

MULTI HAZARD

*Identification and
Risk Assessment*

*A Cornerstone
of the National
Mitigation Strategy*



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and Risk
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*The Cornerstone
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Mitigation Strategy*



A MESSAGE FROM THE DIRECTOR



During a presentation before the U.S. Congress in 1993, I indicated that the United States cannot afford the continuing high costs of natural and technological disasters. We cannot afford the economic costs to the American taxpayer, nor can we afford the social costs inflicted on our communities and citizens.

The Federal Emergency Management Agency (FEMA) has embarked on a full-scale effort to help build safer communities. Our goals include increasing public awareness of hazards and loss reduction (mitigation) measures, reducing the risk of loss of life and property, and protecting our nation's communities and the economy from all types of natural and technological hazards.

FEMA's role in this effort is to provide leadership and programmatic, technical, and financial support to our partners: Federal, State, and local agencies; national and State legislative bodies; colleges and universities; private-sector organizations; volunteer organizations;

and individuals. Our partnerships are accomplished through a comprehensive, risk-based, all-hazards program of mitigation, preparedness, response, and recovery.

FEMA has been busy. In addition to responding to numerous disasters, we have made significant progress in developing mitigation programs. Among many accomplishments, in 1995 we developed a national strategy for mitigation after meeting with our partners across the United States. We have started a process that is vital to successful implementation of pre- and post-disaster mitigation. We have also executed performance-based partnership agreements with all 50 States and the U.S. territories.

An integral part of implementing our mitigation strategy is the transfer and sharing of information and knowledge. *Multi-Hazard Identification and Risk Assessment* supports that objective. We look forward to working with our partners to update and expand scientific knowledge and applied technology so that we will be better prepared for the hazards that will affect our families, friends and neighbors in the future.

A handwritten signature in black ink that reads "James L. Witt". The signature is written in a cursive, flowing style.

James Lee Witt

Director

Federal Emergency Management Agency

A MESSAGE FROM THE ASSOCIATE DIRECTOR FOR MITIGATION



Hurricanes, earthquakes, wildfires, and tornadoes cause millions of dollars in damage. They force individuals and families out of their homes and destroy their belongings. Businesses often lose money or even close their doors for good. Public infrastructure such as roads, bridges, water supplies and sewage systems suffer damage, diminishing our quality of life. These losses tear at the very fabric of our communities and our lives.

What is most saddening is that much of the suffering and losses associated with natural disasters is unnecessary. While we cannot keep natural hazards from occurring, we do know how to reduce their effects. By taking actions in our homes, businesses, and our communities to mitigate risks, we can reduce disaster impacts and break the cycle of losses that we have witnessed in recent years. In a nutshell, we can reduce our nation's vulnerability to natural disasters.

Central to our success in breaking the disaster-loss cycle is our ability to identify the hazards that we face and to assess the level of risk they bring to our lives. The report before you is a product of FEMA's efforts to further develop such a capability at the national level. It documents months of research and coordination and provides a baseline of knowledge concerning the identification of hazards and assessment of the risks. The report was created to be a "working" or "living" reference document for State and local specialists. As such, it is FEMA's intention to periodically update or amend the report to ensure that the best and most accurate information is available to those who need it most.

I believe this report provides State and local decision-makers with a better understanding of the types and magnitudes of the natural and technological hazards which their communities face. This, in turn, will help them evaluate exposure of people and property and assess the consequences of hazard events. With these tools, we can make more informed decisions about reducing future disaster losses. I trust you will find this report useful and informative. We look forward to working together to address natural and technological hazards nationwide.

A handwritten signature in black ink that reads "Michael J. Armstrong". The signature is written in a cursive style with a large, looped "M" and "A".

Michael J. Armstrong

Associate Director for Mitigation

ACKNOWLEDGEMENTS

This report was prepared by the Federal Emergency Management Agency's (FEMA) Mitigation Directorate, with assistance from Michael Baker Jr., Inc., Arthur D. Little, Inc., of Cambridge, MA, and Mr. John Hilson of Boulder, CO. We wish to acknowledge the valuable contributions of these organizations, the staffs of the FEMA Regional Offices, and the following organizations and individuals:

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Photo: Red Cross



Photo: Red Cross

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Photo: FEMA



Photo: Red Cross

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EXECUTIVE SUMMARY

“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 EXPERIENCES ALONE IS INADEQUATE FOR JUDGING VULNERABILITY.”

