

EFFECTIVENESS OF THE TSUNAMI WARNING SYSTEM IN
SELECTED COASTAL TOWNS IN ALASKA

by

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SYNOPSIS

The objectives of the Alaska Regional Tsunami Warning System and the special conditions which necessitate it are stated. A combination of the speed of onset and of physical cues is used to suggest a typology of tsunami events and possible preventive action. Descriptions are given of both pilot research conducted to measure the effectiveness of an attempt to educate coastal inhabitants of Alaska about the tsunami hazard and the warning system, and of the behavior exhibited by residents of Sitka, Alaska, during a summer 1972 tsunami evacuation following a nearby earthquake. Implications for timely and effective actions are noted.

Tsunami watch--message issued when an earthquake has been detected of sufficient magnitude, and in such a location, that the generation of a tsunami is possible.

Tsunami warning--message issued, for the Pacific-wide system, when there is positive evidence from tide gauges that a tsunami exists.

OVERVIEW OF THE SETTING AND RELATED PROBLEMS

The earthquake and tsunami tragedy of March 27, 1964, instigated the formation of the Alaska Regional Tsunami Warning System with headquarters at Palmer, Alaska. (1) The primary function of this system is to provide vulnerable Alaska communities with early warning of locally-generated destructive tsunamis. The system is intended to quickly detect, locate and calculate the magnitude of earthquakes and to issue tsunami watch and warning messages through the use of initial seismic data. Since the time required to secure verifying mareographic data is too great to permit timely warning of communities near the epicenter, initial warnings from the regional system are based on seismic data only. As data from the tide gauges becomes available, the decision can be made on the need to alert towns and cities more distant from the epicenter. These detection and alerting functions are performed continuously. Determination of the need for watch and warning messages for tsunamis of teleseismic (distant) origin is the responsibility (2) of the Pacific-wide Tsunami Warning System headquartered in Honolulu.

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¹ U. S. Department of Commerce, 1969b.

² U. S. Department of Commerce, 1965.

Objectives of the Alaska Regional Warning System. The stated objective of the regional organization is "to detect and locate major earthquakes in the Aleutian-Alaska region and, in the event that tsunami generation is possible or probable, provide timely and effective tsunami information and warnings to those residents of Alaska and the Aleutian Islands likely to be affected."⁽³⁾

To satisfy the first objective, the organization has established and maintained an independent system of seismographs and tide stations, and has developed the telemetering and data processing capabilities required to collect and evaluate data from these sources. With respect to the second objective; that of providing effective warnings, the system has attempted to establish effective communication links with virtually every coastal town and village via the Alaska Disaster Office and several other state and federal agencies. These agencies, in turn, utilize a complex network of interconnections when attempting to get the message through to the local communities.⁽⁴⁾

Tsunami Hazard From the Local Perspective. Very simply, we may say that there are two basic ways for a community to avoid losses from tsunamis, 1) permanent location in safe areas only, and, 2) rapid warning and evacuation from all unsafe areas prior to tsunami impact. However, neither approach is entirely adequate. While most structures and roads, and much human activity in a coastal community can be located and conducted in areas safe from tsunami threat, there are some business and recreational activities that simply cannot be conducted elsewhere. Economic constraints necessitate the location of some businesses on the waterfront. In most U.S. towns and cities prohibition of "unnecessary" structures and activities out of tsunami hazard zones is dependent on locally developed and enforced land use controls; effectiveness rests exclusively on local action. Such land-use management has not been very successful to this date.

Developing fail-safe rapid warning and evacuation procedures--the second approach--is very difficult. Part of the difficulty relates to physical cues and speed of tsunami onset. To simplify presentation, these ideas are summarized in Figure 1.

A Type I event is illustrated by the events on March 27, 1964, in Valdez, Alaska. The water action and collapsing docks occurred almost simultaneously with the earthquake. No type of warning can assist here.

