REDUCING DISASTERS' TOLL

The United States Decade for Natural Disaster Reduction

NATIONAL RESEARCH COUNCIL

Cover Photo: Mount St. Helen's vertical eruption column lofted over 400 tons of ash into the atmosphere on July 22, 1980. These fine ash particles reached heights of 11 mi; within 3 days, winds carried them as far as the Atlantic Ocean. (Source: U.S. Geological Survey.)

REDUCING
DISASTERS'
TOLL

Typical fire behavior in old growth Lodgepole pine stand, during the 1988 Yellowstone fires. An accumulation of fuels in these stands has set the stage for their destruction. (Source: Robert Gale, U.S. Forest Service.)

REDUCING DISASTERS' TOLL

The United States Decade for Natural Disaster Reduction

Advisory Committee on the International
Decade for Natural Hazard Reduction

Commission on Engineering and Technical Systems

National Research Council

National Academy of Sciences

National Academy of Engineering

Institute of Medicine

NATIONAL ACADEMY PRESS
Washington, D.C. 1989

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This project was financially supported by the National Science Foundation, the Federal Emergency Management Agency, the Agency for International Development/Office of U.S. Foreign Disaster Assistance, the USDA Forest Service, and the Thomas Lincoln Casey Fund of the National Research Council.

Limited copies of the report are available from:

U.S. National Committee for the Decade
for Natural Disaster Reduction
Commission on Engineering and Technical Systems
2101 Constitution Ave., N.W.
Washington, D.C. 20418

Printed in the United States of America

ADVISORY COMMITTEE ON THE INTERNATIONAL DECADE FOR NATURAL HAZARD REDUCTION

GEORGE W. HOUSNER, California Institute of Technology, *Chairman*
CHRISTOPHER ARNOLD, Building Systems Development, Inc.
BRUCE A. BOLT, University of California, Berkeley
FREDERICK C. CUNY, Intertect
JOHN A. DRACUP, University of California, Los Angeles
WILLIAM J. HALL, University of Illinois, Urbana
ROBERT D. HANSON, University of Michigan
WILLIAM HOOKE, National Oceanic and Atmospheric Administration
JOHN F. KENNEDY, University of Iowa
JOSEPH E. MINOR, University of Missouri, Rolla
JOSEPH PENZIEN, University of California, Berkeley
JON A. PETERKA, Colorado State University, Fort Collins
FREDRIC RAICHLEN, California Institute of Technology
DWIGHT A. SANGREY, Rensselaer Polytechnic Institute
HARALDUR SIGURDSSON, University of Rhode Island
CHARLES C. THIEL, JR., Consulting Engineer
RALPH H. TURNER, University of California, Los Angeles
T. LESLIE YOUD, Brigham Young University

INTERNATIONAL LIAISON REPRESENTATIVES

ALAN G. DAVENPORT, University of Western Ontario, Canada
LUIS ESTEVA, Universidad Nacional Autonoma de Mexico
EMILIO ROSENBLUETH, Universidad Nacional Autonoma de Mexico
KENZO TOKI, Kyoto University, Japan

U.S. LIAISON REPRESENTATIVES

WILLIAM A. ANDERSON, National Science Foundation
FRED COLE, Office of U.S. Foreign Disaster Assistance
A. J. EGGENBERGER, National Science Foundation
JOHN FILSON, U.S. Geological Survey
ROBERT D. GALE, U.S. Forest Service
MICHAEL GAUS, National Science Foundation
JOSEPH H. GOLDEN, National Weather Service
WALTER W. HAYS, U.S. Geological Survey
DARRELL G. HERD, U.S. Geological Survey
RICHARD W. KRIMM, Federal Emergency Management Agency
PAUL KRUMPE, Office of U.S. Foreign Disaster Assistance
RICHARD MARSHALL, National Bureau of Standards
KISHOR C. MEHTA, Texas Tech University (Wind Engineering Research Council liaison)
J. ELEONORA SABADELL, National Science Foundation
HARESH C. SHAH, Stanford University (Earthquake Engineering Research Institute liaison)
ROBERT L. SCHUSTER, U.S. Geological Survey
ROBERT V. WHITMAN, Massachusetts Institute of Technology (Earthquake Engineering Research Institute liaison)
ARTHUR J. ZEIZEL, Federal Emergency Management Agency

NRC STAFF

STEPHEN RATTIEN, *Deputy Executive Director*, Commission on Engineering and Technical Systems
RILEY M. CHUNG, *Committee Director*
GREGORY MOCK, *Consulting Editor*
VIRGINIA M. LYMAN, *Staff Associate*
MARLA LACAYO-EMERY, *Administrative Assistant*
SUSAN MCCUTCHEN, *Administrative Assistant*
NORMA GIRON, *Senior Secretary*
DANA G. CAINES, *Administrative Secretary*

Earthquakes often trigger massive landslides, such as the one shown here in the Turnagain Heights subdivision in Anchorage, Alaska. The great Alaskan earthquake of March 1964 (magnitude 8.4), liquified sand lenses beneath the subdivision, causing a complex slide with severe surface contortion. During the four minutes of perceptible ground shaking, the front of the slide moved more than 1,000 ft, destroying 35 homes. (Source: G. W. Housner, California Institute of Technology.)

CONTENTS

Acknowledgments

The committee wishes to acknowledge the contribution of the ad hoc working group on the International Decade for Natural Hazard Reduction, chaired by James K. Mitchell and including Abram Bernstein, Lauriston King, Frederick Krimgold, Joseph Minor, and Joanne Nigg. Their work in 1986 provided a considerable resource for the Advisory Committee's efforts.

The committee also wishes to thank the following individuals for their critical review of and constructive suggestions on the draft report, as well as their assistance in providing graphics material for the final report: William Buffum, former United Nations under-secretary; Lloyd Cluff, Pacific Gas and Electric Company; Walter Hays and Darrell Herd, U.S. Geological Survey; Robert Gale, U.S. Forest Service; Joseph Golden, National Oceanic and Atmospheric Administration; Joanne Nigg, Arizona State University; Guy Stever, National Academy of Engineering; Gilbert White, formerly with University of Colorado, Boulder; Robert Wiegel, University of California, Berkeley; and Uniphoto Picture Agency.

PREFACE

Reducing Disasters' Toll is a companion publication to *Confronting Natural Disasters: An International Decade for Natural Hazard Reduction* (Advisory Committee on the IDNHR, National Research Council, 1987). It presents the rationale and framework for the United States Decade for Natural Disaster Reduction (USDNDR), commencing in 1990. Such a Decade would initiate an integrated U.S. program in natural hazard reduction and would form the U.S. contribution to the recently designated International Decade for Natural Disaster Reduction (IDNDR),* also to begin in 1990. The benefits of an International Decade, its possible structure, and some of its suggested projects are described in *Confronting Natural Disasters*. That report recommends that each concerned country organize its own National Decade for Natural Disaster Reduction. The essential features of such a U.S. effort are described in this report, which is intended not only for individuals in the hazard reduction field but also for the broader audience of policy makers and the interested public.

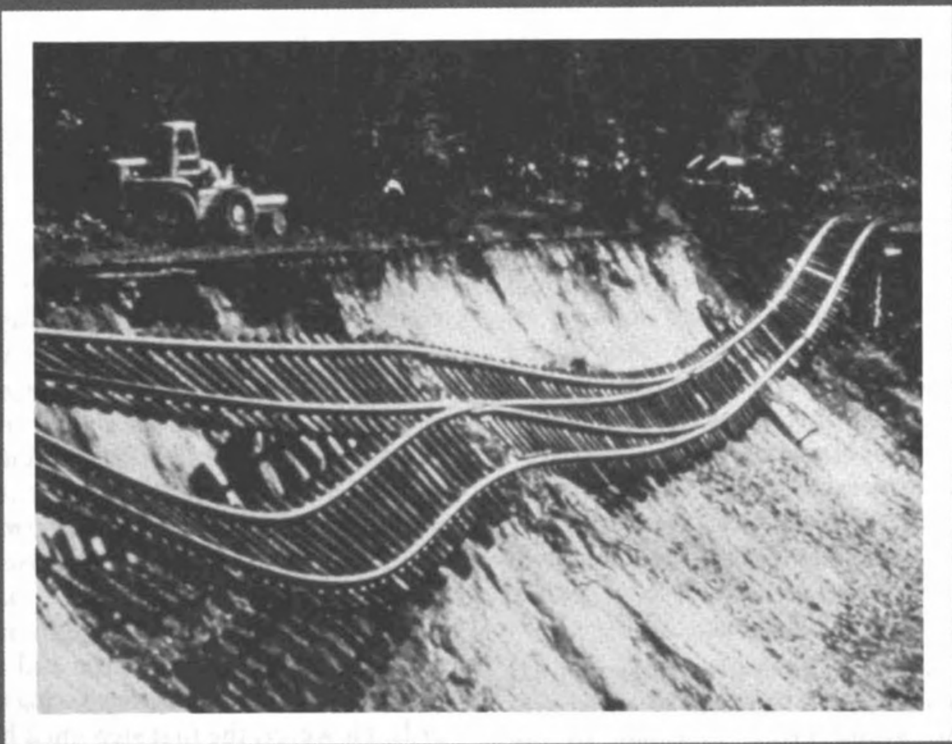
The concept of a cooperative international program to reduce natural hazards was first presented by Dr. Frank Press, president of the National Academy of Sciences, at the Eighth World Conference on Earthquake Engineering in 1984. In his keynote address, he proposed an International Decade for Hazard Reduction, to begin in 1990. As copies of the speech circulated after the conference, international interest began to build, not only with respect to reducing the toll of earthquakes, but also with respect to other natural hazards.

The growing interest in establishing an International Decade led to the appointment of the National Research Council Advisory Committee on the International Decade for Natural Hazard Reduction. It was charged with evaluating the potential for such an effort and how best to realize that potential. The committee, composed of natural hazard experts from many disciplines, was drawn from academia, the private sector, and the federal government.

As set forth by the United Nations, the International Decade for Natural Disaster Reduction will focus on earthquakes, windstorms (cyclones, tornadoes, typhoons, hurricanes), tsunamis ("tidal waves"), floods, landslides, volcanic eruptions, wildfires, and insect infestations. All of these hazards threaten the United States and have caused many notable disasters. Vulnerability to most of these hazards rises with increasing population, and both the risks and consequences of disasters can be expected to intensify unless concerted action is taken. The U.S. national effort will be strengthened through international cooperation—at the scientific and technological levels—with other countries facing the same hazards. However, the first step must be to organize the USDNDR by establishing a national committee and engaging the cooperation of the research and professional communities and of concerned government agencies. This report offers recommendations on how to proceed.

George W. Housner, *Chairman*
Advisory Committee on the International
Decade for Natural Hazard Reduction

*In December 1987, the United Nations General Assembly designated the 1990s as the *International Decade for Natural Disaster Reduction*. In so doing, it replaced the term "hazard," used in the title of the original report, with the term "disaster." To avoid confusion in terminology, the present report and all future references to the Decade, whether national or international, will use the wording of the United Nations resolution, that is, " . . . Decade for Natural *Disaster* Reduction."



Death tolls and the collapse of homes or buildings often grab headlines after an earthquake. But the quake's effects do not end there. Water supply and sewer lines, energy distribution equipment, and transportation systems—collectively referred to as lifelines—are often directly impacted as well. Here, fill beneath a 400-foot section of the Union Pacific rail line outside Olympia, Washington, slid away after a 6.5 magnitude earthquake on April 29, 1965. (Source: University of California, Berkeley.)

Introduction

Year by year, natural disasters in the United States claim their toll in lives lost and property destroyed. Further, the potential for catastrophe is increasing because of a growing population in high-hazard areas, mounting investment and value of structures, and the growing economic interdependence of businesses, communities, and nations.

Worldwide, nearly 3 million people have died and some 820 million more have been injured, displaced, or otherwise affected by natural disasters during the past 20 years. Devastating economic losses have accompanied this toll. Direct property damage is conservatively set at $25 billion to $100 billion for the same period, not counting job losses, reduced productivity, or other crippling effects.

The United States, while thus far having been spared a disaster of these proportions, is threatened by a diversity of hazards. The California and Oregon wildfires in September, the Whittier, California, earthquake in October, the Texas and Arkansas tornadoes in November and December, and the New Year's Eve flash flood and debris flows in Hawaii are just a few examples from the closing days of 1987.

Some hazards are dramatic, occur regularly, and receive wide recognition. Each year, one or more hurricanes strike the Gulf of Mexico and Atlantic Coast states. A single storm is capable of causing billions of dollars in damage, as did Hurricane Agnes in 1972. The nation also experiences some 900 tornadoes each year. And during 1987, wildfires consumed homes, habitat, and timber on nearly 700,000 acres in California alone.

Still other hazards are more intermittent but are perceived as more ominous. The 1980 eruption of the Mount St. Helens volcano in Washington State awakened many to the possibility of volcanic hazard in the western states. Tsunamis (tidal waves) caused by submarine landslides or seismic activity are a constant threat to coastal communities in Hawaii and all the Pacific states. And as many as 70 million people in 39 states face significant risk from earthquakes and secondary hazards, such as earthquake-triggered landslides In the recent Whittier, California, earthquake (magnitude 5.9), less than 5 seconds of ground shaking resulted in property damage exceeding $350 million. The lives lost from a single major earthquake similar to others that have occurred in California in the last 150 years could exceed 20,000, and economic losses could total more than $100 billion.

Other hazards are less dramatic but constant in their toll. Landslides in the United States cause at least $1 billion to $2 billion in economic losses annually. From 1965 to 1985, rainstorms and related flooding accounted for more than 63 percent of federally declared disasters and caused losses exceeding $3 billion each year.

In addition to the large toll in property damage and human resources borne by the private sector, the nation assumes the direct costs of disaster relief and recovery efforts year after year. The Federal Emergency Management Agency (FEMA) alone has spent an average of close to

$400 million per year for disaster relief during the last 20 years. This represents only a small portion of the total federal costs incurred in coping with natural disasters. Simply restoring vital transportation links destroyed by natural events costs the Department of Transportation about $160 million annually. And these resources go not to improving the nation's economy and infrastructure, but merely to restoring what has been lost.