FROM REDUCING DISASTERS' TOLL:
THE UNITED STATES DECADE FOR
NATURAL DISASTER REDUCTION



EXECUTIVE SUMMARY

For decades, most Americans assumed that they were immune to, or could control, the forces and fury of natural hazards. With each new flood, hurricane, tornado, earthquake, avalanche, landslide, or wildfire, that assumption has proven incorrect. Since 1990, the United States has experienced numerous major disasters, among them were Hurricanes Andrew, Iniki, Marilyn and Opal; the Great Midwest Flood of 1993; the Northridge Earthquake; and wildfires in California.

Recent disasters, regardless of scale, have focused the attention of government officials and citizens alike on the economic, human, and environmental costs. With each new event, it becomes more apparent that a unified, concerted approach to lessening if not eliminating the risks is needed. The United States has the technical skill to reduce loss of life and property. Unfortunately, until recently, the will to do so has been unfocused.

Under the leadership of Director James Lee Witt, the staff of the Federal Emergency Management Agency (FEMA) has developed a national approach to mitigating human and economic loss caused by disasters. As one part of the effort, FEMA initiated a research project to clarify and document previous efforts to identify natural and technological hazards, and to assess associated risks. This report, *Multi-Hazard Identification and Risk Assessment*, is prepared as a reference document to summarize the findings.

For specific natural and technological hazards, the report summarizes the state of scientific and technical knowledge on identification and the risks that have been or can be assigned to each hazard. FEMA's recently developed risk assessment methodology, Hazards United States, known as HAZUS, is introduced. Also summarized are the National Mitigation Strategy and highlights from recent successes in each of the five major elements of the Strategy: (1) hazard identification and risk assessment; (2) applied research and technology transfer; (3) public awareness, training, and education; (4) incentives and resources; and (5) leadership and coordination.

Using Geographic Information System technology and available data, selected maps were generated. Often, the maps illustrate areas that appear to be most susceptible to individual and multiple hazards. Some readers may be surprised at the variety and extent of hazards that may occur in various regions of the United States. The maps do not, and are not intended to, depict a final assessment of where hazards exist or where disasters are likely to occur. Uncertainty about risks will always be present, but assessments can be improved.

Brief summaries of existing programs and initiatives, and plans for future mitigation activities, suggest that while a great deal has been accomplished, much more remains to be done.

Multi-Hazard Identification and Risk Assessment is a reference that is available to assist hazard identification, risk assessment, and mitigation specialists in refining our understanding of hazards and their impacts on people and the built environment. FEMA intends to update this report as identification, assessment, and mitigation approaches are refined.






INTRODUCTION

“WANT OF FORESIGHT, UNWILLINGNESS TO ACT WHEN ACTION WOULD BE SIMPLE AND EFFECTIVE, LACK OF CLEAR THINKING, CONFUSION OF COUNSEL UNTIL THE EMERGENCY COMES, UNTIL SELF-PRESERVATION STRIKES ITS JARRING GONG - THESE ARE THE FEATURES WHICH CONSTITUTED THE ENDLESS REPETITION OF HISTORY.”

WINSTON CHURCHILL
SPEAKING TO THE HOUSE OF COMMONS
BEFORE WORLD WAR II



INTRODUCTION

BACKGROUND

Since its creation in 1979, the role of the Federal Emergency Management Agency (FEMA) has been to develop, implement, and support policies and programs for emergency management at the national, State, and local levels. Such policies and programs are necessary because periodically throughout its history the United States has been damaged disastrously by natural and technological hazard events. Many events, even if not disastrous in scope or magnitude, take their toll in terms of life and property. Cumulatively, natural and technological hazard events cost millions each year and affect every State (Figure i-1).

Presidential disaster declarations throughout the United States and its territories from 1975 through 1995 are shown on Map i-1.