In a Type II event the very heavy earth temblors can be felt by local residents for perhaps 30 seconds to several minutes. This physical cue is adequate as a warning device if properly interpreted. Infants, the elderly, those who cannot walk, and persons trying to assist them may not evacuate in time. Quick, decisive action by skilled local officials might aid prompt evacuation. The sounding of sirens and broadcast of

³ U.S. Department of Commerce, 1969a, P. A-1.

⁴ Ibid., pp. A-4 to A-15; and, Alaska Disaster Office, 1969.

specific warning messages are helpful, but these seldom happen in such a short time period. The extent of death and injury in the community is primarily a function of fast and appropriate response by individuals and leaders of small groups, e.g., supervisor of a work crew. No regional detection and warning system can significantly alter the vulnerability of a community to a Type II tsunami event. (5)

Type III characterizes an event in which clearly noticeable, but not severe, earth shocks are felt for up to a few minutes by the residents of the community. The epicenter of the earthquake is sufficiently far away that some 15 to 30 minutes elapses before the arrival of the tsunami. The temblors may act as an alert to the populace of the possibility of tsunami action, but much time will be consumed by individuals attempting confirmation of a probable tsunami. These temblors cannot serve as a warning cue, as is the situation in Type II. When the physical cues serve as an alert, and authoritative word is disseminated that evacuation should take place, there still isn't always enough time for most persons to be evacuated. Evidence suggests that the time constraints (15 to 30 minutes) are such that most persons will not be evacuated; even under the best of circumstances it takes at least 20-25 minutes for the regional warning center to locate the earthquake epicenter and magnitude, send an appropriate message, and have it received and disseminated at the local level. This leaves very little time for even the most alert local officials to assure that evacuation takes place, or for alert residents to go to safe areas of their own volition.

A community being faced with a Type III event is in almost as much peril as those with a Type I event. There is relatively little that a regional detection and warning system can do to reduce the losses. Time is the critical factors; therefore, conscientious local officials and alert citizens can take only a few steps which can realistically reduce the level of loss even a small amount.

With the Type IV event the community is almost totally dependent on some type of external tsunami detection and warning system. There are no physical cues from the earthquake itself because of its distant epicenter. Usually any cues such as "unusual water movement" come too late to be of much value. Effective functioning of a detection and warning center is critical. In many instances, depending on the time limitations, the center can issue first a watch and then a warning message. Where onset time is short, e.g., where the time between the generation and arrival time of the tsunami is between 30 and 60 minutes, any significant delay in the movement of messages from the warning center through intermediate points to the local community means that the community has no warning. If the messages are in time, understood, and acted upon promptly, most persons can move to safe areas, and in long-onset occasions, all valuables and up to 75% of "moveable" property can be saved.

Virtually every coastal community in Alaska faces a complete range

5 Norton and Haas, 1970.

of possible tsunami events varying from Type I through Type IV. Therefore if any community relies only on a regional detection and warning system, its citizens do not have adequate protection from the tsunami hazard. Citizen knowledge about how to interpret physical cues, where safe areas are located, how best to get there, and above all, how fast to evacuate, is also critical. Local organization to assure that rapid evacuation takes place and that persons do not return until the danger is past is equally crucial.

Transmission of Tsunami Messages. It should be noted that for any given tsunami event most, though not all, of the threatened communities will be so distributed geographically that because of the time lapse until local onset, the communities can utilize a warning message if it is sent from the warning center promptly and received at the local level promptly thereafter. But there are problems in transmitting messages, and Alaska has more than its share.

The Alaska Regional Tsunami Warning System is headquartered at the Geophysical Observatory in Palmer, Alaska. Tsunami messages are sent from Palmer to several federal and state agencies. The Alaska Command (military) takes responsibility for transmission of the messages to all appropriate military installations. The Alaska Disaster Office (state) in Anchorage has responsibility for transmitting messages to all civilian communities. As of early 1971 the strategy of the Alaska Disaster Office (ADO) was to try to utilize any and all available radio and land-line nets, both state and federal, to get the needed messages to the coastal towns. The task of transmitting the tsunami messages to the coastal communities, and getting confirmation of receipt, is exceedingly difficult. Contact with these communities ranges from situations of direct and around the clock coverage, through situations entailing one or more intermediaries involved in relay of the message, with these available on a less than full-time basis, to situations of one-way transmissions such as radio and T.V. broadcasts with hope that someone is tuned in.