Despite a growing understanding of hazards and the engineering capability to control them, hazard losses continue to increase due to a failure to reflect this knowledge in engineering design and in public and private policies and investment decisions. This is not to say that there has been no improvement in hazard management practices and policies. Nonetheless, the current approach can be characterized as a patchwork of temporary fixes, incomplete analyses of alternatives, and uncoordinated actions and policies, many working to exacerbate rather than to moderate catastrophe potential.

Yet this cycle of ever-mounting losses can be broken. The heavy toll taken by nature's violent forces is not inevitable, as many successful hazard reduction efforts have demonstrated. Although it may not be possible to prevent the occurrence of natural hazards, the disasters they may cause can often be avoided or mitigated. Application of integrated, economically sound hazard reduction (the process of lessening the effects of a potential event on the social and built environments) can substantially reduce deaths, injuries, property damage, and the destruction of a community's social and economic resources.

Such reductions are now possible through the application of advances in science and technology. Experience demonstrates that the United States already has much knowledge that, if properly applied, can cut human and property losses substantially. There is growing confidence among the scientific and engineering communities that important advances are within reach if a problem-focused national research and application effort is mounted.

It is in this spirit of confidence, and with the promise of substantial rewards for future generations, that the Advisory Committee recommends the establishment of a United States Decade for Natural Disaster Reduction (USDNDR). The benefits of the U.S. Decade could be greatly enhanced by the recent action of the United Nations General Assembly, which in December 1987 adopted a resolution designating the 1990s as the International Decade for Natural Disaster Reduction (IDNDR). Such a Decade would offer the United States the benefits of national programs of research and application developed in other nations facing risks similar to its own. It would also offer an unparalleled opportunity to work with other nations toward the objective of saving lives and property, and maintaining economic vigor in the face of mounting worldwide exposure to natural hazards.

THE INTERNATIONAL DECADE FOR NATURAL DISASTER REDUCTION

By declaring the 1990s as the International Decade for Natural Disaster Reduction, the member nations of the United Nations recognized both the severity of the risk presented by natural hazards and the promise scientific and technical progress holds for understanding these hazards and mitigating their effects. The Decade's objectives and means, as set forth by the United Nations, are entirely consistent with those stated in the National Research Council report *Confronting Natural Disasters: An International Decade for Natural Hazard Reduction.**

As stated by the United Nations, the goals of the IDNDR are fivefold:

1. to improve the capacity of each country to mitigate the effects of natural disasters expeditiously and effectively, paying special attention to assisting developing countries in the establishment, when needed, of early warning systems;
2. to devise appropriate guidelines and strategies for applying existing knowledge, taking into account the cultural and economic diversity among nations;
3. to foster scientific and engineering endeavors aimed at closing critical gaps in knowledge in order to reduce loss of life and property;
4. to disseminate existing and new information related to measures for assessment, predic-

*Advisory Committee on the International Decade for Natural Hazard Reduction. 1987. *Confronting Natural Disasters: An International Decade for Natural Hazard Reduction*. Washington, D.C.: National Academy Press.

tion, prevention, and mitigation of natural disasters; and

5. to develop measures for the assessment, prediction, prevention, and mitigation of natural disasters through programs of technical assistance and technology transfer, demonstration projects, and education and training, tailored to specific hazards and locations, and to evaluate the effectiveness of those programs.

The United Nations has called on all countries to participate in the Decade's activities and structure. It has urged individual nations to establish national committees for the Decade and to pursue national programs of hazard assessment and mitigation—in other words, for each nation to undertake its own National Decade for Natural Disaster Reduction and to cooperate with the programs of other nations.

THE UNITED STATES DECADE FOR NATURAL DISASTER REDUCTION

The Advisory Committee recommends that the United States establish and fund a vigorous, goal-oriented United States Decade for Natural Disaster Reduction to provide a national focus for hazard reduction activities. This will not only be the most fruitful mechanism for contributing to and receiving full benefit from the International Decade, but it also reflects the nation's need to assess its rising hazard risk and to forge comprehensive national policies and programs to reduce that risk.

The nation faces a choice of continuing its current practice of responding to natural hazards primarily through disaster relief efforts, or of acting on the philosophy of hazard management that recognizes the vital role of mitigation efforts to reduce the consequences of hazards, while continuing to provide relief and recovery assistance. In addition, government at all levels can seize this opportunity to take stock of the nation's current hazards programs, to assess their strengths, and to determine where they must be realigned or augmented to function efficiently.

For a variety of reasons, the present hazard management system to a large degree consists of an array of independent programs undertaken by a host of different local, state, and federal authorities—many with conflicting responsibilities—as well as by many private organizations. Coordinating these programs into an integrated hazard reduction system pursuing nationally accepted goals is a challenge that will require an increased and concerted effort from the nation's hazard reduction community—an effort best undertaken in the form of the United States Decade for Natural Disaster Reduction.

To best achieve this effort, the Advisory Committee recommends that a national committee for the Decade be established to: (a) provide leadership for U.S. national efforts; (b) seek support for the national program of loss reduction research and implementation from federal and state governments, foundations, and professional, scientific, and other organizations; and (c) coordinate U.S. participation in the international program in support of the IDNDR. The National Research Council, in consultation with the U.S. government, could establish such a committee. It is desirable that the committee be appointed as early as possible in order to plan adequately the USDNDR program before its recommended start in 1990, in concert with the IDNDR. The committee should include participation from professional organizations, government agencies, universities, and other interested parties.

A massive landslide rent this Sebastopol, California, ranch in March 1983, snapping power lines, severing a well, and damaging nearby houses and barns. When copious winter rains raised the local water level and reduced the binding between layers of bedrock, a large slab of weathered rock and earth broke free, opening a deep rift as it slid downhill in a single block. Though many landslides seem unspectacular, the accumulated losses they incur can be significant. Each year, landslides in the United States cause $1–2 billion in losses and 25–50 deaths. (Source: G. Wieczorek, U.S. Geological Survey.)

The Hazard Reduction Process

Disasters can be avoided or minimized through the application of science and technology. Without the focused use of accumulated knowledge, disasters are likely to increase as the pressures of population and commerce encourage the use of more hazard-prone areas.

Science and technology applications to avoid disasters encompass both physical and social adjustments. Physical adjustments for avoiding the impacts of hazards include:

- planning and building to withstand hazards;
- identifying and avoiding the sites where hazards are likely to occur;
- predicting the occurrences of hazards; and
- preventing hazards or altering their characteristics.

Social adjustments for avoiding hazard impacts include:

- land-use controls and establishing minimum standards and guidelines for avoiding hazardous sites and conditions;
- instituting public awareness campaigns in hazard-prone areas to raise community hazard consciousness;
- initiating emergency preparedness programs to protect life and property once a warning is issued or an event occurs;
- spreading the economic loss among a larger population through insurance, taxation, and monetary grants; and
- reconstructing a community and enhancing its emergency preparedness program so that it is less vulnerable to the next hazard.

These avoidance and loss reduction strategies, when implemented in a systematic fashion, can substantially alter the impacts of natural hazards. When several strategies are pursued together, they can often reduce a potential catastrophe to a moderate disruption. The most appropriate mix of actions depends on the hazards faced by a community, the availability of scientific and technical knowledge, and the values, resources, and goals of the community. What is effective for one location or hazard may not work for another. For instance, design standards for earthquake resistance that are accepted in California, where the frequency of significant ground shaking is high, may prove unacceptable to residents of communities in New England, where the frequency of damaging earthquakes is lower.

Whatever the strategy, avoiding disasters must include *understanding* and *anticipation* of the hazard and its impacts. Yet most measures now in use to cope with natural hazards are reactive: firefighting, search and rescue, emergency medical care, debris clearance, provision of food and temporary shelter, and provision for a temporary water supply and waste disposal. These emergency response measures may be planned in advance, but are not normally put into effect until after a disaster occurs; their mitigation potential

---

This chapter is adapted from *Confronting Natural Disasters: An International Decade for Natural Hazard Reduction.*

On February 9, 1971, the magnitude 6.5 San Fernando, California, earthquake damaged 42 freeway bridges and collapsed five, including these in the Sylmar region of Los Angeles. Since then, California highway officials have required overpass designs to incorporate dynamic analyses and the results of extensive earthquake engineering research. (Source: G. W. Housner, California Institute of Technology.)

is almost invariably low. While both emergency response measures and mitigation measures contribute to reductions in loss of life and property, major reductions in those losses can best be achieved when the emphasis shifts from reaction to anticipation. In other words, emergency response and postdisaster relief are important and will always be needed, but on a declining scale as disaster preparedness, hazard-conscious land-use management, hazard-resistant construction, and other anticipatory measures reduce the nation's vulnerability to natural hazards.

Strategies for avoiding the impacts of natural hazards and areas of applied research and technology that can dramatically reduce the frequency of catastrophes are reviewed in the following sections.

HAZARD AND RISK ASSESSMENT

How does a community begin to reduce the impacts of natural disasters? The first step is to determine the types of hazards likely to occur and their characteristics, frequency, and consequences. Experience is a good teacher, but changes in population patterns, physical characteristics of structures, and economic development during the past century suggest that relying on experience alone is inadequate for judging vulnerability.

Risk assessments of the nature, extent, and consequences of natural hazards lie at the core of adopting effective and economic actions to lessen the potential for catastrophe. There is a natural competition for resources between investment in hazard reduction measures for the future and use of capital and labor that will yield current income or improve the quality of life immediately. Evaluating risks can help in estimating the likely level of hazard and in determining the economic and social costs associated with various levels of investment in hazard reduction. Assessment has three essential features:

1. Assessment of the hazard. This component is often described in terms of hazard or intensity maps of the maximum event likely to occur, frequency of the event (e.g., demarcation of a 50- or 100-year flood area), and the numerical values of design parameters required to withstand the

forces of a natural hazard (e.g., the level of ground motion a structure must accommodate).

2. Determination of the vulnerability of the people, structures, and facilities exposed. This includes individual structures and networks of interacting structures, such as water supply and distribution pipelines, and social institutions, such as fire and hospital services.

3. Determination of the significance of the impacts. This includes a differentiation among saving lives, protecting property, and preserving essential community functions; comparison of the benefits of avoiding a disaster with those of investing in other economic and social functions; recognition of the different roles of structures and institutions in emergency response and recovery activities; and recognition of the different and possibly conflicting goals and values of individuals and institutions within a community.

Knowing that a major natural hazard *may* occur is not sufficient in itself to cause action. California—where nine major earthquakes have occurred in the last 150 years, including four great earthquakes—did not begin a comprehensive earthquake safety program until the seismic threat was clearly understood economically and politically. This understanding came about when the U.S. Office of Science and Technology Policy determined the scale of the impact of a catastrophic earthquake on the local and national economies. The specter of a staggering $100 billion loss—with attendant loss of life and damage to industrial productivity—prompted local, state, and federal governments to begin a concerted effort to prepare for the occurrence of great earthquakes.

The kinds of information that the nation requires to develop and adopt a catastrophe avoidance plan do not vary much from state to state, but the strategies appropriate to different localities obviously do. Formulating goals and taking action depend almost entirely on social organization and on the willingness of the public to accept the consequences of its actions. Some individuals and groups will choose not to act because of an incorrect understanding of what they should do, a lack of education in how to do it, or a vested interest in doing something else. The economic, social, and institutional dimensions of a community may well determine what is appropriate as well as what is possible.

DISASTER PREPAREDNESS

Disaster preparedness is the detailed planning for prompt and efficient response once a hazardous event occurs or seems imminent; it is the first step in adopting an anticipatory approach to natural hazards. This comprehensive effort includes public education and awareness campaigns, provision for issuing warnings, development of emergency response and evacuation plans, and preparations for providing evacuees with emergency food and shelter. Such efforts have been very successful in reducing deaths from natural hazards in some industrialized nations. The challenge during the USDNDR is to further reduce disaster-related deaths in the United States and to cut economic losses and the social suffering they induce.

HAZARD MITIGATION

Disaster preparedness and evacuation can reduce death and injuries, but in most cases they do little to prevent property damage and the sometimes devastating economic impacts associated with disasters. These areas are the province of hazard mitigation, whose benefits can be substantial. For instance, prohibiting basements in new coastal buildings and strengthening their wind resistance by 50 percent might reduce storm losses by up to $1.65 billion per year (1985 dollars) in the United States. Adding siting and construction controls in cities that have none and elevating all new buildings in the 50-year flood plain by 4 feet might lower flood losses by $1 billion annually.

The physical impacts of a hazard can be reduced by preventing or modifying the occurrence of the hazard, avoiding the hazard by siting structures and functions away from the area of concern, or strengthening structures to reduce or eliminate possible damage when an event occurs.

In certain instances, prevention or modification of a hazard is possible. For example, constructing dams, channeling rivers, and building levees are methods widely used to reduce losses from flooding and debris flows. These methods are reasonably well understood and usually entail construction of large-scale civil works. However, modification of most other hazards is still at the research stage. For instance, there are some indications that, in time, weather can be modified to

lessen the likelihood of hail, increase rainfall, and possibly alter the course of large storms. Future earthquakes may even be modified so that a number of small earthquakes would occur rather than individual large ones.

Avoiding a hazard through land-use management is effective in some instances. Land that is prone to flooding, landsliding, wildfire, or liquefaction can be withdrawn from use or limited to those purposes that are least threatening. For example, flood plains can be used for parks and farming; steep slopes can be left undeveloped to avoid triggering landslides; highly flammable vegetation around and near homes can be converted to golf courses or lawns; tsunami inundation areas can be planted as parks, thus both avoiding the hazard and reducing the run-up of the tsunamis by increasing the surface roughness; and critical facilities can be located outside the possible areas that would be affected should an upstream dam fail.

It is not possible to avoid all potentially hazardous areas. Rivers must be crossed. Water, electricity, and fuel must be transported. Commerce must be maintained. The acts of regulating land use and of siting facilities based on potential hazard or the consequences of their failure go right to the heart of how a community functions. Hazard considerations are but a part—often ignored—of the overall decision process. Much remains to be learned about effectively integrating land-use strategies into economic development, but experience from many communities shows that even simple restrictions on the use of flood plains, as mentioned above, can reduce the consequences of flooding.