During the late 1980s and early 1990s, the United States experienced unprecedented devastation from major events, such as earthquakes, hurricanes, tropical storms, floods, landslides, volcanic eruptions, severe winterstorms, and wildfires. Over 500 people lost their lives during these events. Between 1989 and 1994, 291 presidential disaster declarations were issued. Federal disaster assistance made available to affected States, communities, and individuals cost the U.S. Treasury over \$34 billion. Figure i-2 presents information provided by the Insurance Research Council and the Property Claims Service, Inc., on insured losses for selected major natural disasters that occurred from 1989 to 1995.

Under the leadership of Director James Lee Witt, FEMA's efforts have been redefined and better focused. FEMA's primary mission is to reduce the risk of loss of life and property in the United States, and to protect U.S. institutions from the disastrous effects of natural and technological hazards. FEMA accomplishes this mission by leading, coordinating with, and supporting specialists at every level of government (Federal, State, and local) and the private sector in the development of a comprehensive, risk-based emergency management program of mitigation, preparedness, response, and recovery.

The importance and necessity of FEMA's efforts are underscored by the following statistics:

- Estimates indicate approximately 9 to 11 million homes are at risk from flooding, approximately 25

million homes are at risk from severe wind hazards, approximately 2 million homes may be at risk from coastal storm surge, and at least 50 million homes may be located in counties with significant earthquake risk;

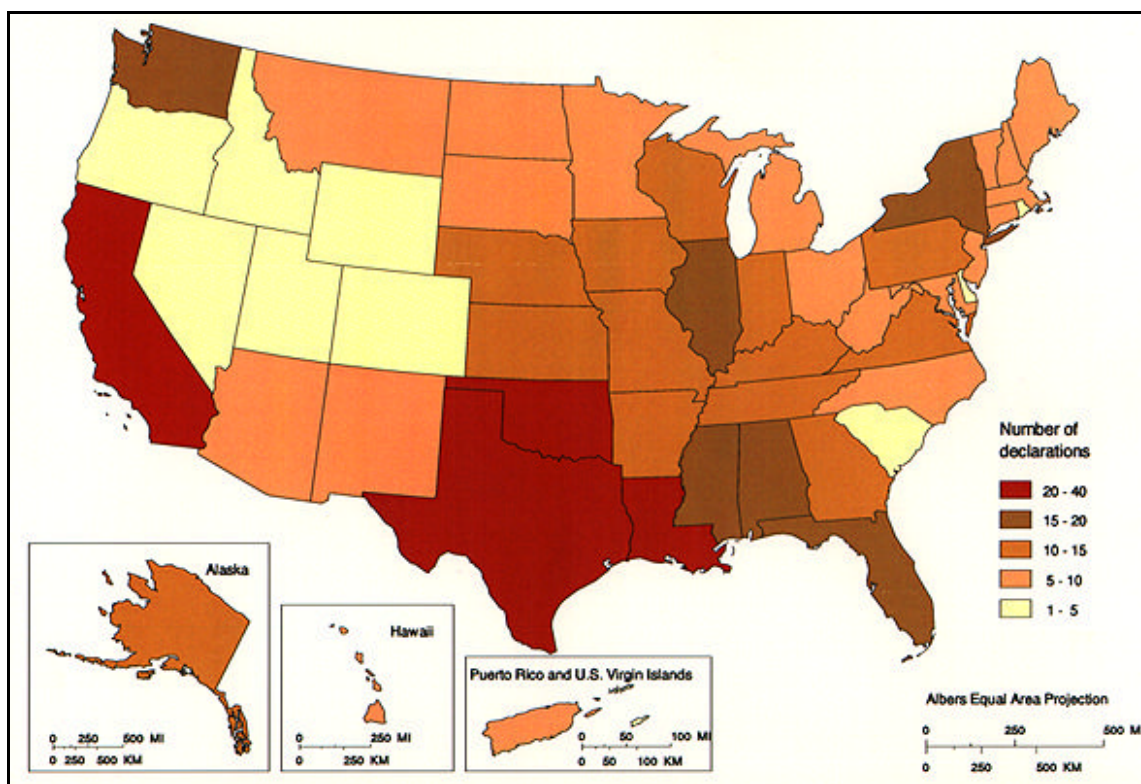
- More than 36 million people live in the most hurricane-prone counties from Maine to Texas, and the number is expected to grow to 73 million by the year 2010; and
- During the last 5 years alone, combined Federal disaster assistance and insurance industry payments totaled over \$67 billion.

