, emergency managers, and policy makers. These programs should include lectures, group dynamics, live-in seminars, travelling seminars, web sites, electronic bulletin boards, audio and visual aids, drawings, pictures for display in public places and on television, radio and television announcements, brochures, and pamphlets. Materials should be developed that can be easily translated and/or otherwise modified to suit the country concerned. Information about the tsunami hazard should also be provided and promoted to other organizations involved in educating the public about natural hazards.

Land Use

As the global population expands, threatened coastal areas are being developed at an ever-increasing rate. While it may not be possible to prevent this development, certain communities have chosen to prohibit the construction in potential inundation zones of facilities such as such as schools and nursing homes that put especially vulnerable parts of the population at risk. Other essential facilities such as police and fire departments or hospitals have also been prohibited. In addition, tourist facilities such as beachfront hotels have

been required to put in place tsunami evacuation procedures to ensure the safety of their guests.

Control of land use as a tool for tsunami mitigation has been largely underutilized. Local governments should be encouraged to take whatever steps they can to prevent certain kinds of development in areas likely to be flooded by tsunamis, particularly the development of facilities where people congregate, or that put children, the elderly, or handicapped persons at risk. Essential facilities such as police and fire departments, and hospitals, that will be needed following a tsunami, should not be located in potential inundation zones. Industrial facilities that could compound a tsunami disaster by leakage or spilling of flammable or hazardous materials should be either hardened against tsunamis or located outside of inundation areas. Tourist facilities often concentrate near the waterfront large numbers of people who may be completely uneducated about tsunamis. They should be required to develop special procedures to inform and evacuate their guests in case of a tsunami.

Engineering

Certain kinds of engineering can help mitigate tsunami effects. Buildings in tsunami zones can be strengthened to withstand forces expected from the impact of waves and strong currents. Foundations can be constructed to resist erosion and undercutting from currents. In some cases the ground floor of oceanfront buildings can be made open to allow seawater to pass through. This helps reduce undercutting flow around the perimeter of the foundation. Hotel rooms can also be built only above the first floor to reduce the threat to hotel guests who may be uneducated about tsunamis. Essential parts of a building's infrastructure such as emergency generators, power distribution centers, and elevator motors can be located on floors unlikely to flood. Heavy objects such as fuel tanks that may float away and act like battering rams can be securely fastened to the ground. Transportation systems can be constructed or modified to facilitate rapid mass evacuation out of inundation zones. In cases where the threat is great and there are adequate resources available, certain kinds of defense works such as sea walls, sea dikes, breakwaters, and river gates can be built to repel tsunamis. Such major efforts have been carried out in Japan, particularly along the Sanriku coast. These activities are motivated in large part by knowledge of potential inundation zones, and damage from past tsunamis.

In most parts of the Pacific, very few engineering efforts have been made in anticipation of tsunamis. Some of the measures that can be taken are relatively simple and inexpensive and can be applied to existing or new construction. Governments are encouraged to incorporate tsunami engineering into building codes. Property and business owners should also be educated about steps they can take voluntarily to protect their investments. When they are necessary and feasible, defense works should be built to repel tsunamis.