Improving building practices offers one of the most effective approaches to limiting the effects of natural hazards. When a structure is designed, constructed, and maintained to resist a hazard, then the event has little or no impact. But the design of a structure to withstand a hazardous event is not a simple matter. What forces will the structure encounter? How will its different elements interact? How will the construction materials perform? Will the structure fail "controllably"? These are questions the engineer must answer.

Many empirical rules have evolved to aid engineers in constructing buildings that perform well during natural hazards. However, building practices throughout the world are developing rapidly, creating both new opportunities and new dangers. Some improved construction techniques have already proved their worth. For example, using cement mortar rather than lime and sand mortar, using reinforcing steel, and attaching diaphragms to walls can reduce the vulnerability of masonry buildings from almost certain collapse in an earthquake to one of modest or light damage. Similarly, securely attaching the roof to the walls and the walls to the foundation of a wood frame house can greatly reduce wind damage during hurricanes, cyclones, and tornadoes.

A camp for victims of the 1906 San Francisco earthquake. (Source: Eric Swenson.)

Certain roof compositions and enclosing eaves and vents can reduce the threat from burning embers that accompany wildfire and that often trigger the loss of a structure.

But rapid change in construction practices also poses new dangers. Techniques are often applied far from where they were developed, without regard to their limitations. Further, their performance may be conjectural, not understood from actual disaster experience. Only observations of actual performance during a disaster—combined with laboratory and field research—can validate new methods. Such investigations do not yield results easily or quickly.

Among the principal tools for safe construction are building codes, regulations, and inspections. They too offer both benefits and problems for transferring experience from one community or country to another. The benefit is that groups of knowledgeable individuals have assessed experience and research results to develop the codes. The problem is that a code responds to the conditions, building materials, and construction practices of the community that originated it; the code may not be entirely applicable outside this context without modification to reflect local hazard conditions and construction practices.

As mentioned earlier, a key limitation to mitigating damage from natural hazards is the large inventory of substandard, even hazardous, structures. Most worldwide research and development of building practices focuses on new buildings, not on rehabilitating existing structures that may be unsafe. Because existing facilities represent the main hazard everywhere in the world, research and performance evaluations of retrofit techniques have much to offer this critical area of concern.

HAZARD PREDICTION

Predicting the occurrence of a major natural hazard event has enormous potential for reducing its disastrous consequences. Even short advance notice gives time to protect life and property; a long period provides an opportunity to relocate and reinforce property. The capability to predict, which varies with the type of hazard, has made considerable strides through research and technical understanding.

Computer modeling of watersheds, when linked to a network of meteorological and hydrographic stations, has enabled accurate flood warnings to be developed. From tornado watch programs linked to weather radar systems, the path of a tornado can be predicted, giving both the occupants of a community and its fire, rescue, and medical services a short time to prepare. The development of Doppler radar has greatly advanced the ability to predict weather-related hazards and has lengthened the time between warning and onset of an event.

In regions of tropical storms, the precision of warnings issued in advance improves as a storm approaches. The collection of data by weather satellites and the availability of high-speed computers to analyze these data and to employ sophisticated models are key factors in this improved predictive capability.

The Automatic Lightning Detection System (ALDS) is another example of U.S. technical progress in hazard reduction. The system links an electronic detection device with a network of remote automated weather stations. With the aid of computers, the ALDS can locate lightning strikes and predict their probability of starting a wildfire. In the area of tsunami prediction, the Pacific Tsunami Warning Center uses input from 22 seismic observatories and 53 tide stations to predict tsunami arrival times for island and coastal communities throughout the Pacific Basin. With its network of member countries, the Pacific Tsunami Warning Center provides yet another excellent illustration of the application of science in a cooperative, mutually beneficial way.

For earthquakes and other hazards, short-term prediction is generally more difficult. The inability to repeat the successful prediction in 1975 of the Haicheng, China, earthquake—where thousands of casualties were avoided because citizens were given time to reach streets and open areas before the quake destroyed large numbers of buildings—is a reminder of the difficulty of prediction, the promise that such a capability portends, and the need to pursue further research to allow routine, accurate prediction.

All of these forecasts rely on mathematical models or empirical understanding of the physical phenomena, the weather patterns, or the tectonic structure of the earth—knowledge that can be continuously updated with observations. These observations sometimes include the actual sighting of a phenomenon, as with tornadoes and hurricanes, and the model then tracks the storm's progress.

As these models improve, so will the accuracy of the prediction. The significance of improving the accuracy of predicting a hurricane's landfall from within 100 miles (160 kilometers) to within 50 miles (80 kilometers) can be measured in the millions of dollars if the storm is near a large city and confidence in the accuracy of the prediction leads to effective damage prevention activities. In the case of wildfires, where the occurrence of the actual events can be lessened or modified, longer range and more accurate weather forecasts are needed to prepare and pre-position fire suppression forces.

As forecasting has improved, the primary constraints to the utilization of greater knowledge are tied to sociological factors and methods of communication. A community's willingness to respond to emergency instructions dictates the type of information to be provided as well as by whom, when, and how it should be disseminated. If the information is perceived to be unreliable, as would occur should an event fail to materialize after being forecast, public skepticism will be enhanced, damaging subsequent attempts to warn the public.

EMERGENCY RESPONSE

The moment of impact of a hazard initiates the emergency response period, when saving lives and controlling property loss become matters of minutes. Typically, the first onsite responses are the spontaneous actions of local residents. Much of their effectiveness depends on training; the speed and efficiency with which community-wide response occurs are determined by planning and rehearsal. In saving lives, prompt and coordinated search and rescue operations are crucial. Fundamental problems in all emergency responses include obtaining accurate information on the nature and scope of the impacts, allocating and managing local resources, marshaling and allocating external resources, and dealing with the convergence of people and materials in the affected areas.

Although projects undertaken as part of the USDNDR will not involve relief operations for specific disasters, they will include careful analysis of responses to disasters under various social and political circumstances. Emergency response generally entails considerable wasted effort and working at cross purposes. Often many urgent tasks remain unaddressed. Contributing to this condition is the fact that police and other public servants must suddenly perform many tasks for which they are not routinely trained. The scale of the operation and degree of necessary cooperation are often overwhelming. Communication can become a major obstacle.

Both technological and sociological solutions are required to improve this situation. For example, development and installation of backup power sources and advance planning for utilizing amateur radio operators have improved emergency response in many disasters. Likewise, various strategies for public education and advance training for emergency response tasks have also been successful.

RECOVERY AND REDEVELOPMENT

As the emergency period wanes, a community enters the long recovery and redevelopment period during which it restores itself. It buries the dead, treats the injured, houses the dispossessed, restores the damaged economy, and takes steps to minimize the consequences of future disasters, among many other activities. If the emergency response period is typically one in which a spirit of unity and cooperation prevails, then the recovery period is typically one in which old divisions and conflicts resurface, exacerbated by the difficult decisions that must be made. Conflicts arise between a strong sentimental force to rebuild the community just as it was before—perhaps on the flood plain or in a seismically vulnerable setting—and a movement to seize the opportunity to make radical changes.

Conflicts can also develop over the use of short-term solutions that interfere with more satisfactory long-term solutions. An example is the introduction of temporary housing, which often becomes permanent. Still other conflicts arise over allocation of inadequate resources and evaluation of contradictory advice from presumably knowledgeable experts. These conflicts often lower community morale and undermine respect for political leadership and institutions, compounding the problems of restoring a community.

Planning for future hazardous events involves several problems during this period. Communities often rely excessively on a single strategy: for example, rebuilding the levees but making them higher and stronger, thus reducing the hazard of mild flooding but increasing the damage potential in the case of more extensive flooding. Planning is also impeded by a sense of immunity. Residents may feel either that "we have had our quake and there won't be another like it in our lifetime," or that "we weathered this hurricane, so we can weather anything nature throws at us."

Errors made in the recovery stage can increase the vulnerability of a community for generations. After flooding, for example, there has been a tendency to rebuild in the flood plain rather than relocate to higher ground. Similarly, in the absence of strong building codes, undesirable construction practices are perpetuated in tornado- or earthquake-prone regions. Comparative studies of recovery in several communities

The lateral blast from the initial eruption of Washington's Mount St. Helens on May 18, 1980, devastated an area as far away as 18 mi from the volcano, leaving the destruction shown here. Economic losses from the eruption and the resulting landslides, lahars, and floods totalled over $860 million. However, evacuation and restrictions on land use prior to the eruption limited the death toll to 62. (Source: U.S. Geological Survey.)

have identified some characteristic errors as well as examples of more successful experiences. However, further study is needed of both the short- and long-term economic consequences of various recovery patterns and their effects on political stability and cultural development.

Distributing the economic loss among a larger unaffected community lessens the severe economic impacts of natural catastrophes on the locality, although this strategy does not directly reduce casualties or damage. Insurance is one common vehicle for redistribution of loss. However, because the magnitude of the loss from many catastrophes can be severe, the willingness or capacity of insurance and financial institutions to provide coverage may be inadequate. Indeed, insurance firms' concerns about limiting their risk exposure could become a major force in promoting investment in hazard avoidance strategies. Besides insurance, another form of redistribution is economic assistance from charitable and private disaster organizations and from governments, through tax receipts and disaster assistance grants.

INSTITUTIONAL ISSUES

Responsibilities for hazard reduction and emergency response are so widely distributed among a variety of organizations that coordination—even for the sharing of information—is a severe problem. Much of the essential activity in reducing the impacts of natural hazards is carried out as a secondary responsibility by organizations whose primary purposes have little to do with hazard reduction. For example, public education for hazard reduction is carried out by the schools, the mass media, voluntary associations, and employers. Equipment for search and rescue is borrowed from building contractors, and its nature and locations are seldom known by those directing emergency response prior to the disaster. To remedy this situation, government must take a more active predisaster planning and coordinating role. Leadership by public officials is essential at all stages of hazard reduction and emergency response to marshal the expertise, resources, and responsibilities of the many groups that can contribute to hazard reduction.

Because disasters occur intermittently, creating organizations solely for hazard reduction is not feasible. Consequently, sustaining and directing work done as a peripheral responsibility by organizations with other primary purposes is a necessity. Unfortunately, case studies show that difficulties arise in the relations among local, regional, and national organizations; between general and special-purpose organizations; between professional and lay groups; between ad hoc and permanent organizations; and among all these groups. Much remains to be learned about promoting communication among organizations and encouraging patterns of coordination that do not stifle the groups involved. A key to reducing the impacts of a hazard is understanding how organizations perform before, during, and after an event. This will come only from systematic observation of many institutions as they plan for and respond to different hazards.

COMMONALITIES AMONG NATURAL HAZARDS

There are common elements in the research and mitigation strategies for a wide variety of natural hazards that have not been exploited because of the historically autonomous research and mitigation activities for each hazard. A concerted effort to identify research on one hazard with applications to other hazards is an important and highly

cost-effective activity for this Decade. Three examples that illustrate the point follow.

1. Hazard mapping has developed to a high level of sophistication within the water resources and flood control communities, but less effort has been expended to apply this concept to other hazard-prone regions, such as those subject to earthquakes or landslides. The application of the techniques developed for flood management to other natural hazards will enhance the quality and reduce the costs of mapping the full range of natural hazards. It will also establish a common basis for the determination of regions at risk, and for the evaluation of insurance coverage, construction investment, or land-use management decisions relating to human and property resources at risk.

2. Earthquake engineering, as applied to the structure of buildings and other public works, has benefited from relatively sizable funding levels during the past decade. As a result, the behavior of structures under earthquake loading is increasingly understood. Application to other hazards of the research techniques used to gain this knowledge could help keep research costs in check and reduce the time needed to gain information.

3. A process known as the Incident Command System (ICS) has been highly successful in enabling the organization of cooperative efforts for the suppression of wildfires. It has a common terminology and set of commands that facilitate organizational cooperation and rapid, efficient response. The system has been widely used by many city and local governments for their crisis management situations. Further, the concept can be adapted to address other natural hazards, thereby improving overall hazard response effectiveness and reducing costs.

On the other hand, some mitigation activities targeted on one hazard work at cross-purposes with activities targeted on another hazard. For example, a flood control dam in an earthquake-prone region can exacerbate the earthquake hazard should the dam be seismically vulnerable. In the same way, in the absence of land-use controls, building roadways to enable the evacuation of low-lying areas subject to flooding might lead to increased levels of development, thus putting more people and property at risk.

The USDNDR would offer the chance to reconcile these competing priorities. Various multihazard reduction projects could be initiated to assess the risks of multiple hazards, or to test various institutional and legal mechanisms for hazard reduction. A "lead" hazard approach can be used in each demonstration project that focuses first on the predominant hazard of the region and then on related secondary hazards. For example, in a seismically active area, the primary focus of a project would be earthquake loss, but it could also address the associated hazards of liquefaction, landslides, and flooding due to dam failure.

In addition to the opportunities to share hazard expertise or to avoid activities at cross-purposes with each other, many opportunities exist for research and application that are generic to all natural hazards. For example, the potential role of telecommunications in hazard reduction continues to grow as the technology progresses and costs are reduced.

Although the role of telecommunications is rarely made the focal point of hazard mitigation discussions, it underlies virtually all elements of the hazard mitigation process. Indeed, the Advisory Committee believes that advances in various aspects of telecommunications and the related field of computer sciences are among the major contributors to the view that technology can do much to blunt the effects of natural hazards.

The advent of the computer, space satellites, and sophisticated remote-sensing technology, and the broad distribution of electronic and print media, have put virtually the entire world into close contact. Media coverage in the United States is essentially ubiquitous, although wire-based (e.g., electric power and telephone) communications are often at risk during and subsequent to a natural hazard event. Historically, communication systems, including the broadcast media, have been exploited primarily in post-disaster response. But it is increasingly clear that communications also have an important role to play in predisaster education, in early warning systems, and in evacuation.

Table 1 presents a matrix detailing the applications of information-gathering and communications systems in mitigating natural hazards. It also illustrates that many fields (e.g., home building, elementary education, highway construction) could benefit from and make important contributions to the Decade. The following list catalogues opportunities in such fields in both the research and implementation areas.