Presidents and the U.S. Congress have exhibited strong leadership in raising awareness concerning the United States' exposure to hazard events. They have provided valuable input to FEMA in the development of its policies and programs. Recently, the U.S. Congress stressed the importance of identifying natural and technological hazards and assessing the risks posed to people and property.

In Senate Report 101-128, which accompanied the 1990 FEMA appropriations bill, the Senate Appropriations Committee directed FEMA to ". . . prepare a study on the principal threats facing communities and local emergency management coordinators . . . The study should rank the principal threats to the population according to region and any other factors deemed appropriate."

From 1990 to 1993, FEMA produced reports that summarized the principal natural and technological threats, or hazards, facing communities and emergency management coordinators. However, the limitations of these rankings were acknowledged in the first report, dated April 1990. Some of the limiting factors cited were the wide variation in application of criteria to the same hazards, differences between the State and regional impacts of particular hazards, applicability of threats from region to region, and variances in amounts and types of data collected on particular hazards.

The April 1990 report cited the following as factors that make relative rankings of hazards, even within regions, very difficult: level of community preparedness; degree to which urban or sparsely populated rural areas are affected by disaster events; and emergency managers' perceptions regarding the potential severity, magnitude, or rankings of particular hazards.



Map i-1. Presidential disaster declarations by State for the period of 1975 - 1995. The Pacific Territories have had 35 declarations. Source: *FEMA, 1995*.

As a direct result of the disasters of the early 1990s, in particular the Midwest Floods of 1993, the U.S. Congress directed FEMA to place its highest priority on working with State and local agencies to mitigate the impacts of future natural hazard events. This marked a fundamental shift in policy: rather than placing primary emphasis on response and recovery, FEMA's focus broadened to incorporate mitigation as the foundation of emergency management.

NATIONAL MITIGATION STRATEGY AND GOAL

In keeping with congressional directive, Director Witt and FEMA staff led the development of the National Mitigation Strategy. FEMA derived 10 fundamental principles for the framework and objectives of the National Mitigation Strategy.

1. Risk reduction measures ensure long-term economic success for the community as a whole rather than short-term benefits for special interests.
2. Risk reduction measures for one natural hazard must be compatible with risk reduction measures for other natural hazards.
3. Risk reduction measures must be evaluated to achieve the best mix for a given location.
4. Risk reduction measures for natural hazards must be compatible with risk reduction measures for technological hazards and vice versa.
5. All mitigation is local.
6. Disaster costs and the impacts of natural hazards can be reduced by emphasizing pro-active mitigation before emergency response; both pre-disaster (preventive) and post-disaster (corrective) mitigation is needed.
7. Hazard identification and risk assessment are the cornerstones of mitigation.
8. Building new Federal-State-local partnerships and public-private partnerships is the most effective means of implementing measures to reduce the impacts of natural hazards.

GEOGRAPHY OF NATURAL HAZARDS

Although occasional events of a particular natural hazard can occur in any area of the United States, most tend to occur more frequently in some areas than in others. The following table lists the hazards that are most prevalent in each area.

