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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROCEEDINGS OF CONFERENCE XL

A WORKSHOP ON "THE U.S. GEOLOGICAL SURVEY'S ROLE IN HAZARDS WARNINGS"

February 2-3, 1987
Denver, Colorado

Sponsored by
The U.S. Geological Survey

Convened under the auspices of the
National Earthquake Hazards Reduction Program

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Foreword

The U.S. Geological Survey (USGS) has long recognized the importance of effective communication of hazards and risk information in emergency and nonemergency situations. In 1978 the USGS convened a conference on "Communicating Earthquake Hazards Reduction Information," that brought together individuals from many disciplines to grapple with the problems of communication. At the conference Professor Gilbert White of the University of Colorado identified and discussed five myths of communication:

(1) Mailing a report constitutes communication.

(2) There is a consistency between what people say and what they do.

(3) There is a general relationship between the provision of scientific information and what is done with the information.

(4) There is a general public or "the public."

(5) Scientific assessment is the equivalent of a group assessment.

As scientists, we still find that we occasionally succumb to believing one or more of these myths in communicating with each other, with public officials, and with "the public." Nevertheless, we have progressed a long way since 1978 having had many experiences, some successful--some otherwise, in communicating hazards and risk information. We shall continue to progress as the recommendations contained in this report are implemented.

Effective communication is a complex process that becomes more critical to our society as our environment and citizens become increasingly interdependent. For this reason, we are committed to improving the process of communicating information on geologic hazards and risk.

John R. Filson
Office of Earthquakes, Volcanoes
and Engineering
U.S. Geological Survey

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BACKGROUND AND SUMMARY FOR
WORKSHOP ON "THE U.S. GEOLOGICAL SURVEY'S ROLE IN HAZARDS WARNINGS"

by
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INTRODUCTION

Thirty-one physical scientists and social scientists participated in a 2-day workshop on "The U.S. Geological Survey's (USGS) Role in Hazards Warnings." The workshop, convened under the auspices of the National Earthquake Hazards Reduction Program, was held in Golden, Colorado, on February 2-3, 1987.

This workshop was the fortieth in a series of workshops and conferences throughout the Nation that the USGS has sponsored since 1977 to provide a forum and permanent record of interactive multidisciplinary discussion of selected topics. Two earlier conferences, Conference V, "Communicating Earthquake Hazards Reduction Information," and Conference XII, "Earthquake Prediction Information," emphasized the importance of communicating hazards and risk information to public officials, emergency planners, engineers, and architects. (A complete listing of conferences can be found in Appendix E.)

The idea for the workshop evolved from a suggestion made by Dr. Dennis Mileti at a 1986 meeting of Nation Research Council's Subcommittee on Earthquake Research in which he encouraged the USGS to consider updating the way it performs its roles in public warning and dissemination of hazards and risk information.

At the Subcommittee meeting, Dr. Mileti suggested that the USGS gather the current social science knowledge on the communication of hazards and risk information as official and unofficial warnings and compare existing knowledge with past experiences to reveal some lessons that could be useful in the future.

As a result of the discussions at the Subcommittee meeting and in recognition of the important role the USGS serves in disseminating hazards and risk information, the following USGS scientists, State geological survey representatives, and social scientists participated in an informal workshop to share research findings and experiences and to take a close look at the way the USGS communicates hazards and risk information.

Robert Alexander	U.S. Geological Survey
S. T. Algermissen	U.S. Geological Survey
Bill Bakun	U.S. Geological Survey
Martha Blair	William Spangle and Associates, Inc.
Jane Bullock	Federal Emergency Management Agency
Michael Carter	Colorado State University
John Filson	U.S. Geological Survey
Paula Gori	U.S. Geological Survey
Tom Hanks	U.S. Geological Survey
Walter Hays	U.S. Geological Survey
Candace Jochim	Colorado Geological Survey
Gary Johnson	Federal Emergency Management Agency

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Bill Kockelman	U.S. Geological Survey
E. V. Leyendecker	U.S. Geological Survey
Dennis Mileti	Colorado State University
Dan Miller	U.S. Geological Survey
Patrick Muffler	U.S. Geological Survey
Elaine Padovani	U.S. Geological Survey
Risa Palm	University of Colorado
Waverly Person	U.S. Geological Survey
Albert Rogers	U.S. Geological Survey
John Rold	Colorado Geological Survey
Bill Schulze	University of Colorado
Bob Schuster	U.S. Geological Survey
Clem Shearer	U.S. Geological Survey
John Sorensen	Oak Ridge National Laboratory
Doug Sprinkel	Utah Geological and Mineral Survey
Donald Swanson	U.S. Geological Survey
Susan Tubbesing	University of Colorado
Gerald Wieczorek	U.S. Geological Survey
Tom Wright	U.S. Geological Survey

This workshop was the first opportunity that USGS scientists who were involved with the communication of hazards and risk information concerning earthquakes, volcanic eruptions, and landslides had to meet together to discuss common experiences, successes, and problems. The workshop, therefore, provided an opportunity for USGS scientists to learn lessons from social science research as well as from the experiences of scientific colleagues. (See Appendix D for list of participants with addresses and phone numbers).

WORKSHOP PROCEDURES

The workshop was designed to enhance interaction between earth scientists and social scientists in order to instill an appreciation of each discipline's contribution to the communication of short- and long-term hazards and risk information. The following procedures were used:

Procedure 1: Plans were made to hold a workshop for 30 individuals to review the advances in communicating hazards and risk information as related to USGS hazards warnings, responsibilities, and experiences.

Procedure 2: A preliminary program was developed by Walter Hays, Paula Gori, Dennis Mileti, and Susan Tubbesing. The program was revised by the participants invited to attend the meeting, incorporating specific topics and speakers.

Procedure 3: The first 1-1/2 days of the workshop were dedicated to presentations by earth scientists and social scientists of current theories and case studies in communicating hazards and risk information. Time was allotted for questions and discussions. The afternoon of the second day was reserved for an in-depth discussion of how hazards and risk information can be communicated more effectively and what the USGS should do next to improve its communication process.

Procedure 4: A proceedings of the workshop was compiled, incorporating the presentation of some of the speakers (not all speakers prepared a formal presentations as the workshop was intended to be informal) and the recommendations of the participants on how the USGS can communicate warnings to the various publics more effectively as well as hazards and risk information.

WORKSHOP PROGRAM

The objectives, themes, and speakers for each session are described below:

Objectives: To review what is known in the information and communication sciences relevant to the communication of short- and long-term hazards (characterization of the physical phenomena) and risk (characterization of the losses) information. To discuss the needs of the USGS and review some recent experiences. To make recommendations for improving the communication of hazards and risk information. Emphasis was on pre-event.

SESSION I: Overview of the problem of communicating hazards and risk information.

Moderator: Walter Hays, U.S. Geological Survey

Introduction of workshop participants, objectives, and procedures.
--Walter Hays, U.S. Geological Survey

Current knowledge on communicating hazards and risk information.
--Dennis Mileti, Colorado State University
--John Sorensen, Oak Ridge National Laboratory

SESSION II: Discussion and introspective evaluation of recent USGS experiences with communicating hazards and risk information.

Moderators: Susan Tubbesing, University of Colorado, Doug Sprinkel, Utah Geological and Mineral Survey, and Bill Kockelman, U.S. Geological Survey

Earthquakes
Southern California long-term earthquake forecast and Parkfield, California
--John Filson, U.S, Geological Survey
--Bill Bakun, U.S. Geological Suvey

Perspectives and discussion of what has been learned from selected experiences in California.
--Risa Palm, University of Colorado

Earthquake scenarios and loss estimation
--Ted Algermissen, U.S. Geological Survey

Time zero plus 30 minutes--dealing with the various publics
--Waverly Person, U.S. Geological Survey

Volcanoes
Mt. St. Helens, Washington
--Dan Miller, U.S. Geological Survey
--Don Swanson, U.S. Geological Survey

Perspectives and discussion of what has been learned from Mt. St. Helens and other similar experiences.
--John Sorensen, Oak Ridge National Laboratory

Kilauea, Hawaii
--Tom Wright, U S. Geological Survey

SESSION III: Discussion and introspective evaluation of recent USGS experiences with communicating of hazards and risk information.

Moderators: Paula Gori, U.S. Geological Survey, John Rold, Colorado Geological Survey, and Waverly Person, U.S. Geological Survey

Volcanoes (Continued)

Perspectives and discussion of what has been learned from Nevado del Ruiz, Colombia, and other similar experiences
--Dennis Mileti, Colorado State University

Long Valley, California
--Dan Miller, U.S. Geological Survey

Perspectives and discussion of what was learned from Long Valley and other similar experiences.
--Martha Blair, William Spangle and Associates, Inc.

Landslides
San Francisco Bay area, California
--Jerry Wieczorek, U. S. Geological Survey

Hurricanes

Perspectives and discussion of what was learned from hurricane emergenices and other similar experiences.
--Mike Carter, Cooperative Institute for Research in the Atmosphere

SESSION IV: Next steps for U.S. Geological Survey to consider

Discussion of how we can communicate hazards and risk information better.

Moderators: Clem Shearer, U.S. Geological Survey, and Dennis Mileti, Colorado State University

DISCUSSION AND RECOMMENDATIONS

The participants addressed the question:

How can communication of hazards and risk information by the USGS be improved with respect to the message, the channels of communication, and the credibility of the source?

Figure 1 represents the problem of communicating hazards and risk information.

RECOMMENDATIONS

The participants suggested the following procedures to improve the communication of short- and long-term hazards information.

1. Communication as a process involving Federal, State, and local interaction:

    a. The issuance of warnings and the communication of hazards and risk information should be seen as a process not as a single act.

    b. Federal, State, and local networks should be established in areas where hazards research is taking place and where hazards warnings are a possible outcome of the research.

    c. The USGS should begin communication with local communities by preparing them with information which will eventually be distributed to the general public.

    d. Where feasible, local communities should be involved at the research stage.

    e. Cooperation between Federal, State, and university researchers should be maintained in order to develop wider expertise and to expand the sphere of credibility.

2. Consideration of local needs:

    a. The public's needs should be taken into account when issuing warnings or communicating hazards and risk information.

    b. Funding should be sought from other agencies to share in operating information centers in hazard-prone areas.

    c. Warnings which are given on the eve of an event must be well thought out, otherwise problems will arise. Messages should be drafted in advance of needs and tested to find potential flaws.

    d. Whenever possible, solutions and recommended actions should be provided along with the hazards and risk information and be a part of the communication of warnings.

3. Refinement of U.S. Geological Survey procedures:

    a. Procedures followed by U.S. Geological Survey's Public Affairs offices should be reviewed and improved (streamlined) where feasible.

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b. The Survey should follow different procedures for communicating short- and long-term hazards and risk information.

c. The Survey should think through the process of communication of hazards and risk information to the news media prior to the occurrence of an event.

d. The Survey should seek at all costs to maintain its high credibility.

e. The language of warnings should be standardized to the extent possible.

4. Establishment of link with social science:

a. The USGS should take advantage of the services of social scientists. For example, a social scientist could work with local communities when there is a possibility of the need to convey hazards and risk information as warnings, lessening the amount of time researchers spend with the public, as well as preventing unforeseen difficulties with communicating hazards and risk information. The social scientist could advise researchers on appropriate language to ensure that hazards and risk information is understandable and that it elicits the appropriate response.

b. A coordinating mechanism should be established in the Office of Earthquakes, Volcanoes, and Engineering for a three-year trial period to continue exploring the "social science" applications of USGS hazards and risk information. One or two workshops should be convened each year.

c. The warnings and notifications issued in the period 1976-1986 should be reviewed with "social science" participation. Revisit sites to ask "Where are they now?" A feedback process with USGS scientists should be formed to develop recommendations for improvement.

d. A few specific projects to assist USGS scientists in improving the communication process with key users and decisionmakers should be undertaken. An example is to incorporate volcanic hazards information into the land-use planning process.

CONCLUSIONS

At the close of the workshop, the participants related what they had learned during the 2-day session. Each individual offered either an impression or a specific suggestion to the group. Some of the thoughts were as follows:

- The USGS is involved in a multitude of efforts concerning geologic hazards. These efforts must be integrated and coordinated to derive maximum benefit.

- The USGS scientists involved in communication of hazards and risk information have much in common despite the fact that they are concerned with different geologic hazards.

- How to communicate information about geologic hazards is important and may be even more important in averting a disaster than assessing and monitoring geologic hazards.

- Scientists need to keep local communities involved. There is really no truth to fearing "panic" on the part of the public or overdoing the amount of information provided. Social scientists can not document either the "panic" syndrome or the "cry wolf" syndrome in hazard warnings.

- The USGS has just begun to "scratch the surface" of hazards warnings. It needs to systematize and routinize its procedures.

- Other organizations which deal with natural hazards have past experiences which can be useful in refining the USGS' hazards warning roles and procedures in communication of hazards and risk information.

- The USGS should evaluate and refine its procedures, incorporating lessons learned from its experiences with communicating hazards and risk information.

- The USGS needs to recognize and reward individuals who are responsible for interacting with the public and State and local government.

- Workshop like this one should be repeated often so that USGS scientists can learn from each other, from scientists studying the behavior of organizations, and from individuals in other agencies concerned with hazards and risk.

PUBLIC WARNING NEEDS

by

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Dennis Mileti, Colorado State University, Fort, Collins, Colorado

A. Introduction and Purpose

Warning publics of impending disaster is an everyday occurrence in the United States. We estimate that warnings are issued at least once a day and perhaps more frequently for some American public at risk to some sort of geological, climatological, technological or civil hazard. The number of people warned in these events vary; most episodes involve only a few persons. However, dozens of events occur annually in which warnings are issued to a population of substantial size. Considered nationally, public disaster warnings are hardly an uncommon phenomenon. At the local level, a warning event is often unique; although there are some communities for which warnings are commonplace, for example, flood warnings along the Mississippi.

History is riddled with warning events in which publics have been encouraged to engage in a variety of alternative protective actions. These actions, for example, include evacuation, sheltering, avoiding certain paarts of a city and so on. The record documents "successful" warning events in which loss of life and property were reduced because warnings were issued. History also catalogues warning systems "failures": despite warnings many lives were lost when disaster struck. There is also emerging evidence which suggests that some human impacts, for example psychological, can emerge after warning even "successful" events. At the most general level, the purpose of this chapter is to seek an answer to the question "Why?" do variations occur in human response to warnings.

We are not the first to attempt an answer to this question. Researchers began to address the question of why publics respond to

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warnings of impending disasters as they do some three decades ago. Early efforts (Moore et al., 1963; Withey, 1962; Mack and Baker, 1961) revealed that patterns did exist in public response to warnings. These efforts were followed by attempts to systematize and conceptualize findings (Mileti, 1975; McLuckie, 1970; Williams, 1957), as well as by systematic research on warning response events (for example, Drabek, 1969). In recent years, research has continued, as have attempts to compile findings (Perry, 1985); in the last decade, the number of actual studies of public response to warnings has almost doubled. There are now about 200 empirical studies of public warning response.

It is the specific objective of this chapter to focus on the public response impacts of emergency warning systems in order to synthesize and appraise empirical findings, gaps in knowledge and implications for research and policy.

A. Theoretical Viewpoint

A key purpose of a public warning system is to elicit protective actions by people in danger. Protective, however, does not flow automatically from hearing a warning. An influential intervening factor between hearing and responding to a warning is the situational perception of risk which people hold. These perceptions impact what people do and do not do in response to warnings, as do perceptions about appropriate response actions. A key purpose for a warning system, therefore, is to provide the public with accurate situational perceptions of risk from the impending disaster commensurate with the actual or objective nature of the risk, and to provide them with sound situational perceptions of what to do to prevent personal harm and loss. As such, warning systems work through people's cognitive processes to influence behavior. Thus, the main

challenge to any warning system is to disseminate information that leads a diverse public at risk to "correct" cognitions and perceptions.

These perceptions are shaped by dialectical forces. The first concerns the sender of warning information; the second concerns the information receiver. A dilemma for the sender is that there is typically, in any warning situation, more than one sender and more than one message. A dilemma for the receiver is that across a heterogeneous public, and even across time for one individual, there can be more than one perception of the impending event, risk and appropriate response.

1. Dilemmas of Perception. In theory, there are four possible categorizations for warning events when one considers the juxtapositioning of sender and receiver attributes. These are poles of continuums; actual events are more likely to be variants of these ideal-types. First, only one warning message reaches the public, and a common public perception is formed. Second, only one message reaches the public, but multiple public perceptions are formed. Third, multiple messages reach the public who form multiple perceptions. Finally, multiple messages go out to the public, but only one common public perception is formed.

A circumstance in which a single warning would go to an endangered public who would then form a single public perception about impending risk and appropriate response to it is not likely in an open and free society. Events such as this have occurred in less pluralistic societies, and one of these is here worth describing. A 7.3 Richter magnitude earthquake occurred on February 4, 1975 near Haicheng, China. Prior to the earthquake, elaborate monitoring led the provincial Revolutionary Committee to issue a public warning for a strong earthquake to hit within two days. The earthquake happened causing major destruction about five

hours later. Accounts suggest that the single warning was issued from the Revolutionary Committee; that when received almost everyone evacuated; and that evacuees remained in open fields in freezing winter temperatures (Mileti, Hutton and Sorensen, 1981:35-36). Warning systems would not pose a complicated problem if all warning situations could parallel Haicheng. In a pluralistic society, information and warnings can not be controlled as occurred in this case, and multiple and mixed public perceptions are more likely.

It is difficult to document other cases in which only a single public message was issued; however, the June 1972 Rapid City flood comes close. This flood occurred following two other historical floods. The most recent occurred about a decade before; it was remembered by many as not a severe threat to life. Earlier in the century, however, a flood occurred that was much the same in magnitude and affect as the 1972 flood in which over 230 persons died. For all practical purposes, only a single warning message was issued for the 1972 flood, single that is in terms of content. It said a flood was coming and that people who lived abutting the creek should evacuate. This single message resulted in multiple public preceptions. For example, some members of the public perceived that the impending flood would be like the minor flood recollected from the last decade, and this recollection constrained evacuation; fewer others perceived the impending flood to be like the earlier-in-the-century flood, and this was an incentive to evacuate. Additionally, some people perceived the word "abutting" to mean property backed onto the creek, while others correctly thought it to mean property within a block or two of the creek; the former perception constrained evacuation while the latter was an incentive to evacuate. This tale illustrates that a vague

singular warning message can result in a heterogeneous set of public perceptions about the risk, and result in as varied a set of warning reponses as there are perceptions.

We feel reasonable in the conclusion that the Three Mile Island Accident in 1979 provides a textbook example of almost everything that could go wrong with a warning system from a public response viewpoint. The event catalogues a series of conflicting and inconsistant public messages. These include: a twenty-five mile area was at risk versus a five mile area; there could be an explosion versus there would not be one; there was no danger versus the Catholic Church had granted general absolution of sins for local residents; and so on. An inspection of public perceptions elicited by these confused messages reveals multiple outcomes; for example, many people evacuated, but many did not; and many perceived that risk to life and health was high, but many did not.

Relatively complex multiple messages are needed to enable a heterogeneous public to reach single and accurate perceptions about who is and who is not at risk in an emergency, as well as who should and who should not do anything about it; the 1972 Tropical Storm Agnes provides an example. Agnes was one of the largest storms ever to hit the United States. Several states were impacted, thousands of people evacuated, thousands others sheltered and yet thousands others did nothing. For the most part, people did the "correct" response based on accurate perceptions of risk which were quite heterogeneous across the multi-state area. The reason was that a multitude of different and detailed warning messages were disseminated and these helped almost everyone perceive risk, and then act, reasonably. In this hurricane, like others in recent years, many people came to a shared perception of the storm, and then appropriate

action. As a result, few people lost their lives in comparison to what could have occurred if the warnings were like they were at Three Mile Island or in Rapid City. In the next section we review the process by which multiple and single, inaccurate and accurate, perceptions are formed when the public receives a warning.

2. The Warning Response Process Why do multiple public perceptions of risk arise among the members of an endangered public who all receive the same single warning message? Why does human response to a warning differ among individuals when they receive the same information about how to respond? In this section, we elaborate upon the process by which these differences occur.

Human decision making when confronted by a warning resembles a lexiographic decision process: people go through a sequential process where various aspects of the decision confronting them are considered before acting. We illustrate this process in Figure One. The sequence may not be the same for every person; and each stage is not necessary for response. The process is initiated by notification, or hearing an initial warning. This leads to various psychological and behavioral outcomes. The process is shaped by sender (those issuing the warning) and receiver (those hearing the warning) factors. Mediating the process are information seeking and confirmation activities. Each component is now discussed in the order we believe characterizes a typical decision sequence.

The first stage of public warning response is hearing the alert or message. It cannot be assumed that by broadcasting a warning or by sounding a siren that people will hear it. Even when it is physically

Figure One

THE GENERAL WARNING-RESPONSE SEQUENTIAL PROCESS MODEL

ATTRIBUTES	NOTIFICATION	OUTCOMES	
		PSYCHOLOGICAL	RESPOND
Sender Characteristics	Hear	Understand	Respond
Receiver		Believe	
Characteristics		Personalize	
◄—Information Seeking and Confirmation—►			

possible to receive the warning, it may, so to speak, fall on deaf ears because of habituation (e.g., they never really listen to television), selective perception (e.g., they hear only what they want to), or physical constraints (e.g., they are out of siren range). The failure to hear a warning generally precludes response.

Once heard, the warning must be understood. By understanding, we do not refer to interpretation, but rather to the attachment of meaning to the message. Those meanings can vary among people and may or may not conform to the understandings intended; for example, a flood warning may be understood as a wall of inundating water to one person, but ankle-high runoff to another. A fifty percent probability may be interpreted as certain by some or unlikely by others. In this sense, understanding includes the perception of risk.

It is also helpful for people to believe that the warning is real and that the contents of the message are accurate. Believability is influenced by a large number of factors associated with the method and contents of the warning. The classic case is the "cry-wolf" syndrome: people will not believe a true warning following frequent false alarms. This may be a legitimate concern, however, it has not been proven to be true for hazard warnings in general.

People think of warnings in personal terms, that is, the implications for themselves or group such as their family. If people do not feel they are warning targets, they may well ignore it. This is illustrated by the "it can't happen to me" syndrome where people deny risk they do not want to face. Personalizing warnings is an important prerequisite of response.

At this stage of our model a person has heard the warning, understood it, believed what is being said, and established the belief that he or she

will be personally affected by the hazard. Having gone through this process, it is necessary to decide what to do. People, in general, do what they think is best for them to do. Often this is interpreted as irrational by the expert, but it is in fact rational for the person making the response. Deciding does not automatically lead to protective action. After a decision, events may take place to prevent intended behavior from occurring. A family may decide to evacuate but a missing pet may prevent the relocation from taking place.

Throughout the warning period a person typically goes through the stages of the model (hear-understand-believe-personalize-decide and respond) just outlined each time new information is received. Thus, warning response is not a single but instead follows from a series of decisions. Additionally, people do not passively await the arrival of more information; most people actively seek out additional knowledge and data. This behavior has typically been refered to as the confirmation process (Mileti et al., 1975; Drabek, 1969). That is, when warning information is received, many people try to verify what they have heard by seeking out information from another message, another source or another person.

The confirmation process causes people to be "information hungry" following the first warning alert. Rarely are people overwhelmed by information in a disaster warning context. Instead, there is a void of information, particularly in rare or unfamiliar events. This often creates a demand for more information than is being disseminated in the warning message, and a need for repetitive messages to enable people to absorb all the knowledge they wish to possess.

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Confirmation plays an important role in the model of warning response. It is an ongoing process that effects each stage of the process. It is more accurate to break the concept of confirmation into its basic components. A number of sender and receiver determinants are part of the confirmation process. These include the number and frequency of warnings received, the number of different sources utilized, the type and number of channels used to get information, and the role of social ties in the response process.