- *Civil and structural engineering:* greater utilization of hazard-related tools (e.g., shake tables, wind tunnels) to develop both standardized and specialized structures and other facilities (e.g., buildings, roadways, power dams) more resistant to the ravages of natural hazards.
- *Space technology:* development of improved models for predicting severe storms and the capability for measuring rainfall to permit early warning of hurricanes, tornadoes, and floods; measurement of strain accumulation in tectonically active areas to contribute to earthquake prediction; contemporary land use mapping and development of geographic information systems to provide a basis for hazard mapping.
- *Space communications:* Transmission of environmental information from remote, unmanned, ground-based sensors to central computing and analytical facilities to provide timely disaster warnings.
- *Behavioral sciences:* developing a better understanding of how individuals and society in general view natural hazards and the degree to which improved public awareness can lead to reduction of hazard exposure. Among the topics that would benefit from greater understanding are the public's perception of high-consequence, low-probability events (e.g., earthquakes and volcanic eruptions) versus its perception of generally lower-consequence, higher-probability events (e.g., hurricanes, floods, landslides, tornadoes, wildfires), and the trade-offs between those hazards generally viewed as life threatening and those thought of primarily as hazards to property (e.g., landslides).

TABLE 1 Applications of Information-Gathering and Communication Systems for Natural Hazards Mitigation

Hazard	Satellite Sensors	Radio and Television	Print Media	Terrestrial Sensors
Earthquake	Strain accumulation measurement	Transmitting warnings and safety instructions	Education for hazard safety, including evacuation and building techniques	Strain accumulation measurement; vibration sensors
Landslide	Slope, porosity, and soil moisture measurement	Transmitting warnings	Education for hazard safety, including evacuation and building techniques	Strain accumulation measurement; wetness monitoring
Tsunami	Wave surge detection	Transmitting warnings	Education for hazard safety, including evacuation and location techniques	Subsea vibration monitoring
Volcano	Gastype and temperature measurement	Transmitting warnings	Education for hazard safety, including evacuation and location techniques	Vibration and thermal gradient measurement
Flood	Rainfall and severe storm prediction	Transmitting warnings	Education for hazard safety, including evacuation and location techniques	Flow, rain, and river height monitoring
Typhoon	Severe storm models	Transmitting warnings	Education for hazard safety, including evacuation, location, and construction techniques	Meteorological monitoring of storm surge and wind speeds
Tornado	Severe storm model development	Transmitting warnings plus specialized monitors with sensors	Education for hazard safety, including construction and protection techniques	Tornado tracking (Doppler radars)
Wildfire	Biomass, soil moisture and temperature, and fire perimeter determination	Transmitting warnings	Education for hazard safety, including prevention and fire resistance topics	Optical and thermal monitoring to support visual siting

Each year, one or more hurricanes strike the Gulf and Atlantic Coast states. This satellite view of Hurricane Diana was taken three days before it came ashore on the North Carolina coast in September 1984. Though significant attempts at hurricane protection had been made, Diana caused an estimated $80 million in economic losses. (Source: Hasler and Pierce.)

The Need for the United States Decade for Natural Disaster Reduction

The establishment by the United Nations of the International Decade for Natural Disaster Reduction is premised on the belief that the world has made great strides in its ability to predict and mitigate the most severe effects of natural hazards, but that application of this knowledge is lagging. Worldwide, many scientists, engineers, and policy makers view the decade of the 1990s as an opportune time—indeed, a critical time—for a concerted effort to organize and apply this knowledge, as well as to begin focused research efforts to address gaps in knowledge.

Obviously, the outcome of the International Decade assumes great importance in the developing world, where exposure to risk is rising rapidly as a consequence of increasing population and strong economic pressures that encourage development in disaster-prone regions. But, despite the United States' affluence, a Decade for Natural Disaster Reduction is also of critical importance here as well. Surprisingly, the gap between knowledge and application is perhaps most conspicuous in the United States, and the nation's exposure to economic loss, if not to deaths and injuries, is the greatest in the world. Among industrialized nations, the United States is uniquely at risk from every major natural hazard. In spite of some notable successes, the nation has often been helpless to confront the earthquakes, tornadoes, hurricanes, wildfires, floods, landslides, and volcanic eruptions that it regularly faces.

It is widely recognized that losses from hazards are rising in the United States despite significant research efforts and that more people and more property will be put at risk in the future in the absence of a focused program of hazard reduction. For various reasons, valuable capital investments—houses, factories, and infrastructure—are increasingly located in hazard-susceptible areas. These areas include the nation's coastlines, flood plains, earthquake-prone zones, and steeper slopes and river fronts in various metropolitan areas. As a result, it is estimated that more than $100 billion in damage could occur in the likely event of a major California earthquake, and losses of more than $7 billion are possible from a single hurricane.

At the same time that potential losses are growing, society has developed greater expectations about the degree of safety it desires. Natural hazard losses—measured in lives or dollars—have never been completely acceptable, but today there is an expectation that technology will limit these losses and that the insurance industry—or government—should be liable for disaster losses, holding citizens personally harmless.

Unfortunately, expectations and reality differ and the gap between expectations and actual performance grows increasingly wide. While federally funded research efforts, as well as parallel efforts abroad, have greatly improved the knowledge base in some areas of technology, hazard-related activities nonetheless continue to stress postdisaster response. In this sense, they are reactive in nature rather than anticipatory. Although postdisaster relief efforts are a necessary component of any hazard reduction program, they have limited potential relative to hazard avoidance measures, which act to defeat the disaster process before it begins.

The need for the United States Decade for Natural Disaster Reduction is driven by the mismatch between the nation's potential for hazard mitigation and its accomplishments to date. By applying what has been learned, the United States can do much more to reduce the toll from natural hazards. A greatly improved knowledge base in science and technology, improved sensors and telecommunications, and the growing awareness of common elements in mitigating diverse natural hazards can be exploited at low cost and with considerable potential benefit.

The past 20 years of research into the causes and mechanisms of natural hazards have yielded extraordinary successes, providing the United States with unprecedented opportunities to reduce the potential for disaster. It is the sense of this committee that the costs of applying this knowledge and acquiring valuable new knowledge are far below the costs in lives and property of allowing the nation's present mode for hazard preparedness to persist.

However, the current mode for hazard preparedness is not likely to change markedly in coming years without the promotion and execution of a comprehensive plan to address national hazard risks—a plan such as that embodied in the United States Decade. This reluctance to change in the face of rising risk is due, in part, to the transient nature of many natural hazards, the limited financial resources available—particularly at the local level—and the present limited dissemination of hazard reduction philosophy and techniques. Unless the level of national hazard consciousness, among the business and professional community as well as the general public, is raised and the cost- and life-saving potential made known, the nation will likely face the twenty-first century with greater vulnerability to natural hazards.

Present and prospective losses from natural hazards, while severe, would perhaps be tolerable were the nation not aware of opportunities to reduce them in a cost-effective manner. The essential rationale for both the International Decade and the companion United States Decade is that many of these losses are tragically unnecessary. They are caused by the failure to apply knowledge already in hand or to acquire additional knowledge that, when applied, would lead to very considerable savings of lives and property.

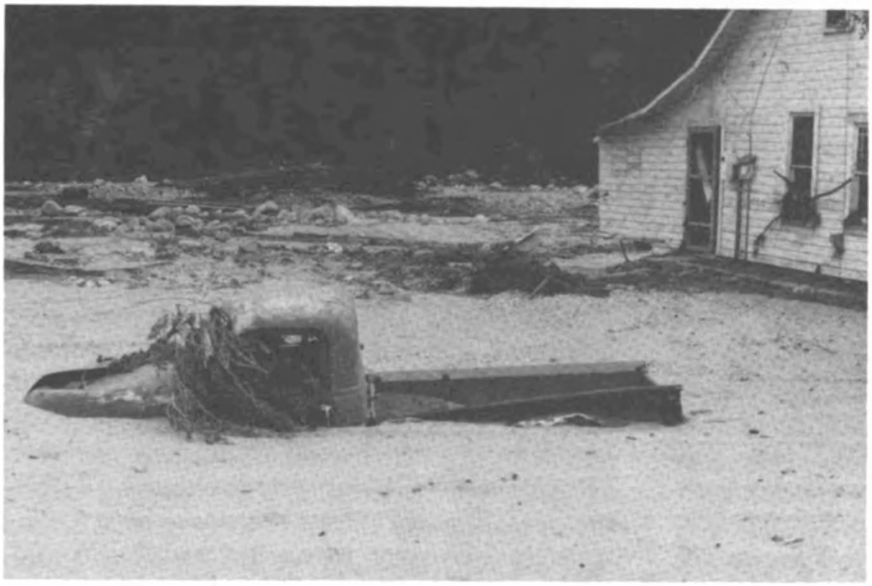
LIMITATIONS OF THE PRESENT SYSTEM

One reason for the present gap in the nation's ability to address natural hazard losses efficiently is that U.S. efforts in hazard mitigation have evolved slowly over many decades. They can be characterized as broken up, with responsibilities shared among federal, state, and local governments, as well as the private sector, professional organizations, voluntary organizations, the insurance industry, and the public in general. This diffusion of responsibilities stems partly from the historic role in government reserved for states and localities, and partly from the traditional perspective on natural hazards that views them as acts of God for which little anticipatory action is possible and to which postdisaster humanitarian relief is the most important response.

It is perhaps inevitable that the responsibilities for hazard mitigation will continue to be divided among a variety of organizations and agencies, both public and private. For example, land-use planning—such as control over the use of flood plains, steep slopes, and other hazard-prone areas—and adoption and upgrading of building codes will clearly remain local responsibilities, with hazard mitigation being balanced against other local objectives and constraints.

Thus, in the absence of a conscious effort to identify common objectives among diverse groups of interested parties, the fractionated approach to hazard management will be perpetuated. And yet it is clear from Chapter 2 that planning for and responding to natural hazards is a complex undertaking that, at its most successful, requires the integration of a diversity of planning and implementation activities. At present, the whole of the nation's hazard management activities is considerably less than the sum of its parts; a focused Decade is necessary to link the individual pieces in a coordinated and fruitful manner.

The nation's efforts in hazard management lack this coordination and the coherent focus it implies. At the federal level, the present program, both of research and implementation, reflects a piecemeal assemblage of activities as Congress



Flash floods in the United States commonly occur during the summer months, proving especially dangerous where terrain is steep. On Saturday evening, July 31, 1976, an intense thunderstorm stalled over a small portion of Big Thompson Canyon, Colorado, dropping 10 or more inches of rain in a 3-hour period. Aided by the steep mountain topography, the heavy runoff quickly formed a virtual wall of water displacing everything in its path. The toll: 139 dead and property damage exceeding $41 million. Here, a pickup truck rests partly buried in sand deposited by the North Fork (in background) near its confluence with the Big Thompson (stream flow is from left to right). (Source: U.S. Geological Survey.)

created new programs year by year—the National Flood Insurance Program in 1968 or the National Earthquake Hazard Reduction Program in 1977, for example—to address specific areas of concern. In other words, the nation's effort in hazard management is not the elaboration of a single policy of national need, drawn from an integrated view of the nation's overall hazard risk.

This is not to minimize the successes of present efforts and organizations, which represent the natural evolution of hazards policy as new science and technology and changing national priorities alter the perception of risks and the proper response to them. In fact, there have been notable examples of cooperation among federal agencies, as well as state and local governments. For example, the relatively small number of casualties during the volcanic eruption of Mount St. Helens in 1980 was a direct result of the cooperation of the U.S. Geological Survey (USGS), the U.S. Department of Agriculture's Forest Service, the Federal Emergency Management Agency (FEMA), and state and local government entities to restrict use of the area as much as 8 weeks prior to the eruption.

Nonetheless, the fact remains that the nation's hazard management capability is inadequate, fragmented, and generally focused on near-term and postdisaster activities. Perhaps because decision makers are not fully aware of the economic and humanitarian benefit potential of hazard mitigation, it is generally funded at a low level. Thus, the present U.S. system cannot address the task of reducing hazard risk in a comprehensive manner.

To acknowledge that the nation is largely ineffective in confronting natural hazards in an organized and anticipatory way is less a criticism of the present system of hazard management than a recognition of the fundamental progress that has been made in understanding hazards. The past two decades have been characterized by a revolution in knowledge of the origins of natural hazards. And, very simply, the mechanisms for absorbing and applying this knowledge to hazard reduction have not kept pace.

Evidence of the nation's recent and fundamental advances in hazard science abounds. For example, wide acceptance of the theory of tectonic plates has occurred only within the past 20 to 30 years. It is from this theory that the present understanding of subduction and other geological phenomena is derived—an understanding that underpins the ability to predict the location and likely timing of earthquakes, tsunamis, and volcanic eruptions, as well as the secondary effects (e.g., landslides, floods) they induce. Similarly, the science of meteorology has shifted dramatically in the last several decades from the descriptive to the predictive. Reasonable long-range forecasts are now possible, as well as highly accurate near-term predictions. For example, tornado occurrence probabilities and hurricane paths have been defined for the United States, and warning systems for these events have been improved significantly. In addition, for engineering design purposes, the estimation of maximum wind speed in tornadoes has been reduced from 500 mph to a more rational value of 250 mph.

This scientific progress is itself the result of technological advances enabling the acquisition and processing of data with much greater efficiency and accuracy than ever before. The advent of the computer as a research tool and the availability of satellite and remote-sensing equipment and telemetry devices have, to a great degree, provided the basis for this improved acquisition and interpretation of data. Even in the applications area—such as the structural analysis of buildings under wind load, or the performance of dams under earthquake excitation—analytic tools have greatly advanced the engineer's design and predictive capabilities.

In essence, it has been largely the success of federally sponsored research programs in the past 20 years that has brought the nation to the threshold of a cost-effective Decade for Natural Disaster Reduction and the tangible improvements in hazard mitigation it promises. If executed effectively, the activities of the Decade will embody a significant return on the hundreds of millions of dollars in research funds channeled over the years through the National Science Foundation (NSF), U.S. Geological Survey, National Oceanic and Atmospheric Administration (NOAA), Federal Emergency Management Agency, National Institute of Standards and Technology (formerly the National Bureau of Standards), U.S. Forest Service, and other government entities, as well as on the comparable activities of their counterpart organizations throughout the world. The message that it is now time to capitalize on the nation's research successes should be conveyed to key decision makers at all levels of government and in the private sector.