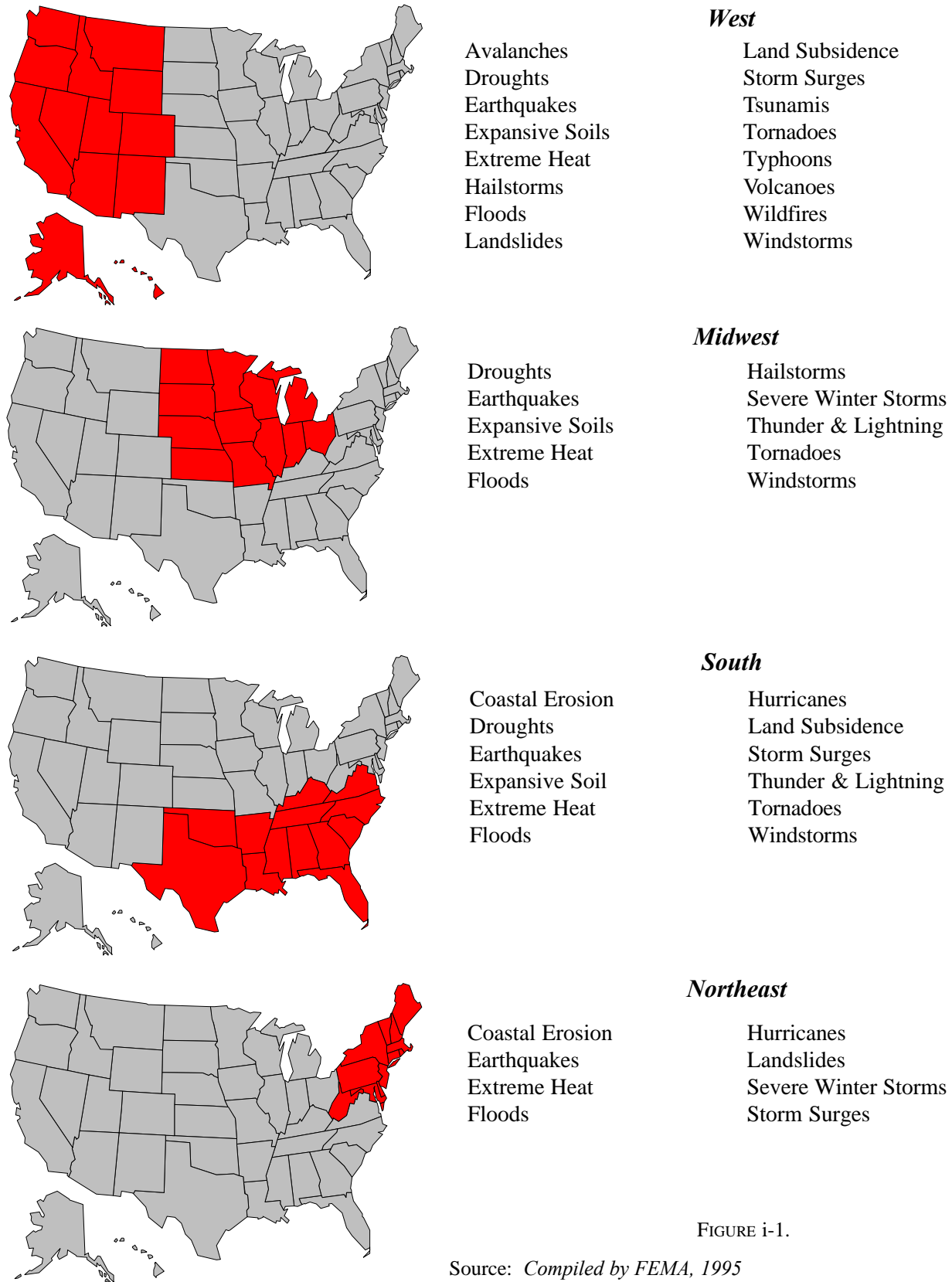


FIGURE i-1.