3. Conclusions. Our theoretical viewpoint is grounded in the premise that human response to warnings is based largely on the perceptions and definitions of the situation which people form about both risk and response options. These definitions are situationally determined and negotiated out of a dialectical process involving the information received by an actor in the warning setting, and characteristics of the actor receiving that information for, among other reasons, these characteristics can affect how warning information is processed. This symbolic interactionist prespective now forms the structure for our review of empirical research findings.

C. Determinants of Human Response

Empirical research to document the determinants of human response to warnings has a long-standing tradition. Research began in ernest in the 1950's, as part of the research program in the National Academy of Sciences (NAS), to investigate natural and technological emergencies. Research continued 1960's by individual researchers. In the 1970's and beyond, warning response studies placed less emphasis on describing human response to warnings, and on discovering how single factors (like sex, age, and others) covaried with response alternatives. Later studies

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emphasize attempts to model complex sets of determinants, their interaction and effects on warning response. Available empirical studies, therefore, vary in terms of methodological soundness, theoretical quality, the hazard type case event being studied (floods, flash-floods, hurricanes, nuclear power plant accidents, and so on), and the type of behavior and reasons for that behavior being examined. It is the purpose of this section of this chapter to review and systematize available empirical findings. These findings focus on alternative explanations for the hear-understand- believe-personalize-decide and response warning response process. The findings we catalogue are divided into five sections, one section each for each factor in the warning response process. Additionally, however, we catalogue empirically documented covariants of these warning response process factors according to two typoloties suggested by the empirical evidence.

A review of research on human response to warnings suggests that determinants fall into two categories. These are sender determinants and receiver determinants. Sender determinants are attributes of the actual warnings received by members of the public. Sender -- or warning -- determinants fall into four general categories. These categories are attributes of the messages, attributes of the channels through which messages are conveyed, attributes of the frequency with which messages are given, and attributes of the person(s) and/or organization(s) from which the messages eminate which we label as source attributes. Empirical findings suggest that message attributes important to consider vary in reference to both message content and style. Message content is relevant to consider along three lines: information about risk location, the character of that risk (for example, effects of impact and time to

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impact), and guidance about what people should do before impact. Message style is also important. Important style attributes are: specificity (the degree to which the message is specific about risk, guidance and location); consistency (the degree to which a message is internally consistent, as well as consistent across separate messages regarding risk, guidance and location); accuracy (the extent to which message content about risk, location and guidance is accurate); certainty (the degree to which those giving the warning message seem certain about what they are saying about risk, location and guidance); and clarity (the degree to which risk, location and guidance information in the message is stated in words that people can understand).

In addition to message attributes, the sender characteristics of channel attributes (the type of channel used -- for example, personal versus impersonal -- and the number of different channels used); frequency attributes (the number of times a particular message is conveyed, the number of different messages, and the pattern between different conveyances -- for example, every 15 minutes, randomly and so on); and source attributes (the level of familiarity of those giving the message to those receiving it, the degree to which the message giver is an official, and the credibility level of the message giver to those who receive the message) are equally important to consider in cataloging sender determinants of human response to warning response process factors.

Research also documents warning receiver characteristics that are important; and these are typologized into four categories. The first is attributes of the receiver's environment when the warning is received. Environmental attributes worth noting are physical and social cues; for example, if it is raining when flood warnings are received or if neighbors

are seen evacuating in concert with receiving evacuation advisements.

Social attributes of the receiver have been grouped into five categories. Aspects of the social network of which the warning recipient is a member is one category; it includes factors such as whether or not the family is united, social ties and bonds, the existence of close-by friends and relatives and so on. Resource characteristics is another category and refers to physical resources, for example, having access to car in which to evacuate; economic resources, for example, having the money to pay for a hotel; and social resources, for example, having a local social support system. Aspects of the role of the warning recipient is another important social attribute category. Role characteristics include, for example, sex and age. Cultural characteristics such as ethnicity, language, and social class are another illustrated dimension of social attributes. The last category of social attributes is activity characteristics, that is, various dimensions of the social activities in which the warning recipient is participating when the warning is received. These include activities like sleeping, working and recreating.

The third set of attributes of the warning recipient revealed by past research as important are psychological attributes. These include pre-warning knowledge about, for example, the risk associated with a particular hazard agent, protective actions, and the existence of emergency plans; pre-warning cognitions such as psycho-social stress level and locus of control of the warning recipient; and experience with the hazard agent, for example, type of experience and its recency.

The last set of warning recipient attributes in the typology are physiological attributes. Scant empirical research has been performed on physiological attributes; however, factors such as physical disabilities,

deafness, blindness, and so on can effect warning process and response.

In the ensuing parts of this section we document the research record of sender and receiver characteristics in reference to their effect on warning process and response.

1. Hearing Warnings. Relatively few empirical findings exist on the determinants of why some members of the public hear warnings of impending idsaster while others do not. This is likely the case because few researchers have included this factor in studies. Enough evidence exists, however, to conclude that it would be imprudent to presume that all members of a public would hear a warning just because one is issued. Additionally, research evidence exists to document that hearing a warning is influenced by both sender and receiver determinants.

1.a. Sender Determinants. The information channel used for the dissemination of emergency public warnings has a clear affect on enhancing the number of people who hear the warning. The mass media is typically the most effective (Perry, Lindell and Greene, 1982b:201; Carter, 1980:5; Quarantelli, 1980b:79) and the broadcast media of television and radio have been the primary source of hearing warnings among all types (Hiroi, Mikami and Miyata, 1985:23; Turner, 1983:316). Some evidence suggests that television is more effective than radio (Turner et al., 1981:23; Turner et al., 1979:116; Baker, 1979:12); however, an equal amount suggests that radio is more effective than television (Dillman, Schwalbe and Short, 1981:178; Dynes et al., 1979:151; Drabek and Stephenson, 1971). Additionally, it has been found (Turner, 1983:316) that the electronic media are more effective initially, but that newspapers are more important as time goes by over several weeks or months. It has also been documented (Perry and Lindell, 1986:65) that personal contact with

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the public can be an effective way to enhance the number of people who hear a warning. The number of different information channels used to disseminate warning messages enhances the number of people who hear and/or remember that they heard a warning (Turner et al., 1981:26).

These findings are scant compared to other areas in warning research. The empirical base is also limited in the sense that findings largely rest on simple statistical analyses in singular case studies, rather than on hypothesis-testing multivariate analyses. Nevertheless, the following conclusions seem warranted. It appears that the number of people who hear a warning message can be maximized if multiple electronic mass media channels (radio and television) are used to issue a public warning, supplemented by personal contacts with the public and, in the case of long-term warnings, additionally supplemented by the use of the printed mass media, i.e., newspapers.

1.b. Receiver Determinants. Both categories of environmental receiver factors have been documented as enhancing the odds that a member of the public will hear a warning. Observing cues consistent with an impending disaster's strike, for example, observing others evacuating positively relates to hearing a warning (Lardry and Rogers, 1982:3). Additionally, proximity to the potential impact site enhances hearing a warning (Rogers and Nehnevajsa, 1984:99; Lardry and Rogers, 1982:3,6; Frazier, 1979:343; Mileti et al., 1975:45; Diggory, 1956). Social network characteristics also have clear affect on hearing a warning. Membership in voluntary associations has been found to increase the number of warnings received (Perry, Lindell and Greene, 1981:156). General community involvement is also positively related to hearing warnings (Perry and Lindell, 1986:68; Perry and Greene, 1982:327; Turner et al.,

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1981:26; Sorensen and Gersmehl, 1980:130,133; Turner et al., 1979:20; and Scanlon and Frizzell, 1979:316). Other network characteristics found to enhance hearing warnings are frequent interaction across a kinship system (Lardry and Rogers, 1982:3; Perry and Greene, 1982b:327; and Perry, Lindell and Greene, 1981:155), and the maintenance of close relationships with relatives (Lardry and Rogers, 1982:3; Perry, Lindell and Greene, 1981:155; and Perry, 1979:35).

Aspects of social role affect the probability of hearing a warning. Older people are less likely to hear a warning than middle-aged or younger people (Rogers, 1985:7; Perry, Lindell and Greene, 1981:156-157; Turner et al., 1979:15; Perry, 1979:35; Turner, 1976; Mileti, 1975b:22; Friedsam, 1962,1961; and Mack and Baker, 1961). One study, however, proposes findings that age is not related to hearing a warning (Hutton, 1976:262,265). Other aspects of role associated with hearing a warning are socio-economic status (Perry and Greene, 1982:327; Turner, et al., 1981:25; and Turner et al., 1979:17) which is positively related to hearing a warning; having children increases the likelihood of hearing a warning (Turner et al., 1981:24; and Turner, et al., 1979:19); and women are more likely to hear a warning than men (Turner et al., 1981:25; and Turner et al., 1979:17). Cultural elements of the people who could hear a warning have also been shown to affect hearing a warning. For example, Perry, Lindell and Greene (1981:102,157-158) have documented that belonging to a closely-knit subculture like that of the Mexican-Americans enhances their odds of hearing a message, hearing specific as opposed to general messages, hearing multiple messages, and receiving personal as opposed to general warning messages. The final social subcategory of determinants found to be related to hearing a warning is social activity.

Sorensen (1985:13) pointed out that people who are away from home when warnings are issued have a lower probability of hearing the warning.

Three categories of psychological receiver factors have been shown to affect hearing a warning. The first is knowledge about the disaster agent (Turner et al., 1984:24) which is positively related to hearing a warning. Second, fatalism is negatively related to hearing a warning (Lardry and Rogers, 1982:3; and Turner et al., 1981:33). Third, prior disaster experience is positively related to hearing a warning (Perry and Lindell, 1986:27; Lardry and Rogers, 1982:3; Turner et al., 1981:25,27; and Anderson, 1969a).

Finally, the perhaps most obvious question deals with the physiological ability of receivers to hear warnings. Only one empirical effort has been located regarding the physiological capacity of people to hear warnings. Nehnevajsa (1985:4) concludes that there is a decrease in the ability of people to hear warning signals on summer nights when windows are closed and air conditioners or fans are in operation.

The findings available on the affect of receiver factors to inflate or deflate the odds of a member of the public hearing an emergency warning suggest three conclusions. First, some members of society are more likely to hear a warning because they are part of a social network (association member, community system, kinship network, subculture) and/or social role (higher socio-economic stratum, young, female, parents) that leads them to have more links to others who might give them informal warning notification. Even these people, however, have a lesser chance of hearing a warning when removed from access to their social networks, for example, when they are engaged in activities away from home or work. Informal notification is likely less likely for people not in close proximity to a

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potential disaster site since their social networks would likely contain fewer contacts with people who already have received a warning. Second, some people are less likely to hear a warning because they are less quick to pick-up on the cues around them and/or make interpretations that would lead them to seek out a warning. Such people, for example, would be those without environmental cues, those without disaster experience, knowledge or a contact who knows about the hazards and the fatalistic. Third, and finally, there are some people with physiological constraints to hearing a warning.

These conclusions suggest that the number of members of the public who receive a warning can be maximized by not ignoring the physiological constraints that will constrain some from hearing a warning, but instead planning to overcome them; not ignoring the natural tendency for informal notification to carry warning messages to others, but by planning to capitalize on it; and that warning system planning should recognize that some of those who should be warned may not be, because of their innate passive character in a low-cue environment, unless cues are provided which very few could ignore, for example, the use of sirens.

2. Understanding Warnings. Once a warning is heard, it must be understood by those who received it. Understanding refers to the attachment of meaning to a warning. Research findings on the range of factors which affect the understanding of warnings are divided into the categories of sender and receiver determinants.

2.a. Sender Determinants. A variety of attributes of the warning message(s) itself have been demonstrated as impacting public understanding of warnings. Specificity, for example, of a warning message has an affect on the understanding of that warning by those who receive it (Quarantelli,

1984:512; Greene, Perry and Lindell, 1981:60; Perry et al., 1981; Warrick et al., 1981:103; Perry and Greene, 1980:61; Drabek, 1968). The range of findings illustrate that vagueness in the message in regard to the location of impending impact, guidance about what those at risk should do, the impending hazard itself and time to impact acts as a constraint to enhancing understanding of the warning. The consistency of warning messages, both within one message as well as across multiple warnings, impacts understanding (Rogers, 1985:5; Sorensen, 1985:13). People are able to more readily understand a warning if the messages that they receive are consistent in terms of the information being given, or at least address why changes or inconsistencies in informational content have occurred. The level of certainty about what is being said in a warning that is conveyed in a warning also affects understanding (Warrick et al., 1981:103). Although not all message attributes have been empirically demonstrated to affect public understanding of warnings, enough evidence does exist to conclude that what and how it is said has an important outcome in terms of what those who would respond to warnings come to understand.

The second category of sender determinants, channel attributes, deals with the channel(s) through which warning messages are delivered, and channel attributes have an affect on understanding. The type of channel of communication used to disseminate a warning message affects understanding. For example, Lachman, Tatsuoka and Bonk (1961:1406) found that siren warnings alone do not result in good understanding of a warning; it has also been found (Turner et al., 1981:70; Carter, 1980:228) that media warnings can enhance understanding when those warnings contain adequate information (Turner et al., 1981:70), but media warnings can deflate

understanding when they are too general and non-specific (Carter, 1980: 228). Public understanding of warning messages has been shown to increase when the warning is communicated over multiple communication channels (Rogers, 1985:5; Turner et al., 1981:25).

Frequency attributes also affect public understanding. Put simply, the more that warning messages are repeated, the greater is public understanding of what is being said (Mikami and Ikeda, 1985:109-110; Rogers, 1985:5; Turner, 1983:323; Turner et al., 1979:17).

Finally, warning source attributes impact public understanding. It is documented (Quarantelli, 1980:120), that warnings from official sources affect understanding by being more convincing that protective public action is necessary.

The empirical record on the affect of sender determinants on public understanding of warning messages is not elaborate. However, sufficient evidence exists to suggest how it is that sender determinants in a warning situation impact understanding. It appears that public understanding of a warning cannot be assumed just because a warning is issued. Further, there does appear a way that sender characteristics could be configured to maximize public understanding. Public warnings which are specific, consistent and certain about the location of impending impact, what people should do, the hazard and time to impact; delivered through a set of communication channels that includes the mass media rather than being limited to one channel; are delivered frequently; and which are from sources which clearly include official sources are more likely to be understood by more members of an endangered public than other sorts of warnings.

2.b. Receiver Determinants. The environmental attribute of proximity to the potential impact site has been shown to affect public warning message understanding. The closer is a warning recipient to the potential impact area, the greater will be that recipient's understanding of the actual magnitude and character of the risk (Hodge, Sharp and Marts, 1979:232; Diggory, 1956). This may be because people further away are not the targets of warnings, and form understan- dings on the basis of second-hand information.

Social attributes of warning recipients also affect understanding. The network category of social attributes seems particularly important to consider. Understanding of emergency warnings, for example, is enhanced if one has a job related to the hazard (Perry and Lindell, 1986:55), lives in a larger rather than smaller sized household (Nehnevajsa, 1985:5), is able to engage in informal discussions with others (Turner et al., 1981: 25,70), has lived in the community a longer amount of time (Hodge, Sharp and Marts, 1979:241), and has a higher versus lower level of perceived attachment to the community (Turner et al., 1979:20). These findings suggest that people who are part of social networks have more access to more information and to more chances to discuss warnings with others. This likely results, holding other factors constant, in better understanding of emergency warnings. This interpretation also likely holds for the finding that rural dwellers are more likely to under- stand warnings than urban dwellers (Oliver and Reardon, 1982:53) since rural communities traditionally have more personal social networks.

The second major category of social attributes found to affect the understanding of warnings is role. The specific findings on this front have been documented. Understanding of a warning is a positive function of

having school-aged children in the household (Perry and Lindell, 1986:56), being better educated (Turner et al., 1981:25; Turner et al., 1979:17), and being older (Turner et al., 1981:25; Turner et al., 1979:15). The interpretation we impose on these findings is that people in roles of responsibility or with life experience are more likely to seek out additional information in a warning circumstance that facilitates understanding; and that the higher one is in socio-economic status, the more well equiped one is to understand information. These interpretations, however, are tentative since the relationship between role and understanding is far from well-documented.

All three categories of psychological attributes (knowledge, cognitions and experience) have been empirically demonstrated to affect understanding of warnings. Pre-emergency knowledge about a hazard enhances understanding of warnings (Perry and Lindell, 1986:52; Foster, 1980:76-77; Haas, Cochrane and Eddy, 1976). Cognitions such as perceived personal risk (Perry and Lindell, 1986:48), perceived property at risk (Perry and Lindell, 1986:50), belief in the scientific capacity to predict the occurrence of an impending disaster (Turner et al., 1981:25) and thinking about a particular hazard (Perry and Lindell, 1986:46) each enhance the understanding. Experience with disaster impact also enhances ability to understand warnings (Perry and Greene, 1983:64; Perry, Lindell and Greene, 1981:125; Quarantelli, 1980b:40; Smith and Tobin, 1979:108; Drabek and Boggs, 1968; Demerath, 1957). It has also been found, however, that experience can limit understanding (Quarantelli, 1980:40; Hultaker, 1976:19-11).

Obviously, psychological factors impact the ability of people to understand emergency warnings. It would seem that pre-emergency knowledge

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about a hazard enhances being able to understand warnings about the potential impact of that hazard; that understanding is also enhanced if people have something to loose should the hazard impact; understanding is greater for people who believe that the capacity to predict a disaster is sound; and that experience with a hazard can sometimes enhance understanding (likely when warned impact is similar to experienced impact) and sometimes detract from understanding (likely when warned impact is different from experienced impact).

The research available on how receiver determinants work to affect public understanding of warning messages can be summarized as follows. First, some members of the public are better able to understand a warning because they have access to items which facilitate understanding, for example, social networks for discussions, experience and knowledge for recollections and better cognitive abilities gained through or as a consequence of education. Second, some members of a public are better able to understand warnings because they have more reason to be vigilant and form an understanding; motives can include, for example, being clearly at risk due to proximity to the impact area, or being in a role of responsibility for the safety of others. These interpretations suggest that warning systems should presume that understanding is not a homogeneous phenomenon for all members of a public given inherent differences between people, and that steps should be taken to facilitate understanding through sender characteristics given that some receiver characteristics could serve to inhibit public understanding of warnings.

2.c. Process Determinants. One process factor has been documented to affect public understanding of warning messages. It is that the process of warning confirmation enhances the ability of the warning

recipient to understand the situation, and the warning being conveyed (Perry, 1982:62; Hammarstrom and Thornstam, 1977:16-17). This finding is an important one since it suggests that understanding a warning message is likely a process that is facilitated by the receipt of multiple warning messages.

3. Believing Warnings. A warning message may be heard and understood but it is also important that it be believed by those who receive it to maximize the odds that appropriate warning response will eventually ensue. Although important, belief is hardly a complex concept and it refers only to the extent that those who receive a warning message accept what is said as true.

3.a. Sender Determinants. Believability is influenced by a variety of sender determinants, and message attributes have been repeatedly documented as impacting upon belief. A range of studies (Quarantelli, 1984:512; Perry and Greene, 1982:326-327; Perry, Lindell and Greene, 1982a:100, 103; Sorensen, 1982:20; Greene, Perry and Lindell, 1981:60; Perry Lindell and Greene, 1981:153; Lindell, Perry and Greene, 1980:13; Perry and Greene, 1980:61; Perry, 1979:34; Drabek, 1969, 1968; Fritz, 1957) provide evidence of basically the same research conclusion; non-specific or vague warning messages are simply less believable to those who receive them than warnings which are specific about the location of impending impact, what people should do, the time to impact and the character of the risk. The level of consistency within a warning message or between multiple messages in regard to these same factors also affects warning belief. Belief increases as a positive function of consistency (Sorensen, 1982:20; Turner et al., 1981:64; Foster, 1980:1920; Mileti, 1975b:21; Withey, 1962; Mack and Baker, 1961; Goldstein, 1960; Schatzman,

1960; Demerath, 1957; Fritz, 1957; Clifford, 1965; University of Oklahoma Research Institute, 1953). The third message attribute, certainty has been shown to function as a dual concept in its affect on belief. It has been concluded, for example, that the greater is the probability of impact as specified in a warning, the greater will the level of warning belief by warning recipients (Mileti, Hutton and Sorensen, 1981:79; Perry, Lindell and Greene, 1981; Turner et al., 1979:61). Additionally, it has also been found that belief increases as a positive function of the degree to which warning messages are delivered with certainty (Mileti and Beck, 1975:43-44). It seems safe to conclude that warnings which are specific, consistent and certain enhance the believability of warnings.

Attributes of the channel through which warning messages are delivered also impact warning believability; both the channel type and number of different channels used to communicate a warning affects belief of that warning. Research by Perry and Greene (1983:55-57), Perry, Greene and Muskatel (1983:69), Sorensen (1982:20), Perry, Lindell and Greene (1981:53), Moore (1963), and Clifford (1956) provides evidence that warnings delivered through direct personal contact are more likely believed than warnings delivered through more impersonal channels of communication. Other research (Perry and Greene, 1983:52; Perry, Greene and Mushkatel, 1983:68; Perry and Greene, 1980:52; Flynn, 1979:24) documents case events in which the electronic mass media produced the most believable public warnings; still other research (Turner et al., 1979:120) found that the printed media was viewed as providing the most believable warnings and information. These apparently inconsistent findings apparently suggest belief of a warning message is affected, as it is, by a multitude of factors, and that other factors like message attributes are

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likely more important in determining belief than is channel type. What is likely is that in historical cases that these other determinants covaried differently with particular channels which produced statistically significant relationships between channel type and belief. Finally, one study (Turner et al., 1981:29) has documented that warning belief is highest if messages are received through more than one channel of communication.

The frequency attribute of the number of warnings received has also been researched in terms of its affect on warning belief. It seems conclusive that believability of emergency warnings is escalated the more frequently people receive additional warnings (Perry and Greene, 1983:66; Turner, 1983:312; Perry and Greene, 1982:326-327; Sorensen, 1982:20; Perry Lindell and Greene, 1981:156; Turner et al., 1981:69-70; Baker, 1979:13; Perry, 1979:34; Mileti, 1975:21; Mileti and Beck, 1975:41; Drabek, 1969; Drabek and Boggs, 1968; Fritz, 1961). This is likely the case because increased exposure to multiple warnings would facilitate a confirmation process.

The final category of sender characteristics found to affect warning belief is source attributes of those from whom warning messages eminate. First, warnings from officials are more believable than those from non-official sources (Rogers, 1985:6; Rogers and Nehevajsa, 1984:113; Perry and Greene, 1983:50; Perry, Greene and Mushkatel, 1983:66; Sorensen, 1982:20; Leik et al., 1981; Perry, 1981; Perry and Greene, 1980:50; Quarantelli, 1980:120; Flynn, 1979:23; Mileti, 1975b:21; Wenger, 1972:52-53; Drabek, 1969; Drabek and Boggs, 1968; Lachman, Tatsuoka and Bonk, 1961:1407). Second, warning belief is a positive function of the credibility of the warning source (Perry, 1982:62-63; Perry and Greene,

1982:326-327; Mileti, Hutton and Sorensen, 1981:79; Turner et al., 1981:10,22,28; Perry, 1979:34; Turner et al., 1979:37; Committee on the Socioeconomic Effects of Earthquake Predictions, 1978:18). Finally, Simpson and Riehl (1981:290) found that warnings are less believable if they are from anonymous sources as opposed to known ones.

The accumulated research on the affect of sender determinants on warning belief does provide a basis for configuring warnings that maximize the probability that they will be believed by the public. Such warnings would be specific about impact location, what people should do, the time to impact and the character of risk. Additionally, they would be consistent, certain, address why they should be acted on if the probability of impact is not very high, delivered through multiple channels of communication, be often repeated and be labelled as coming from a set of sources including officials and a mix of credible sources for a population with potentially diverse ideas about who is credible and who is not.