THE FEDERAL ROLE IN HAZARD MANAGEMENT

More effective and cost-efficient federal programs are one possible result of the Decade's activities. Clearly, much expertise in research and application is already at hand in various levels of government, albeit divided among many separate agencies with differing responsibilities. Within the federal system, at least 11 agencies have significant involvement in hazard reduction and response. For example, FEMA, in cooperation with state and local governments, identifies the nation's potential emergencies and facilitates mitigation, preparedness, and response measures. While FEMA holds this broad mandate, the responsibilities for hazard warning, assessment, research, data collection, planning, and mitigation, as well as disaster response, are shared by a number of federal authorities.

Each of the agencies contributing to national hazard management has its own emphasis. For example, under the National Earthquake Hazard Reduction Program, USGS plays the lead role in carrying out fundamental research for earthquake prediction and applied research for developing seismic hazard maps. USGS also administers the Landslide Hazards Reduction Program, which sponsors fundamental research on landslide processes for prediction, instrument development, warning, and landslide-susceptibility mapping for regional hazard reduction. In concert with FEMA and NSF, USGS also participates in communicating the results of its hazard assessments to the general public.

NOAA, through the National Weather Service, is responsible for meeting the nation's needs in weather forecasting. In addition, it conducts research relevant to floods, droughts, hurricanes, and tornadoes. In cooperation with USGS, NOAA also operates the nation's Tsunami Warning Program. NSF funds hazard-related research and development activities primarily at universities and in the private sector. In recent years, NSF has also begun to emphasize information dissemination.

The U.S. Forest Service operates the nation's wildfire program, which includes protecting 187 million acres of federal land, operating the national fire danger rating system, providing technical and financial assistance to state fire suppression programs, and conducting a major wildfire research program. In recent years, the Forest Service, working with the Office of U.S. Foreign Disaster Assistance (OFDA), has also cooperated actively in joint international activities.

The designation of the United States Decade will bring the prospect of uniting these many programs into a more integrated and functional whole. By fostering a multihazard approach to hazard management to replace the present practice of viewing hazard types singly, the Decade will engender a broader view of the nation's hazard risk. Already this view has begun to permeate the federal agencies. USDNDR will provide a coherent structure to allow this vision to manifest itself through better communication among agencies and in their dedication to a common list of priorities spanning all existing programs.

In addition, by raising the awareness of the risk of natural hazards, the Decade will encourage other agencies not presently involved in natural hazards management to contribute to the national program. The Department of Energy, the Environmental Protection Agency, and the Department of Defense (DOD) are examples of agencies having limited activities relating to natural hazard issues, but whose involvement in the Decade and in long-term hazard mitigation programs would be beneficial to meeting their mission objectives.

Participation of DOD would be particularly important. Aside from the activities of the U.S. Army Corps of Engineers, Naval Facilities Engineering Command, and Naval Civil Engineering Laboratory, the Department of Defense expends virtually no funds to cope with natural hazards as a threat to national security. This is true in spite of the considerable risk that natural hazards pose to many military facilities and sole-source defense

TABLE 2 U.S. Federal Expenditures for Research and Dissemination Activities on Natural Hazards, Excluding Drought, 1985 ($millions)

Agency*	Earthquake	Wind	Landslide	Flood	Wildfire	All Others With Remarks
FEMA	4.5	1.0	—	50.0	—	0.5[a]
NSF	28.0	0.8	1.0	0.8	—	—
USGS	32.0	—	2.0	—	—	—
NIST	0.5	—	—	—	—	—
NOAA	—	2.0	—	—	—	31.0[b]
DOT	—	0.2	—	—	—	—
USDA/SCS	—	—	—	2.0	—	—
USDA/FS	—	—	—	—	30.0	—
USACE	—	—	—	0.8	—	—
DOI/BuRec	—	—	—	0.02	—	—
HUD	—	—	—	—	—	0.2[c]
Total	65.00	4.0	3.0	53.6	30.0	31.7

*Total 1985 expenditures were $187.3 million.

NOTE: FEMA—Federal Emergency Management Agency; NSF—National Science Foundation; USGS—U.S. Geological Survey; NIST—National Institute of Standards and Technology (formerly National Bureau of Standards); NOAA—National Oceanic and Atmospheric Administration; DOT—Department of Transportation; USDA/SCS—U.S. Department of Agriculture/Soil Conservation Service; USDA/FS—U.S. Department of Agriculture/Forest Service; USACE—U.S. Army Corps of Engineers; DOI/BuRec—Department of Interior/Bureau of Reclamation; and HUD—Department of Housing and Urban Development.

[a]Dam safety.
[b]Meterological research.
[c]Subsidence, expansive soils, and wind and coastal flooding.

On February 26, 1972, heavy rains caused a coal refuse disposal dam to fail along Buffalo Creek in West Virginia, flooding the valley below and causing 118 deaths. The event left nearly 4,000 homeless and destroyed or seriously damaged about 850 houses and mobile homes. (Source: Uniphoto.)

manufacturers. According to a 1987 National Research Council study:

> Many defense installations are located in highly seismic areas of the United States and the world. Others are in areas of relatively low seismicity, but where major earthquakes—those of magnitude 6.0 and higher—can occur. . . . About 50 percent of the United States' missile and space vehicle business, 75 percent of its domestic microchip industry, 40 percent of its semiconductor business, and 20 percent of its optical instrument business are based in a highly seismic region in California.

A single major earthquake would thus have immediate as well as long-term consequences for the nation's military capability.

Table 2 summarizes the 11 federal agencies' 1985 budgets for hazard-related research and dissemination activities. (Disaster relief and fire suppression costs are not included.) As shown, significant levels of funding have been provided for certain programs: the national earthquake program, FEMA's flood mapping program, and the Forest Service's wildfire research. However, beyond these programs, the lack of effort in other areas is alarming. For example, in 1985, the nation spent only $4 million on wind research, $3.6 million on flood research (excluding the mapping program), and $3 million on landslide research. In the same year, damage from six hurricanes in the southeastern United States totaled $1.4 billion, while landslide losses exceeded $1 billion, according to several estimates.

Allocation of sufficient funds for the Decade's work must be based on the conviction that risk from natural hazards is a national priority with profound social and economic implications. With adequate resources provided, the nation can begin in earnest to build a sound hazard management program under the framework of the United States Decade. It also offers the opportunity to go beyond existing programs—to reach into areas of new technology and mitigation practice, to encourage more enlightened policy development, and to attain a higher level of hazard consciousness on the part of the public.

THE ROLE OF STATES AND LOCALITIES

The federal government must play a major role in the nation's efforts to reduce the toll from natural disasters, but it must be recognized that primary responsibility for emergency preparedness and response to natural disasters remains largely a state and local affair. In fact, significant responsibility for hazard reduction lies with local authorities; land-use planning and the adoption and enforcement of building codes being two examples. Both strategies, when based on thorough consideration of local hazards and then implemented over an extended period, are among the most effective measures available for saving lives and minimizing disruption should a major natural disaster occur.

Unfortunately, just as with the federal government, most state and local governments do not count natural hazard management among their highest priorities. Generally, a policy of inaction prevails until danger is imminent. This is not, sociologists have found, because people do not fear the threat of disaster. Rather, both citizens and public authorities become naturally preoccupied with more immediate concerns. In addition, even though hazards are very common in the aggregate, they are relatively rare from the standpoint of a given locale.

Despite this seeming public indifference, studies show that when given accurate and understandable information on the risks of a natural hazard, citizens—and their governments—will act. Information transfer concerning the nature of natural hazard threats and what can be done to minimize them is thus a key to reducing the impact of natural hazards on society. Government at all levels is involved in this process of public education, but current efforts are inadequate to meet the challenge of promoting hazard consciousness and to keep alive the spirit of readiness during the long periods between disasters. The U.S. Decade will constitute an ideal vehicle to initiate and perpetuate public hazard awareness. In addition to aiding in public awareness campaigns, the Decade will also emphasize research into the sociological component of hazard management: how and when risk is perceived or how hazard warnings are best communicated, for example.

BEYOND THE GOVERNMENT ROLE

Even though much of the authority for disaster response and hazard reduction lies with various levels of government, the expertise to effect these tasks is often scattered among many other organizations. Universities, for instance, provide a diversity of skills and resources, from the theoretical to the applied, in the physical sciences and engineering, and in the political and social sciences. Educators, too, represent a resource for raising public hazard consciousness to strengthen the grass-roots support for hazard mitigation and for training future hazard professionals.

The private sector—especially design and construction firms—also has invaluable practical experience in the application of mitigation strategies. Nor should the potential contributions of volunteer organizations, such as the Red Cross and Salvation Army, be overlooked. Their considerable talents and organizational structures, already invaluable in dispensing emergency aid, might also be useful in other parts of the hazard reduction effort. The U.S. Decade will seek to involve all of these many sources of hazard expertise, both in drawing up the Decade's plan of action and in effecting it at all levels.The private sector also plays an important role in shaping such policy tools as construction standards and land-use policies, and it is critical that the expertise of professional societies—industry standard setting groups, for example—be brought to bear in assuring that future practice is more hazard conscious. Indeed, much can be gained by a concerted effort to draw together the expertise and interests of a relatively broad array of professional societies, voluntary organizations, trade associations, industry standard setting groups, the media, and others with a special interest in and concern for the impacts of natural hazards. It is through these groups that professional awareness and expertise is enhanced, and information about advanced mitigation techniques is disseminated. They also provide an effective means for bringing new ideas to the attention of government bodies and the general public.

Among the key participants must be the insurance industry and the financial community in general. Successful natural hazard management includes the ability to compensate for hazard-induced losses and to maintain sufficient financial stability to allow stricken communities to rebuild their economic bases. This requires the insurance and banking industries to be fully conscious of the possible consequences of natural disasters and to have adequate resources and flexibility to cope with major natural disasters. Yet, until recently, financial institutions have largely ignored the dangers that such events might pose.

In the wake of a natural disaster, a well-prepared insurance industry can do much to alleviate the burden on financial institutions, on government, and on the general public. In the past few years, the nation's insurers have made great progress in assessing the impact of natural hazards on their industry. A recent study* conducted by the All-Industry Research Advisory Council (AIRAC) found that, in general, the existing insurance system works well in spreading risk from a major (perhaps $5 billion to $10 billion in losses) hazard event.

Unfortunately, the AIRAC study also demonstrated that the insurance system has definite limits in its ability to tolerate loss. For instance, while the industry could weather a single $7 billion storm with only moderate damage to its underwriting capability, a second $7 billion loss would damage enough companies to cause major market dislocations. In addition, the AIRAC study found that a single $14 billion insured loss, such as might be caused by a major earthquake, would be much more damaging to insurers than the two successive $7 billion losses, since many more companies would exhaust their reinsurance coverage. Clearly, faced with a $100 billion loss—the maximum property loss predicted for a major earthquake in southern California—the industry's capacity for compensating loss would be quickly exhausted.

A tsunami ("tidal wave") generated by a magnitude 7.2 earthquake on the Island of Hawaii washed debris into this Hawaiian lagoon on November 29, 1975. Tsunamis cause significant damage and loss of life in many regions of the world. The nation's entire western coastal region, including Alaska and Hawaii, are at risk from these destructive waves, which have killed nearly 6,000 people worldwide in the last decade alone. (Source: Internal Tsunami Information Center.)

This suggests that the insurance industry should work as a prime participant in United States Decade activities, with a view toward reducing its own exposure in hazard-prone areas. Insurers' risk will provide a major incentive for encouraging their customers to employ hazard-resistant design and construction practices and to consider the severity and frequency of likely hazards when selecting building sites for new facilities.

Insurers will also find rewards in working with professional societies, standard-setting groups, local governments, and volunteer organizations, as well as with the federal government, to foster the adoption of better predisaster planning, early warning systems, and postdisaster relief efforts. In other words, the insurance industry will prove a steady contributor to the Decade and a ready customer for the innovations in hazard mitigation and the increase in hazard-consciousness it could bring.

*Catastrophic Losses Committee. 1986. *Catastrophic Losses: How the Insurance Industry Would Handle Two $7 Billion Hurricanes*. Oak Brook, Ill.: All-Industry Research Advisory Council.

Framework for the United States Decade for Natural Disaster Reduction

FORMATION OF A U.S. NATIONAL COMMITTEE

The organizational mechanism needed to formalize and carry out an agenda for the United States Decade, identify the roles of the various participants, establish priorities and funding requirements, and perform many other critical tasks associated with the Decade does not exist and will thus have to be created. The first step in the organizational process is the formation of a U.S. National Committee to develop a detailed agenda for the Decade, using the committee's expertise to establish realistic research, implementation, and outreach goals.

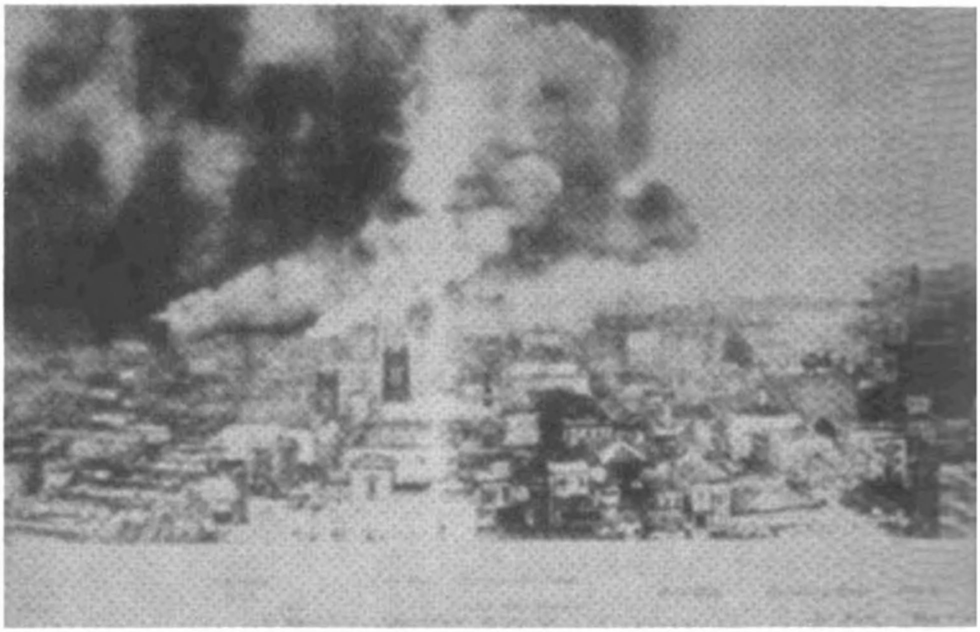
The agenda for the U.S. National Decade is clearly broad-based. It must encompass the full range of natural hazards and all the scientific, technological, behavioral, and cultural skills required to deal with them; public policy formulation at all levels of government; and data and information gathering and dissemination. It must also foster enhanced interaction among, and clarification of the roles of, professional societies, industry standard-setting groups, volunteer organizations, and corporations, as well as of educational institutions and the media. And, of course, the agenda must embody formal actions through policy, engineering, or education to lessen the nation's exposure to risk.