Source: Compiled by FEMA, 1995

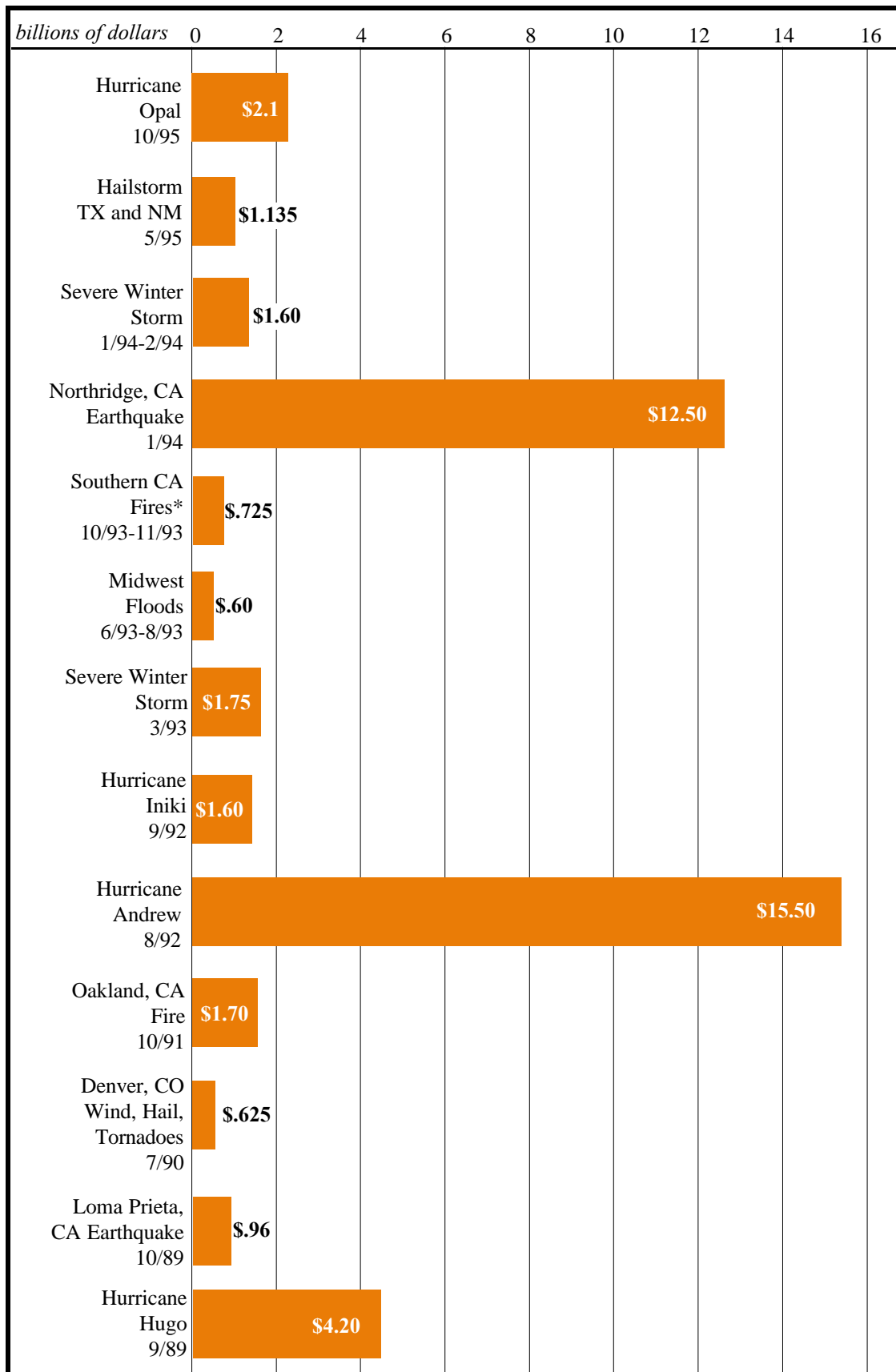


FIGURE i-2.—Total insured losses for major natural disasters: 1989-1995.

Source: *From Property Claim Services, 1997; and Insurance Research Council, 1995*

* Only 2 of the 27 fires were officially classified by the insurance industry as catastrophes. Costs associated with other fires at the same time may have caused losses to reach \$0.95 billion.

9. Those who knowingly choose to assume greater risk must accept responsibility for that choice.
10. Risk reduction measures for natural hazards must be compatible with the protection of natural and cultural resources.

Using these principles as guidance, FEMA established a National Mitigation Goal to be accomplished by the year 2010. The two components of the goal are (1) to substantially increase public awareness of natural hazard risk so that the public demands safer communities in which to live and work, and (2) to significantly reduce the risk of loss of life, injuries, economic costs, and destruction of natural and cultural resources that result from natural hazards.

To meet the National Strategy Goal, FEMA set specific objectives for five major "elements" of the Strategy:

- Hazard identification and risk assessment;
- Applied research and technology transfer;
- Public awareness, training, and education;
- Incentives and resources; and
- Leadership and coordination.

INTENT OF THIS REPORT

This report is intended to serve as a baseline for hazard identification and risk assessment efforts. The research and reviews documented in this report are not intended to be exhaustive evaluations of hazards and the risks they pose throughout the United States. The research, monitoring, mitigation measures, recommendations and federal programs described herein are current as of 1995. The report may be updated as hazard identification and risk assessment techniques are refined and improved, and as Federal, State, and local programs evolve.