3.b. <u>Receiver Determinants</u>. The variety of ways in which the people who recieve warnings can be different one-from-another can and does act to influence the probability of a warning being believed, all other things held equal. Warnings are more readily believed, for example, if environmental cues exist for the warning recipient to experience which support the risk or hazard being discussed in the warning (Saarinen and Sell, 1985:156; Perry and Greene, 1982:326-327; Sorensen, 1982:20; Quarantelli, 1980b:107; Mileti, 1975b:21; Drabek, 1969:343-344; Mack and Baker, 1961:46); for example, if it is raining during a flash flood warning or if sirens were sounded during a nuclear power plant emergency. Additionally, the environmental attribute of proximity to the potential

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impact area has been documented to positively affect warning belief (Sorensen, 1982:20; Turner et al., 1981:14; Flynn and Chalmers, 1980:51; Diggory, 1956).

Three of the five potential categories of social attributes have been empirically demonstrated to affect the believability of emergency warnings. The first of these concerns networks in which a warning recipient is a member. For example, Drabek and Stephenson (1971) and Mack and Baker (1961) have both concluded that warnings are more likely believed if the family unit is united at the time a warning is received. Additionally, it has been found (Mack and Baker, 1961; Clifford, 1956) that people in a group of peers, rather than a family, are less likely to believe a warning, as is also the case for persons who emersed in the mebership of a large complex organization (Moore et al, 1963; Mack and Baker, 1961). These findings regarding social networks characteristic are likely more indicative of role rather than network attributes; that is, membership in roles of responsibility (the family) rather than in roles of non-respon- sibility for others like in a group of peers (everyone is equal) or in a bureaucracy (safety is someone else's job) elicit a greater tendency to believe warnings since to do so is consistent with a role involving responsibility for others.

Empirical observations based more clearly on role attributes lead to the same conclusion. For example, women (who traditionally are socialized to the protective mother role) are more ready to believe emergency warnings than men (Turner et al., 1981:27; Yamamoto and Quarantelli, 1982:44; Drabek, 1969; Mack and Baker, 1961). Additionally, age is inversely related to belief (Turner et al., 1981:27; Hodge, Sharp and Marts, 1979:229; Friedsam, 1962, 1961; Mack and Baker, 1961); while

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socioeconomic status is positively related to it (Sorensen, 1982:20; Turner et al., 1981:27; Mileti et al., 1975:47). Culture also affects belief; minority group membership decreases the odds that a warning would be believed (Perry, Lindell and Greene, 1982:103; Turner, 1976:183; Moore et al., 1963:125).

Psychological attributes are also documented by research to affect believability of emergency warnings. Liek, Carter, Clark et al. (1981:433-434), for example, concluded that knowledge about a hazard enhanced warning belief. Cognitions also impact warning belief. Several studies document that understanding higher levels of personal risk positively relates to warning belief (Rogers, 1985:12; Perry and Greene, 1983:101; Perry, Greene and Mushkatel, 1983:280; Yamamoto and Quarantelli, 1982:44; Turner et al., 1981:27,29). Other cognitions found to enhance belief are confidence in the scientific ability to predict impact (Turner et al., 1979:29), non-fatalistic attitudes (Turner et al., 1981:27), and perceived shortness of time to impact (Sorensen, 1982:20). Finally, Quarantelli (1980b:107) has concluded that people under stress are less likely to interpret warnings on the basis of anything other than the known and familiar; consequently, stress is negatively related to warning belief. Experience, the third category of psychological attributes has received the most reserch attention. The general conclusion is that people who have experienced the impact of a disaster agent in the past are more likely to believe future warnings about the impact of hazard (Hodler, 1982:46; Perry and Greene, 1982:326-327; Sorensen, 1982:20; Turner et al., 1981:27,29,51; Foster, 1980:76-77; Perry and Greene, 1980:64; Quarantelli, 1980:40; Perry, 1979:34; Haas, Cochrane and Eddy, 1977; Hultaker, 1976:19; Turner, 1976:182; Ponting, 1974:11; Drabek and Boggs, 1968; Fritz, 1961;

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Mack and Baker, 1961; Demerath, 1957; Williams, 1957; Wallace, 1956; Instituut Voor Sociaal Ondersoek Van Het Nederlandse Vok Amsterdam, 1955; University of Oklahoma Research Institute, 1953). One research finding (Hodge, Sharp and Marts, 1979:229) reports a negative effect of experience on warning belief; but this was for experience with warnings for a particular hazard that did not materialize.

This research record suggests several conclusions about how the varying character of the people who receive warnings can impact upon warning belief. In general, we conclude that several processes seem to operate. First, it would appear that some people are better equipped to believe warnings than others because of factors including knowledge, education, and a non-fatalistic approach to life. Second, it seems also that some people are in positions that would suggest that they should believe a warning; for example, because of confidence in science to predict hazards, being in positions of responsibility for others, environmental cues, experience, personal risk perception, and little time to impact. Third, there are some constraints to warning belief that stem from a lack of trust in those who give warning information (as would be the case for a disinfranchised minority group), those who are excessively stressed and who cannot process warning information well as a consequence; and the elderly who seem reluctant to believe that a break from the routine of life is possible.

3.c. Process Determinants. The empirical record documents one process factor that has had a consistent effect on enhancing warning belief. It is that the successful confirmation of a warning message increases the probability that a warning recipient will believe a warning (Quarantelli, 1984:512; Perry, Greene and Mushkatel, 1983:287; Hodler,

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1982:46; Perry and Greene, 1982:326-327; Perry, Lindell and Greene, 1981:31; Perry and Greene, 1980:75; Irish and Falconer, 1979:323; Mileti and Beck, 1975:41; Drabek and Stephenson, 1971; Drabek, 1969; Drabek and Boggs, 1968; Withey, 1962; Danzig et al., 1958). Confir- mation can and has occurred in a multitude of ways which each appear somewhat equal in terms of enhancement of warning belief. These include obtaining confirmation from an alternative warning source, a different channel of communication, hearing repeated warning messages, talking with others and so on.

4. Personalizing Warnings. Once a warning is heard, understood and believed another factor can facilitate adaptive response; the warning must be personalized by the warning recipient. A personalized warning is one in which the recipient defines itself as part of the intended warning audience. Non-personalized warnings are those defined by a warning receiver as intended for someone else. Personalizing a warning by those at risk, and not personalizing a warning by those not at risk, is an important prerequisite for understanding subsequent public warning response; although there is less than a perfect correlation between personalization and response (people do not always act in ways consistent with whether or not they have personalized a warning since other factors also influence behavioral outcomes).

4.a. Sender Determinants. Two categories of message attributes have been documented to affect the extent to which warnings are personalized by those who receive them. The first is the amount of specificity contained in a warning, for example, about what areas are and are not at risk. The more specificity there is in a warning message regarding risk and non-risk location, the greater is the personalization

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of warnings for those at risk, and the less is personalization of warnings for those not at risk (Perry and Greene, 1983:60-61; Perry, Greene and Mushkatel, 1983:62, 282; Perry and Greene, 1982b:327; Perry, Lindell and Greene, 1982:101-103; Perry, Lindell and Greene, 1981:153; Lindell, Perry and Greene, 1980:13; Perry, 1979b:34). Additionally, the level of consistency across warnings regarding the locale of risk also acts to affect personalization. The empirical records suggest that inconsistency in warning messages regarding risk location increases the personalization of warning message by those who receive them including those who may not be at risk (Lindell and Perry, 1983:52), as well as inconsistency having a negative effect on the personalization of warning message by those who are at risk (Foster, 1980:192; McDavid and Harai, 1968). These apparently inconsistent findings are not inconsistent. It is likely that in some circumstances inconsistency enhances personalization while in others it detracts from personalization. What is important is that specificity and consistency can help make the personalization of warning messages across a public more accurate. Not well explored, one study (Perry, Lindell and Greene, 1981:154) has concluded that warnings from neighbors, as opposed to any other source, enhance personalization. This may well be because neighbors infer great location of risk specificity to neighbors by virtue of their geographical colocation with warning recipients. Additionally, it is also documented that as the number of warnings received increases, that the personalization accuracy of warnings by those who receive them also increases (Perry, Lindell and Greene, 1982b:201; Turner et al., 1981:31; Perry, 1979b:34; Mileti and Beck, 1975:39). The same consequence has been documented as a result of warnings from officials (Perry, Lindell and Greene, 1981:52) and credible sources (Perry, Greene and Mushkatel,

1983:66; Perry and Greene, 1982b:327; Perry, 1979b:34).

The research findings accumulated to data regarding the affect of sender characteristics on the personalization of warning messages by those who receive them can be readily summarized. The accuracy with which people personalize or do not personalize emergency public warnings can be enhanced with warnings which are specific and consistent as to risk location, frequent and repetitive, and from an official and credible source.

4.b. Receiver Determinants. Less than a handful of studies have explored the affect of environmental attributes on the personalization of emergency warnings. Perry and Greene (1982:327) have documented that environmental cues enhance personalization, and Perry and Lindell (1986: 85) and Flynn (1979:32) have found that proximity to the potential impact site increase personalization.

Role characteristics of those who receive warnings, however, have been more elaborately documented as affecting personalization. Socio-economic status, for example, has been documented to negatively affect personalization (Perry and Greene, 1982:327; Yamamoto and Quarantelli, 1982:44; Mileti, Hutton and Sorensen, 1981) as well as positively affect it (Flynn, 1979:29). Age has a negative affect on personalization (Flynn, 1979:29), and women are more likely to personalize warnings than men (Yamamoto and Quarantelli, 1982:44; Flynn, 1979:29; Hodge, Sharp and Marts, 1979:239). Additionally, it has been found that membership in a disinfranchised ethnic group (Perry, Lindell and Greene, 1982a:101; Perry and Greene, 1982b:327) deflates the probability that warnings will be personalized.

Psychological attributes of those who receive warnings also affect the

extent to which those warnings are personalized. Knowledge about a hazard, for example, enhances personalization for those at risk (Perry and Lindell, 1986:95; Turner et al., 1981:31; Turner et al., 1979:51). Cognitions such as fatalistic life outlook (Turner et al., 1981:33) detract from personalization; while understanding higher levels of personal risk positively relates to warning personalization (Perry and Lindell, 1986:37; Turner et al., 1981:52). Experience has a positive effect on the personalization of warning messages (Saarinen et al., 1984:66; Hannson, Nowlles and Bellovich, 1982:184; Perry and Greene, 1982b:327; Perry, Lindell and Greene, 1981:70; Turner et al., 1981:31; Perry 1979b:34).

The findings on which and how receiver determinants affect the personalization of emergency warning messages is similar to how these factors affect warning belief, and they can be summarized in a similar although not identical way. First, some people are better equipped to be able to personalize risk through emergency warnings, for example, because of a non-fatalistic approach to life and knowledge about a hazard. Second, some people are in positions that act as incentives for them to personalize a warning; for example, because of being in positions of responsibility for others, personal risk perceptions, environmental cues, close proximity to impact and experience. Third, there are constraints to warning personalization that stem from a lack of trust in those who give warnings (as would be the case for a disinfranchised minority group), and the elderly who seem reluctant to admit that a break in the routine of life is possible. These findings are virtually identical to the ones catalogued for warning belief with one exception. Socioeconomic status is negatively related to the personalization of risk through warning

messages, while it was positively related to warning belief. It seems, therefore, that the better educated may be better equipped to understand a warning and believe that a disaster will occur, but they are less likely to admit to personal danger and impending personal loss.

4.c. Process Determinants. Personalization of warnings has been documented to be affected by three process attributes. Warning understanding (Hodler, 1982:46), warning belief (Perry and Greene, 1983:101), and warning confirmation (Perry and Greene, 1982:327; Perry, Lindell and Greene, 1981:152). Each facilitate the personalization of risk from warnings.

5. Responding to Warnings. The most frequently examined aspect of public warning studies has been the actual response of members of the public. Actual response can take a variety of forms, for example, evacuation, taking shelter, bringing in the lawn furniture and range to doing nothing. Some studies have examined the full range of potentially adaptive responses to warnings in the particular emergency being investigated; most studies have focused on evacuation. The findings catalogued from this research are now summarized in reference to sender, receiver and process determinants.

5.a. Sender Determinants. The effect of message attributes on public response to emergency warnings is relatively well documented. A range of studies have concluded that the probability of a public engaging in protective response to warning is enhanced as the specificity of warning messages (location of risk, guidance about public response, the impending hazard, and time to impact) increases (Rogers, 1985:11,16; Houts et al., 1984:36; Perry, 1983:43; Perry and Greene, 1983:60-61; Ikeda, 1982:55; Moore et al., 1982:26; Perry and Greene, 1982:326; Paulsen,

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1981:12-13; Perry, 1981:60; Perry, Lindell and Greene, 1981:152; Simpson and Riehl, 1981:290; Carter, 1980:228; Flynn and Chalmers, 1980:21; Perry and Greene, 1980:60; Quarantelli, 1980:104; Dynes et al., 1979:152; Flynn, 1979: 19; Perry, 1979:34; Sime, 1979:211-214; Mileti and Beck, 1975:45). As well, the level of consistency within and between different warning messages concerning risk location, guidance about appropriate public response, the hazard and time to impact increases the odds of an adaptive public response (Chiu et al., 1983:115; Perry, 1983:43; Turner et al., 1981:40; Perry, 1981:53; Quarantelli, 1980:104; Flynn, 1979:18; Mileti et al., 1975:48). The clarity with which a warning message is spoken, the ease of understanding, the greater the likelihood of adaptive public response (Quarantelli, 1980:104; Mileti et al., 1975:48; McLuckie, 1975:48).

In addition to the three message attributes of specificity, consistency and clarity impacting public warning response, the attribute of the type of channel through which the warning is communicated has also been empirically shown to affect public response, but in a confused way. Baker (1979:12) found communcation channel to be unrelated to response. Gray (1981:363) and Perry, Lindell and Greene (1981:133) found that face-to-face communication channels had a higher probability of eliciting adaptive public response than mass media channels; but Flynn (1979:21), Windham et al. (1977:33), and Mileti and Beck (1975:39) found the opposite to be the case. It seems logical to conclude that in historical cases, other factors such as warning specificity and consistency likely covaried with a particular form of communication channel, and that channel correlations with response were likely spurious relationships.

The frequency attributes of number of warnings and warning pattern

have both been demonstrated to enhance appropriate public response to warnings. The more warnings received, the greater the likelihood of adaptive public response (Perry, Lindell and Greene, 1981:156; Quarantelli, 1980:104; Turner et al., 1979:108; Grunfest, 1976:19; Mileti and Beck, 1975; Drabek, 1969; Lachman et al., 1961; Fritz and Mathewson, 1957; Fritz and Marks, 1954). Additionally, the probability a response to warnings increases the shorter the amount of forewarning (Chiu et al., 1983:115; Perry, Greene and Lindell, 1980a:440; Quarantelli, 1980:104; Hultaker, 1979:9).

The source attributes of those giving the warning message, the last category of sender characteristics, has also been documented as affecting response to emergency warnings. Warnings from sources that are official (Baker, 1986:20; Rogers, 1985:15; Saarinen and Sell, 1985:161; Baker, 1984; Perry, 1983:40; Goldstein and Schorr, 1982:51; Perry and Greene, 1982:89; Perry, 1981:57; Perry, Lindell and Greene, 1981:53; Perry and Greene, 1980:55; Quarantelli, 1980:73; Windham et al., 1977:33; Treadwell, 1961:24) have a higher probability of eliciting adaptive public response than non-official warnings. Recently (Sorensen, 1984; Flynn, 1979) it was revealed that scientists are an effective source of warning information. Also credibility of a warning source is positively related to adaptive public response (Stallings, 1984:13; Lindell and Perry, 1983:52; Perry, Lindell and Greene, 1981:152; Simpson and Riehl, 1981:290; Quarantelli, 1980:104; Turner, 1976:183; McLuckie, 1970) as is familiarity with the source of the warning message (Perry and Lindell, 1986:122; Perry, 1983:41; Perry and Greene, 1982:89; Perry, 1981:57; Perry, Lindell and Greene, 1981:53; Perry and Greene, 1980:55).

The set of findings on how sender characteristics affect public

warning response reveals some relatively straightforward conclusions. These are that the likelihood of adaptive public response to emergency warnings is increased if those warnings are specific, consistent, clear, frequent in number, able to foretell a soon-to-impact event, and from sources which are official and scientific, credible and familiar.

5.b. Receiver Determinants. The effect of receiver determinants on public warning response is perhaps the most well-documented research area in warning system research.

Environmental cues function to affect warning response in a couple of ways. First, observing others like neighbors responding to warnings serves as a basis for modelling behavior and increases the odds that a warning recipient will engage in the same sort of adaptive response (Perry, 1983:41; Cutter and Barnes, 1982; Perry and Greene, 1982:89; Perry, 1981:57; Christensen and Ruch, 1980:207,209; Baker, 1979:21; Frazier, 1979:344; Dynes and Quarantelli, 1976:3; Treadwell, 1961:24). As well, perceiving environmental cues consistent with the risk conveyed in a warning (for example, heavy rain and flood warnings) also increases the likelihood that a warning recipient will engage in a protection response (Perry, 1983:40; Perry and Greene, 1982:89; Liverman and Wilson, 1981; Perry, 1981:57; Perry, Lindell and Greene, 1981:133; Flynn, 1979:19). Proximity to the potential impact site also enhances the probability of adaptive response (Houts et al., 1984:33; Yamamoto and Quarantelli, 1982:96-97; Liverman and Wilson, 1981; Perry, 1981:60; Baker, 1979:18,19; Dynes et al., 1979:70,151; Flynn, 1979:14,17,31).

Social attributes of warning recipients affect the odds of engaging in adaptive response to warnings. Aspects of the social networks in which a warning recipient is engaged have a set of well documented response

effects. First, persons immersed in elaborate social networks (as indicated by a variety of factors such as large local friend and kinship networks, long-term community residency, contacts or membership in community organizations, level of community involvement, and so on) are more likely to engage in protective actions than persons with access to more limited networks (Anderson et al., 1984:75; Perry, 1983:36,41; Mileti, Hutton and Sorensen, 1981:112-114; Perry, Lindell and Greene, 1981:79,87,155-156; Turner et al., 1981:39; Perry, Lindell and Greene, 1980:40; Baker, 1979:17-21; Dynes et al., 1979:152; Perry, 1979:35; Turner et al., 1979:109; Windham et al., 1977:27,33; Worth and McLuckie, 1977:72; Grunfest, 1976; Clifford, 1956). Additionally, persons who are able to discuss the situation with other network members have a greater probability of engaging in protective action (Rogers, 1985:15; Baker, 1979:21). Network characteristics can also serve as constraints to engaging in protective actions. For example, Houts et al., (1984:33), Perry (1981:60) and Baker (1979:19) have documented that network aspects like not being able to leave from one's place of work can constrain protective actions such as evacuation. Additionally, a variety of findings exist to suggest that protective actions like evacuation have a higher probability of occurring if people are in a united as opposed to a separated nuclear family unit (Perry and Greene, 1983:66; Perry, 1982:103; Perry and Greene, 1982:86-87; Perry, Lindell and Greene, 1981:45; Perry and Greene, 1980:87; Perry, Lindell and Greene, 1980:40; Flynn, 1979:32; Frazier, 1979:343; Dynes and Quarantelli, 1976:4; Quarantelli, 1960); although there is some evidence to suggest that family unity is unrelated to response with very rapid onset emergencies (Mileti, 1974).

A small set of findings exist regarding the role of resources in

affecting public warning response. It appears (Houts et al., 1984:33; Mileti, Hutton and Sorensen, 1981; Baker, 1979:21) that possessing resources like access to transportation, or cash in the case of protective actions requiring it, facilitate adaptive warning response.

The role membership of warning recipients has a clear affect on public response to emergency warnings. Persons in roles of responsibility for others (for example, by being parents) are more likely to engage in protective action response to warnings than persons not in such roles (Houts et al., 1984:33; Carter, Kendall and Clark, 1983:102-103; Perry, 1981:53; Turner et al., 1981:39; Quarantelli, 1980:42-43; Flynn, 1979:21; Wilkinson and Ross, 1970:16). Socioeconomic status (level of education, income, and so on) is also positively related to adaptive warning response (Stallings, 1984:14; Mileti, Hutton and Sorensen, 1981; Turner et al., 1981:39; Baker, 1979:19; Dynes et al., 1979:152; Flynn, 1979:32; Windham et al., 1977:24; Wilkinson and Ross, 1970:16; Lackman et al., 1961). Sex, in the sense that women are more likely than men to engage in adaptive warning response, is also related to response (Yamamoto and Quarantelli, 1982:126; Flynn and Chalmers, 1980:24; Flynn, 1979:21; Wilkinson and Ross, 1970:16). Age has had mixed relationships with the performance of adaptive response to emergency warnings. It has been reported to have a negative effect (Perry, Lindell and Greene, 1981:156-157; Dynes, 1979:152; Flynn, 1979:32; Perry, 1979:35; Grunfest, 1976:23; Mileti, 1975b:22; Wilkinson and Ross, 1979:16; Moore et al., 1963); a positive effect (Cutter and Barnes, 1982; Yamamoto and Quarantelli, 1982:86,174; Perry, Lindell and Greene, 1981:93); and no effect at all (Baker, 1979:21). A few studies (Stallings, 1984:14; Dynes et al., 1979:152; Flynn, 1979:19) report that having a job which precludes leaving can be a constraint to

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protection actions like evacuation.

The cultural aspect of social attributes has also had an empirical effect on disaster warning response. Membership in a minority group decreases the odds of engaging in adaptive warning response (Perry, Greene and Mushkatel, 1983:45; Perry, Lindell and Greene, 1982:103,104,157-158; Perry, Lindell and Greene, 1981:101; Turner et al., 1981:40; Wilkinson and Ross, 1970:14; Drabek and Boggs, 1968:447). All other things equal, blacks are more likely than other ethnic groups to respond adaptively to warnings (Perry, Greene and Mushkatel, 1983:43).