To ensure that these diverse elements are adequately addressed, the formation of a U.S. National Committee is critical, since responsibility spanning this range of interests and expertise is not centered in any one government agency or nongovernmental body. The committee should have expertise that can address the needs of each affected region in the nation, and it should benefit from the network of disaster experts found in various government agencies, universities, professional scientific and engineering societies, and other nongovernmental organizations.

The initial task of the national committee should be to oversee the preparation of the USDNDR work plan that identifies appropriate roles for key participants in the Decade—the relevant agencies of the federal government, state and local governments, the research and professional communities, volunteer agencies, and industry. Formation of such a national committee should be undertaken immediately so it can quickly begin developing a national agenda of activities for the Decade. This is critical because the results of the committee's efforts should dovetail with future federal budget processes as well as with other nations' activities undertaken under the aegis of the International Decade declared by the United Nations.

At the completion of the planning phase for the Decade the national committee should prepare a report detailing the Decade's goals, objectives, structure, and required resources. The report should be drawn in sufficient detail that it can be used to help guide both agency (federal, state, and local) budgets and programs as well as legislative initiatives.

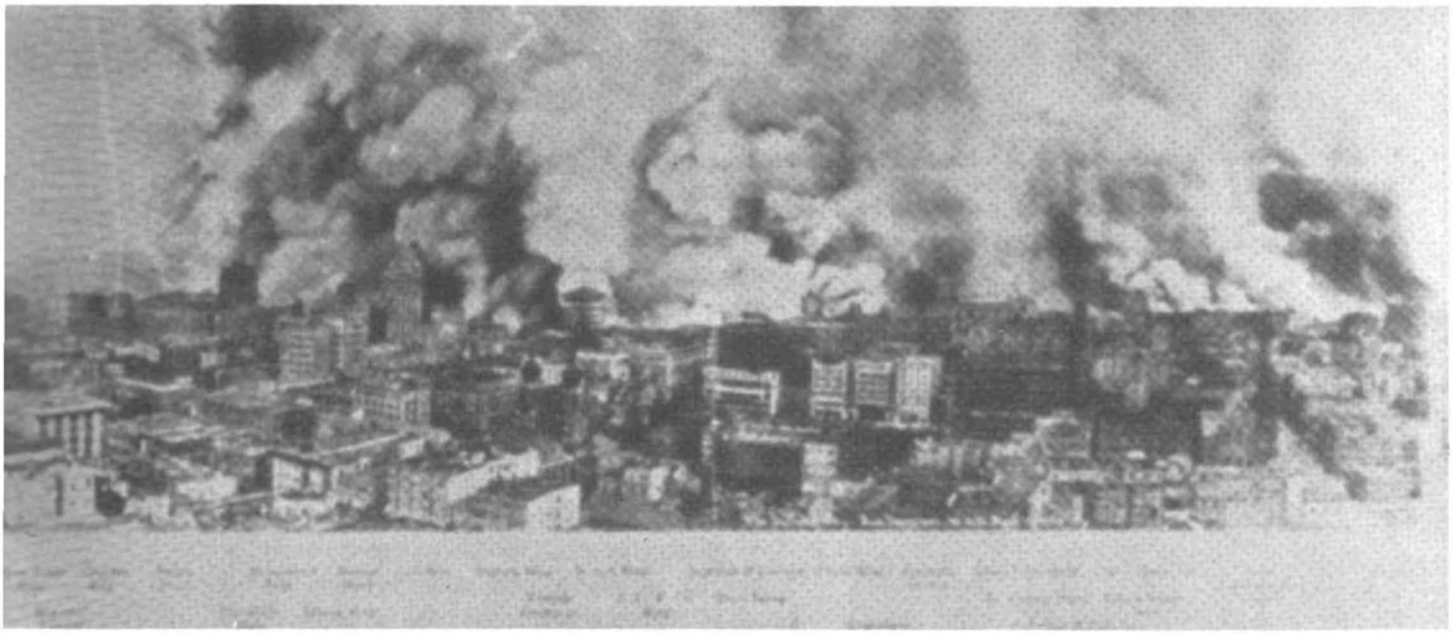
In addition to the national agenda, which is



The Great San Francisco earthquake of April 18, 1906 (magnitude 8.3), is recognized as one of the most significant earthquakes in modern U.S. history. A combination of quake damage and ensuing fires destroyed much of the city. This view from Mason Street at 10:00 a.m. on April 18—5 hours after the quake—shows a panorama of the city in flames. (Source: NOAA/NGDC.)

inherently tied to the federal government, the national committee will play an important role in coordinating regional efforts to develop specific plans and projects for the USDNDR. Consistent with the spirit of the United States Decade, individuals drawn from interested groups in all regions at risk from natural hazards should be involved in formulating these plans. One way to achieve this objective is to reach out regionally to assure broad participation in the planning process. Participants at the regional level should be encouraged to use common criteria to formulate USDNDR projects. Representative criteria to be invoked in defining projects include:

- access to study areas and data that are otherwise unavailable;
- efficient use of national experimental test facilities and laboratories;
- existence of a critical mass of knowledge and experience in the participating regional institutions and investigators;
- availability of a critical mass of investigative capabilities and commitments;
- enhancement of the flow of information and experience across local and regional geographic boundaries; and
- the promise of demonstrable results within the period of performance that clearly advance scientific and engineering understanding and that can be put into practice.



ISSUES FOR THE DECADE

The first task at hand is to identify and prioritize the Decade's scientific and technological activities. Creating this agenda is a complex task because of the rapid evolution in how each hazard is viewed and managed and because of the limited resources available for hazard mitigation. Nonetheless, the Decade will not want for issues. The extensive hazard research and mitigation activities of recent years have resulted in a host of opportunities for achieving meaningful hazard reduction in the course of the United States Decade of activities. These opportunities range from basic and theoretical research to technology and policy implementation, and they affect all stages of the hazard mitigation process, from predisaster planning to postdisaster reconstruction.

The following section is intended to illustrate the types of issues the Decade might include. It is not intended to be comprehensive or to rank the issues in terms of importance in the hazard reduction process—that is a role for the U.S. National Committee. Rather, this section suggests areas of activity, likely participants, and potential benefits, so that those considering the merits of the United States Decade for Natural Disaster Reduction will have a sense of its potential breadth and depth.

Prediction

Activities pertaining to prediction might include:

- standardization of predictions and warnings to assure both credibility and common understanding;
- interaction with the media for proper dissemination of both warnings and action advice;
- evaluation of predictions aimed at improving their credibility and value; and
- upgrading of the quality of warnings or of their lead time.

Land-Use Planning

Suggested land-use planning activities are:

- application of the knowledge of various hazards to zoning and other land-use planning techniques;
- coordination of land-use planning among the variety of hazards as well as among the many government entities involved;
- tying of land-use planning to hazard insurance programs to assure complementary, rather than conflicting, objectives;
- education and training of local government officials and land-use planners in addressing hazard risks; and
- minimization of risk for critical facilities, including the siting of hospitals, evacuation routes, and hazardous facilities.

Transported by flood waters from its original site along Buffalo Creek, this local church ended its journey straddling damaged railroad tracks. In addition to the loss of life and personal property it caused, the Buffalo Creek flood also destroyed critical infrastructure elements, such as power, water, and sewer facilities, bridges, highways, and rail lines. (Source: Uniphoto.)

Construction

This issue area might include the following activities:

- improvement of design criteria for earthquake, wind, and flood resistance;
- development of means for testing existing structures to determine whether they are hazard prone;
- development of improved retrofit techniques for existing hazard-prone structures;
- improvement of risk-based analysis for buildings and communities;
- improvement of siting and construction techniques for critical facilities;
- training of architects, engineers, and others involved in design and construction in issues associated with natural hazard resistance; and
- development of construction techniques with "controllable failure modes" (e.g., for dams and high-rise structures).

Lifeline Maintenance

Lifeline maintenance activities might include:

- location of critical facilities (hospitals, evacuation routes, evacuation facilities, telecommunications equipment, emergency equipment, and critical utilities such as water, sewer, and energy lines) so as to reduce their exposure to risk;
- prevention or mitigation of the effects of fires following earthquakes; and
- development of redundant systems for providing critical services.

Insurance

Insurance activities might include:

- evaluation of the role of the private insurance industry in fostering hazard-resistant design and construction;
- development of public programs and their impact on private sector investment in hazard-prone areas;
- incorporation of hazard reduction criteria into federal grant programs for such facilities as schools, residences, highways, airports, industrial development facilities, and recreation areas;

▸ improved correlation of insurance costs with likely risks; and

▸ mandating of insurance as a means for reducing exposure by internalizing the cost of risk into public and private decision-making processes.

Education

Education activities might include:

▸ development of formal training programs for hazard reduction specialists, covering not just postdisaster response, but also predisaster planning relating to land use, telecommunications, emergency services, infrastructure protection, building codes, and hazard mapping;

▸ introduction of hazard mitigation concepts into coursework in architecture, civil engineering, geology, land-use planning, finance, insurance, and other subjects contributing to the hazard reduction cycle;

▸ provision for the continuity of research and application efforts after the Decade has elapsed by assuring a reliable supply of trained personnel with advanced university degrees to carry on and strengthen the work of reducing the consequences of natural hazards;

▸ development of programs that cut across individual hazards, so that mitigation techniques do not work at cross-purposes and efficiencies in the provision of mitigation services are provided efficiently; and

▸ development of curricula for elementary and secondary schools to raise the level of awareness of the general public about how to plan for and respond to natural hazards.

Postdisaster Programs

Suggested postdisaster program areas are:

▸ training of emergency search and rescue and medical workers;

▸ maintenance of the public health; and

▸ meeting of infrastructure needs.

Social Science

Suggested social science activity areas are:

▸ understanding of public attitudes in regard to low-probability, high-risk events, such as earthquakes, volcanic eruptions, or tsunamis;

▸ development of a means for conveying warnings or instructions in an efficient and unambiguous manner while avoiding panic or disbelief;

▸ identification of similarities and differences in behavior when confronting various hazards, and application of this knowledge to improve hazard mitigation practice; and

▸ study of cultural issues within the United States and abroad that affect the delivery and understanding of messages on hazard risk and the response to this risk.

Intra- and Intergovernmental Issues

Governmental issues might include the following:

▸ strengthening of communication links among federal officials;

▸ building of improved links among federal, state, and local levels of government;

▸ assuring that the federal government receives inputs from officials at the state and local levels; and

▸ development of efficient lines of authority for decision making in single- and multiple-hazard events.

Demonstration Projects

Such demonstration projects might include:

▸ performance of a multihazard risk assessment for a selected region, including analysis of the reduction in risk offered by various mitigation strategies; such a demonstration project could be followed by disseminating what is learned to other areas of the country, as well as to other nations through the IDNDR framework;

▸ performance of jointly funded activities among various levels of government and the private sector (e.g., the insurance industry) so that costs are shared equitably and all participants are committed to implementing the results; and

▸ post hoc evaluation of such projects to determine their general validity and potential for broad dissemination.

Basic Research

Basic research activities might include the following:

- identification of key research areas in which potential advances could lead to significant improvements in the effectiveness or efficiency of hazard mitigation;
- identification of key laboratory equipment and other facilities needed to continue significant advances in hazard mitigation;
- comparison of research requirements for many different hazards to identify common research opportunities;
- development of possible experimental mechanisms for testing hypotheses at lower risk or lower cost than full-scale demonstration projects;
- identification of skill groups critical to assuring continued advances in hazard science; and
- agreement on suggested roles for the federal government, universities, and others in supporting research, training, and implementation activities.

Data Handling and Information Flow

Suggested activities are:

- clarification of the role of the media in disseminating predisaster warnings and in reporting on postdisaster needs—both in support of the specialist community and the general public;
- improvement of data volume and quality via upgraded sensors and reporting mechanisms;
- standardization of data, particularly on an international level, to improve their comparability;
- implementation of improved data storage and retrieval; and
- development of enhanced analytical methods to improve prediction.

International Activities

International activities might be:

- establishment of a liaison, as appropriate, with the United Nations Secretariat, which is responsible for coordinating the International Decade for Natural Disaster Reduction;
- interaction and cooperation with other national committees or counterpart organizations formed by countries participating in the IDNDR;
- communication with foreign and international organizations or institutions representing the disciplines and professions associated with natural hazards;
- development of a consistent international monitoring and telecommunication system to provide early warnings throughout the world for all classes of natural hazards;
- development of consistent data base methodologies to improve the accuracy of data collection and to enhance availability;
- comparison of alternative technological, cultural, sociological, and geopolitical means for addressing similar hazards;
- dissemination of information from the U.S. hazard reduction community to other countries, and transmittal throughout the United States of information offered by other countries; this would include significant research activities and results, publications of broad interest, and announcements of conferences or other special calendar events;
- coordination of activities with the Agency for International Development's Office of U.S. Foreign Disaster Assistance, abiding by policy directives and legislation governing U.S. international disaster assistance as established under the Foreign Assistance Act of 1961, as amended;
- coordination of cooperative scientific and engineering investigations through appropriate U.S. agencies (e.g., NSF, FEMA, USGS, NOAA) under bilateral agreements established in cooperation with the Department of State; and
- promotion of the timely planning of actions to follow the occurrence of a natural disaster in the United States or other countries and the signing of bilateral and multilateral agreements for implementing these actions; such planning should cover the provision of mutual assistance, the sending or receiving of reconnaissance missions, and the performance of postdisaster studies.