FEMA initiated this report to focus primarily on identification of hazards and factors important to risk assessment: probability and frequency, exposure, and consequences. FEMA also began development of a consistent methodology to assess risks posed by natural and technological hazards.

The baseline of knowledge was developed by identifying and contacting Federal and State agencies, research institutes, and universities known to have leading experts in each specialty area. For example, experts from the National Oceanic and Atmospheric

Administration were contacted regarding atmospheric hazards; experts from the U.S. Geological Survey were contacted regarding geologic, seismic, and volcanic hazards; and experts at the Natural Hazards Research and Applications Information Center at the University of Colorado were contacted for information on multiple hazards.

KEY TERMS AND DEFINITIONS

Terminology is important because variations in meaning lead to differences in hazard identification and measures of risk. The following key terms and definitions are used in this report:

HAZARD means an event or physical condition that has the potential to cause fatalities, injuries, property damage, infrastructure damage, agricultural loss, damage to the environment, interruption of business, or other types of harm or loss.

HAZARD IDENTIFICATION means the process of defining and describing a hazard, including its physical characteristics, magnitude and severity, probability and frequency, causative factors, and locations/areas affected.

RISK means the potential losses associated with a hazard, defined in terms of expected probability and frequency, exposure, and consequences.

PROBABILITY AND FREQUENCY means a measure of how often an event is likely to occur. Frequency can be expressed as the average time between occurrences or exceedances (non-exceedances) of an event or the percent chance or probability of the event occurring or being exceeded (not exceeded) in a given year or a longer time period.

EXPOSURE means the number, types, qualities, and monetary values of various types of property or infrastructure and life that may be subject to an undesirable or injurious hazard event.

CONSEQUENCES mean the damages (full or partial), injuries, and losses of life, property, environment, and business that can be quantified by some unit of measure, often in economic or financial terms.

RISK ASSESSMENT means a process or method for evaluating risk associated with a specific hazard and defined in terms of probability and frequency of occurrence, magnitude and severity, exposure, and consequences.

MITIGATION means sustained action taken to reduce or eliminate long-term risk to people and property from hazards and their effects. Mitigation distinguishes actions that have a long-term impact from those that are more closely associated with preparedness for, immediate response to, and short-term recovery from a specific event.

PREVIOUS HAZARD IDENTIFICATION AND RISK ASSESSMENT ACTIVITIES

Over the past 12 years, FEMA and State emergency managers have developed a variety of tools to assist with hazard identification and risk assessment. Two such cooperative programs—the Integrated Emergency Management System (IEMS) and the Capability and Hazard Identification Program (CHIP)—have evolved and have contributed significantly to hazard identification program activities.

FEMA instituted IEMS in 1983. Its objective was to develop and maintain a credible emergency management capability nationwide by integrating activities along functional lines at all levels of government and, to the fullest extent possible, across all hazards. Through a 13-step process, IEMS collected basic information from State and local emergency management organizations on which reasonable and justifiable plans could be made and implemented to increase emergency management capabilities nationwide.

The 13 steps in the IEMS process were: (1) hazards analysis, (2) capability assessment, (3) emergency operations plan development, (4) capability maintenance, (5) mitigation efforts, (6) emergency operations, (7) emergency operations evaluation, (8) capability short-fall determination, (9) multi-year development plan development, (10) modification of multi-year development plan for annual increments, (11) estimate of State/local financial resource requirements, (12) estimate of Federal financial resource requirements, and (13) annual review of completed work. Based on the review completed in Step 13 each year, the process was begun again.

Under CHIP, instituted in 1989 to replace IEMS, FEMA established a national database of information on the status of emergency preparedness and the impact of FEMA funds on State and local government operations. Emergency management data were collected for 3,300 communities and maintained in a comprehensive and easily accessible database. However, a drawback of the "self-assessment" was the lack of consistent criteria for reporting, which resulted in incomplete and inaccurate information.

Through regular updates of the CHIP database, local government officials provided information on natural hazards in their areas, including the likelihood and frequency of events and the impacts on local population and property. They also provide information on local emergency management expenditures, including totals expended and the sources of funding. By answering questions separated into five topic areas, local governments provided information to allow assessment of their capability to deal with disasters. The five topic areas are: planning, logistics, training and education, operations, and administration.