All three psychological attributes, knowledge, cognitions and experience, have been empirically demonstrated to impact upon emergency warning response. Knowledge about appropriate response (for example, about evacuation routes in the case of evacuation) has a positive effect on response (Rogers, 1985:15; Perry, Greene and Mushkatel, 1983:281; Perry and Greene, 1982:326; Leik et al., 1981:433-434; Liverman and Wilson, 1981; Perry, Lindell and Greene, 1981:153; Warrick, 1981:13; Perry, Lindell and Greene, 1980:40; Perry, 1979:34; Windham et al., 1977:54; Swithey, 1976:129). Warning response is also positively effected by knowledge about the hazard for which a warning is issued (Perry and Lindell, 1986:117; Dynes et al., 1979:52). Recent work (Sorensen, 1986:438-457) helps put this finding in context. Prior hazard knowledge is useful in upgrading warning response, but is likely not sufficient to elicit appropriate response in-and-of itself. Cognitions have been documented to affect emergency warning response in the following ways. Persons with a fatalistic life outlook are less likely to respond adaptively to disaster warnings than those without this approach to life (Perry and Greene, 1982:326; Turner at al., 1981:40; Flynn, 1979:19; Sims

and Bauman, 1972:1391). For the protective action of evacuation, fear over looting is negatively related to evacuation (Quarantelli, 1984:513; Perry, 1983:43; Perry, 1981:60; Flynn, 1979:19). A third cognition found to affect warning response is habitualized behaviors. Several studies have concluded that people have a tendency in responding to emergency warnings to do things as they do habitually, for example, evacuate over routes that they typically traverse (Pauls and Jones, 1980; Glass, 1970; Anderson, 1968; Demerath, 1957; Kilpatrick, 1957). Risk, or a person's perceived loss also affects response (Houts et al., 1984:33; Mileti, Hutton and Sorensen, 1981; Baker, 1979:18-19; Flynn, 1979:17-21; Windham et al., 1977:24); for example, mobile home dwellers are more likely to evacuate in response to hurricane warnings than regular homeowners because the perceived risk of staying is greater, and pregnant women were more likely to evacuate during Three Mile Island because they were labelled as a high risk group. The Three Mile Island accident also revealed another cognition as positively related to evacuation, it was fear over a possible forced evacuation which people sought to avoid (Perry, 1981:53; Flynn, 1979:18). Finally, it has been documented that in the case of evacuation, the perceived length of time that people think they will be away from their homes increases the probability of evacuation (Liverman and Wilson, 1981) as well as the use of public shelters (Perry, Greene and Lindell, 1980a:440-441). The third and last psychological attribute category, hazard experience, is also demonstrated to affect warning response. Experience with the hazard for which warning has been issued has a positive affect on adaptive warning response (Perry and Lindell, 1986:119-120; Perry and Greene, 1982:326; Perry, Lindell and Greene, 1981:70,152-153; Turner et al., 1981:39; Perry and Greene, 1980:66; Baker,

1979:17; Frazier, 1979:343; Irish and Falconer, 1979:323; Perry, 1979:34; Smith and Tobin, 1979:108; Westgate, 1978:25; Regan and Fazio, 1977:41; Hutton, 1976:265; Grunfest, 1976:19; Turner, 1976:182; Lachman, Iatsuoka and Bonk, 1961:1409; Treadwell, 1961:24). The effect of experience on warning response is not monolithic, however. It has also been found that it is the recency of experience which positively impacts warning response (Perry, Lindell and Greene, 1981:153; Perry, Greene and Lindell, 1980a:441; Hutton, 1976:265; Anderson, 1969a; Moore et al., 1963; Fogleman, 1958). There is also evidence to suggest that a lot of experience with a particular hazard can create routine and effective public response to warnings (Perry, Greene and Lindell, 1980a:441) as well as complacency and increased risk taking (Windham et al., 1977; Baker, 1979:16-17; Wilkenson and Ross, 1970:20).

It has also been concluded that physiological constraints can detract from adaptive public response to emergency warnings (Houts et al., 1984:33); for example, because persons are too sick or disabled to engage in evacuation.

There is, obviously, an elaborate research record to document the affect of receiver determinants on public response to emergency warnings, and we have reached the following conclusion concerning the empirical record. First, some members of the public are better equipped to respond to warnings because of pre-emergency knowledge about the hazard and response, education and socioeconomic status, they possess the resources to facilitate response, and they are unencumbered by physiological constraints which preclude certain response options. Second, some people are in positions that act as incentives to respond adaptively to warnings, for example, because of being in positions of responsibility for others,

the presence of environmental and social modelling cues for adaptive response, experience, personal risk perceptions, being socialized into protector roles, proximity to impact area and therefore access to less distorted information and a clearer risk perception, and access to an elaborate social network to enhance response options like evacuation, the tendency to follow habit, membership in minority cubcultures that produces distrust, and the general although not ironclad tendency to engage in some protective actions as a united nuclear family.

5.c. Process Determinants. All possible process determinants (hear, understand, believe and personalize) have been empirically documented to affect response. Hearing a warning enhances the probability of an adaptive response (Saarinen and Sell, 1985:66; Turner, 1983:328; Turner et al., 1981:39; Baker, 1979:13; Turner et al., 1979:58,104; Grunfest, 1976:19). Understanding warnings also enhances the odds of adaptive public response (Turner, 1983:326; Baker, 1979:15; Turner et al., 1979:108; Windham et al., 1977:56; Wilkinson and Ross, 1970:31). Believing a warning enhances adaptive public response (Perry, 1983:42; Perry and Greene, 1983:101; Perry, Greene and Mushkatel, 1983:280; Perry and Greene, 1982:326-327,343; Perry, Lindell and Greene, 1982:99,102; Perry, Lindell and Greene, 1981:154-155; Lindell, Perry and Greene, 1980:13; Perry and Greene, 1980:78-80; Perry, Lindell and Greene, 1980:40; Baker, 1979:13-16; Perry, 1979:34; Hultaker, 1976:8; Mileti and Beck, 1975:45). Personalization of the risk conveyed in warnings has a positive effect on taking adaptive emergency warning response, and this is perhaps the most elaborately documented process relationship in warning system response research (Perry and Lindell, 1986:114-118; Quarantelli, 1984:512; Zeigler and Johnson, 1984; Perry, 1983:36-40; Perry and Greene, 1983:101;

Perry, Greene and Mushkatel, 1983:51,279; Goldsteen and Schorr, 1982:51; Ikeda, 1982:55; Perry, 1982:327; Perry and Greene, 1982:327,343; Perry, Lindell and Greene, 1982:99,102; Yamamoto and Quarantelli, 1982:96-97; Mileti, Hutton and Sorensen, 1981:79,100,107; Perry, 1981:53-60; Perry, Lindell and Greene, 1981:39-40,72,78,151,158; Baker, 1979:14-19; Dynes, 1979:152; Turner et al., 1979:106; Flynn, 1979:29; Perry, 1979:34; Windham et al., 1977:51-59; Hultaker, 1976:8; Withey, 1976:128; Mileti and Beck, 1975:39; Glass, 1970:64-67; Bates et al., 1963; Demerath, 1957; Fritz, 1957).

Last, a unique type of warning response is to seek to confirm the original warning message received. Confirmation, acting to affect response toward enhancing belief and presonalization, has been documented to be a general descriptive response to receiving emergency warnings (Rogers, 1985:16; Perry, Greene and Mushkatel, 1983:286; Leik et al., 1981:36-39; Paulsen, 1981:14; Irish and Falconer, 1979:323; Drabek, 1969:344); a positive function of lead time (Perry, Lindell and Greene, 1981:31,152), perceived personal risk (Leik et al., 1981:433-434; Danzig, 1958), and messages received from the mass media (Dillman, Schwalbe and Short, 1981:176; Frazier, 1973:343; Drabek, 1969:343), and family unity (Drabek and Stephenson, 1971); and a negative function of the number of warning messages received (Mileti, 1975b:21) which is itself confirmation, prior knowledge about the hazard (Rogers, 1985:14) and the level of specificity contained in the original warning received (Perry and Greene, 1983:60-61; Cutter and Barnes, 1982).

D. Conclusions for Policy and Applications

1. The Non-behavioral Aspects of Response. Public response to warnings cannot legitimately be viewed solely as behavior. People respond

to warnings through a social process; to comprehend warning response means a comprehension of that process. Planning for future public warning response means planning should address that process, which ends in actual adaptive behavior. The process is a straightforward one: (1) the odds of an adaptive public response are enhanced if warnings are personalized by those who should personalize them, and not personalized by those not at risk; (2) the probability of effective personalization increases as a direct function of the level of belief elicited in emergency warnings; (3) belief can have its best effect on personalization, and eventually response, if it is prefaced by accurate public understanding of what is being said in a warning, and (4) understanding warning presumes that warnings must be heard. Our first general conclusion, therefore, is that public warning response is best understood, explained and planned for if it is viewed as a series of sequential dependent variables, ordered as a social process, and comprised of hearing warnings, understanding what is said, believing what is heard, personal- izing what is believed as is appropriate, and then human behavior. Of course, the process we outline does not always function this way in the real world. For example, it is possible in any evacuation to find evacuees who did not believe that the disaster would impact the area; consider a teenager who evacuated only because it was a chance to cut school and party with friends in another town. Our point is that for most people in most circumstances, that the process we outline will help explain most of the reasons why most people did or did not do whatever it is that they did in response to warnings. Exceptions to the general rule will exist, but these are not reason to dismiss the general rule.

2. Response Process Determinants. Who in an endangered public does

and does not hear, understand, believe, personalize and respond adaptively to emergency warnings is not up to random chance. These process outcomes are the consequences of the effects of empirically demonstrated and known determinants which we have grouped into the categories of receiver and sender determinants. The conclusions we are able to reach regarding these determinants are based on the reviewed empirical record, and now follow.

First, different members of a public are members of different communcation networks, and have access to different communication linkages to the outside world. Consequently, the probability of maximizing the number who hear a warning is enhanced by warning systems which disseminate warning messages over enough different channels of communication to the public to access the full range of communication networks over which that heterogeneous public receive information.

Second, the understand-believe-personalize-respond process outcomes all appear facilitated by warning systems capable of providing emergency information that is both convincing and reasonable from the public's point of view; and the empirical record well documents what comprises reasonable and convincing warning information from the public's viewpoint. Warnings are perceived by the public to be convincing and reasonable if they are specific, consistent and certain as to the location of the area of risk; guidance is provided about what the public should do; the character of the hazard is revealed as is the amount of time to its impact; changes in the content of warnings which would make them appear inconsistent with others explained; uncertainty in the content of warnings regarding, for example, the probability of impact is explained, as well as why the public should act upon inevitably uncertain information as if it were certain. Warnings should also be repeated frequently, it is insufficient to issue a warning

once or so infrequently as to not provide for the public being able to hear the warning a multiple of times. Additionally, warnings should best come from a source that maximized the credibility of the warning information. Who is credible for one person, however, may not be credible for another; therefore, it seems imoportant that warnings stem from a panel of sources that could include, for example, scientists, officials, a familiar local personality and a disaster response group familiar to most, such as the Red Cross. Credibility of warning information is also enhanced by the confirmation process and the frequency with which a particular warning message is heard.

Third, any public is a heterogeneous group. People have inherent differences of fact and circumstance that they bring to an emergency warning response setting, and which would "predispose" them to different warning response process outcomes were it not for sender determinants. These differences appear numerous when one views the empirical record. But these variables, in our view, are a multitude of different indicators selected by different researchers which actually reflect different ways of operationalizing and measuring a handful of the same more general concepts. It is these concepts which provide an avenue of understanding how public differences of fact and circumstance predispose variation in warning response. Four concepts stand out as capable of explaining and organizing the empirical record regarding the affect of receiver determinants on warning response process outcomes. These are variation in ability to process risk information, access to social and physical networks; incentives to be vigilent, take a warning seriously or err on the side of caution; and constraints to desirable warning response process outcomes.

People vary in their ability to process risk information, like that contained in warnings. Variability exists because of factual differences between people such as education, cognitive abilities, pre-emergency knowledge, experience with a hazard and the degree of fatalism with which people approach life. Variability in the ability to process risk information also exists because of circumstances characterizing a warning event. For example, it is easier for people to impute meaning to risk information when their environment provides cues or models supporting the content of the received risk information; for example, like sirens in the event of an invisible radiological emergency, or seeing neighbors evacuating. Human variation in the ability to process risk information, for either or both factual or circumstantial reasons, will lead to variation in warning response process outcomes holding all other factors constant.

Warning recipients also differ in terms the access they have to social and geographical networks and events. These differences also lead to differences in warning response process outcomes when all other factors are held constant. A range of social network attributes, for example, can make for differences in response process outcomes. For example, persons who are part of established pre-emergency social networks are more likely to receive informal warnings, or to give them, and therefore more likely to confirm warnings, as well as understand, believe, personalize appropriately and engage in adaptive response. Network membership also enhances the odds that people have someone to talk to as they seek to define the warning situation and arrive at a meaning for it. Network membership also increases options for response, for example, having the home of a friend to evacuate to, or receiving an invitation to do so.

Persons who by circumstance are not at home when they receive a warning are denied at least partial access to their networks and have a lower probability of achieving sound warning response process outcomes. Geographical proximity to the area at risk also affects process outcomes. The further away from the area, the more distorted the emergency information one has access to and the less informed are warning response outcomes. Human variation in network access, either by factual differences between people regarding networks or differences due to circumstance, will lead to variation in warning response process outcomes holding other factors constant.

People who receive warnings also differ in terms of factors which act as either constraints or incentives to sound warning process outcomes. Some people have more of an incentive to be vigilent, take a warning seriously, investigate what is happening and confirm a warning, and/or to err on the side of caution; others simply lack some or all of these incentives. Incentives can exist for a variety of reasons including being in a role of responsibility for children, being socialized into and adhering to a protective/nurture role like that of female or mother, or being predisposed to perceive risk in one way or another to a particular hazard. Incentives can also be circumstantial, for example, having only a very short-time to impact and, therefore, not being afforded the luxury of being able to socially negotiate the meaning of an impending disaster's warning. Incentives, either factual or circumstantial will lead to variation in warning response process outcomes holding all other factors constant, as will constraints. Some people, again by virtue of factual or circumstantial differences are constrained from sound warning understanding, belief, personalization and response. Constraints are

varied and include lacking the resources necessary to act (not having a car in which to evacuate), being unable to engage in some actions for physiological reasons, belonging to an ethnic group which simply discounts information that comes from the mainstream, being of a pre-emergency psychological state that precludes sound or unbiased judgement (being particularly stressed, or being elderly enough to not be open to the occurrence of low probability disasterous events), ascribing to unfounded fears and superstitions like the fear of looting, and simply not being willing to consider engaging in some actions until a person can check on or be assured of the safety of a loved one and/or other intimate(s).

In sum, sender characteristics vary across warning events. In warning events that provide convincing and reasonable emergency warning information to the public, the understanding, belief, personalization and response of the public can be sound. Receiver characteristics vary widely between members of a public in any one warning circumstance, as well as between different events; and receiver characteristics can be factual (things that simply exist and can not be changed) as well as circumstantial (things which occur by chance during the emergency like whether or not it is raining heavily when flash flood warnings are issued). The effect of receiver determinants on warning process outcomes are not laws of nature which cannot be changed as is the case with the laws of a physical science. It is possible for a warning system to design its sender characteristics to not only maximize the application of knowledge about how sender characteristics can elicit sound warning response process outcomes, but also to eliminate, reasonably well, most of the negative impacts that receiver characteristics can have on process outcomes. The configuration of sender determinants which the empirical

research record has revealed as important to achieving this end follow. First, warning messages should be as specific, consistent, accurate, certain and clear about location and character of risk, guidance about what people should do and how much time they have to do it as is possible. Changes in these items over time, should be explained. Second, the more communication channels used to reach a public, the better since different people are part of different communication networks. Third, warnings should be systemati-
cally repeated often in a predictible pattern. Fourth, warnings should be labelled as from a set of sources including a mix of scientists, officials and a familiar local figure. These prescriptions could be achieved by a range of planning alternatives; and specific planning elements to achieve these goals would vary from hazard to hazard and across entities. The basic principles and planning goals, however, should be the same across hazards and planning entities.

3. The Confirmation Process. Our third conclusion is that underlying the warning-response process, and the affect of sender and receiver deter- minants on the outcomes of that process, is the concept of confirmation which is itself a social process. People are not easily convinced that the unthinkable can happen. Many concern that a public will panic when faced with news of an impending catastrophe, and fear of public over-reaction has been documented as a constraint to issuing warnings in the first place (Mileti, Sorensen and Bogard, 1985). Many others presume that a warning will be immediately followed by prudent public action in response to hearing the message. Still others speculate on the basis of misinterpreted evidence that some types of impending disaster, when warned for, will elicit dramatic and immediate public

flight (for example, fleeing American cities on the heels of initial notifications of an impending nuclear attach or a radiological emergency at a nuclear power plant). The accumulated empirical evidence strongly suggests that the first warning response (and perhaps even the second and third) of most people is to seek to confirm that message; that is, to get more information, talk over the warning with others, and/or hear the same message again, instead of believing the news at first blush. Confirmation of warning messages is necessary for most people before acting in ways that go beyond seeking confirmatory information.

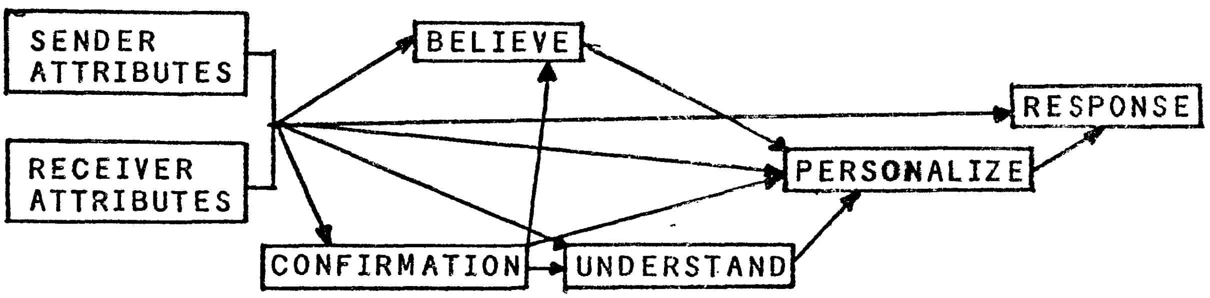
E. Conclusions for Research

Our last last conclusion in reference to public response to emergency warnings is, perhaps, best cast as extremely well informed speculation. It is to attempt to construct a model, presumed to depict cause and effect, to summarize the process, determinants and consequences of public response to warnings of impending disasters and catastrophes. Figure Two presents our attempt to construct such a model informed by the empirical record recorded in earlier sections of this chapter. The boxes in the model represent the concepts that have been discussed in detail in this chapter, and the arrows represent cause and effect between the concepts.

The model presented in Figure Two is best viewed as one in need of future empirical test. It does well represent, and then hypothesize, the character of cause and effect suggested by the empirical record. It was, obviously, induced from the existing data. To the best of our knowledge no one research effort has sought to systematically measure each factor or concept in the model and analyze the entire system in a multivariate format. Although it is possible to hypothesize the model with empirical confidence, it is impossible to conclude it to be scientific fact.

Figure Two

A MODEL OF THE CAUSES AND EFFECTS OF PUBLIC RESPONSE
TO WARNINGS OF IMPENDING DISASTER



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There are few other areas of research in the social sciences that have compiled as extensive a research record as is the case in public response to emergency disaster warnings. Additionally, even fewer other areas exist in which the accumulated knowledge base promises to be as useful to society as does knowledge about public warning response.

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A CHRONOLOGY OF U.S. GEOLOGICAL SURVEY HAZARDS WARNINGS 1976-1986

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HAZARDS WARNINGS, PREPAREDNESS, AND TECHNICAL ASSISTANCE

The U.S. Geological Survey (USGS) has general and broad authority to investigate geologic and hydrologic hazards, to notify appropriate Federal, State, and local authorities of these hazards, and to provide information as necessary to insure that timely and effective warning of potential disasters is provided. The USGS has been given these responsibilities under the Organic Act of 1879 and Executive Order delegations of the Disaster Relief Act of 1974.

The Director of the Geological Survey of the Department of the Interior is charged with the Federal responsibility to issue geologic hazards warnings, and, in particular, earthquake predictions. Specifically, Section 202 (a and b) of the Disaster Relief Act of 1974 stipulate that "The President shall insure that appropriate Federal agencies are prepared to issue warnings of disasters to State and local officials," and that "appropriate Federal agencies provide technical assistance to State and local governments to insure that timely and effective disaster warning is provided." In the 1980 reauthorization of the Earthquake Hazards Reduction Act of 1977, the Director of the USGS was given the authority to issue an earthquake advisory or prediction as deemed necessary.

Hazards warnings issued by the USGS are sent to concerned State agencies. Principal State contacts are designated by the State governors and are usually an official of the State's office of emergency services or the State geologist. Two general systems have been used for issuing hazards warnings. The first served the USGS from 1976 to 1984; the second after 1984.

The USGS has also designed separate systems for particular situations. The Hawaiian and Cascades Volcano Observatories have developed their own systems of notifying federal and state agencies of imminent eruptions. The two observatories have excellent records of successful predictions of eruptions and well organized warning and response procedures with the officials in the area.

HAZARDS NOTICES ISSUED BY USGS PRIOR TO APRIL 1984

From 1976 to 1984, the system for evaluating and transmitting notifications of hazards included Notices of Potential Hazard, Hazard Watches, and Hazard Warnings (predictions). The three levels of notifications, which were outlined in the Federal Register, April 12, 1977, volume 42, no. 70 (see Appendix A), were defined as:

(1) Notice of Potential Hazard--information on the location and possible magnitude of a potentially hazardous geologic condition. However, available evidence is insufficient to suggest that a hazardous event is imminent or evidence has not been developed to determine the time of occurrence.

(2) Hazard Watch--information, as it develops from a monitoring program or from observed precursors, that a potentially catastrophic event of a generally predictable magnitude may occur within an indefinite time (possibly months or years).

(3) Hazard Warning--information (prediction) as to the time, location, and magnitude of a potentially disastrous geologic event.

Table 1 lists the 16 formal hazard notices issued by the U.S. Geological Survey from March 1976 to March 1984. All notices except the last one for Mauna Loa volcano were issued under the system outlined in the Federal Register of April 12, 1977.

TABLE 1

FORMAL HAZARD NOTICES ISSUED BY U.S. GEOLOGICAL SURVEY 1976-1984

03/03/76	Southern California Uplift - Hazard Watch (News release issued 03/18/76) Updated 07/03/80 (Follow-up report and news release issued 08/15/80) Updated 10/09/81
02/02/77	Billings, Montana Rockfall - Notice of Potential Hazard
05/10/77	Ventura, California Active Fault - Notice of Potential Hazard (Follow-up report and news release issued 07/19/77)
04/10/78	Las Vegas, Nevada Subsidence - Notice of Potential Hazard (Follow-up report and news release issued 06/13/78)
05/10/78	Kodiak, Alaska, Pillar Mountain Landslide - Notice of Potential Hazard (Follow-up report and news release issued 06/16/78)
09/08/78	Mount Shasta Volcano, California - Notice of Potential Hazard (Follow-up report and news release issued 09/29/78)
12/20/78	Mount Baker & Mount St. Helens Volcano, Washington - Notice of Potential Hazard (Follow-up report and news release issued 01/12/79)
02/02/79	Wrightwood, California, Landslide - Notice of Potential Hazard (Follow-up report and news release issued 02/21/79)
05/31/79	Yakataga, Alaska, Earthquake - Notice of Potential Hazard (News release issued 06/01/79)
12/03/79	Clodine Fault, Houston, Texas - Notice of Potential Hazard
03/27/80	Mount St. Helens - Hazard Watch Updated 04/03/80 (News release issued 04/03/80) Updated 04/30/80 (News release issued 04/30/80) Updated 05/29/80
06/23/80	Columbia Glacier, Alaska - Hazard Watch (News release issued 06/25/80) (Follow-up report and news release issued 12/07/81)
07/11/80	Mt. Hood Volcano, Oregon - Hazard Watch (News release issued 07/11/82) Terminated 08/04/80 (News release issued 08/05/82)
05/27/80	Mammoth Lakes Earthquake, California - Notice of Potential Hazard (News release issued 05/30/80) Updated 10/07/81 (Follow-up report and news release 11/16/81)
05/25/82	Mammoth Lakes, California - Notice of Potential Volcanic Hazard (News release issued 05/25/82) (Follow-up report and news release issued 06/10/82)
10/08/82	China Lake and Ridgecrest, Southern California - Advisonry of earthquake potential (News Release issued 10/15/82) Background letter 08/06/82
03/29/84	Mauna Loa Volcano, Hawaii - Geologic Hazards Warning (News release issued March 30, 1984)

In 1984 the U.S. Geological Survey revised the criteria and terms used in issuing notices concerning geologic-related hazards. It should be noted that throughout this discussion, the term geologic-related hazards includes a broad range of geologic and hydrologic phenomena. As outlined in the January 31, 1984, Federal Register, Volume 49, No. 21 (see Appendix B), the term Hazard Warning is reserved for those situations posing a greater than normal risk and "warranting considerations of a timely response in order to provide for public safety. Information regarding hazardous conditions that do not meet the criteria for a Hazard Warning may, however, also be sent to public officials as it becomes available. Transmittal of such information would not constitute a Hazard Warning.