Message Dissemination at the Local Level. Any message prepared by the regional warning center can accomplish the intended objective only if the following specific circumstances apply. 1. If the message is received at the local level without alteration, (a) it must be received promptly, and (b) it must contain clear, concise information which can be easily and quickly understood by the local recipient, whether official or other resident.⁽⁶⁾ 2. If the local official or other local recipient successfully disseminates the information to all relevant local persons, (a) the information must be received promptly, and (b) the message or signal must contain information necessary for residents to make rapid, rational decisions about appropriate actions. 3. If the local resident interprets the message or signal correctly, (a) he must know what action should be taken, and (b) he must be motivated to take the appropriate actions. 4. If the action taken is to be appropriate, the local resident (a) must take action to prevent loss of life and injury, (b) must be able to reach

⁶ Anderson, 1970.

a "safe area" in time, and (c) must take action to minimize property damage. IF ANY ONE OR MORE OF THESE CONDITIONS IS ABSENT THE INTENDED OBJECTIVE OF THE WARNING SYSTEM WILL NOT BE ACHIEVED. There are many links in this effective warning chain. The total or partial absence of any link precludes the successful completion of any effective warning. Thus, each link is of the same critical importance.

What becomes obvious from the above listing is that a tsunami message alone cannot save lives and property. At a minimum, local officials must designate, in advance, safe areas and fail-safe arrangements for quick dissemination, by signal or message, of the warnings. The residents must know in advance what to do, when, and where to go. A very large part of the responsibility rests at the local level.

How well prepared the Alaskan coastal towns and cities are to fulfill this responsibility, and what can be done most effectively and efficiently to increase the local preparedness level, are some of the basic questions which prompted the experimental pilot research effort which was conducted between 1969 and 1971 in Alaska.

TSUNAMI HAZARD EDUCATION PROGRAM

The initial objectives of the research effort were: (1) to examine the extent and accuracy of citizen knowledge regarding tsunami hazard and action to be taken when watch and warning messages are received; (2) to develop techniques to be used in a limited number of short-term public education efforts designed to improve the speed and relevance of resident response to tsunami warnings; and (3) to evaluate the effectiveness of the public education programs in the communities where applied.

The basic research design consisted of a field quasi-experimental approach. Three experimental communities in which educational programs would be conducted, and one control community in which no program would be planned, were selected. The experimental communities were Kodiak, Homer, and Seward, and the control Sitka. A special effort was made to contact all local officials who might be involved in relevant policy decisions, or who would be involved in the carrying out of warning procedures. We inquired regarding (1) officials' understanding of the various tsunami messages that might be received, (2) the existence of any relevant warning and evacuation plan, (3) past local experience with tsunamis or watch and warning messages, and (4) officials' willingness to cooperate and assist in the conduct of a local Tsunami Hazard Education Program. Local mass media representatives were also contacted regarding their possible cooperation.

The interview schedule was pre-tested in July, 1969, and then revised. During the fall, 1969, the first series of interviews were conducted. In each town a random sample of 30 residents, half male and half female adults, were interviewed using a structured interview format composed primarily of "closed-choice" questions. The questions dealt with the following issues: (1) respondent's perception of the severity of the tsunami threat, local and coastal in general; (2) respondent's knowledge of tsunami generation and behavior; (3) knowledge about the regional warning system and beliefs about its effectiveness; (4) knowledge about the meaning of tsunami watch

and warning messages and appropriate actions that should follow; (5) ability to identify various local emergency siren signals; (6) respondent's probable behavior in the event of a tsunami warning; (7) respondent's past experience with tsunamis and other disasters; (8) knowledge about local tsunami evacuation or safe areas; and, (9) social and demographic data that we felt would help us explain how different types of persons responded to public education efforts. The interview data were then analyzed and the results utilized in designing the three public education programs.