The additional volume of new data expected during the decade is enormous. If activities are to be successful—with information accessible to all—it is crucial that attention be focused on handling these new data and organizing them into a useful information system. Communicating this information also requires attention. A

The United States leads the world in the occurrence of tornadoes. On average, 900 tornadoes—some with wind speeds approaching 300 mph—strike the nation's midsection each year. On December 14, 1987, a tornado touched down in West Memphis, Arkansas, with wind speeds estimated at 150–200 mph. The twister killed six people and destroyed 140 houses, 200 apartments, and 30 businesses at a total cost of $35 million. The roof and walls of Maddox Elementary School, shown here, suffered total collapse. Fortunately, the school was unoccupied at 9:30 p.m. when the tornado struck. (Source: National Research Council.)

primary focus of the USDNDR should be to improve communication between researchers and those responsible for applying the knowledge gained from research. New routes—such as clearinghouses—for disseminating data should be explored, and special education programs for builders, local planning and building officials, emergency managers, and other professionals should be developed.

STRUCTURE OF THE U.S. NATIONAL COMMITTEE

The U.S. National Committee should be compact, with an upper limit of perhaps 20 people. To the degree possible, it should embody expertise on the full spectrum of natural hazards to which the nation is exposed. This expertise should reflect both research and practice, including the roles of government at all levels.

Realistically, the spectrum of hazards is so broad, as is the scientific and technological expertise drawn on in mitigating natural hazards, that no single committee can possibly accommodate members drawn from all the interested groups in academia, government, industry, professional societies, and volunteer organizations. Thus, the core committee will have to develop mechanisms to assure that the full breadth of issues is considered and that communications are established among previously autonomous groups with common interests. Such mechanisms could include regional workshops, and perhaps specialized subcommittees or linkages with professional societies in relevant fields.

As implied above, the national committee's core membership should draw heavily from experts in hazard science and implementation, since it is the recent progress in these areas that forms the basis for the very concept of the United States Decade. At the same time, the national committee must also include or establish liaison with representatives of federal, state, and local governments, as well as with volunteer organizations, professional societies, and trade groups. A successful decade will require the concurrence of these latter groups in adapting current practice to reflect the improved base of knowledge.

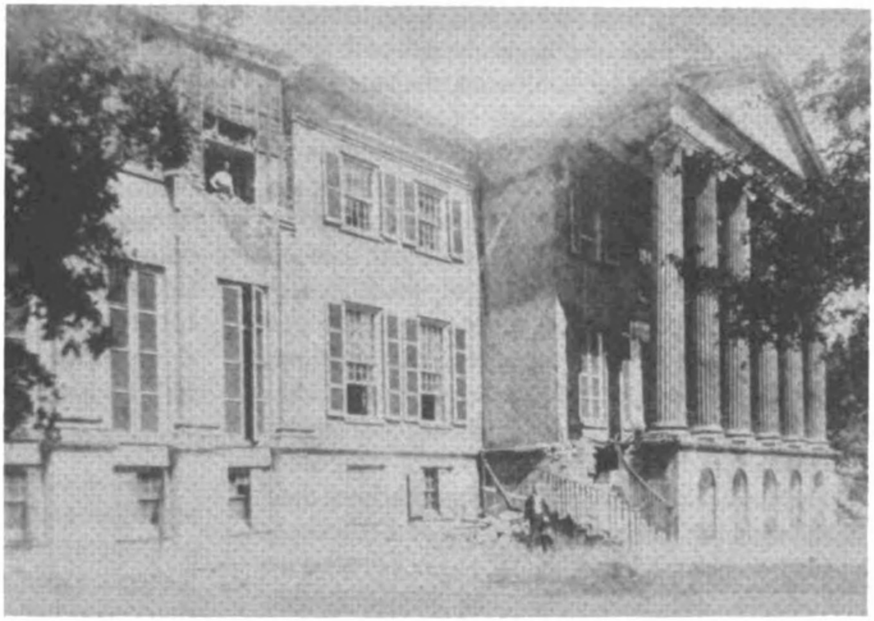
Although planning for and responding to natural hazards is the responsibility of many levels of government, as well as others in volunteer organizations and industry, the federal government plays several uniquely important roles in hazard mitigation. First, because of its national and international perspectives, the federal government maintains a broader and more comprehensive view of the problems and opportunities in hazard management than do other participants in the process. The federal government also facilitates (often through the National Research Council) the creation of mechanisms to bring together a wide variety of scientific and technological expertise. This coordinating role—whether for research, information dissemination, or hazard response—provides the means that will allow the advances of the past two decades to be brought to bear on future hazard mitigation efforts. In addition, the federal government is the predominant source of funding in the United States for the research that has enabled the hazard knowledge base to expand so significantly.

Realistically, formation of the U.S. National Committee requires a federal impetus. Outside the federal government the hazard mitigation community is even more fractionated than within it and must operate with much more limited resources than its federal peers. Nonfederal entities could and should participate in a national committee, but are less expected to initiate or financially support such an activity. However, benefits accruing to the federal government from its support are expected to more than outweigh the government's initial contributions. For example, the committee could enhance the level of dialogue between research-oriented and implementation-oriented agencies within the federal system. It also could serve to review objectively the historic agendas of federal agencies and suggest possible alternatives based on agency performance and the changing priorities in the field of hazard management.

Thus, it is the view of the Advisory Committee that the federal government should play a leadership role in fostering the United States Decade for Natural Disaster Reduction. The federal government will be a major beneficiary of the likely activities in the form of more efficiently allocated funds; improved synergy among its diverse programs; improved transfer of knowledge from the federal government to other levels of government, as well as to volunteer groups, industry, and the public in general; and reduced exposure to loss both at federal facilities at risk and through the federal insurance and disaster relief programs.

Agency

Government agencies with significant responsibilities in hazard mitigation include the Federal Emergency Management Agency, National Science Foundation, U.S. Geological Survey, National Oceanic and Atmospheric Administration, U.S. Army Corps of Engineers, U.S. Forest Service, Agency for International Development, and Department of State. More specialized roles are played by the Department of Defense, National Institute of Standards and Technology, Environmental Protection Agency, Department of Energy, Nuclear Regulatory Commission, General Services Administration, Department of Housing and Urban Development, Department of Education, and others. The United States is confronted by all the rapid-onset natural hazards addressed in the International Decade for Natural Disaster Reduction called for by the United Nations, namely earthquakes, volcanic erup-



On August 31, 1886, a magnitude 7.7 earthquake struck Charleston, South Carolina, killing 60 people and serving as a reminder that the East Coast is not immune from major seismic activity. Damage to Charleston College is shown here. (Source: South Carolina Art Association.)

tions, tsunamis, landslides, floods, tropical storms, tornadoes, wildfires, and insect infestations. The federal role ranges over the spectrum from planning and research to prediction and postdisaster relief. The specific roles include basic and applied research; predisaster planning (hazard mapping, hazard data gathering and analysis, information dissemination); monitoring and early warning systems (including linkages with local officials and with the public media); hazard mitigation technologies (including flood control, dam construction and maintenance, selected land-use controls, particularly on public lands, and construction standards for federally reviewed or supported facilities); education of key groups (including local civil defense officials and, selectively, the general public); postdisaster relief (including both civil defense and national guard activities); and financing mechanisms (including flood plain insurance and disaster area designations).

PARTICIPANTS IN AND BENEFICIARIES OF A U.S. NATIONAL COMMITTEE

The U.S. National Committee, in addition to serving the obvious needs of the federal government, will have considerable value to the following sectors.

▸ *State and local governments*. While the federal government has principal responsibility for hazard warning (e.g., through the activities of USGS and NOAA), states and localities are principally responsible for land-use planning; building codes; fire, police, and other protective services; and postdisaster relief efforts.

▸ *Volunteer organizations*. The American Red Cross, volunteer firefighters, and other volunteer organizations play a critical supportive role in postdisaster relief efforts. These organizations have expressed an interest in fostering a greater level of preparedness. They can play a key role in evacuation efforts as well as in ensuring that communities are better educated about hazard preparedness and are more cognizant of opportunities to enhance hazard mitigation.

▸ *Insurance industry*. Property insurers, as well as financial institutions, have the potential to play a greater role in reducing natural hazards if they have an improved basis for making insurability and rate decisions. Building construction techniques, the presence of warning systems, and the proximity to fire hydrants have always played a role in fire insurance rates and access to mortgages, for example. Improved data bases and knowledge concerning mitigating techniques not only can improve the performance of the insurance industry, but also can make it an effective tool in promoting hazard-resistant behavior on the part of the insured or the borrowing public.

▸ *Professional societies*. Organizations of scientists, engineers, and others with direct or partial interests in hazard mitigation can utilize the Decade as a means for coalescing their activities and for disseminating state-of-the-art knowledge to their members. The Decade and the national committee can provide a forum for bringing the expertise of these groups to bear on reducing the impact of natural hazards.

▸ *Research community.* A highly visible, public discussion of the status of knowledge and of critical research issues to be addressed can help to set national research priorities, create better linkages among researchers both within and across disciplines and throughout the world, and identify adjunct activities or resources, such as data bases, that can enhance the quality and efficiency of future research.

▸ *Media.* The principal role of the media, whether electronic or print, is to report and analyze events as or after they occur. The electronic media, when coupled to the predictive capabilities that the federal government has developed and the evacuation plans drawn up by state and local governments, can play an especially important role in hazard reduction through early warnings and suggested protective actions. Public and commercial television networks, for example, could play a useful role in developing and presenting educational programs for public education. The print media can address the longer-term issues of public information and education and can serve as a forum for discussions of how land-use planning and other hazard mitigation strategies can be implemented.

▸ *Voluntary standard-setting groups.* These groups play critical roles in where and how various buildings and facilities are designed and constructed. Their membership is drawn from professional societies, trade organizations, and other practitioners and user groups. Thus, enhancing their awareness of hazard mitigation strategies can have an enormous impact on future construction practices through their input to building codes, zoning regulations, and other land-use planning tools.

▸ *User groups.* Groups ranging from individual citizens to large corporations with lives or major facilities at risk will have a focal point to which to address their questions and to help them gain sufficient knowledge to make intelligent decisions about new investments or the protection of existing facilities.

▸ *The general public.* The public should be viewed as a direct user and beneficiary of the Decade's efforts. Greater public awareness of natural hazards and basic mitigation strategies can have salient effects on predisaster planning (e.g., selecting housing), and on actions taken during a hazard event (e.g., heeding broadcasted warnings), or subsequent to an event (knowing first aid or having access to emergency supplies). Involvement of the general public in disaster drills, as is commonplace in Japan, is one potentially valuable Decade activity.

One means for portraying skill groups with potential involvement in the Decade, and for visualizing opportunities for synergistic research, is by arraying the various categories of natural hazards against the different types of expertise that can enhance the United States' ability to cope with these hazards. If a three-dimensional matrix were prepared, the axes would consist of:

▸ the various types of *hazards;*

▸ scientific, technological, and other professional *skill groups;* and

▸ prediction, prevention, preparedness, and postdisaster *activities.*

The *hazards* axis would consist of earthquakes, volcanic eruptions, tsunamis, landslides, floods, hurricanes, tornadoes, wildfires, and insect infestations.

The *skill groups* axis, at a minimum, would consist of meteorologists, seismologists, geophysicists, geologists, geotechnical engineers, structural engineers, land-use planners, hydrologists, behavioral and social scientists, government specialists, and communication experts.

The *activities* axis would consist of the four broad categories delineated below—prediction, prevention, preparedness, and postdisaster activities.

1. *Prediction:* the process of identifying reliably and in a timely fashion an oncoming natural hazard event. Embodied within the rubric of prediction are:

- ▸ Technical strategies—monitoring systems (satellites, remote sensors, and telemetry equipment), data collection and sharing, and computer modeling; and
- ▸ Social considerations—communication for effective public and institutional responses, mobilization of emergency personnel and

equipment, evacuation strategies, and assurance of the credibility of the warnings.

2. *Prevention:* the process of eliminating a hazard before it can cause damage. This element includes:

- Technology in hand—flood control dams, diversion structures for debris flows, fire breaks, and other techniques to eliminate a hazard; and
- Possible future technologies—such as, altering weather patterns and diffusing pent-up earthquake stresses.

3. *Preparedness:* the use of technical, institutional, financial, public policy, educational, and sociological means to reduce the exposure to hazards and hazard-related losses. Preparedness includes:

- Technical measures—zoning and building codes and evaluation and retrofitting of existing buildings; and
- Social measures—training of emergency personnel in medical as well as psychological and spiritual support, public education for effective individual disaster response and evacuation, and financial buffers for individuals and institutions.

4. *Postdisaster:* the immediate disaster response effort as well as the longer-term process of restoring the physical and social environments to a noncrisis state. Within the postdisaster domain are the following:

- Technical responses—telecommunications systems for directing relief personnel and equipment; rescue, clean-up, and reconstruction technologies; structural analysis and damage assessment techniques; and seeding and replanting vegetation; and
- Social responses—emergency medical support; psychological and spiritual support; effective emergency food, clothing, housing, and information systems; and financial strategies for reconstruction and recovery.

CONCLUSION

The Advisory Committee believes that establishing a United States Decade for Natural Disaster Reduction offers an effective means to marshal the nation's expertise in all areas of hazard mitigation and to unite its many separate hazard reduction programs into an integrated national effort. In addition, it also provides the appropriate mechanism for U.S. participation in the International Decade for Natural Disaster Reduction.

Thus, the need for a U.S. Decade is driven by the mismatch between the nation's potential for hazard mitigation and its accomplishments to date. With relatively little additional resources the United States can do significantly more to reduce the toll from natural hazards. The nation's greatly improved knowledge base in science and technology, its improved sensors and telecommunications, and the awareness of common elements in mitigating diverse natural hazards can now be exploited at low cost and with considerable potential benefit. It is apparent that the nation's means for organizing hazard mitigation activities has not adapted to the changing level of knowledge and expertise available. Facilitating organizational changes and enhanced cooperation among key participants would be a significant goal of the Decade.