(1) The criteria for a Geologic-Hazard Warning are:

a. A degree of risk greater than normal for the area; or a hazardous condition that has recently developed or has only been recently recognized; and

b. A threat that warrants consideration of a near-term public response.

(2) A Geologic-Hazard Warning consists of:

a. A description of the geologic or other pertinent conditions that cause the concern;

b. Factors that indicate that such conditions constitute a potential hazard;

c. Location or area that may be affected;

d. Estimated severity and time of occurrence, if such estimates are justified by available information;

e. If possible, a probabilistic statement on the likelihood of a given event or events with a specified time period; and

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f. A description of continued Geological Survey involvement and estimate of what and when additional information might be available."

As a result of the issuance of the revised hazards warning terminology, the notices listed in Table 1 were reexamined. As a consequence of this review, nine notices failed to meet the criteria for a formal hazard alert as defined above. Three other notices, those for Mt. Hood, Mauna Loa, and Mammoth Lakes, were discontinued due to reduction in risk. Table 2 outlines the disposition of each notice given between 1977 and 1984. Only Mt. St. Helens volcano and Columbia glacier met the new criteria of a hazard warning.

The change in hazard warning terminology of the USGS, adopted in 1984, resulted from a year-long review of the Geological Survey's responsibility and performance in notifying State and local governments of important geologic hazards. The review considered both the utility of its public statements in assisting State and local jurisdictions in conducting their public safety functions, as well as the efficiency of internal USGS procedures in developing and distributing the warning messages. The evaluation showed that many of the Notices of Potential Hazards described geologic conditions that were well known by the public and its officials. Also some of the "Notices" were vague about the time or probability of occurrence and the hazards did not necessarily warrant any particular action to protect public safety. Furthermore, the "Hazard Warning" category established by the 1977 Federal Register was not used because the Geological Survey did not have an operational capacity to issue predictions of hazardous geologic phenomena.

The Geological Survey simplified the three-fold system into a single "Hazard Warning" category focusing on near-term public safety. Other significant information about hazards that did not satisfy the new criteria would be sent to state authorities for consideration in their hazards mitigation and public awareness programs.

TABLE 2

DISPOSITION OF HAZARD NOTICES 1976-1984

LOCATION	HAZARD	ACTION
Billings, Montana	Rockfall	Fails 1984 Federal Register criteria. No new warning will be issued.
Ventura, California	Fault	Fails 1984 Federal Register criteria. No new warning will be issued.
Las Vegas, Nevada	Subsidence	Fails 1984 Federal Register criteria. No new warning will be issued.
Kodiak, Alaska	Landslide	Fails 1984 Federal Register criteria, No new warning will be issued.
Mt. Shasta, CA	Volcano	Fails 1984 Federal Register criteria. No new warning will be issued.
Mt. Baker, WA	Volcano	Fails 1984 Federal Register criteria. No new warning will be issued.
Houston, Texas	Fault and Subsidence	Fails 1984 Federal Register criteria. No new warning will be issued.
Wrightwood, CA,	Landslide	Fails 1984 Federal Register criteria. No new warning will be issued.
Mammoth Lakes, CA	Earthquake	Fails 1984 Federal Register criteria. No new warning will be issued.
Yakataga, Alaska	Earthquake	Decision pending.
Southern California	Earthquake	Decision pending.
Columbia glacier, AL	Glacier	Meets 1984 Federal Register criteria. Water Resources Division action.
Mt. St. Helens, WA	Volcano	Meets 1984 Federal Register criteria. Cascades Volcano Observatory action.
Mt. Hood, Oregon	Volcano	Terminated hazard notice on August 4, 1980.
Mammoth Lakes, CA	Volcano	Terminated hazard notice due to reduction in hazard potential on July 11, 1984.
Mauna Loa, Hawaii	Volcano	Terminated hazard warning on April 17, 1984.

HAZARDS COMMUNICATIONS AFTER APRIL 1984

Following the revision of terminology in 1984, the number of hazard-warning communications decreased because most geologic hazards did not satisfy the criteria necessary for a "geologic-hazard warning." However since 1984, communications about geologic hazards have continued in the form of offical communications by USGS to State officials. The experiences since 1984 are summarized below.

Parkfield, California

On April 4, 1985, the Director of the USGS, formally notified the State of California, through its representative, Director of the California Office of Emergency Services, that there was "a high probability of an earthquake of about magnitude 6 within the next several years in the Parkfield region." However, the Director of the USGS stated that he did not consider that the evidence and evaluation warranted issuing a "geologic hazard warning" by the USGS at that time. The Director went on to explain what the scientists were finding and doing in the Parkfield region. A press statement was released the following day informing the public about the work being carried out in the Parkfield region which included a long-term forecast of a 5.5-6 earthquake within the 1985-1993 time frame. Subsequently, both the National Earthquake Prediction Evaluation Council (NEPEC) and the California Earthquake Prediction Evaluation Council (CEPEC) reviewed and advised the Geological Survey and the California Office of Emergency Services, respectively, that the Parkfield forecast constituted a scientifically credible earthquake prediction.

Bishop, California

A second communication about a geologic hazards occurred on July 21, 1986, when the Director of the USGS formally advised the Director of the California Office of Emergency Services that an earthquake swarm was in progress 15 miles north of Bishop, California, in the Chalfant Valley. The Director related information concerning the potential for a magnitude 7 event to occur in the area experiencing the earthquake swarm. The Director promised that the USGS would continue to monitor the situation and update the "advisory" on July 24,

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1986, unless the situation changed significantly prior to that date. On July 24, the Director of the USGS advised the Director of California Office of Emergency Services that earthquake activity in the Chalfant Valley had diminished and that further damaging earthquakes were unlikely and that the possibility of their occurrence would diminish with time. No press releases were issued.

San Diego, California

On June 17, 1985, Geological Survey seismologists at Pasadena, California, in consultation with the Chief, Office of Earthquakes, Volcanoes, and Engineering, analyzed a swarm of earthquakes along the Rose Canyon fault in the San Diego, California, area. USGS procedures stipulate that scientists are to notify the proper local authories directly if they believe that additional delay in warning the public would jeopardize public safety. Based upon their analysis and recent research on the pattern of foreshocks in southern California, they released the following statement to State officials "...there is a 5% chance of a magnitude 5 or greater earthquake in the next 5-day period." These notifications received neither scientific review nor Director's approval.

CONCLUSION

The recent experiences with communications to State officials, short of issuing a hazard warning, represent a trend in alerting States and the public about potential hazards. The communications are specific in describing the present situation and the probable future situation. They state what the USGS will do to monitor the situation and procedures it will follow in issuing further hazard communications.

The evolution of hazard communication, particularly the change in warning terminology, reflects a continual evaluation by USGS scientists and administrators as well as consideration of comments from officials of other governmental agencies, earth scientists, and social scientists.

The new hazard warning system will undoubtedly result in fewer formal hazard notices. However, by limiting hazards warnings to potentially imminent, short-term events, the need for public response will be emphasized. The effects of the recent hazard warning program upon public safety, hazards mitigation, and public awareness will be closely monitored in the coming years. And, if necessary, the program will be further modified.

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PERSPECTIVES AND DISCUSSION OF WHAT WAS LEARNED FROM THE CALIFORNIA EXPERIENCES

by

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I would like to address my remarks to the issue of communicating hazards and risk information in Southern California so that the USGS or any other agency can evaluate the possibilities and problems in communicating environmental hazard warnings.

I will address three issues in this brief set of remarks:

1. We have evidence that individuals frequently respond inappropriately to hazard information - particularly when such information concerns a high risk-low probability event such as an earthquake warning. Some of the explanation of this type of response seems to lie in some generalizations about human response to low-probability events that seem to be impermable to manipulation.

2. The political economy has a very significant role in determining response to hazards information. In general, actors in this economy do not have a sufficient time-horizon to propertly deal with long-term hazard warnings - and also do not have the economic motivation to respond in an optimum way. I would like to illustrate this point with the case study of the response of property developers to California legislation specifically aimed at affecting their location decisions.

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3. Human geography is important - Hawaii and Mt. St. Helens are not southern California. We must be congnizent of population trends in southern California that will interfere with the "best laid plans" for hazard communication.

1. Let's begin then with the first theme -

Individual response to low-probability events.

This line of research - particularly in the field of experimental psychology - has a long tradition. Several psychologists have suggested that individual routinely depart from the expected utility model when responding to low level events.

Recent work by William Schulze and Gary McClelland Schulze, McClelland and Hurd, 1986) indicates that the expected utility model (risk aversion) works when probabilities of occurrence are at 20 percent or higher. At lower probabilities of loss, the expected utility model progressively fails. At risk levels of 1% or less, they found that bids for insurance are bimodally distributed - that is that people tend to either over-estimate the loss and to over-insure or to completely ignore the loss and not insure at all.

This bimodality in the experimental study designed by Schulze and McClelland very much is in accord with interpretations previously given by psychologists studying the phenomenon of inaccurate interpretation of low-probability events.

The first explanation has been called "editing" and has been put forward by Kahneman and Tversky (1979) as well as Slovic and his colleagues (1977). In "editing", individuals DISMISS the risk of loss below a certain threshold - they behave as if there were no threat at all, and treat the low probability as if it were zero.

The second explanation is known as "anchoring and adjustment" and has been proposed by Slovic (1967), Tversky and Kahneman (1974) and Einhorn and Hogarth (1985). In this process, individuals begin by anchoring on the full value of the loss and then work downward to tke into account the fact that the loss will only occur some of the time. This results in an over-estimate of the loss most of the time.

A third explanation for miscalculation of low probability events has been termed the "gambler's fallacy". What this means is that individuals tend to attribute higher and higher probabilities to a low-probability event that has not yet occurred, and to reduce the probabilities of such an event if it has just recently occurred. The easiest translation of this notion is the statement that "lightning never strikes twice in the same place" - that once a place has had a lightning strike, it is relatively safe. In the 100-year flood zone, residents may feel that after such a flood they are safe for another 100 years. In the case of earthquakes, it is less clear how such a homily would accord with reality - aftershocks are certainly common, and yet there is some truth to the notion that there are recurrence intervals in which residents would be relatively more secure. I fear that we do not

know enough about these intervals, however, to make adequate predictions about "correct" or "incorrect" response.

With respect to response to earthquake hazard communication, we have conflicting evidence. The generalized information about Alquist-Priolo special studies zones or the general Hazard Warning issued for southern California has certainly resulted in what could be charitably called an "under-response", based on my studies of house values, the response of real estate agents, the response of homeowners, and the response of real estate appraisers. On the other hand, there is some evidence from studies conducted by David Brookshire and Bill Schulze and their colleagues (Thayer et al, 1986) that the Earthquake Hazards Watch (May 27, 1980) and the notice of potential Volcanic Hazard (May 26, 1982) resulted in an over-response. In this case, both the risk perceptions of property owners with respect to the risk of dying and potential for property damage and also in terms of the market value of homes were greatly increased by these announcements, and do not seem to have recovered after the withdrawal of the announcements in 1984. Similar over-response has also found by Bill Schulze and Gary McClelland in a recently-completed study of the response of residence to a hazardous waste site in the Montebello/Monterery Park area of Los Angeles.

These variations seem to be attributable at least in part to some generalizable responses to low-risk events - that is, at levels of risk below 1%, there is a bifurcation in individual responses where virtually none of the sample population responds at an appropriate level - either people completely ignore the hazard or else they respond at far too high a level to be accounted for by expected utility theory. Schulze, McClelland, Brookshire and I hope to explore this notion of bifurcation with respect to earthquake hazards further - and are working on a proposal to be submitted to NSF on this topic.

2. The second general topic I want to discuss with you is the over-whelming impact of politcal economic setting on response -

The example I would like to share with you is one where there is a clear directive to a select occupational group to respond to generalized information about the locations of earthquake hazard. The conclusion from this example is that when such regulations run counter to the time-frame or the economic interests of the target population, that population will do everything in its power to obey the law to its letter, but evade the full share of responsibility for responding to the hazard.

What I am reporting today is as yet unpublished but is scheduled to appear in the International Journal of Mass Emergencies and Disasters early in 1987.

As you well know, the Alquist-Priolo special studies zones act was added to the California Code in 1972, and has been amended and modified several times. According to this legislation, its purpose was to "prohibit the location of developments and structures for human occupancy across the trace of active faults" (ch. 7.5, sect. 2621.5). Cities and counties are charged to "require prior to the approval of a project, a geologic report defining and delineating any hazards of surface fault rupture" (Ch 7.5, sect. 2623). The legislation was aimed at developers of four or more units, and was intended to prevent further housing development directly astrict active, known sufrace fault traces.

Has this legislation been successful?

1. Developers have certainly not AVOIDED the special studies zones. As of July 1, 1984, 79 geologic reports had been filed (one for each new development) just in the area on the San Andreas fault in the San Bernardino North and Harrison Mountain quadrangles within San Bernardino (map 6.9).

130 or more had been filed for the Hayward fault zone in San Jose East and Calavaras Reservoir quadrangles (map 6.95).

60 had been filed for San Fernando (6.96) and about another 60 for Inglewood/Hollywood (6.97).

Development has not stopped - but that was not the purpose - it was to ensure that layouts adjusted to the fault traces. Has this happened?

2. Surveys of county and state officials and of developers themselves generally indicate NO IMPACT on the development process.

Indeed state officials provided some rather surprising information on the response of developers:

quote 1.

> There has been some "dreambusting" on the smaller sites, where re-design is not feasible. Larger developers shift buildings around, or may align roads with the fault.

quote 2.

> When planning a site to conform to a special studies zone study, developers will put STREETS OR UTILITIES ON OR NEAR THE FAULT, complying with the mandated setbacks for the houses, but in effect TRANSFERRING THE RISK AND POTENTIAL DAMAGE FROM THEMSELVES OR THE HOMEOWNER TO THE CITY AND THE TAXPAYERS AT LARGE.

Needless to say, this is not what was intended by the legislation, but it is a predictable response of developers who have a short time-frame of involvement with the land (2-3 years at the maximum is intended to plan, develop, take a profit, and move on), and have no economic interest in doing any more than complying with the law. The effect has actually been to shift MORE RISK to society at large.

Developers are not villains in this piece - they simply have no personal investment in any way (except legal liability for faulty construction imposed upon them by local or state law) in the longterm value of the area. Furthermore, their goals are usually primarily to make a profit from the development of the area - this is their business, just as it is the business of the USGS to attempt to find out about the seismic risk and to communicate that risk. Since the developers have time-horizons that are not congruent with the risk time-frame, and goals that are not congruent with longterm survival of the area, they cannot be expected to behave in a fashion that the USGS might see as rational given their own perspective. It is therefore up to government agencies - or those with more congruent time-references and values - to take action to protect residents or to ensure that proper building and land use practices are upheld.

Simple risk communication, or legislation that does not specifically forbid certain building/planning purposes is inadequate.

3. Finally, and most importantly, we must remember that human geography is important - and the target population is not the same everywhere. In the case of southern California, we must not forget the nature of the population that WE think <u>should</u> be responding - they are certainly not all middle class, native-born Americans with fairly long time-horizons for investment decisions. Who are these people?

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The six-county Southern California Association of Governments region is an appropriate area to consider. This region includes the six counties of Imperial, LA, Orange, Riverside, San Bernardino and Ventura. It had a 1980 population of about 11.6 million.

It houses peoples of extremes in terms of wealth and poverty - at the same time as it contains approximately 11,000 housing units valued at 1.25 million or more, it also contains at least 30,000 homeless individuals.

Migration to this region is taking place at a high rate - the population is growing at about 1.4% per year (an increase of almost a million people between 1980 and 1984). It is estimated that undocumented aliens arrive at the rate of 60,000 per year, and legal immigrants at the rate of 65,000 per year. The Southern California Association of Governments has drawn up population estimates for the year 2000 based on various immigrant schemes. Under assumptions of continued legal immigration levels at rates experienced during the 1970s and high end estimates of undocumented immigration during the same period, they figure that between 1980 and 2000,

1. the number of non-Hispanic whites will decrease in these counties by 1.4 million;
2. the number of Asians will increase by 731,000,
3. the number of Blacks will increase by 86,000
4. and the NUMBER OF HISPANICS WILL INCREASE BY ABOUT 3.2 million!!!!!

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The Asians are in large part Korean-speaking - and a very large proportion cannot speak English at all. The Spanish-speaking population come from several nations - including Mexico, El Salvador, Nicaragua, and the Phillippines - many cannot speak or read English.

Since most of the immigrants settle in the urban core areas of Los Angeles county and in Long Beach, Santa Ana and San Bernardino core areas, their increased numbers are housed in existing housing stock. What this means, is that there is an increasing concentration of immigrant population in the regions of the San Andreas fault (in San Bernardino) and in the Newport-Ingelwood fault zone in the southern sector of Los Angeles.

The state Department of Finance's population estimates indicate that numerous communities (long ago completely built up) have had population increases between 1980 and 1984 of 13-30%, with only a 5% or less increase in housing units. An example was the city of Lynwood (map) which had an increase in 80% in household size between 1980 and 1984 (from 2.86 persons to 3.62)

children, but rather to occupancy of the housing stock by larger families or by multiple households.

This means an increase not only in household SIZE, but also in the NUMBER OF HOUSEHOLDS PER UNIT (a phenomonen that we have not experienced in the United States since a brief period after WWII, and before that since the turn of the century in eastern U.S. cities).

Most Hispanic and Asian immigrants are seeking shelter at the lower end of the price spectrum. These people are no doubt living in over-crowded conditions, and in houses that by no means meet the California building code. In 1980, 57% of the recent immigrant Hispanics lived in overcrowded conditions (8% overall population).

In order to house people, much nonresidential space is being converted into residential units - much of this done illegally. Garages are the favored source of such new housing - indicated by the census as "housing units lacking some or all plumbing facilities"). In LA county alone, there was a 14% increase in such housing between 1970 and 1980.

Economists refer to the creation of new housing threw means other than new construction or legal additions to existing structures as the "shadow-market". This includes conversion of nonresidential space to residential use (e.g. conversions of garages or areas over factories to housing units). Obviously illegal conversions of this type meet no building codes - and indeed residential building codes were never intended to cover such units constructed for other than human habitation.

Of course, in some large cities including Los Angeles there has been legal conversion of non-residential structures for middle- and upper-income persons - examples are the creation of "loft apartments" in New York City occupied by artists and later by Yuppies. These conversions are usually done legally - with appropriate reconstruction where necessary. It is the illegal conversions that are of concern.

How much of such illegal conversion is taking place? How much housing for low income people is being provided by new construction? According to the Bureau of Census Components of Invnetory Change data, while 18% of all upper price rental units created between 1973 and 1980 were created from new construction. Only 7% of very low units were created in this way.

On the other hand, only 1 percent of upper-rental units were created by "other means" - including the shadow market, while 12% of very low price rental units were created through the shadow market. And note that this is the Census figure - which no doubt under-estimates the contrast.

William Baer, a professor of Urban and Regional planning at the University of Southern California, summarizes the problem thus:

> It is likely that the immigrant populace will solve its housing problem itself, albeit at a rudimentary level, without much specific governmental assistance in the near term, just as it does in the Third World.

Housing the immigrants in southern California is thus comparable to the problems of housing faced by in-migrants to burgeoning third world cities.

We must remember that the problem of providing shleter is an overwhelming one - in that context, how significant are thoughts of earthquake hazard mitigation, and the enforcement of earthquake-resistant building standards on a day-to-day basis ?

How can anyone reasonably expect a recent Korean or Salvadoran immigrant household with utterly no economic resources, and virtually no choice of housing - living in an illegally converted garage or with 4 other households in a pre-1930's single family dwelling to respond?

The priorities for such households are survival and the availability of some kind of dwelling - almost any kind of dwelling to live in - the notion of an earthquake over the next 20 years or more is completely and reasonably irrelevant. Even if it were not so, the individual (household) resources available to cope with this situation are inadequate to do anything at all - the property does not belong to them, they cannot do anything about insurance (insuring what?) or indeed about structural modifications.

If we are to face the situation in southern California realistically, we must be cognizant of these very real problems in the southern California housing market. Without this context, we can never come up with solutions to the problem of communicating hazard information and the even more serious issue of such information being translated into significant practical actions.

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FORECASTS AND PREDICTIONS*

by

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In recent volcanologic literature, the terms forecasts and predictions have generally been considered synonyms. Wadge and Guest (1981), however, in assessing the possibility that Mount Etna would erupt before May 1982, stated that "these are not predictions of specific events but general forecasts...based on the behavior of the volcano during the past seven years." Lockwood et al. (1976) used the term forecast in anticipating an eruption of Mauna Loa before the summer of 1978 on the basis of historical records. In contrast, Wood and Whitford-Stark (1982) used the terms forecast and prediction synonymously when they anticipated an eruption of Krafla before the end of May 1982 by projecting records from 1975 to the end of 1981; in terms defined here, this statement was a forecast. The fact that all three of these forecasts proved incorrect indicates the relative uncertainty of simply projecting past records and it suggests the desirability of distinguishing, whenever possible, such general statements from more specific predictions based on repeated measurements of changing phenomena on a short time scale.

Three types of written public statements about volcanic activity at Mount St. Helens are issued by scientists at the Cascades Volcano Observatory of the U.S. Geological Survey and at the Geophysics Program of the University of Washington:

A "factual statement" describes current conditions but does not anticipate future events; such statements are revised when warranted to keep the public and government informed of new developments.

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* Originally published in EOS, July 12, 1983, p. 452.

A "forecast" is a comparatively nonspecific statement about activity expected to occur weeks to decades in advance, issued commonly without data from repeated monitoring, and based on a projection of geologic, geophysical, or geochemical records. Another kind of forecast used monitoring data whose implications are not well understood. Forecasts aid particularly in land use planning and in the development of emergency response plans.

A "prediction" is a comparatively specific statement giving place, time, nature, and-ideally-size of an impending eruption. The likelihood of an eruption should also be stated, but such a statement is difficult to quantify.

Predictions are generally based on measurements of relatively short-term changes in longstanding patterns of activity. Predictions may evolve from forecasts and should be increasingly more specific as the eruption nears. At Mount St. Helens, a prediction is issued a few hours to a few weeks before an eruption-any time there is a relatively clear view of future activity as judged from current similarities with past precursory patterns and from interpretations of the active volcanic processes. Predictions reduce risk to life and property and provide a public test of scientific hypotheses about volcanic processes.

Stratigraphic studies led to a 1975 forecast of renewed activity at Mount St. Helens "perhaps before the end of this century" (Crandell et al., 1975). On the basis of seismic, geodetic, and geologic data, forecasts for an eruption and landslide(s) in the near future were issued in March and April 1980 before the catastrophic eruption on May 18, 1980. Forecasts in March and August 1981 anticipated dominantly nonexplosive behavior over the next months unless some reversal in geophysical or geochemical indicators occurred; these forecasts remain in effect.

Correct predictions were made of all 13 eruptions at Mount St. Helens from June 1980 to the end of 1982 on the basis of intergraded geophysical, geochemical, and geologic monitoring. Predictions several days to 3 weeks before eruptions were based largely on patterns and rates of ground

deformation of the crater floor and lava dome; predictions within about 3 days of eruptions depended chiefly on rates of cumulative seismic-energy release and increased numbers of shallow, volcanic earthquakes. Predictions in February and March 1983 were not as successful, owing in large part to poor weather, which curtailed most monitoring, and perhaps to subtle changes in behavior of the volcano.

Subdividing the broad category of anticipatory statements into relatively nonspecific forecasts and relatively specific predictions may have general applicability in volcanology. Volcanologists commonly are called upon to make statements about the future that are based either on projections of past geologic or geophysical records or on insufficient or poorly understood data. Such statements can profitably be distinguished from those based on adequate, up-to-date data on changing conditions at a volcano; such a distinction is scientifically honest and can help public authorities in their evaluation of the statement. These will always be gray areas; in such instances, forecasts rather than predictions should probably be made. In many cases, however, the distinctions are relatively well defined, and the procedure used at Mount St. Helens can be considered.