Two of the key elements in appropriate response to an oncoming tsunami are correct interpretation of relevant messages and signals, and evacuating to safe areas as necessary. There were no clearly established signals or official safe areas prior to the study in the three experimental communities. Discussions with local officials resulted in the necessary designations being made, these then being incorporated into the education programs.

In March, 1970, on the week of the sixth anniversary of the 1964 earthquake and tsunami disaster, the three education programs were conducted. No education program was conducted in the control community, Sitka. In Kodiak we utilized the mass media (radio, T.V., newspaper) saturation approach for one full week. Wherever possible, local persons were incorporated into the programming.

In Homer every postal patron was sent by first class mail a set of specially prepared materials including: a colorful brochure presenting the most critical information about the local tsunami signals, appropriate protective behavior, and the location of the safe area; a brightly colored sticker to place near one's radio or telephone which contained a summary of information on watch and warning signals and appropriate action; and a U.S. Coast and Geodetic Survey brochure describing the operations of the regional detection and warning systems.

In Seward the personal contact approach was used. Local officials had arranged for us to meet with a wide range of schools, groups, clubs, and organizations. Five persons, all Alaskans, each expert in some phase of tsunamis or warning systems, took turns doing the presentations. They each delivered a standard presentation including all of the basic information and each utilized visual aids and extensive question and answer periods.

The second series of interviews with the same sample of residents in the four towns was carried out 4-1/2 months after the education efforts. Analysis of these data focused on two points: (1) what changes in knowledge, attitudes, or expressed intended behavior, e.g., "what will you do if---?", were associated with the education efforts; and (2) any differences in effectiveness between the educational programs. One-way analysis of variance was used to check on possible differential effectiveness of the three education programs, and the t-test was used to compare each experimental town with the control community.

In brief, none of the programs appeared to have effected any significant change in what residents knew about tsunamis or the warning system, in how reliable they felt the warning system was, nor in their expressed

intended behavior in response to a tsunami warning. Significant increases in the respondent's perceptions of the severity of the local tsunami threat were found to be associated with the personal contact approach (Seward) and the mass media approach (Kodiak).

One pilot study such as this should not be taken as adequate evidence for any generalization. Nevertheless, the evidence we gathered consistently leads to one conclusion: short-term public education efforts, even intense ones dealing with matters of high salience, do not have a measurable lasting effect. Almost everything that the residents may have learned, and whatever attitude change may have occurred, were no longer significant 4-1/2 months after the public education program.

During the period of this research effort, there were no tsunami warnings issued at the local level in the experimental or control communities. About two years after the final interviews, however, Sitka, the control community, did have what we shall call a "tsunami warning event." The final section of this paper provides a brief summary of this event and our research findings.

WARNING AND EVACUATION PROCESSES IN SITKA, ALASKA

On a sunny Sunday, July 30, 1972, at approximately 2:45 p.m., Sitka was jarred by an earthquake of 7.3 Richter magnitude. By 3:04 p.m. the epicenter had been located as 30 miles west of Sitka in the Pacific Ocean. Palmer Observatory issued a tsunami warning for Sitka. No unusual water action developed, and by 3:22 p.m. the Observatory issued an "all clear."

Later we were told by Sitka Observatory personnel that if the earthquake had generated a tsunami, the first water action would have affected Sitka about 7 minutes after the earthquake. Had an initial wave of even moderate height materialized, an estimated 85% of those in low lying areas (15 feet about mean sea level) would have been killed or injured. Even though the first warning issued to Sitka officials from Palmer was transmitted in an unprecedented time of about 10 minutes, at least another 10 minutes is estimated to have passed before extensive dissemination of the warnings to Sitka residents was accomplished. Therefore, the action and inaction that occurred in Sitka may be viewed as a prototype case of a Type II tsunami event (See Figure 1).