On the Federal level, the information from CHIP was used to prepare reports to the U.S. Congress on the status of emergency management capabilities. It also was used to evaluate the effectiveness of FEMA programs in delivery of financial and technical assistance to State and local governments. At the local level, CHIP was used as a planning tool, guiding local jurisdictions through a logical sequence: identify hazards; assess capabilities to address those hazards; set priorities for improving those capabilities; and schedule process activities to improve those capabilities.

REPORT CONTENT AND FORMAT

Two categories of hazards are covered: natural hazards and technological hazards. Natural hazards, the largest single contributor to catastrophic or repetitive damage to communities nationwide, evolve from atmospheric or weather, geologic, hydrologic, and seismic events. They pose threats in all areas of the United States.

The impacts of natural hazards can be local or widespread, predictable or unpredictable. Resulting property and infrastructure damage can range from minor to major, depending on whether hazard events affect major or minor population centers.

Technological or manmade hazards have expanded dramatically throughout the 20th century. Like natural hazards, their effects can be local or widespread. They are frequently unpredictable and have the potential to cause substantial loss of life in addition to property damage. Some technological hazards can be significant threats to infrastructure. For the purposes of this report, the discussions of technological hazards are limited to those that have been or may be triggered by natural events.

To present what is known today with respect to hazard identification and risk assessment, this report is organized to allow location of information on a specific hazard or a group of hazards. It is intended as a reference document for use by emergency management and miti-

gation specialists in all levels of government and the private sector.

For each hazard, the chief characteristics necessary for hazard identification are described, followed by the factors required in risk assessment: probability and frequency, exposure, and consequences. Each chapter includes brief summaries on previous and on-going research, data collection and monitoring activities, and brief discussions of mitigation measures and recommendations.

The report is divided into five major parts:

- **Part I** "Natural Hazards" presents atmospheric, geologic, hydrologic, seismic, and other hazards.

Subpart A includes chapters on atmospheric hazards: tropical cyclones, thunderstorms and lightning, tornadoes, windstorms, hailstorms, snow avalanches, severe winterstorms, and extreme summer weather.

Subpart B includes chapters on geologic hazards: landslides, land subsidence, and expansive soils.

Subpart C includes chapters on hydrologic hazards: floods, storm surges, coastal erosion, and droughts.

Subpart D includes chapters on seismic hazards: earthquakes and tsunami events.

Subpart E includes chapters on two other natural hazards: volcanoes and wildfires.

- **Part II** "Technological Hazards" presents dam failures, fires, hazardous materials events, and nuclear accidents.
- **Part III** "Risk Assessment Approaches" presents risk assessment methodologies. One chapter addresses a method developed by the National Institute of Building Sciences, in cooperation with FEMA. The initial methodology estimates potential losses from earthquake events, but will be modified for other hazards. When completed, FEMA will make it available to State and local agencies along with many inventory databases. Components of other risk assessment methodologies are discussed briefly in a separate chapter.
- **Part IV** "Activities Under the National Mitigation Strategy," summarizes the major elements of the National Mitigation Strategy and provides information on existing programs, recently completed activities, and future initiatives of FEMA, other Federal agencies, State and local agencies, and others.

- **Part V** "Summary and Conclusions" presents an overall summary of the report and some general conclusions drawn from the research.

To illustrate graphically the breadth and extent of both natural and technological hazards, color maps produced using Geographic Information System technology are included in Parts I and II. The source of data used to prepare each map is cited below the map caption for ready reference. A notation is made if information is not available for a particular State, territory, or region.

STATE AND LOCAL PARTICIPATION IN REPORT UPDATE PROCESS

Consistent definitions for, and a comprehensive identification of, natural and technological hazards can best be achieved through Federal-State-local partnerships and through cooperative efforts with private sector organizations, research and academic institutions, and individuals. The information in this report is intended to provide a baseline of knowledge.

Future research on methodology, identification, assessment, and application will prove to be invaluable as risk-based strategies are refined. This report is a living document, and all Federal and State agencies, the scientific community, local government officials, emergency management specialists, and informed and concerned private sector organizations and individuals are encouraged to contribute to its enhancement and expansion in the coming years.

To assist in the effort, comments may be submitted to:

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