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MOUNT ST. HELENS EMERGENCY PROCEDURES

by

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U.S. Geological Survey
Vancouver, Washington

The U.S. Geological Survey (USGS), Washington Division of Emergency Management (WDEM) and the U.S. Forest Service (USGS) have agreed to utilize the following strategy that has as it basis three levels of statements concerning volcanic activity:

1) INFORMATION STATEMENT,
2) VOLCANO PREDICTION, and
3) VOLCANO ALERT.

INFORMATION STATEMENT

Weak events such as vigorous gas emissions (with or without minor ashfall outside the crater), small avalanches, rockfalls (with or without dustfall outside the crater), small mudflows, thunderstorms, and slash burning often attract media and public interest and inquiry. These events do not fit into any other information category. If they pose no significant threat or are short-lived, the USGS or the USGS will attempt to verify what has occurred and its extent. Due to frequent public and media inquiries that result from such events, the USGS will need to initiate informal telephone calls to selected cooperators so that they can respond to the public and media. Almost all of these events are very localized, so it is generally not necessary to make more than a few strategic phone calls to key cooperators. Normally these will include Cowlitz County, Skamania County, WDEM, MSHNVM Manager, and Randle District Ranger. The USGS also issues daily and monthly updates, which present general volcano information of non-emergency nature, are transmitted through the mail or via computer to all cooperating agencies, and need no action by the USGS.

VOLCANO PREDICTION

This category is used when the USGS can first confirm changes that may lead to eruptive activity. At such time, the USGS will issue a prediction of the time and if possible the nature of the expected activity. This information will be conveyed to the USGS before the prediction is issued to the media or to other agencies. The USGS will consult and advise the key cooperating agencies before any information releases are made to the news media. The USGS will need to make a number of informational telephone calls to constituents including WDEM, Cowlitz County, Skamania County, Randle Ranger District, MSHNVM, and the Corps of Engineers. The prediction can be updated to an UPDATED VOLCANO PREDICTION as the time of the expected eruptive activity nears.

VOLCANO ALERT

Information will be provided under this title when monitoring by the USGS suggests that eruptive activity will begin within a period of hours to 1-2 days and that, as a consequence, hazards are significantly elevated and pose a potential threat to life or property. The VOLCANO ALERT is usually preceded by one or more VOLCANO PREDICTIONS and may itself be updated as conditions warrant. The updated version will be termed an UPDATED VOLCANO ALERT. Because messages in this category are of emergency nature and because the NAWAS system is used by the USGS for wide dissemination, the message must be concise. The USGS should be advised by the USGS that a VOLCANO ALERT is about to be issued. The written statement should be given to the USGS, which then notifies other agencies before the alert is released to the media. A VOLCANO ALERT is ended by issuing an END OF VOLCANO ALERT.

When a VOLCANO ALERT is in effect, the USGS may request a continuing transport-winds forecast from the National Weather Service; request radar monitoring from the Portland National Weather Service; consider aircraft monitoring of the volcano, consider or effect a closure and evacuation of the hazard zone; and consider expanding the closure area.

RESPONSE TO A WARNING OF VOLCANIC HAZARDS

LONG VALLEY, CALIFORNIA*

by

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3240 Alpine Road

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INTRODUCTION

On May 26, 1982, the U.S. Geological Survey issued a "notice" of potential volcanic hazard for the eastern side of Sierra Nevada. The notice stemmed from growing concern by USGS scientists that an eruption might occur in the Long Valley caldera which was formed by a massive eruption about 700,000 years ago. A series of earthquake swarms and discovery of a resurgent dome in the caldera led to the concern which was heightened because the seismic activity was similar to that which occurred prior to the eruption of Mount St. Helens. Figure 1 is a map showing the location of Long Valley, the caldera, the resurgent dome, the recently active (500 years or so) Inyo-Mono crater chain, and the area of seismic activity.

* This paper is based on research supported by the National Science Foundation Grant #ECE-8302302. However, the opinions, conclusions, and recommendations are those of the authors and do not necessarily relect the views of the foundation. Copies of the final project report, Living with a Volcanic Threat: Response to Volcanic Hazards in Long Valley, California, are available from William Spangle and Associates, Inc.

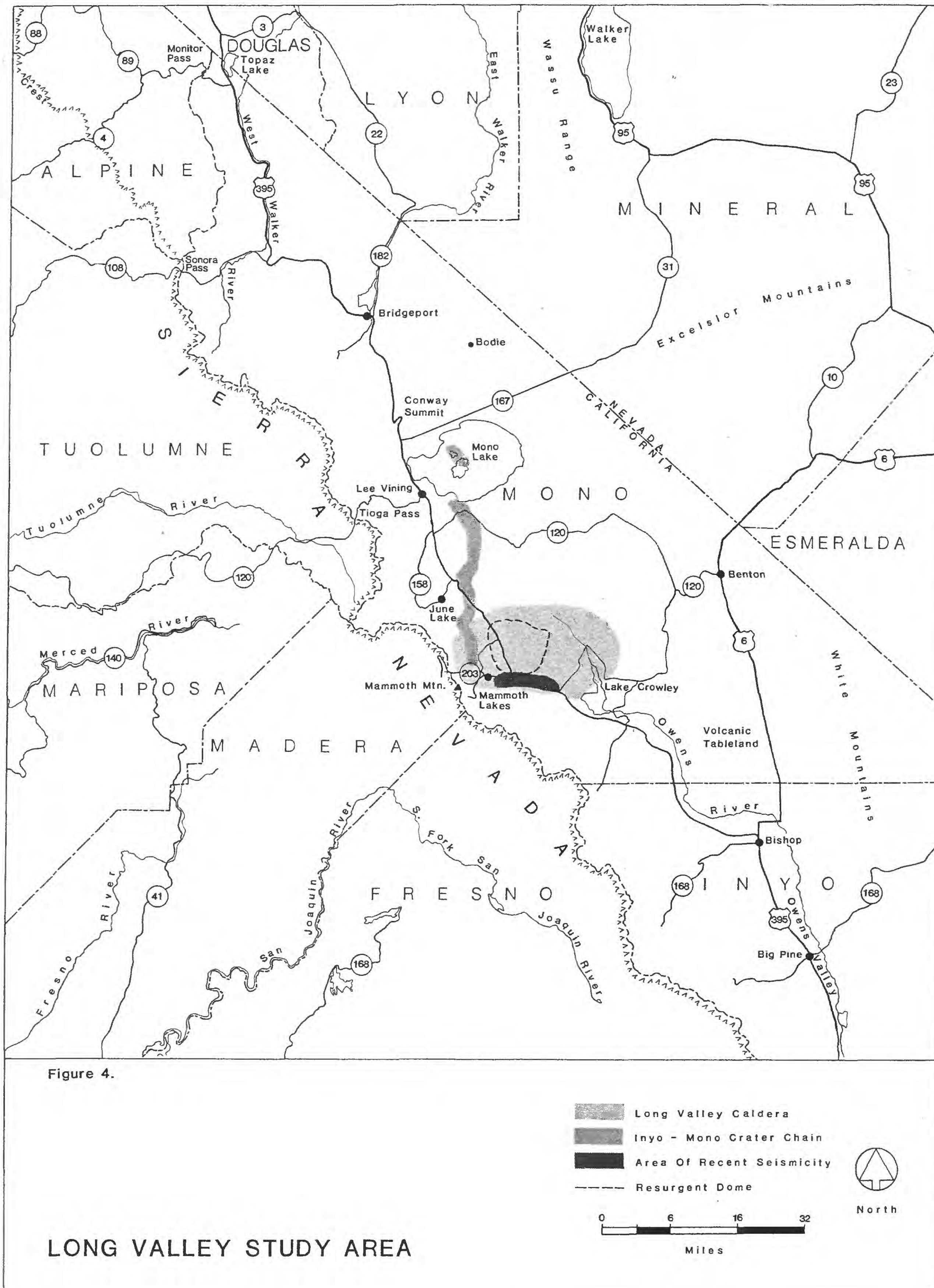

Figure 1. Long Valley study area

In 1982, a "notice" was the lowest level of a three-level (notice, watch and warning) geologic hazards warning system used by USGS to convey hazard information to state and local governments. The notice and an accompanying press release emphasized the high degree of scientific uncertainty regarding the potential for an eruption. In 1984, USGS changed to a one-level hazard notification system, effectively removing the official USGS recognition of the potential hazard in Long Valley.

The Town of Mammoth Lakes is in the center of the area of concern. The town's economy is based on recreation and tourism--particularly skiing in the winter. Figure 2 is an aerial photograph showing the town and the Mammoth Mountain Ski Area. The economy is highly sensitive to national economic ups and downs and the weather. Residents of Mammoth Lakes voted to incorporate in 1984, and the new city is explicitly attempting to become a year-round destination resort drawing visitors from all over the country to ski, hike, hunt and fish and generally enjoy the spectacular scenic and recreational resources of the area. Currently, however, most skiers come from Southern California. There is no regularly scheduled airline service to the area and only one all-weather highway, U.S. 395, links the area with the state's metropolitan regions. With the closure of Tioga Pass in Yosemite National Park in the winter, access to the region by car from Northern California becomes inconvenient.

Mammoth Lakes, with a permanent population of about 4,000, is the largest community in Mono County. All but about 5 percent of the land in Mono County is owned and controlled by the U.S. Forest Service, Bureau of Land Management and Los Angeles Department of Water and Power. Mammoth Lakes is basically an enclave entirely surrounded by the Inyo National Forest. Local residents are

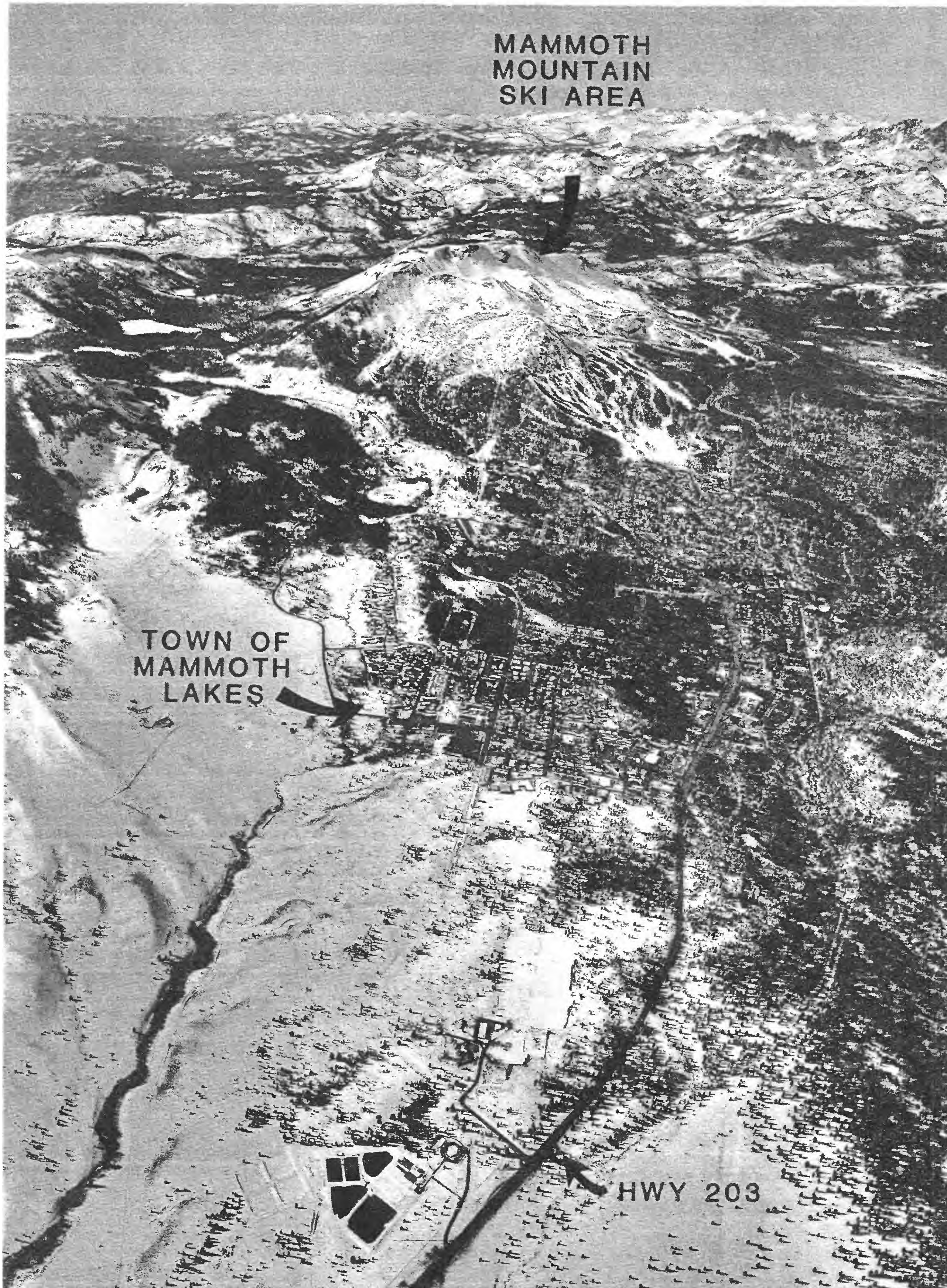

Figure 2. Town of Mammoth Lakes and Mammoth Mountain ski area

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sensitive to anything that can be perceived as an attempt by outsiders to usurp the little local control that exists.

NEGATIVE ASPECTS OF THE NOTICE

In this context, the USGS notice of potential volcanic hazard was viewed as a direct threat to the local economy. Our study identified four basically negative effects or aspects of the notice:

- Town officials and businessmen in Mammoth Lakes believe that the economy was adversely impacted by the notice.
- The method of release put public officials on the defensive.
- Press coverage exaggerated the hazard.
- The risk is still not well-defined.

Impact on Economy

Image is very important to a resort town which relies on favorable publicity to draw visitors. Recreation is a discretionary expense for most people and there are many options for spending recreational dollars. Mammoth Lakes is very sensitive to any kind of adverse publicity that might change people's mind about spending time and investing in real estate in the Town. The perceived economic impact of the notice is undoubtedly much greater than the actual impact. In Mammoth Lakes considerable overbuilding of both condominiums and commercial space had occurred prior to the notice. Figure 3 shows a new condominium development in Mammoth Lakes located on the western edge of the caldera. The notice also coincided with a national recession and a general downturn in recreational spending. Bad weather in late 1982-83 reduced visitor use of the area. In general, whatever impact the notice did

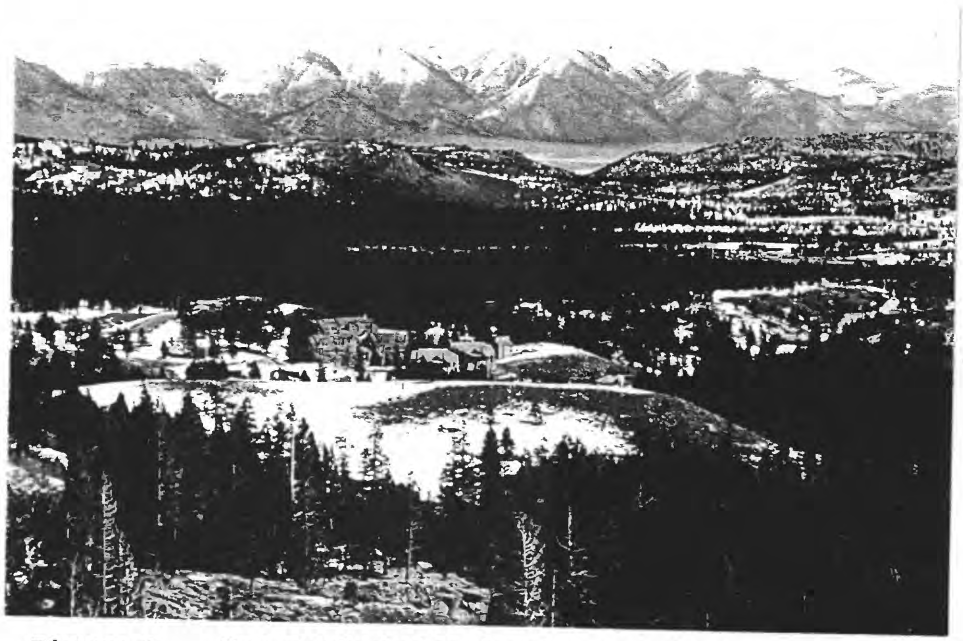


Figure 3. New condominium development in Mammoth Lakes located on the western rim of the caldera

have was short-lived. Visitor use of the area has remained high--up to 50,000 people on peak weekends--with variations explainable almost entirely by weather conditions.

Method of Noticing

Local public officials first learned about the USGS notice from an article in the Los Angeles Times. This occurred inadvertently and was clearly contrary to USGS noticing procedures. However, it did happen and this fact, coupled with the fact that the release of the notice came just before the important Memorial Day weekend, angered local officials. This anger set the tone for the local reaction to the notice which was characterized by animosity toward the USGS scientists.

Press Coverage

What was locally perceived as exaggerated press reports of the hazard worried some town officials more that the volcano. Figure 4 shows a collection of typical headlines appearing in newspapers around the state in the wake of the notice. Fear of bad publicity has been the driving force in the response of Mammoth Lakes businessmen and public officials. This is based on the fear of the economic impacts of bad publicity. For a resort town dependent on decisions of people with lots of other choices, fearing bad publicity more than the uncertain threat of eruption is not totally irrational.

Uncertain Risk

All major parameters of risk--timing, location, effects, probability--were described with high levels of uncertainty. USGS Circular 877, Potential

Figure 4. Montage of newspaper headlines

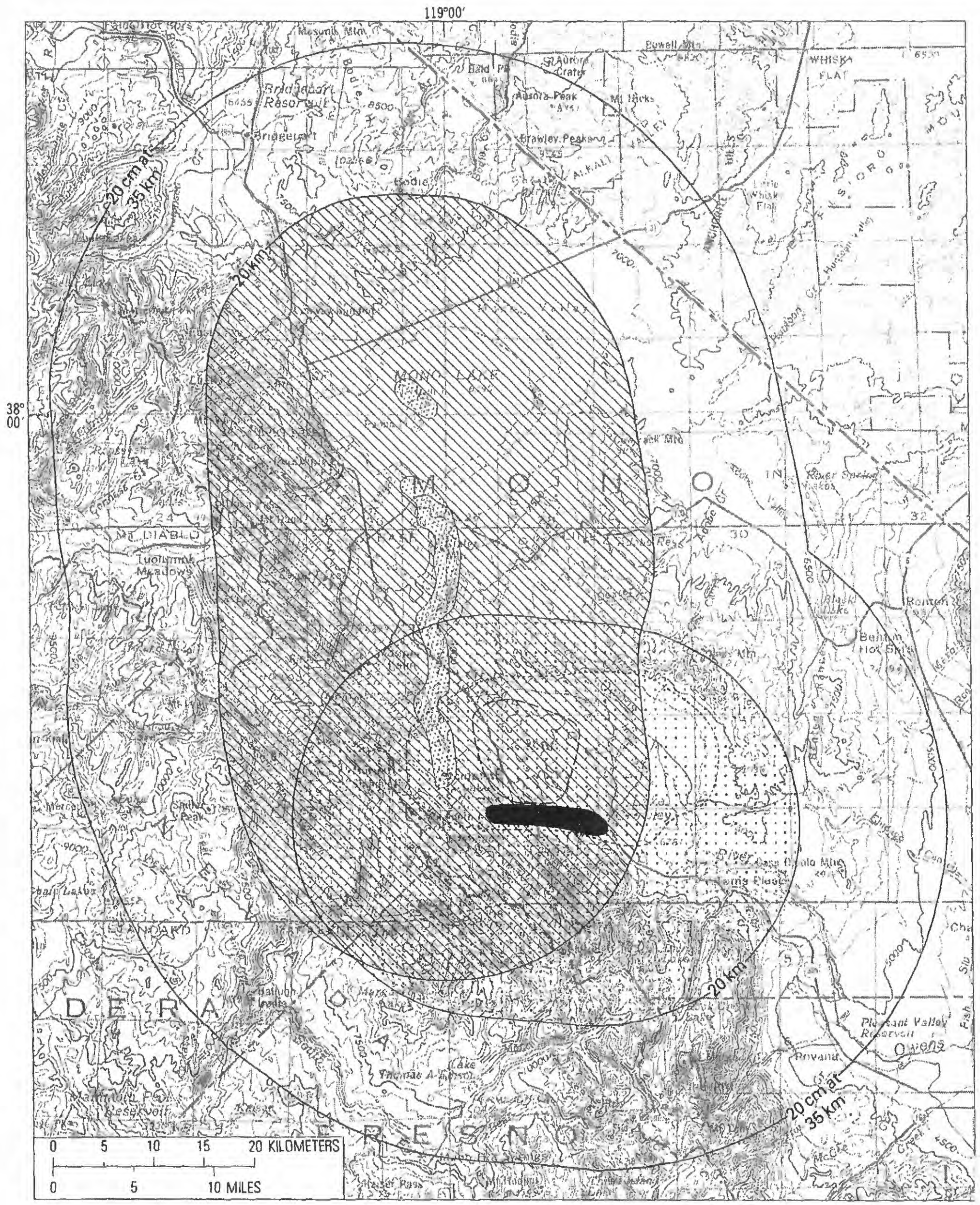
Hazards from Future Volcanic Eruptions in the LongValley-Mono Lake Area, East Central California and Siuthwest Nevada--A Preliminary Assessment, was released in preliminary form about two weeks after the notice. This circular is still the principal source of information evaluating the volcanic hazard in the area. It contains a map of volcanic hazard zones as shown in Figure 5. The generalized zones, based on distances from several possible source vents, does not meet the needs of local officials for specific guidance about what areas were most hazardous and what to do about it. Both the nature of the hazards and their probabilities of occurring at any given location within a hazard zone are very uncertain.

No matter how much explaining the scientists were willing to do about their reasons for the notice, the fact remained that the risk was inadequately defined for decisive public action. There was simply not enough known about the nature of the hazard to satisfy local public officials who looked for a more certain basis for action.

POSITIVE ASPECTS OF THE NOTICE

Although the negative aspects of the notice have drawn the most attention, they are not the whole story. Some of the positive aspects are:

- The volcanic notice got attention.
- The USGS Circular 877, CDMG scenarios and a workshop effectively communicated what was known by scientists about the risk.
- An evacuation route from Mammoth Lakes was constructed.
- A state emergency response plan, Plan Caldera, was prepared.
- Some land use plans were improved.