Achieving the goals of the United States Decade requires a major program of research, technical development, policy development, implementation, and public education and communication. Such a program must be planned for quickly if it is to be implemented by 1990. To do so requires the establishment of a U.S. National Committee for the United States Decade; the Advisory Committee recommends that this be done as soon as possible. The national committee should have federal support and its membership should consist of national leaders engaged in hazard mitigation research and implementation activities.

The overall objective of the Decade is to set in motion programs and policies that will stimulate public hazard consciousness, resulting in wider use of proven hazard mitigation practices and the development of new information and improved practices in the future. The intent is to reduce significantly the impacts of natural hazards during the Decade and to set in place mechanisms that will assure continued progress thereafter. A successful Decade can greatly reduce this nation's toll in lives and property lost due to natural hazards, and can establish institutional mechanisms and public attitudes that will have a lasting beneficial effect on hazard mitigation.

Principal Source Materials

Advisory Board on the Built Environment. 1983. Multiple Hazard Mitigation. National Research Council. Washington, D.C.: National Academy Press.

Advisory Committee on Emergency Planning. 1975. Earthquake Prediction and Public Policy. National Research Council. Washington, D.C.: National Academy Press.

Advisory Committee on the International Decade for Natural Hazard Reduction. 1987. Confronting Natural Disasters: An International Decade for Natural Hazard Reduction. Washington, D.C.: National Academy Press.

Alesch, D. J., and W. J. Petak. 1986. The Politics and Economics of Earthquake Hazard Mitigation. Program on Environment and Behavior Monograph No. 43. Boulder, Colorado: Institute of Behavioral Science.

Alexander, R. H. 1987. Recent developments in digital map data bases and geographic information systems (GIS) as they may apply to earthquake loss estimation. Synopsis of presentation to the Earthquake Loss Estimation Panel, January 8, 1987, National Research Council, Washington, D.C.

Algermissen, S. T., and K. V. Steinbrugge. 1984. Seismic hazard and risk assessment: Some case studies. The Geneva Papers on Risk and Insurance, vol. 9, no. 30, January 1984.

American Meteorological Society. 1976. The Hurricane Problem. Bulletin of the American Meteorological Society 57:8.

Arnell, N. W. 1984. Flood Hazard Management in the United States and the National Flood Insurance Program. Geoforum 15:525-542.

Arnold, C., and R. K. Eisner. 1984. Planning Information for Earthquake Hazard Response and Reduction. San Mateo, California: Building Systems Development, Inc.

Baker, E. J. 1977. Public Attitudes Toward Hazard Zone Controls. Journal of the American Institute of Planners 43:401-408.

Benoit, L. J., S. Whyte, and M. Phaneuf. 1987. Legislation and Implementation of Research on Natural Disasters Mitigation. Report submitted to the National Science Foundation. Washington, D.C.: National Science Foundation.

Blair, M. L., and W. E. Spangle. 1979. Seismic Safety and Land-Use Planning: Selected Examples from California. U.S. Geological Survey Professional Paper 941-B. Reston, Virginia: U.S. Geological Survey.

Bolt, B. A., W. L. Horn, G. A. MacDonald, and R. F. Scott. 1975. Geological Hazards. New York: Springer-Verlag.

Burby, R. J., and S. P. French. 1981. Coping with Floods: The Land Use Management Paradox. Journal of the American Planning Association 47:289-300.

Burton, I., R. W. Kates, and G. F. White. 1976. The Environment as Hazard. New York: Oxford University Press.

Catastrophic Losses Committee. 1986. Catastrophic Losses: How the Insurance Industry Would Handle Two $7 Billion Hurricanes. Oak Brook, Illinois: All-Industry Research Advisory Council.

Comfort, L. K. 1988. Managing Disaster—Strategies and Policy Perspectives. Durham, North Carolina: Duke University Press.

Committee on the Alaska Earthquake. 1973. The Great Alaska Earthquake of 1964. National Research Council. Washington, D.C.: National Academy Press.

Committee on Disasters and the Mass Media. 1980. Disasters and the Mass Media. National Research Council. Washington, D.C.: National Academy Press.

Committee on Earthquake Engineering. 1987. Review of Phase I of the National Earthquake Engineering Experimental Facility Study. National Research Council. Washington, D.C.: National Academy Press.

Committee on Ground Failure Hazards. 1985. Reducing Losses from Landsliding in the United States. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1978. Flood of July 1976 in Big Thompson Canyon, Colorado. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1981. The Kalamazoo Tornado of May 13, 1980. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1983. Hurricane Iwa, Hawaii, November 23, 1982. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1984. The Tucson, Arizona Flood of October 1983. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1984. The Utah Landslides, Debris Flows, and Floods of May and June 1983. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1985. Hurricanes Iwa, Alicia, and Diana—Common Themes. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1985. The Los Angeles, California Tornado of March 1, 1983. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1986. An Advance Report: Recommendations for Improving the Existing Warning System for an Impending Eruption of the Nevado del Ruiz Volcano, Colombia, S.A. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1986. Hurricane Diana, North Carolina, September 10-14, 1984. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1986. Research Agenda: Learning from the 19 September, 1985 Mexico Earthquake. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters. 1986. The October 1985 Landslide at Barrio Mameyes, Ponce, Puerto Rico. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters/California Institute of Technology. 1982. Storms, Floods, and Debris Flows in Southern California and Arizona—1978 and 1980. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters/Earthquake Engineering Research Institute. 1981. Earthquake in Campania-Basilicata, Italy, November 1980. National Research Council. Washington, D.C.: National Academy Press.

Committee on Natural Disasters/U.S. Geological Survey. 1984. Debris Flows, Landslides, and Floods in the San Francisco Bay Region, January 1982. National Research Council. Washington, D.C.: National Academy Press.

Cuny, F. C. 1983. Disasters and Development. New York: Oxford University Press.

Drabek, T. E. 1986. Human System Responses to Disaster: An Inventory of Sociological Findings. New York: Springer-Verlag.

Drabek, T. E., A. H. Mushkatel, and T. S. Kilijanek. 1983. Earthquake Mitigation Policy: The Experiences of Two States. Program on Environment and Behavior Monograph No. 37. Boulder, Colorado: Institute of Behavioral Science.

Federal Emergency Management Agency (FEMA). 1988. Report to the United States Congress—National Earthquake Hazards Reduction Program: Fiscal Year 1987 Activities. Washington, D.C.: FEMA.

FEMA. 1980. An assessment of the consequences and preparations for a catastrophic California earthquake: Findings and actions taken. Prepared from analyses carried out by the National Security Council Ad Hoc Committee on Assessment of the Consequences and Preparations for a Major California Earthquake. Washington, D.C.: FEMA.

FEMA. 1985. National Multihazard Survey Instructions (TR-84). Washington, D.C.: FEMA.

Fernandez, A. 1979. The Relationship Between Disaster Assistance and Long-Term Development. Disasters 3(1):32-36.

Friesema, H. P., J. Caporaso, G. Goldstein, R. Lineberry, and R. McCleary. 1979. Aftermath: Communities After Natural Disasters. Beverly Hills/London: Sage Publications.

Fujita, T. T., et al. 1976. U.S. Tornadoes 1930-1974 (map). The University of Chicago, Chicago, Illinois.

Funaro-Curtis, R. 1982. Natural Disasters and the Development Process: A Discussion of Issues. Prepared for the Office of U.S. Foreign Disaster Assistance. Washington, D.C.: Agency for International Development.

Geipel, R. 1982. Disaster and Reconstruction. London: Allen and Unwin.

Haas, J. E., R. W. Kates, and M. Bowden, eds. 1977. Reconstruction Following Disaster. Cambridge, Massachusetts: MIT Press.

Kreimer, A. 1978. Post-Disaster Reconstruction Planning: The Cases of Nicaragua and Guatemala. Mass Emergencies 3(1):23-40.

Laube, J., and S. A. Murphy, eds. 1985. Perspectives on Disaster Recovery. East Norwalk, Connecticut: Appleton-Century-Crofts.

Mileti, D. S., T. E. Drabek, and J. E. Haas. 1975. Human Systems in Extreme Environments: A Sociological Perspective. Boulder, Colorado: Institute of Behavioral Science.

Ministry of Construction, Japan. 1983. Reference Manual on Erosion Control Works. Erosion Control Department.

National Oceanic and Atmospheric Adminstration. 1984. Tsunamis in the Pacific Basin 1900-1983. National Geophysical Data Center and World Data Center A for Solid Earth Geophysics.

Office of U.S. Foreign Disaster Assistance. 1987. Disaster History: Significant Data on Major Disasters Worldwide, 1900-Present. Washington, D.C.: Agency for International Development.

Olson, R. S., and D. C. Nilson. 1982. Public Policy Analysis and Hazards Research: Natural Complements. Social Science Journal 19(1):89-103.

Petak, W. J., and A. A. Atkisson. 1982. Natural Hazard Risk Assessment and Public Policy: Anticipating the Unexpected. New York: Springer-Verlag.

Petak, W. J., ed. 1985. Emergency Management: A Challenge for Public Administration. Public Administration Review, Vol. 45. Washington, D.C. American Society for Public Administration.

Quarantelli, E. L. 1982. General and Particular Observations on Sheltering and Housing in American Disasters. Disasters 6(4):277-281.

Rubin, C. B. 1979. Natural Disaster Recovery Planning for Local Public Officials. Columbus, Ohio: Academy for Contemporary Problems.

Rubin, C. B., M. D. Saperstein, and D. G. Barbee. 1985. Community Recovery from a Major Natural Disaster. Program on Environment and Behavior Monograph No. 41. Boulder, Colorado: Institute of Behavioral Science.

Rubin, C., B. A. M. Yezer, Q. Hussain, and A. Webb. 1986. Summary of Major Natural Disaster Incidents in the U.S.: 1965 to 1985. Washington, D.C.: Federal Emergency Management Agency.

Saarinen, T. F., ed. 1982. Cultivating and Using Hazard Awareness. Program on Environment and Behavior Monograph No. 35. Boulder: University of Colorado Natural Hazards Information Center.

Scheidgger, A. E. 1975. Physical Aspects of Natural Catastrophes. New York: Elsevier.

Schuster, R. L., and R. J. Krizek, eds. 1978. Landslides: Analysis and Control. Transportation Research Board Special Report 176. National Academy of Sciences. Washington, D.C.: National Academy Press.

Schuster, R. L., and R. W. Fleming. 1986. Economic Losses and Fatalities Due to Landslides. Bulletin of the Association of Engineering Geologists 23(1):11-18.

Slosson, J. E. 1969. The Role of Engineering Geology in Urban Planning. Colorado Geological Survey Special Paper, pp. 8-15.

Southern, R. L. 1979. The Global Socioeconomic Impact of Tropical Cyclones. Australian Meteorological Magazine 27(4):175-195.

Tilling, R. I. 1975. Volcanoes. U.S. Geolgical Survey. Washington D.C.: U.S. Government Printing Office.

Turner, R. H., J. M. Nigg, and D. H. Paz. 1986. Waiting for Disaster: Earthquake Watch in California. Berkeley: University of California Press.

U.S. Geological Survey. 1982. Goals and Tasks of the Landslide Part of a Ground-Failure Hazards Reduction Program, Circular 880. Reston, Virginia: U.S. Geological Survey.

Water Science and Technology Board. 1985. Drought Management and Its Impact on Public Water Systems. National Research Council. Washington, D.C.: National Academy Press.

White, G. F., and J. E. Haas. 1975. Assessment of Research on Natural Hazards. Cambridge, Massachusetts: MIT Press.

Working Group on Earthquake Hazards Reduction. 1978. Earthquake Hazards Reduction: Issues for an Implementation Plan. Office of Science and Technology Policy. Washington, D.C.: Executive Office of the President.

Wright, J. D., P. H. Rossi, S. R. Wright, and E. Weber-Burdin. 1979. After the Clean-Up: Long-Range Effects of Natural Disasters. Beverly Hills/London: Sage Publications.

Zaruba, O., and V. Mencl. 1982. Landslides and Their Control. New York: Elsevier.

General Reading

Ballard, F. M. 1984. Volcanoes of the Earth. Austin: University of Texas Press.

Blair, M. L., T. C. Vlasic, W. R. Cotton, and W. Fowler. 1985. When the Ground Fails: Planning and Engineering Response to Debris Flows. Program on Environment and Behavior Monograph No. 40. Boulder, Colorado: Institute of Behavioral Science.

Breznitz, S. 1984. Cry Wolf: The Psychology of False Alarms. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gere, J. M., and H. C. Shah. 1984. Terra Non Firma: Understanding and Preparing for Earthquakes. New York: W. H. Freeman and Company.

Hays, W. W., ed. 1981. Facing Geologic and Hydrologic Hazards, Earth-Science Considerations. Geological Survey Professional Paper 1240-B. U.S. Geological Survey. Washington D.C.: U.S. Government Printing Office.

Institute of Geological Sciences. 1983. Earthquakes. London, England.

Lowrance, W. W. 1976. Of Acceptable Risk: Science and Determination of Safety. Los Altos, California: William Kaufmann, Inc.

Maybury, R. H., ed. 1986. Violent Forces of Nature. Mount Airy, Maryland: Lomond Publications, Inc.

Committee on Disasters and the Mass Media. 1980. Disasters and the Mass Media. National Research Council. Washington, D.C.: National Academy Press.

National Geographic Society. 1986. Nature on the Rampage, Our Violent Earth. Washington, D.C.: National Geographic Society.

Rues, E. H. 1986. Facing the Volcano: The Experience of a Hotelier in El Salvador, Central America. San Salvador: Rues.

Tilling, R. I. 1982. Eruptions of Mount St. Helens: Past, Present, and Future. U.S. Geological Survey. Washington, D.C.: U.S. Government Printing Office.

Tilling, R. I., C. Heliker, and T. L. Wright. 1987. Eruptions of Hawaiian Volcanoes: Past, Present, and Future. U.S. Geological Survey. Washington D.C.: U.S. Government Printing Office.

[redacted]