The principal findings from our interview survey in Sitka (3.5% of all households) conducted two weeks after the event are contained in the following points. 1. The various combinations and sequences of behavior were so numerous that even the findings of major trends are difficult to display. (See Figure 2.) 2. Fifty-eight percent of the respondents immediately thought of the possibility of a tsunami after feeling the earthquake. Most of the others became aware of the possible danger later via radio (18%) or face-to-face contact (14%). Only two persons got their first indication from roving police cruisers with loudspeakers. 3. After first suspecting or learning of the possibility of a tsunami, only 23% left promptly, while 26% continued routine activity. Others sought additional information, waited for or attempted to contact family members, or began preparing for the possibility of evacuation. These were the first actions taken. 4. Most of the households (82%) contained a family rather

than a single individual. More than half of those families were separated at some time before their evacuation was completed. 5. The basic information which a warning message ought to contain is: definite statement that a tsunami is coming; definite evacuation notice; estimated time of arrival; deadline for evacuation; and specific location of safe areas. About half of the respondents reported that the verbal message received called for immediate evacuation and an equal number said that safe areas had been identified. Only a few persons could recall receiving the other types of basic warning information. 6. A very large proportion of the respondents (82%) reported that they did not check on the accuracy of the initial warning they received. 7. Within every family there was either immediate or eventual consensus on whether the family should evacuate or stay. In only 5% of the cases was the family view divided at the outset. 8. Two-thirds of those evacuating took time to collect things to take along, including pets. Most frequently taken items included clothing, blankets, food, water, and personal possessions. 9. Of those that evacuated, 61% went directly and stayed away until the cancellation message came. However, most of the rest engaged in some type of "unsafe" action such as leaving from some place other than home but stopping by the house on the way to evacuation, leaving a safe place to check on relatives, or leaving a safe place to get something from home and then returning to an evacuation place. 10. About half the leavers, when asked, indicated one or more things they would do differently should they receive another similar tsunami warning in the future. The intention to respond faster and more purposefully to a similar warning was indicated by 66% of them.

As part of the follow-up interviews of the Tsunami Hazard Education Program in 1970 in Sitka, we had asked a series of "what would you do if---?" questions. Since in 1972 the earthquake rather than the regional warning system gave the first indication of a possible tsunami, many of the answers to our 1970 questions were not strictly relevant to the events of 1972. Two comparisons are that fewer Sitkans took time to collect things to take along than had said would (80% vs. 68%), and separated families did attempt to contact each other about as would have been predicted by their intentions recorded in 1970.

SUMMARY

Even a superbly designed and functioning regional detection and warning system cannot insure against all casualties and unnecessary damage. Some protection from economic loss can be secured through the application of carefully drawn and strictly enforced land use controls, but the political process seldom permits this to happen. The same may be said for potential building code regulations for tsunami-resistant structures.

For certain tsunami events, especially for those in Type II, citizen knowledge of physical cues and safe areas is critical. Significant protection against Types I and III tsunami events is essentially unattainable. Fortunately, most events fall into Type IV, where a well planned warning and evacuation system at the local level can be effective, if it can be kept operational over the long periods between tsunami warnings.

Warning and evacuation processes at the community level are exceedingly complex as revealed in the recent Sitka experience. The evidence presented

for three other coastal towns suggests that intensive short-term public education efforts offer little hope for reducing the potential losses of life and property to tsunamis. This would seem to suggest that rapid and complete movement of all persons to safe areas requires forced evacuation.

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FIGURE I

Typology of Tsunami Events

Speed of Onset Types	Physical Cues	Approx. Time For Evac.	Maximum Credible Preventive Action
I	Yes (?)	Less than a minute	Be very quick or dead
II	Yes	5-10 min.	Persons who are ambulatory can be evacuated plus a few valuables
III	Yes	15-30 min.	A few persons can be evacuated
IV	No	45 min. to 12 hrs.	Most persons can be evacuated and up to 75% of all "moveable" property

FIGURE 2. Simplified Representation of Warning and Evacuation Processes, Sitka, Alaska, July 30, 1972