EXPLANATION

FEATURES OF THE LONG VALLEY CALDERA

- Outline of Long Valley caldera floor
- Outline of resurgent dome within the Long Valley caldera

AREAS INFERRED TO BE POSSIBLE SITES OF FUTURE ERUPTIONS

- Area of explosive silicic vents active during the last 10,000 years
- Potential vent area indicated by seismicity since 1980 and by proximity to the Long Valley ring-fracture system

HAZARD ZONES FROM ERUPTIONS OF THE SIZE AND CHARACTER OF THOSE THAT HAVE OCCURRED WITHIN THE LAST 10,000 YEARS IN THE LONG VALLEY-MONO LAKE AREA—The following hazard zones are drawn around relatively likely sites of future eruptions. During a future eruption, the appropriate hazard zone would be that part of the zone shown on the map that is circumferential to the erupting vent or vents

- Flowage-hazard zone around existing explosive vents—Areas adjacent to and within 20 km (12 mi) of volcanoes or vents subject to eruption of pyroclastic flows and clouds of hot ash, pyroclastic surges, lava flows, and domes, and, at some vents, mudflows and floods. Some parts of the hazard zone have not been affected by geologically recent events, but could be affected in the future
- Flowage-hazard zone around possible future vents inferred from seismicity—Areas adjacent to and within 20 km (12 mi) of possible future vents at or near the epicentral location of earthquake swarms since 1980 and along a part of the caldera ring-fracture system. Areas within this zone are subject to eruption of pyroclastic flows and clouds of hot ash, pyroclastic surges, lava flows, and domes, and, at some locations, mudflows and floods
- 20 cm at 35 km — Ashfall-hazard zone—Areas within 35 km (22 mi) of potentially erupting vents subject to ash accumulations of 20 cm (8 in) or more downwind from a vent. In general, thickness of ash accumulations gradually decreases with increasing distance from a vent

Figure 5. Potential Volcanic Hazard Zones (U.S.G.S., Circular 877, 1982)

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Attention

Public officials did not like the notice, but they were not able to completely ignore it. Although they focused on the notice, rather than the hazard, some spillover occurred and the hazard did begin to get some public attention. In 1983, when another earthquake swarm occurred, local officials and residents took the potential for volcanic activity seriously. Many people prepared to evacuate if necessary and daily briefings by local public officials and scientists were well-attended.

Information

The provision of information was very important. Each piece became a building block. The USGS Circular, scenarios prepared by the California Division of Mines and Geology for emergency response planning and a workshop bringing together scientists and local officials in Mammoth Lakes in August 1982 were particularly important. At the workshop some local officials began the process of deciding what needed to done to respond to the threat.

Evacuation Route

Figure 6 shows the sign on U.S. 395 for the Mammoth Scenic Loop. Allthough the road is called the Mammoth Scenic Loop, it was built and will function as an evacuation route from Mammoth Lakes to U.S. 395. The loop, which is constructed on the alignment of an unpaved Forest Service road, was approved after the 1983 earthquake swarm which lent reality to the notice. From conception to construction took nine months--a bureaucratic miracle.

Figure 6. Mammoth Scenic Loop sign at junction with US 395

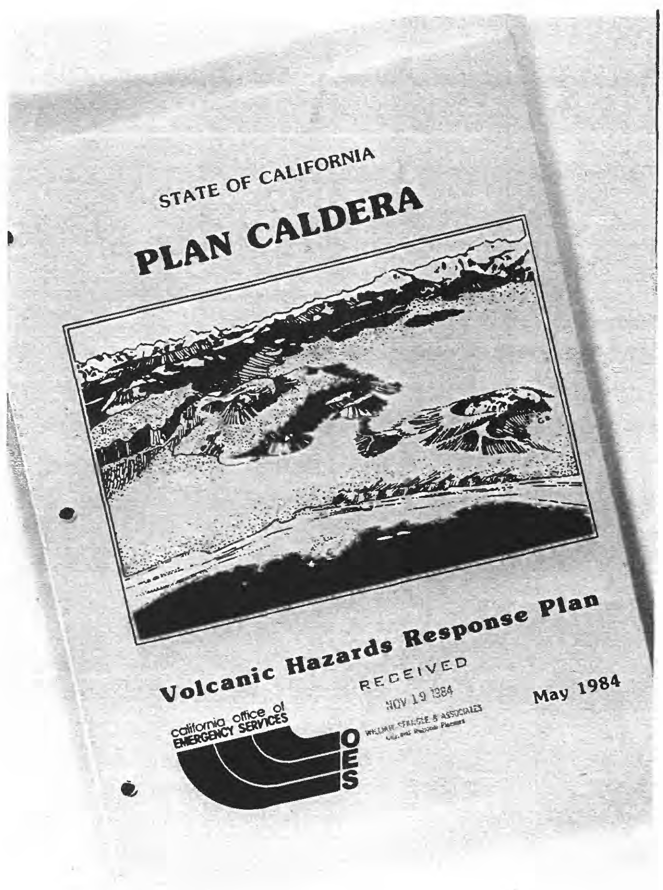

Figure 7. Plan Caldera (California Office of Emergency Services, 1984)

Plan Caldera

Plan Caldera is the state emergency response plan for the area (Figure 7). It represents a significant improvement in preparedness for the area. Local support for emergency preparedness has been stronger than for other forms of mitigation. Perhaps the most significant thing about this has been the forging of new intergovernmental relationships and building of a response structure centered on the Incident Command System.

Land Use Plans

Prior to the notice, most land use plans in the area addressed volcanic hazards as an interesting part of ancient history, in spite of the fact that eruptions occur in the region every 500 to 600 years. The exception was the Mono County Seismic Safety Element which recommmended establishing a Volcanic Hazard Management Zone, similar to an Alquist/Priolo Special Studies Zone, along the Inyo crater chain. This suggestion has not been implemented.

Three plans affecting local land use have been drafted since the notice was issued:

Management plan for the Inyo National Forest
Draft General Plan for Mammoth Lakes by Mono County
Draft General Plan for Mammoth Lakes by the newly incorporated city.

All three plans explicitly acknowledge the volcanic hazards of the region. No land is currently regulated on the basis of the hazard, but the two draft plans for Mammoth Lakes note that more intensive land uses should be located in those areas of the community which are least susceptible to seismic and volcanic damage. These two plans emphasize evacuation planning as the key

response to the threat of an eruption. All three plans indicate a level of awareness and willingness to respond that are greater than before the notice.

FINDINGS

On the whole, the issuance of the notice has led to actions which make the area better prepared to respond to a volcanic eruption than it was prior to the notice. Findings pertaining to the issuance of the notice, which are included in the final report of the study, include:

1. The decision to issue the warning was based on the best judgment of scientists who felt a sense of ugency based in part on the similarity between events at Long Valley and precursers of the Mount St. Helens eruption.

2. The notice itself was cautiously worded to convey a very high degree of uncertainty about all aspects of the situation--timing, character, location and probability of an eruption.

3. In spite of the careful wording, the notice was greeted with anxiety and sometimes exaggerated public reaction. When catastrophy is a potential it may be that even a very tenative warning is likely to produce overreaction.

4. The timing of the notice was based on the scientific judgment that an eruption might be imminent. The fact that it came just before the Memorial Day weekend was unfortunate, but reflects the uncertain state of scientific knowledge about volcanoes rather than thoughtlessness on the part of scientists.

5. The fact that, contrary to established procedures, local officials learned about the notice from an article in the Los Angeles Times created ongoing problems in the relationship between USGS and Mammoth Lakes officials and businessmen.

6. The notice itself contained very little supporting information and at least two weeks passed before substantial documentation of the hazard was available to local officials and the public. This gap created opportunities for confusion about what to do and imaginative reporting.

7. Some local reactions reflected a preference for placing blame rather than facing the potential hazard. This reaction is probably typical when clearly defined responses for dealing with a potential hazard are not presented or available.

8. Local officials and businessmen saw the notice as a direct threat to the local economy. In a sense, the notice was perceived as the threat, rather than the possibility of an eruption. The actual economic impact of the notice seems to have been shortlived and certainly no more important than the impact of a national recession, overbuilding of condominium and commercial space and the weather.

9. The 1984 change in the USGS warning system from a three- to a one-level system raises the question of what will happen in the future in a similar case. Presumably no hazard warning would have been issued in the Long Valley area if the new system had been in effect in 1982. There is a need to formally notify local officials of a potential hazard that is not yet imminent or does not yet require decisive local response.

RECOMMENDATIONS

The following recommendations with respect to issuance of the notice are included in the final report.

1. A formal, official means for USGS to convey to local officials information about low probability hazards is needed. The one-level warning system adopted by USGS in 1984 will not, by itself, serve this need, because the warning would probably not be issued in time to take constructive actions to prepare for the threat. Informal notice, in the form of scientific reports that do not receive public attention, are unlikely to be sufficient to stimulate action.

2. When a notice or warning is issued by USGS, it should be accompanied by supporting technical information. Local officials need clear information about the hazard in order to respond appropriately and effectively.

3. Scientific investigations of volcanism in the Long Valley region should be continued. The local response is predicated on the faith that the USGS will be able to provide warning of an eruption far enough in advance to allow the evacuation of the area.

federal register

TUESDAY, APRIL 12, 1977

PART III

DEPARTMENT OF THE INTERIOR

Geological Survey

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WARNING AND PREPAREDNESS FOR GEOLOGIC-RELATED HAZARDS

Proposed Procedures

ERRATA

Page 19292, column 3, delete parentheses in first paragraph 2"(a)" to read 2"a". Delete parentheses in first paragraph 2"(b)" to read 2"b".

Page 19293, column 1, paragraph 2(b) (1) (c) (ii), line 15, "like" should read "likely".

Page 19295, column 1, paragraph 3e(2), line 3, "scientic" should read "scientific".

Page 19295, column 1, paragraph 3f(2), line 5, "assistane" should read "assistance".

Page 19296, column 1, 4th bibliographic reference, map scale "1:500,000" should be "1:5,000,000".

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DEPARTMENT OF THE INTERIOR

Geological Survey

WARNING AND PREPAREDNESS FOR GEOLOGIC-RELATED HAZARDS

Proposed Procedures

GEOLOGICAL SURVEY AUTHORITY FOR ISSUING WARNINGS OF GEOLOGIC-RELATED HAZARDS

Under the broad responsibilities assigned to the Geological Survey by its Organic Act of 1879 for the "examination of the geological structure" of the United States, the Survey has for many decades undertaken studies of earthquakes, volcanoes, and other natural hazards. In recent years, as knowledge of these and related geologic phenomena has increased, the Survey has also developed capabilities for predicting some potentially hazardous events in some areas, and has the implicit obligation to inform civil authorities and the public of such predictions.

On May 22, 1974, Congress enacted Public Law 93-288 (88 Stat. 143), which is known as the "Disaster Relief Act of 1974" (hereinafter, "the Act") "to provide an orderly and continuing means of assistance by the Federal Government to State and local governments in carrying out their responsibilities to alleviate the suffering and damage which result from * * * disasters * * *" Section 202(a) of the Act states that "The President shall insure that all appropriate Federal agencies are prepared to issue warnings of disasters to State and local officials." In addition, Section 202(b) states that "The President shall direct appropriate Federal agencies to provide technical assistance to State and local governments to insure that timely and effective disaster warning is provided." The disasters included are "hurricane, tornado, storm, flood, high water, wind-driven water, tidal wave, tsunami, earthquake, volcanic eruption, landslide, mudslide, snowstorm, drought, fire, explosion, or other catastrophe * * *" The Act further states in Section 308 that "The Federal Government shall not be liable for any claim based upon the exercise or performance of or the failure to exercise or perform a discretionary function or duty on the part of a Federal agency or an employee of the Federal Government in carrying out the provisions of this Act."

Executive Order 11795 entitled, "Delegating Disaster Relief Functions Pursuant to the Disaster Relief Act of 1974" (30 FR 25939, July 11, 1974) delegates to the Department of Housing and Urban Development the authority to exercise certain of the powers and authorities of the President with respect to Federal disaster assistance. Pursuant to the authority conferred by Section 1 of E.O. 11795, the U.S. Department of Housing and Urban Development conferred limited responsibility under the Act to the Secretary of the Interior (40 FR 52927, November 13, 1975). This authority was, in turn, redelegated by the Secretary of the Interior (Departmental Manual, 220 DM 8, Release 1883, May 3, 1976), "subject to the general policy guidance and coordination of the Assistant Secretary—Energy and Minerals," to the Director, Geological Survey, who is "empowered to exercise the authority, functions, and powers granted by Section 202 of the Disaster Relief Act of 1974 with respect to disaster warnings for an earthquake, volcanic eruption, landslide, mudslide, or other geological castastrophe."

PURPOSE OF STATEMENT

The purpose of this statement is to describe the Geological Survey's capabilities and limitations for advance recognition and warning of various kinds of geologic-related hazards and the procedures proposed to carry out the responsibilities delegated under the Act, and to elicit public comment on the proposed procedures. Application of these capabilities and procedures is largely limited to areas where Geological Survey research and field studies are ongoing. This statement should not be interpreted as indicating the existence of a nationwide operational capability to issue notifications, watches, and warnings of hazardous conditions wherever and whenever they may exist.

Comments regarding these procedures and policies are invited. Comments received by June 30, 1977 will be taken into account in subsequent revisions as appropriate. Comments should be addressed to:

Director, U.S. Geological Survey, National Center, 12201 Sunrise Valley Drive, Reston, Virginia 22092.

V. E. MCKELVEY,
Director,
U.S. Geological Survey.

1. DEFINITIONS

For the purpose of this statement, a geologic hazard is a geological condition, process, or potential event that poses a threat to the health, safety, or welfare of a group of citizens or to the functions or economy of a community or larger governmental entity. A geological disaster or catastrophe is the occurrence of a severe hazardous event. In the context of this statement, the terms "Notice of Potential Hazard," "Hazard Watch," and "Hazard Warning" refer to the issuance of technical information to officials responsible for public safety and to the news media; recommendations or orders to take defensive actions are issued by officials of State and local governments, where the police and public safety authority rests in our governmental system. These terms are defined as follows:

Notice of potential hazard.—The communication of information on the location and possible magnitude or geologic effects of a potentially hazardous geologic event, process, or condition.

Hazard watch.—The communication of information, as it develops from a monitoring program or from observed precursor phenomena, that a potentially catastrophic event of generally predictable magnitude may be imminent in a general area or region and within an indefinite time period (possibly months or years).

Hazard warning.—The communication of information (prediction) as to the time (possibly within days or hours), location, and magnitude of a potentially disastrous geologic event or process.

2. CAPABILITIES TO PREDICT HAZARDOUS EVENTS

(a) Geologic processes and conditions that could result in harm to people and property include earthquakes, volcanic eruptions, landslides, mudflows, subsidence, faulting and fissuring of the ground surface, and glacier-related phenomena such as release of glacier-dammed lakes and rapid ice surges or retreats. Under certain conditions, these events may occur suddenly and affect large numbers of people and property over a wide area; in other instances, however, the processes involved occur slowly or affect very limited areas so that few if any people are endangered.

(b) The present capability of scientists to predict hazardous events varies greatly as to the type of event and as to knowledge of its time, place, and magnitude of effects.

(1) Earthquakes.

(a) *Geographic distribution.* Much of the United States is subject to some degree of earthquake hazard. The western states of Alaska, California, Hawaii, Idaho, Montana, Nevada, New Mexico, Utah, Washington, and Wyoming are particularly susceptible, but major earthquakes have also struck the eastern and central parts of the United States (Hadley and Devine, 1974), particularly Arkansas, Georgia, Kentucky, Indiana, Illinois, Massachusetts, Mississippi, Missouri, New York, North Carolina, South Carolina, and Tennessee.

(b) *Effects.* (i) Earthquake-generated ground shaking, in many instances, causes the most widespread earthquake damage, principally through failure of buildings. Earthquakes also give rise to various geologic processes that may cause injuries and property damage, including surface faulting, landsliding and associated ground failures, generation of large waves in water bodies, and regional vertical movements (downwarping and upwarping).

(ii) The surface effects of earthquakes have been evaluated on the basis of geologic and seismologic studies in parts of Alaska (Page, et al., 1972),[1] California (Borcherdt, 1975), Idaho (Witkind, 1972), Nevada (Bingler, 1974), Utah (U.S. Geol. Survey, 1976), Washington (Pitt, 1972; and U.S. Geol. Survey, 1975), and the eastern United States (Dutton, 1889). The results of regional studies underway in these and other states will be published as they are completed.

(c) *Prediction capability.* (i) Predictions of the precise location, time, and magnitude of specific earthquakes cannot generally be made now. Certain precursors, such as ground tilting and changes in water levels in wells, the magnetic field, and seismic wave velocity

[1] References here and elsewhere in this statement are representative rather than exhaustive of descriptions of the phenomena involved.

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characteristics in rock, may be useful in predicting earthquakes. Experimental instrumental arrays have been installed in a few research areas, such as near Hollister, California, to evaluate these precursors and to help develop an earthquake prediction capability.

(ii) Locations of faults that may be the source of future damaging earthquakes have been determined in some regions of the country, particularly in parts of Alaska, California, Nevada, Idaho, Montana, and Utah. Geologic and seimologic studies in these regions, however, are not adequate to assure that all such faults have been delineated. Geologic studies of recurrence intervals of earthquakes have been made on only a few faults, principally in California. Some of these studies provide a basis for estimating the magnitudes of earthquakes that are like to be generated by movement along a particular fault. Broad-scale estimates of the susceptibility of the various regions of the U.S. to earthquake hazards have been made and are published in earthquake hazard maps and reports (Algermissen and Perkins, 1976) which will be updated as new information is acquired. These maps, and the more detailed studies on which they are based, identify those regions known to be highly susceptible to earthquakes, even though they may not identify all faults along which movement may take place.

(iii) Regional earthquake hazard assessments are also underway in parts of New Mexico, New York, South Carolina, and Washington, and in the lower Mississippi Valley.

(2) Volcanic eruptions. (a) *Geographic distribution.* At the present time, volcanoes are active in Alaska and Hawaii; volcanoes in California, Oregon, and Washington are dormant, but have erupted within the last 150 years. The likelihood of future eruptions damaging to man is greatest in the vicinity of volcanoes in these States. Geologic evidence indicates that volcanic activity could occur in other areas, such as Arizona, Nevada, New Mexico, Wyoming, and Idaho (Mullineaux, 1976), where eruptions have occurred as recently as 350 years ago; there is no current evidence, however, to suggest that volcanic activity may occur in these areas in the near future. Broad estimates have been made of regional susceptibility and types of volcanic hazards in the conterminous U.S. and Hawaii and are being published (Crandell, 1976; Crandell and Mullineaux, 1975; Mullineaux, 1976; and Powers, 1948); these will be updated as new information is acquired.

(b) *Effects.* (i) Volcanic eruptions produce a wide variety of primary and secondary hazards to life and property, stemming mainly from hot avalanches, mudflows, ash falls, lava flows, volcanic gases, hot particle and gas clouds, and floods.

(ii) Studies of the products of past volcanic activity in the Cascade Range, including lava flows, ash falls, mudflows, and hot avalanches, have been completed on the volcanoes of Mt. Baker (Hyde and Crandell, 1975), Lassen Peak (Crandell, et al, 1974), Mt. Rainier (Crandell, 1973), and Mt. St. Helens (Crandell and Mullineaux, 1976; Crandell, et al, 1975); similar studies are planned or in progress for other major volcanoes in the Cascade Range, such as Mt. Hood and Mt. Shasta, and for Augustine Volcano in Alaska.

(iii) Detailed studies at Kilauea and Mauna Loa volcanoes in Hawaii show that the products of most historic and prehistoric eruptions are lava flows; subordinate products include ash falls and hot particle and gas clouds. Eruptions issue from fissures and vents, both in the summit areas and along rift zones on the flanks of the volcanoes. Assessments of hazard-susceptible areas have been made for the islands of Hawaii (Mullineaux and Peterson, 1974) and Oahu (Crandell, 1975).

(c) *Prediction capability.* (i) Kilauea and Mauna Loa volcanoes are monitored by an array of instruments and by systematic measurements which permit assessing the likelihood of impending activity (Waesche and Peck, 1966; Kinoshita, et al, 1974). Physical precursors often permit predictions to be made within time frames of weeks or days, and sometimes highly specific signals precede eruptions by one to several hours (Swanson, et al, 1971; Fiske and Kinoshita, 1969).

(ii) A study of the historic cycles of activity on Mauna Loa indicates the possibility of long term prediction of the general locality and the general time frame (months or years) of the next eruptive event (Lockwood, et al, 1976).

(iii) Predictive capability has not been achieved for volcanoes in the Cascade Range or Alaska, although it is possible that the methods developed in Hawaii might be modified and adapted to be useful in these regions. Detailed estimates of hazard-susceptible areas surrounding some of these and other volcanoes have been made as indicated in section (b) ii and iii. Other studies are underway and will be published as completed.

(3) Landslides (including mudflows and mudslides). (a) *Geographic distribution.* Landslides and related hazards occur in every state in the United States. They occur largely in areas of steep terrain, but also along river, valley, and beach bluffs in otherwise flat country. The general distribution of landslide incidence and susceptibility has been assessed for the conterminous U.S. and published as a national overview map at 1:7,500,000-scale (Radbruch-Hall, et al., 1976). This map will be updated as new information becomes available.

(b) *Effects* (i) Many landslides move slowly and commonly are not a great hazard to people. However, they are estimated to cause more than $1 billion damage to property annually.

(ii) Mud and debris flows generated by intense rainfall or rapid snowmelt, large landslides that move abruptly, rockfalls, and landslides into large reservoirs may be hazardous to people and property. Similarly, landslides that dam streams inundate property upstream and can produce severe and dangerous flooding downstream if the barrier is breached suddenly.

(c) *Prediction capability.* (i) A capability to predict the time, place, and magnitude of landslides is possible, but is limited to very small individual landslide areas in which detailed geologic and engineering studies have been conducted, including test borings and laboratory analysis. Consequently, general information on areas potentially susceptible to slope failures will be communicated as a Notice of Potential Hazard. Detection of precursors may allow prediction and warning of landslides in areas of special topical studies, as in the Santa Monica Mountains of southern California (Campbell, 1975).

(ii) In addition to the national overview map of landslide incidence and susceptibility, maps that show landslide deposits at a scale of 1:500,000 have been prepared for the State of Colorado (e.g., Colton, et al., 1976). Larger-scale (1:125,000, 1:62,500, and 1:24,000), more detailed assessments of landslide susceptibility have been made of a number of small areas and a few regions in various parts of the U.S. (Briggs, 1974; Nilsen, 1973; and Simpson, 1976). Such maps are published as they are completed.

(iii) Landslide hazards are evaluated incidental to regional mapping programs or as a part of general geologic hazards studies in selected areas. The Geological Survey is also attempting to delineate and reduce landslide hazards on a nationwide basis.

(4) Glacier-related phenomena. (a) *Geographic distribution.* Large glaciers that are most likely to be hazardous to people and property occur in Alaska and Washington. Smaller glaciers also occur in California, Colorado, Idaho, Montana, Oregon, and Wyoming. Although no regional or national overview of all glacier-related hazards has been made, the distribution of potentially hazardous surging glaciers has been analyzed (Post, 1969), and the areas susceptible to outburst flood hazards have been determined in Alaska (Post and Mayo, 1971) and the Pacific Northwest (Richardson, 1968).

(b) *Effects.* (i) The rate of advance and retreat of glaciers is generally so slow that there is little cause for concern except in the case of glacier surges and where glacier changes result in floods or icebergs. Rapidly advancing glaciers, and especially surging glaciers, may advance over transportation corridors or other works of man or may dam valleys, causing the formation of glacier-dammed lakes. Such lakes, which may also be formed by glacier retreat, may burst out periodically or sporadically, resulting in downstream flooding. Downstream flooding can also be caused by the periodic outbreak of water stored within or under glaciers.

(ii) Icebergs, which are formed by calving from the front of glaciers that end in the sea or large lakes, may be discharged at greatly increased rates when

a glacier starts to retreat or advance (Post, 1975). Retreating ice may also release ice-dammed lakes, resulting in potential flooding of downstream areas.

(iii) The effects of glacier-related hazards have been monitored in only a few isolated instances, such as flooding from glacial Lake George (Post and Mayo, 1971) and glacier outburst floods in Washington (Richardson, 1968).

(c) *Prediction capability.* (i) Long-term prediction of glacier advance and retreat is not possible; however, short-term predictions may be possible with adequate field measurements on the glacier itself. The outbursts of some glacier-dammed lakes can be predicted through the monitoring of lake levels if an adequate history of previous outbursts is available, or if the rate of inflows and the configuration of the glacier bed are known. The prediction of outbursts of water, from within a glacier may be possible, in some cases, given a history of past events and the continuous monitoring of the ice flow pattern of the glacier. Prediction of the size and rate of ice calving from glaciers fronting in the sea or lakes may be possible using photography.

(ii) Areas of susceptibility to glacier-related hazards, as indicated under (a), have been observed, using aircraft and satellite imagery, but available resources do not permit a systematic monitoring program.

(5) Subsidence. (a) *Causes and geographic distribution.* Subsidence is the slow lowering or sudden collapse of the land surface and is common in many areas of the United States. Subsidence, both man-induced and natural, may result from:

Slow compaction of sediments from withdrawal of (1) ground water, as in parts of Arizona, California, and Texas, (2) hydrocarbons, as in parts of Californi.. and Texas, and (3) potentially, fluids for geothermal production in California and the Gulf Coast;

Slow to rapid collapse of the roof above mines because of inadequate support as in many coal mine areas of Colorado, North Dakota, Pennsylvania, and Washington, or where solution mining creates excessively large underground openings as in Kansas, Michigan, and Texas;

Slow to rapid compaction of certain types of materials in which the soil structure collapses when water is added, as in the San Joaquin Valley, California, or when water is expelled as the result of liquefaction during earthquakes,

Slow to rapid collapse over caves, caverns, and solution openings in limestone (karst) areas, as in many southern states and elsewhere; and

Rapid earthquake movement or earth flexuring, principally in Alaska, California, and Hawaii.

The results of topical research projects are released in maps and reports as they are completed.

(b) *Effects.* i. Subsidence normally is a slow process and is not hazardous to life. However, under certain circumstances, where the ground above mines and caverns collapses suddenly, where subsided ground in coastal areas may be inundated by storm waves, and where localized subsidence is severe and affects critical structures such as dams, damage to property, and indirectly to life, may be extensive (Castle and Yerkes, 1976).

ii. Earth fissures (large open cracks) can develop from fluid withdrawal or collapse over cavities. These fissures can damage structures and render property virtually useless for most purposes.

(c) *Prediction capability.* i. Specific subsidence events caused by ground-water withdrawal can be anticipated in certain areas, such as in parts of Alabama (Newton, 1976), California (Lofgren, 1975; and Poland, 1971), and Texas (Gabrysch, 1969), where studies are underway. Once subsidence involving slow compaction of sediments is initiated, the rate can be measured, and in some cases, the ultimate amount can be estimated.

ii. There is no nationwide subsidence program; however, efforts are underway to identify or delineate areas of existing or potential subsidence at small scale (Poland and Davis, 1969; and Davies, et al., 1976). Such hazards also are mapped incidental to general research projects completed or underway in several areas of the country.

3. Provisional Procedures To Report Hazardous Conditions

When and where information is obtained that suggests the development of a hazardous condition, the U.S. Geological Survey will attempt to authenticate it, and communicate such information to appropriate State, local and Federal authorities and to the public. The U.S. Geological Survey recognizes that providing earth-science information, in accordance with its expertise, is only the first of the inputs needed by State and local governments and the public in mitigating the effects of geologic hazards. The actual adoption of the most effective mitigation measures by local authorities will result from a cooperative effort by agencies at all governmental levels and by non-governmental organizations and the public. Decisions for adoption of such mitigation measures should be based upon a broad range of earth-science, engineering, and socio-economic information.

a. *Hazard Identification.*—Information acquired by Geological Survey personnel that indicates a region, area, or locality may be susceptible to geologic or hydrologic conditions or processes that could pose a significant potential hazard to life or property will be conveyed promptly to the Director of the Gological Survey with all supporting evidence and documentation.

b. *Hazard Evaluation.* (1) The Director will submit information pertaining to potentially hazardous conditions or events to carefully selected scientific evaluation panels for review of the scientific basis for the hazard identification. Such panels may be established formally, such as the Survey's Earthquake Prediction Council, which relies on scientific expertise pertaining to a specific type of hazard; or informally, with scientist members changing according to their expertise with different types or areas of potential hazards. Upon review of the evidence, the evaluation panel(s) will transmit the findings and recommendations to the Director. The panel may find that:

(a) A hazard to life or property is unlikely or insufficiently defined to justify a Notice of Potential Hazard without additional information;

(b) A potential hazard to life and/or property exists;

(c) The potential hazard exists and that monitoring by the Geological Survey could lead to a better definition of location or magnitude, extent, or timing of the hazard; or

(d) The hazard conditions are sufficiently well defined as to location, magnitude, and time to warrant the issuance of a Hazard Watch or a Hazard Warning.

(2) Similarly, the Director will also undertake to have reviewed and evaluated identifications or predictions of potentially hazardous events made by scientists outside the Geological Survey, as deemed appropriate or upon the request of the head of an appropriate State or Federal agency. The requestor will be notified promptly of the findings of the evaluation panel and, if appropriate, a Notice of Potential Hazard, a Hazard Watch, or a Hazard Warning will be issued.

c. *Notice of Potential Hazard.* (1) Where the Director has authenticated identification of an area as susceptible to a potentially hazardous condition, but available evidence is insufficient to suggest that a hazardous event is imminent or evidence has not been developed to determine the time of occurrence, the information will be prepared for normal publication.

(2) The Director or his designee will transmit such information, as soon as possible, as a Notice of Potential Hazard to appropriate Federal, State, and local officials responsible for the public safety and welfare and to the public by a press release. The reports and maps cited earlier that show the distribution of earthquake, volcanic, landslide, and subsidence hazards are examples of identifications of potentially hazardous conditions that will form the basis for notices of potential hazards.

(3) Notices of Potential Hazard will be accompanied by a description of the geologic and hydrologic conditions that exist, the factors that suggest that such conditions constitute a potential hazard, and the location or area they may affect. In most instances, it will not be possible to estimate the severity of the hazard or the time it might occur. Information such as possible earthquake recurrence intervals will be given, however, if justified by available information.

(4) Where available evidence suggests that a hazardous event could occur and that precursory phenomena exists that will better define the time, location, and magnitude of the event, the geologic conditions or processes likely to trigger a hazardous event will be monitored by the U.S. Geological Survey within the limits of available funds and manpower

d. *Hazard Watch.* (1) If existing or new information indicates that a region, area, locality, or geologic condition is undergoing change that may be interpreted as a precursor to a potentially hazardous event within an unspecified period of time (possibly months or years), such information will be evaluated and, if authenticated, the Director will assure that such information is transmitted promptly to civil authorities and the public as a Hazards Watch.

(2) Federal, State, and local officials responsible for public safety will be notified in advance of the intent to issue a Hazard Watch to enable them to invoke emergency preparedness plans for an orderly public response.

(3) Hazard Watches will be accompanied, to the extent possible, by a definition of the parameters of the expected event, including, in addition to the place, magnitude, and general time, the possible geologic or hydrologic effects and the uncertainties associated with each.

e. *Hazard Warning.* (1) When developing information from precursory phenomena, which have been monitored through an experimental or operational hazard assessment program, appears to signal a potentially hazardous event within a specific period of time(possibly days or hours), the information will be conveyed promptly to the Director for evaluation and consideration as a hazard prediction.

(2) The Director or his designee will determine whether or not the prediction has a sound scientic basis and is authenticated by a comprehensive evaluation. If a prediction is issued as a result of this review and authentication process, any uncertainties that may exist will be evaluated and stated.

(3) The Director, upon authentication of a prediction of an event of possible catastrophic proportions, will assure that such information is promptly transmitted as a Hazard Warning, first to Federal, State, and local officials responsible for public safety, to enable them to invoke emergency preparedness plans for an orderly public response, and then to the news media.

(4) Hazard Warnings will be accompanied, to the extent possible, by a definition of the parameters of the expected event including, in addition to the time, place, and magnitude, the possible geologic or hydrologic effects, and the uncertainties associated with each.

f. *Communication of Notices of Potential Hazard, Hazard Watches, and Hazard Warnings.* (1) Information leading to a Notice of Potential Hazard or a Hazard Watch will generally be obtained well in advance of an event and can be transmitted directly to concerned officials by letters and to the public by press releases to the news media.

(2) Where potentially hazardous conditions are monitored, local, State, and Federal authorities will be informed periodically of the results of such investigations and technical assistane, to the extent possible, will be extended as requested by these officials to assist in developing possible mitigation measures.

(3) At the present time, a capability to predict a geologic event of possible catastrophic proportions within days or hours does not exist except in rare cases. In such cases, where the information becomes available that suggests a potentially disastrous event may be imminent, public officials will be notified by telephone and such information will be transmitted directly to the public as a Hazard Warning. Public and existing Federal communication facilities, such as the Department of Commerce's Weather Radio System and the Department of Defense's National Warning System will be utilized whenever possible and appropriate.

(4) The Geological Survey will also communicate to responsible Federal Agencies and State and local governments, as soon as practicable, all available new knowledge as to geologic conditions or processes that may affect or alter public response to Notices of Potential Hazard, monitoring programs, Hazard Watches, or Hazard Warnings. This may result in the cancellation of the notice, watch, or warning, or a change in the hazard classification to better reflect an increased degree of uncertainty as to the time of occurrence of the event or a lessened sense of urgency.

(5) Notices of Potential Hazard, Hazard Watches, and Hazard Warnings to governmental agencies will also include:

(a) A statement of the authority of the U.S. Geological Survey for issuing the notice, watch, or warning:

(b) Copies of scientific papers or authentication reports that form the basis of the notice, watch, or warning;

(c) An offer to consult with any reviewers that the Governor or Governors of affected States may wish to appoint;

(d) An offer to provide appropriate technical assistance within areas of expertise in the Geological Survey in evaluating possible geologic hazards, as they may affect people and property;

(e) A statement of what additional steps, if any, the U.S. Geological Survey proposes to take to better define the degree or area of hazard; and

(f) A list of all parties to whom the notice, watch, or warning is being transmitted.

g. *Technical assistance.* (1) As used in this statement, technical assistance pertains to:

(a) advice of available Geological Survey personnel on subjects within their area of expertise—geology, hydrology, chemistry, and, to a limited extent, soil engineering, structural engineering, and land-use planning; and

(b) Deployment of available instruments to better define hazardous conditions, processes, or events.

(2) Technical assistance should not be interpreted to refer to:

(a) Funding for public works or hazard mitigation projects for which funds have not been allocated to the Geological Survey:

(b) Assignment of personnel or equipment to assess hazardous conditions outside geographical or topical areas of ongoing research or mapping programs except for unusual or compelling reasons.

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Geological Survey

Revision of Terminology for Geologic Hazard Warnings

AGENCY: U.S. Geological Survey, Interior.

ACTION: Notice.

SUMMARY: This notice describes changes in the terms and criteria used by the U.S. Geological Survey for issuing statements concerning geologic-related hazards to public officials and the public.

For the purpose of this statement, a geologic hazard is a geologic condition, process, or potential event, such as an earthquake, volcanic eruption, or landslide, that poses a threat to the health, safety, or welfare of the public or to the functions or economy of a community or larger governmental entity. In this context a Geologic Hazard Warning is a formal statement by the Director of the U.S. Geological Survey that discusses a specific geologic condition, process, or potential event that poses a significant threat to the public, and for which some timely response would be expected. Directives or advisories to the public to take action, based on a Geologic Hazard Warning, may be issued by officials of State and local governments, and other Federal agencies, with authority and responsibility to use such statements.

The term Hazard Warning is reserved for those situations posing a risk greater than normal and warranting considerations of a timely response in order to provide for public safety. Information regarding hazardous conditions that do not meet the criteria for a Hazard Warning may, however, also be sent to public officials as it becomes available. Transmittal of such information would not constitute a Hazard Warning.

1. The criteria for a Geologic Hazard Warning are:

a. A degree of risk greater than normal for the area; or a hazardous condition that has recently developed or has only been recently recognized; and

b. A threat that warrants consideration of a near-term public response.

2. A Geologic Hazard Warning consists of:

a. A description of the geologic or other pertinent conditions that cause the concern;

b. Factors that indicate that such conditions constitute a potential hazard;

c. Location or area that may be affected;

d. Estimated severity and time of occurrence, if such estimates are justified by available information;

e. If possible, a probabilistic statement on the likelihood of a given event or events within a specified time period; and

f. A description of continued Geological Survey involvement and estimate of what and when additional information might be available.

If a life or property-threatening event is thought to be imminent, and immediate response is warranted by the public and public officials, the emergency nature of the Hazard Warning will be stated clearly either in the heading or the first sentence of the text of the warning statement. If the immediate crisis passes, either with or without the anticipated event, a revised statement will be issued to reflect the changed conditions and a re-evaluation of the geologic hazard.

These changes in the terms and criteria do not entail or imply any changes to the *procedures* the U.S. Geological Survey uses to notify State and local governments, other Federal agencies, the public, or the news agencies and services.

SUPPLEMENTARY INFORMATION: The Federal Register of April 12, 1977, Vol. 42, No. 70, pages 19292 to 19296 describes the previous terminology as well as the U.S. Geological Survey's authority to issue warnings of geologic-related hazards, capabilities to predict hazardous events, and provisional procedures to report hazardous conditions.

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APPENDIX C

GLOSSARY OF TECHNICAL TERMS

Acceptable Risk - a probability of social or economic consequences due to earthquakes that is low enough (for example in comparison with other natural or manmade risks) to be judged by appropriate authorities to represent a realistic basis for determining design requirements for engineered structures, or for taking certain social or economic actions.

Active Fault - a fault that on the basis of historical, seismological, or geological evidence has a high probability of producing an earthquake. (Alternate: a fault that may produce an earthquake within a specified exposure time, given the assumptions adopted for a specific seismic-risk analysis.)

Attenuation Law - a description of the behavior of a characteristic of earthquake ground motion as a function of the distance from the source of energy.

B-Value - a parameter indicating the relative frequency of occurrence of earthquakes of different sizes. It is the slope of a straight line indicating absolute or relative frequency (plotted logarithmically) versus earthquake magnitude or meizoseismal Modified Mercalli intensity. (The B-value indicates the slope of the Gutenberg-Richter recurrence relationship.)

Coefficient of Variation -- the ratio of standard deviation to the mean.

Damage - any economic loss or destruction caused by earthquakes.

Design Acceleration - a specification of the ground acceleration at a site, terms of a single value such as the peak or rms; used for the earthquake-resistant design of a structure (or as a base for deriving a design spectrum). See "Design Time History."

Design Earthquake - a specification of the seismic ground motion at a site; used for the earthquake-resistant design of a structure.

Design Event, Design Seismic Event - a specification of one or more earthquake source parameters, and of the location of energy release with respect to the site of interest; used for the earthquake-resistant design of a structure.

Design Spectrum - a set of curves for design purposes that gives acceleration velocity, or displacement (usually absolute acceleration, relative velocity, and relative displacement of the vibrating mass) as a function of period of vibration and damping.

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Design Time History - the variation with time of ground motion (e.g., ground acceleration or velocity or displacement) at a site; used for the earthquake-resistant design of a structure. See "Design Acceleration."

Duration - a qualitative or quantitative description of the length of time during which ground motion at a site shows certain characteristics (perceptibility, violent shaking, etc.).

Earthquake - a sudden motion or vibration in the earth caused by the abrupt release of energy in the earth's lithosphere. The wave motion may range from violent at some locations to imperecptible at others.

Elements at Risk - population, properties, economic activities, including public services etc., at risk in a given area.

Exceedence Probability - the probability that a specified level of ground motion or specified social or economic consequences of earthquakes, will be exceeded at the site or in a region during a specified exposure time.

Expected - mean, average.

Expected Ground Motion - the mean value of one or more characteristics of ground motion at a site for a single earthquake. (Mean ground motion.)

Exposure - the potential economic loss to all or certain subset of structures as a result of one or more earthquakes in an area. This term usually refers to the insured value of structures carried by one or more insurers. See "Value at Risk."

Exposure Time - the time period of interest for seismic-risk calculations, seismic-hazard calculations, or design of structures. For structures, the exposure time is often chosen to be equal to the design lifetime of the structure.

Geologic Hazard - a geologic process (e.g., landsliding, lequefaction soils, active faulting) that during an earthquake or other natural event may produce adverse effects in structures.

Intensity - a qualitative or quantitative measure of the severity of seismic ground motion at a specific site (e.g., Modified Mercalli intensity, Rossi-Forel intensity, Housner Spectral intensity, Arias intensity, peak acceleration, etc.).

Loss - any adverse economic or social consequence caused by one or more earthquakes.

Maximum - the largest value attained by a variable during a specified exposure time. See "Peak Value."

Maximum Credible
Maximum Expectable
Maximum Expected

These terms are used to specify the largest value of a variable, for example, the magnitude of an earthquake, that might reasonably be expected to occur. In the

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Maximum Probable — Committee's view, these are misleading terms and their use is discourage. (The U.S. Geological Survey and some individuals and companies define the maximum credible earthquake as "the largest earthquake that can be reasonably expected to occur." The Bureau of Reclamation, the First Interagency Working Group (Sept. 1978) defined the maximum credible earthquake as "the earthquake that would cause the most severe vibratory ground motion capable of being produced at the site under the current known tectonic framework." It is an event that can be supported by all known geologic and seismologic data. The maximum expectable or expected earthquake is defined by USGS as "the largest earthquake that can be reasonably expected to occur." The maximum probable earthquake is sometimes defined as the worst historic earthquake. Alternatively, it is defined as the 100-year-return-period earthquake, or an earthquake that probabilistic determination of recurrence will take place during the life of the structure.)

Maximum Possible - the largest value possible for a variable. This follows from an explicit assumption that larger values are not possible, or implicitly from assumptions that related variables or functions are limited in range. The maximum possible value may be expressed deterministically or probabilistically.

Mean Recurrence Interval, Average Recurrance Interval - the average time between earthquakes or faulting events with specific characteristics (e.g., magnitude $\geq$ 6) in a specified region or in a specified fault zone.

Mean Return Period - the average time between occurrences of ground motion with specific characteristics (e.g., peak horizontal acceleration $\geq$ 0.1 g) at a site. (Equal to the inverse of the annual probability of exceedance.)

Mean Square - expected value of the square of the random variable. (Mean square minus square of the mean gives the variance of random variable.)

Peak Value - the largest value of a time-dependent variable during an earthquake.

Response Spectrum - a set of curves calculated from an earthquake accelerogram that gives values of peak response of a damped linear oscillator, as a function of its period of vibration and damping.

Root Mean Square (rms) - square root of the mean square value of a random variable.

Seismic-Activity Rate - the mean number per unit time of earthquakes with specific characteristics (e.g., magnitude $\geq$ 6) originating on a selected fault or in a selected area.

Seismic-Design-Load Effects - the actions (axial forces, shears, or bending moments) and deformations induced in a structural system due to a specified representation (time history, response spectrum, or base shear) of seismic design ground motion.

Seismic-Design Loading - the prescribed representation (time history, response spectrum, or equivalent static base shear) of seismic ground motion to be used for the design of a structure.

Seismic-Design Zone - seismic zone.

Seismic Event - the abrupt release of energy in the earth's lithosphere, causing an earthquake.

Seismic Hazard - any physical phenomenon (e.g., ground shaking, ground failure) associated with an earthquake that may produce adverse effects on human activities.

Seismic Risk - the probability that social or economic consequences of earthquakes will equal or exceed specified values at a site, at several sites, or in an area, during a specified exposure time.

Seismic-Risk Zone - an obsolete term. See "Seismic Zone."

Seismic-Source Zone - an obsolete term. See "Seismogenic Zone" and "Seismotectonic Zone."

Seismic Zone - a generally large area within which seismic-design requirements for structures are constant.

Seismic Zoning, Seismic Zonation - the process of determining seismic hazard at many sites for the purpose of delineating seismic zones.

Seismic Microzone - a generally small area within which seismic-design requirements for structures are uniform. Seismic microzones may show relative ground motion amplification due to local soil conditions without specifying the absolute levels of motion or seismic hazard.

Seismic Microzoning, Seismic Microzonation - the process of determining absolute or relative seismic hazard at many sites, accounting for the effects of geologic and topographic amplification of motion and of seismic microzones. Alternatively, microzonation is a process for identifying detailed geological, seismological, hydrological, and geotechnical site characteristics in a specific region and incorporating them into land-use planning and the design of safe structures in order to reduce damage to human life and property resulting from earthquakes.

Seismogenic Zone, Seismogenic Province - a planar representation of a three-dimensional domain in the earth's lithosphere in which earthquakes are inferred to be of a similar tectonic origin. A seismogenic zone may represent a fault in the earth's lithosphere. See "Seismotectonic Zone."

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Seismogenic Zoning - the process of delineating regions having nearly homogeneous tectonic and geologic character, for the purpose of drawing seismogenic zones. The specific procedures used depend on the assumptions and mathematical models used in the seismic-risk analysis or seismic-hazard analysis.

Seismotectonic Zone, Seismotectonic Province - a seismogenic zone in which the tectonic processes causing earthquakes have been identified. These zones are usually fault zones.

Source Variable - a variable that describes a physical characteristic (e.g., magnitude, stress drop, seismic moment, displacement) of the source of energy release causing an earthquake.

Standard Deviation - the square root of the variance of a random variable.

Upper Bound - see "Maximum Possible."

Value at Risk - the potential economic loss (whether insured or not) to all or certain subset of structures as a result of one or more earthquakes in an area. See "Exposure."

Variance - the mean squared deviation of a random variable from its average value.

Vulnerability - the degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given magnitude or intensity, which is usually expressed on a scale from 0 (no damage) to 10 (total loss).

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February 2-3, 1986

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APPENDIX E

CONFERENCES TO DATE

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Conference III	Fault Mechanics and Its Relation to Earthquake Prediction Open-File No. 78-380
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Conference V	Communicating Earthquake Hazard Reduction Information Open-File No. 78-933
Conference VI	Methodology for Identifying Seismic Gaps and Soon-to-Break Gaps Open-File No. 78-943
Conference VII	Stress and Strain Measurements Related to Earthquake Prediction Open-File No. 79-370
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Conference XII	Earthquake Prediction Information Open-File No. 80-843
Conference XIII	Evaluation of Regional Seismic Hazards and Risk Open-File No. 81-437
Conference XIV	Earthquake Hazards of the Puget Sound Region, Washington Open-File No. 82-19
Conference XV	A Workshop on "Preparing for and Responding to a Damaging Earthquake in the Eastern United States" Open-File No. 82-220
Conference XVI	The Dynamic Characteristics of Faulting Inferred from Recording of Strong Ground Motion Open-File No. 82-591
Conference XVII	Hydraulic Fracturing Stress Measurements Open-File No. 82-1075
Conference XVIII	A Workshop on "Continuing Actions to Reduce Losses from Earthquakes in the Mississippi Valley Area Open-File No. 83-157
Conference XIX	Active Tectonic and Magmatic Processes Beneath Long Valley Caldera, Eastern California Open-File No. 84-939

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Conference XX	A Workshop on "The 1886 Charleston, South Carolina, Earthquake and its Implications for Today" Open-File No. 83-843
Conference XXI	A Workshop on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in the Northeastern United States" Open-File No. 83-844
Conference XXII	A Workshop on "Site-Specific Effects of Soil and Rock on Ground Motion and the Implications for Earthquake-Resistant Design" Open-File No. 83-845
Conference XXIII	A Workshop on "Continuing Actions to Reduce Potential Losses from Future Earthquakes in Arkansas and Nearby States" Open-File No. 83-846
Conference XXIV	A Workshop on "Geologic Hazards in Puerto Rico" Open-File No. 84-761
Conference XXV	A Workshop on "Earthquake Hazards in the Virgin Islands Region" Open-File No. 84-762
Conference XXVI	A Workshop on "Evaluation of the Regional and Urban Earthquake Hazards in Utah" Open-File No. 84-763
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Conference XXX	A Workshop on "Reducing Potential Losses From Earthquake Hazards in Puerto Rico Open File No. 85-731
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